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Eva Ludi

# Economic Analysis of Soil Conservation: Case Studies from the Highlands of Amhara Region, Ethiopia

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# Economic Analysis of Soil Conservation: Case Studies from the Highlands of Amhara Region, Ethiopia

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# Economic Analysis of Soil Conservation: Case Studies from the Highlands of Amhara Region, Ethiopia

UNIVERSITY OF BERNE SWITZERLAND INSTITUTE OF GEOGRAPHY

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Cover photo In Mesobit & Gedeba soil conservation has a long tradition.
Photo by Eva Ludi, May 1998.

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## Preface

I first came in contact with economic issues related to soil conservation when I attended a graduate seminar in the summer of 1990 led by Prof. Bruno Messerli and Prof. Hans Hurni. Based on his long and intimate knowledge of Ethiopia, and his experience in dealing with problems of natural resource degradation and rural development in mountain areas for more than a decade, Prof. Hans Hurni proposed looking at economic issues related to soil conservation in the Ethiopian Highlands. Considerable knowledge had been acquired about the erosion process itself, its negative ecological consequences, and the positive effects of conservation. But less was known about the incentives for farmers to either degrade or conserve their land. What could be observed was that farmers did not like the proposed conservation technologies. Many factors were responsible for this, amongst them insufficient profitability from the farmer's point of view.

Before I started to work on the seminar essay, I first had to learn more about Ethiopia in general and about soil erosion and soil conservation in particular. Since then, and especially since my first field research in Ethiopia in 1992, my interest in both has not diminished. On the contrary: the longer I spent in different regions of this fascinating, but problem-ridden country, and the more I learned about the needs, opportunities and constraints of its land users, the more I realised that soil conservation is not an end in itself. Mechanical soil conservation is a necessity in many areas to reduce soil erosion, but it has to fit into highly complex land use and livelihood systems which are under considerable pressure from ongoing resource degradation, population pressure, rural impoverishment and unfavourable economic and political conditions.

The present study was carried out at the interdisciplinary Centre for Development and Environment (CDE) at the Institute of Geography, University of Bern. It was designed in a way that contributes to the work of the Soil Conservation Research Programme (SCRP), a collaborative programme of the Ethiopian Ministry of Agriculture and the University of Bern. Hopefully it will also contribute to the further adaptation and development of soil conservation measures that become profitable for the farmers who implement them on their land in the Ethiopian Highlands.

My greatest thanks go to Prof. Hans Hurni, who awakened my interest in Ethiopia and in the issue of sustainable development in mountain areas. Thanks to him, I was able to carry out this study. He provided creative ideas that spurred my own thinking. His expertise, constructive comments, and advice were of great value. He also supported me in numerous other ways that allowed me to gain valuable experience, be it with regard to adaptive research in the context of developing countries, research partnerships, or inter-cultural interactions. My future work will be greatly influenced by what I learned from him.

I benefited from a study commissioned by the SCRP on an economic appraisal of soil conservation in the Ethiopian Highlands, conducted by Prof. Rolf Kappel, an economist at the Swiss Federal Institute of Technology, Zürich, and my second advisor. His study was a starting point for my research, and I am grateful for his constructive comments and support.

This study would have not been possible without the support and contributions of numerous persons and organisations. I wish to give special thanks to the following individuals, without implying less gratitude for the support I received from the many individuals who are not explicitly mentioned:

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Eva Ludi, March 2002

# Summary

Soil degradation is widespread in the Ethiopian Highlands. Its negative impacts on soil productivity contribute to the extreme poverty of the rural population. Soil conservation is propagated as a means of reducing soil erosion, however, it is a costly investment for small-scale farming households. The present study is an attempt to show whether or not selected mechanical Soil and Water Conservation (SWC) technologies are profitable from a farmer's point of view. A case study approach has been chosen because input parameters and variables in an economic analysis of SWC are highly situation specific. Of the seven research sites of the Soil Conservation Research Programme (SCRP), the three sites located in Amhara Region, namely Maybar, Andit Tid and Anjeni, have been selected as study sites. The findings from these areas are supplemented by information collected in the Simen Mountains and Mesobit & Gedeba.

The aspect of the profitability of environmental investments can be linked to discussions of sustainable use of renewable natural resources. On the one hand, it concerns the proper valuation of natural resources. On the other hand, it contributes to discussions about striking a balance between the ecological, economic and socio-cultural sustainability of investments. It is thus an attempt to make 'sustainability' operational by showing that weak sustainability can be achieved if the considered technologies at least show a positive Net Present Value (NPV). In order to be acceptable, SWC investments must be profitable from a farmer's point of view. From an outsider's point of view, the ecological sustainability of SWC is often in the foreground, especially the contribution of SWC to reducing soil erosion and land degradation in the long run.

A financial Cost-Benefit Analysis (CBA) is carried out to assess whether or not the considered SWC technologies are profitable from a farmer's point of view. The CBA is supplemented by an evaluation of aspects from the economic and institutional environment.

In order to assess the profitability of SWC investments, it was first necessary to know what the effect of soil erosion on yield performance would be. Soil depth is taken as a proxy indicator for soil characteristics, which have an influence on yield performance, such as rooting depth, water storage, nutrient storage, and physical and chemical properties favouring crop growth. Yield samples and associated soil depth measurements are available in large numbers from the three SCRP research stations and allowed estimates of linear regressions of yield expressed as a function of soil depth and slope gradient. Per one centimetre soil depth reduction at constant slope gradient, yield declines are estimated to be in the order of 0.25% in Maybar, 0.62% in Andit Tid, and 0.16% in Anjeni. Taking into account annual soil loss rates as measured on cultivated Test Plots (TP), annual yield reductions on unconserved land are estimated to be in the order of 0.07% in Maybar, 0.91% in Andit Tid, and 0.23% in Anjeni. Mechanical conservation structures can reduce soil loss rates considerably. Soil loss reductions are in the order of 55% in Maybar, 59% in Andit Tid, and 68% in Anjeni. Annual yield declines on conserved land are thus reduced to 0.04% in Maybar, 0.37% in Andit Tid, and 0.07% in Anjeni.

In the CBA, two conservation technologies, namely introduced SWC and adapted SWC, and two forms of soil erosion, namely sheet erosion and sheet & rill erosion, are considered. Introduced SWC is characterised by a considerable loss of arable land in the order of 30% on steep slopes. Adapted SWC tires to simulate the situation found on farmers' fields. It is assumed that adapted SWC occupies only 10% of the arable land on steep slopes. The price of this reduced land loss is less effective soil erosion reduction, which is assumed to be half of what could be achieved with introduced SWC. For adapted SWC less labour investments are necessary, but also less additional benefits, e.g. fodder grass planted on conservation structures, can be realised. The two forms of soil erosion differ insofar as in the first case only sheet erosion is considered while in the second case rill erosion is also taken into account. In the CBA, soil depth reduction and its effect on yields is modelled according to the different assumptions presented above. It is further assumed that once soil depth has reached 10 cm, crop cultivation is given up because it is no longer economical. For the four cases here (i.e. introduced SWC, adapted SWC, sheet erosion, and sheet & rill erosion) the situation with and without fertiliser application is modelled as well as the situation with different opportunity costs for labour.

Net Present Values (NPV) are calculated for the considered conservation technologies and soil erosion forms based on the assumptions presented above and expressed as Discounted Net Gain (DNG) from switching from an erosive to a conserving practice. In a CBA, future costs and benefits are discounted to present values. Because the analysis of the profitability of SWC investments is carried out from a farmer's point of view, individual discount rates had to be assessed. An experimental set-up was designed, where farmers could choose between variable amounts of grain in future or a lower, but constant amount of grain at the time the interview as conducted. Based on the choices of the respondents, discount rates were derived. Median discount rates were calculated to be in the order of 148% to 228% in Andit Tid and 18% to 37% in Maybar. In the CBA, discount rates of 5%, 12%, 58% and 148% were used to represent the various choices of the respondents. Time periods for the evaluation of costs and benefits of 10, 25, 50 and 100 seasons (i.e. 5, 12.5, 25 and 50 years) are considered.

Based on the model used here and its associated assumptions with regard to input parameters and variables, the generalised results of the CBA for the two considered SWC technologies compared to the situation with sheet & rill erosion show the following tendencies:

- Because soil erosion rates in Andit Tid and Anjeni are about five times higher than in Maybar, the likelihood that the DNG of the considered SWC technologies is positive is higher in Andit Tid and Anjeni than in Maybar, mainly because soil depth is faster reduced to the threshold depth of 10 cm. With soil conservation, soil depth reductions are smaller and crop cultivation can be practiced for a longer period.
- A comparison of fields with the same slope gradients and same soil erosion rates shows that SWC on shallow soils is more likely to be profitable than on deep soils.
- On more gentle slopes, SWC is more likely to be profitable than on steeper slopes.
- Adapted SWC is more often profitable than introduced SWC, because of lower costs despite the lower efficiency in reducing soil erosion.
- Applying artificial fertiliser with the associated yield increase often offsets the area loss and investment costs and can make SWC a profitable investment.
- A combination of fertiliser induced yield increases and subsidising labour costs for SWC investments, including maintenance costs, helps in some cases to make SWC profitable.
- Whether or not SWC investments are profitable also depends on the farming system, e.g. on cropping intensity.
- If no fertiliser is applied and labour costs are not subsidised and the discount rate is set at 12%, introduced SWC is, if at all, profitable after 25 years. Adapted SWC is, if at all, in most situations already profitable after 12.5 years.
- With no fertiliser application, no subsidised labour, a time frame of analysis of 25 years, and a discount rate of 12%, introduced and adapted SWC would be profitable in 3 and 17 of the 26 cases analysed, respectively. Reducing the discount rate to 5% would make introduced and adapted SWC profitable in 11 and 23 of the 26 cases considered, respectively.

Comparison of the internal and external views shows that from the farmer's point of view SWC is not really a solution because the immediate costs, e.g. reduced amount of arable land and labour costs, are higher than the future benefits, e.g. reduced yield decline, although farmers recognise that uncontrolled soil erosion has a negative effect on crop production in the longer term. To an outsider with a long-term perspective, SWC is an option because damage to the land can be postponed. This would make it possible to search for profitable technologies.

Whether or not the considered SWC technologies prove to be profitable also depends on the economic environment. It has been shown that in areas such as Mesobit & Gedeba, which are fairly well integrated in a market system, the attitude towards SWC is much more favourable. Transaction costs are lower, thus it is profitable to sell goods on the market. Because cash is available to buy artificial fertilisers, SWC becomes an indispensable part of the farming system, as fertiliser is otherwise lost through runoff.

Two important institutions are examined in more detail: land tenure regimes and regulations related to religion. Secure land tenure is often considered a prerequisite for long-term investments. Because land in Ethiopia belongs to the state and regular land distributions are carried out, farmers often mentioned tenure insecurity as a reason for not investing in SWC. Religious regulations in Christian areas concern the high number of Saint days. Fieldwork is allowed only on about 160 days. Additional labour demands, such as the labour needed for SWC, are difficult to accommodate without compromising fieldwork.

Whether or not soil conservation is profitable from a farmer's point of view depends on a broad range of factors from the ecological, economic, political, institutional and socio-cultural sphere and also depends on the technology and the prevailing farming system. Because these factors are closely interlinked, it is often not sufficient to change or influence one to make SWC profitable. Several recommendations are formulated with regard to improving the profitability of SWC investments from a farmer's point of view. They concern technology-specific recommendations, recommendations for activities at the household and communal level (e.g. collective action), and recommendations for action at regional and national level (e.g. initiating multi-stakeholder negotiations, empowering rural societies, intensifying and diversifying the farming system, strengthening agricultural research and extension, formulating conducive policies, and improving physical infrastructure and services). To enable the Ethiopian Government and concerned land users to initiate actions that help improve livelihood conditions and sustainable management of natural resources, the international community is called upon to continue the debt relief measures and support recapitalisation of natural capital stocks.

Because the reasons for unsustainable resource use are manifold and highly interlinked, only a multi-stakeholder, multi-level and multi-objective approach is likely to offer solutions that address the underlying problems adequately.

# Abbreviations and Acronyms

| | |
|---|---|
| ADLI | Agricultural-Development-Led Industrialisation |
| ANRS | Amhara National Regional State |
| asl | Above sea level |
| ASP | Autarky Shadow Price |
| BCR | Benefit-Cost ratio |
| BoA | Bureau of Agriculture |
| C | Consumer Unit |
| CBA | Cost-Benefit Analysis |
| CBO | Community Based Organisation |
| CDE | Centre for Development and Environment |
| CEC | Cation Exchange Capacity |
| CfW | Cash-for-Work |
| CS | Consumer Surplus |
| CVM | Contingent Valuation Method |
| CV | Coefficient of Variance |
| DA | Development Agent |
| DAP | Di-Ammonium Phosphate |
| DNG | Discounted Net Gain |
| DTM | Digital Terrain Model |
| EARO | Ethiopian Agricultural Research Organisation |
| EB | Ethiopian Birr (approximate exchange rate 2000: US$ 1 = EB 7.6) |
| EDT | External Dept Stock |
| ENSO | El Niño Southern Oscillation |
| EP | Experimental Plot |
| EPRDF | Ethiopian Peoples Revolutionary Democratic Front |
| ERP | Economic Reform Programme |
| FDRE | Federal Democratic Republic of Ethiopia |
| FfW | Food-for-Work |
| GDP | Gross Domestic Product |
| GIS | Geographic Information System |
| GLASOD | Global Assessment of the Status of Human-induced Soil Degradation |
| GNP | Gross National Product |
| HH | household |
| HIPC | Heavily Indebted Poor County |
| IAR | Institute of Agricultural Research |
| IRR | Internal Rate of Return |
| KA | Kebele Association |
| LDC | Least Developed County |
| MAC | Marginal abatement costs |
| MCA | Multi-Criteria Analysis |
| MD | Marginal damage |
| MoA | Ministry of Agriculture |
| MP | Micro-plot |
| MW | Mean |
| NFIU | National Fertiliser and Input Unit |
| NGO | Non-governmental Organisation |
| NIE | New Institutional Economics |
| NPV | Net Present Value |
| ODA | Official Development Assistance |
| OECD | Organisation for Economic Co-operation and Development |
| P | Producer Unit |
| PADETES | Participatory Demonstration and Training Extension System |
| PPP | Purchasing Power Parity |
| RA | Research Assistant |
| RARC | Regional Agricultural Research Centres |
| SCRP | Soil Conservation Research Programme |
| SD | Standard Deviation |
| SDA | Sustainable Development Appraisal |
| SDC | Swiss Agency for Development and Cooperation |
| SG 2000 | Sasakawa Global 2000 Programme |
| SMNP | Simen Mountains National Park |
| SNSF | Swiss National Science Foundation |
| SWC | Soil and Water Conservation |
| TLU | Tropical Livestock Unit |
| TP | Test Plot |
| UNDP | United Nations Development Programme |
| VCR | Value-Cost Ratio |
| WFP | World Food Programme |
| WTA | Willingness to Accept |
| WTP | Willingness to Pay |

# Glossary of Amharic Terms

| | |
|---|---|
| Alekt | A leech affecting mainly cattle. |
| Belg | Short rainy season. |
| Berbere | Hot paprika. |
| Chat | A slightly hallucinogenic plant. |
| Derg | Leading group of former military government. |
| Gesho | A shrub of which the leaves are used as hop to make talla. |
| Gibbto | An indigenous pulse (*Lupinus albus var. termis*). Gibbto is sown as green fallow. |
| Ginch | A weed. |
| Gommen | The leaves of Abyssinian cabbage (*Brassica carinata*), eaten during Kremt (hunger food). |
| Gult | A feudal grant of land given to nobles by the emperor in recognition of their services (prior to 1974). A gult did not normally become hereditary property. Its possessor was entitled to tax surpluses produced by farmers working the land, and he also had certain duties. All cultivated land was designated as gult, under either secular or clerical conditions. The actual owner of the land was not the gultegna but the kin group. |
| Gultegna | The feudal lord of a gult prior to the revolution of 1974. The gultegna had no direct control over peasants, but had the right to collect tithes and taxes in the name of the emperor. In return he was required to provide local administration, maintain law and order (judiciary and police functions) and perform military service for the emperor in wartime. |
| Idir | A funeral association which provides financial support for the family of the deceased. |
| Injera | A staple food, injera is a sour, flat bread made from tef, barley, maize or sorghum. |
| Iqub | A savings association. Each member contributes a monthly sum that is paid out in turn to individual members or saved for an important common benefit (purchasing cattle for the Christmas celebration). |
| Kebele | Lowest administrative unit. |
| Kremt | Long rainy season. |
| Mahiber | An association of several households to pay homage to a saint. Each month one household entertains all the others by providing a traditional meal. Members of a mahiber are obligated to provide mutual aid. |
| Meher | Crops grown during the Kremt rainy season |
| Quintal | Unit of measurement, 100 kg. |
| Rist | 1) Prior to 1974, the right to use a feudal land grant belonging to a kin group. This right could be bequeathed through either the maternal or the paternal line. The kin group was composed of all descendants of a founding patriarch.<br>2) Cultivated land, i.e. rist rights in practice. |
| Ristegna | Farmer who cultivated rist land in a gult (prior to 1974) and who was largely able to determine his own land use practices. Ristegnas were obliged to pay duties and taxes to a gultegna, and to perform service in wartime as well as other compulsory service. |
| Shengo | Local judge. |
| Talla | Local beer made from barley or maize. |
| Tef | Tef (*Eragrostis tef*) is the most highly regarded of all Ethiopian cereals. It is used exclusively for making injera. |
| Timmad | An unofficial measure of area. The size of the timmad depends on steepness and soil quality as well as the condition of oxen. A timmad is the amount of land that can be ploughed with a pair of oxen in one day. |
| Webera | An association of several households formed to provide mutual aid in performing labour-intensive and time-consuming fieldwork (standardised tasks and meals). |
| Wenfel | Mutual aid among relatives in performing tasks, similar to webera (tasks and meals not standardised). |
| Wereda | Several Kebele Associations together form a district (Wereda). |

# PART I

# INTRODUCTION

# 1 An Introduction to Soil Degradation and Conservation in the Ethiopian Highlands

*Figure 1: Soil erosion and conservation in the Ethiopian Highlands.*
*[Photos: U. Bosshart, 1992 (left), E. Ludi, 1998 (right)]*

August, rainy season in Anjeni. Herder boys are standing by and watch how runoff and soil from arable land flows towards the river. Such events can be observed frequently in highland areas of Ethiopia during the rainy season. Groundcover is low or even absent at this time of the year because the land has just been ploughed and crops sown. Several weeks will pass before the plants are big, dense and strong enough to reduce the impact of raindrops and diminish the velocity of runoff. Soil loss in the order as shown could be tolerated in the area if it happened only every few years. Like most highland areas, however, land use intensity in Anjeni is so high that fields have to be planted every year and fallow periods which would allow the soil to regenerate are almost entirely absent. Hence, year after year, valuable nutrients are lost and the soil depth where plants can root and where water and nutrients can be stored decreases. Decreasing nutrient availability and decreasing soil depth negatively affect soil productivity and plant growth. A vicious circle can be observed whereby soil erosion negatively affects soil properties, thus plant growth is reduced and cannot prevent erosive rainfall to further degrade the soil. Because soil productivity declines, farmers are forced to use the land even more intensively or to cultivate erosion-prone marginal areas to compensate the yield declines.

Although soil cover is considered a highly efficient means for controlling soil erosion, it is not always feasible. In the agricultural production system of the Ethiopian Highlands it is not possible to maintain a permanent vegetation cover over the whole year under given ecological, economic, and social circumstances. Technologies such as zero-tillage or mulching are not feasible due to the prevailing farming system, available farming technologies, and available financial means of the small-scale farming households. Structural measures such as the stone terraces shown on the picture to the right are necessary during critical times of the year and an indispensable component of Soil and Water Conservation (SWC) for the control of runoff and erosion.

Both, soil erosion and soil conservation are costly – to the farmer as well as to society at large. Soil erosion and soil degradation can affect crop production negatively. Income for farm households thus decreases and because other income sources are lacking, poverty is increasing. However, costs for establishing SWC structures are also high. Land users have thus to find a balance between the costs of soil erosion and the costs for soil conservation. The present study is positioned at this interface of costs of soil degradation and costs and benefits of soil conservation. It aims at evaluating the economic performance of SWC technologies from the farmer's point of view, because it is ultimately the farmers deciding how much soil is lost or how much they can afford to invest in SWC.

## 1.1 Environment and Development Problems in the Ethiopian Highlands

*"Small farmers in developing countries scratching thin soils on steep slopes are certainly directly threatened by the degradation processes affecting their land. They are marginal people who have no chance to take up their way of life in another area, and they will suffer from the decreasing productivity of their land. [...] Increasing degradation, an increasing number of farmers sharing the same land, and worsening terms of trade for products offered to such farmers have greatly increased their vulnerability to undernourishment, which may eventually lead to deadly famine situations."*
*(Kebede Tato & H. Hurni, 1992, 1)*

### 1.1.1 Main environmental problems

Many people know Ethiopia because of its widespread poverty and devastating famines which occurred in the mid 1970s and mid 1980s, and also in the centuries before. Famines are not natural disasters, but cultural catastrophes following natural events.[1] Drought may lead to shortfalls in production of the subsistence-oriented agricultural sector. Because production levels are low and hardly any food reserves exist, both at the level of households and at national level, climatic irregularities can be responsible for such disastrous situations in combination with economic and political crises. Environmental degradation due to deforestation, overgrazing and soil degradation must be considered as important underlying reasons for low levels of production and the vulnerability of the Ethiopian society to famine.

Because the Highlands of Ethiopia[2] are characterised by favourable conditions of altitude, climate and soils, high concentrations of people and livestock and an intensive agricultural system is possible today and has been possible for several thousand years. Land degradation processes such as land and soil degradation, deforestation and overgrazing are as old as human settlements and land use history. However, population pressure in many areas has accelerated these processes.[3]

***Land and soil degradation***

Land degradation as a general term is defined as *"substantial decrease of biological productivity of a land system as a result of human activity, rather than natural events"*.[4] Land degradation is a global threat to human populations and has been described widely and gained public attention significantly since the Earth Summit in Rio de Janeiro, 1992 and the formulation of the *Agenda 21*.[5] An article published in *Science* claims that *"about 80% of the world's agricultural land suffers moderate to severe erosion"*,[6] leading to the destruction and abandonment of arable land as a result of non-sustainable farming practices. GLASOD experts estimate for Sub-Saharan Africa that 65% of soils on agricultural lands have become degraded since the middle of the 20th

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1 Hurni, 1993, 20.

2 Usually defined as the area above 1,500 m asl.

3 Hurni, 1993, 34.

4 Turkelboom, 1999, 1.

5 Desertification as the most dramatic process of land degradation is estimated by the authors of *Agenda 21*, Chapter 12 on 'Managing Fragile Ecosystems: Combating Desertification and Drought' as *"[...affecting] about one sixth of the world's population, 70% of all drylands, amounting to 3.6 billion hectares, and one quarter of the total land area."* (Agenda 21: http://www.un.org/esa/sustdev/agenda21chapter12.htm)

6 Pimentel et al., 1995, 1117.

century. Serious degradation affects 19% of agricultural land. The most widespread cause of soil degradation is erosion by water, followed by wind erosion.[7] To demonstrate the severity of land degradation, productivity losses at country or regional level are estimated. Yield reductions for Sub-Saharan Africa are estimated to be between 2% and 40% due to past erosion.[8]

Accelerated soil erosion caused by rainfall and runoff is as old as the history of agriculture. Soil degradation[9] is assumed to have played an important role in the decline of several ancient civilisations.[10] In Ethiopia, it is hypothesised that kingdoms in the northern and central part of the Ethiopian highlands declined because soil degradation weakened their economic foundation and made them vulnerable to climatic, economic or political shocks.[11] Soil degradation is especially severe in areas of early settlement and agriculture such as Tigray, Wello, Gonder and northern Shewa. It is no coincidence that these areas were most severely affected by the droughts in the mid 1970s and mid 1980s.[12]

Under current agricultural practices, soil loss rates in Ethiopia are highest from cultivated land and are estimated at 42 t/ha*a on the average. Total soil loss from all land is estimated at almost 1.5 billion tons per year, of which 45% originates from cropland alone.[13] Of this soil loss, it is estimated that about 90% are deposited downslope,[14] and the remaining 10% of these sediments are leaving Ethiopia and transported to Egypt, where they will significantly reduce the original life-span of Lake Nasser.[15] Nevertheless, the impact of soil erosion on reducing soil depth, reducing water storage and removing nutrients, hence reducing soil productivity locally, are tremendous.

Not only soil degradation in the form of soil erosion is a major problem, but also chemical degradation,[16] mainly nutrient removal through eroded material and through the uptake of plants, physical degradation,[17] and biological degradation.[18] Pressure on arable land is growing because of population increases. More marginal areas have to be converted to arable land. On the one hand this leads to further soil erosion, on the other hand former areas used as grazing land are converted to arable land. Animals have to be fed for a longer period of the year from crop residues, which are thus lacking as a soil conditioner. Because forest resources are very few and further decreasing, people are forced to use animal dung as a fuelwood substitute. Organic matter is thus not brought back to the soil but used for other purposes. For the whole of Sub-Saharan Africa nutrient losses due to uptake by crops, erosion, leaching, and N volatisation are only partly compensated for by crop residues left on the field, manure and fertiliser application, and atmospheric input. It is estimated that the NPK balance is negative with minus 22-26 kg N, 6-7 kg $P_2O_5$, and 18-23 kg $K_2O$ per hectare and year for the period 1983-2000.[19]

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7 Oldeman, Hakkeling, and Sombroek, 1991, quoted in Scherr, 1999, 26.

8 Scherr, 1999, 25; Eswaran, Lal & Reich, 2001, 22.

9 Soil degradation is a narrower concept than land degradation, as land encompasses the natural environment including such factors as climate, topography, soils, hydrology and vegetation. Soil degradation is defined as a process which lowers the current and/or the potential capability of the soil to produce (quantitatively and/or qualitatively) goods or services of value to humans. (Douglas, 1994, 11; Drechsel & Gyiele, 1999, 2)

10 Juo & Wilding, 2001, 13.

11 Butzer, 1981, quoted in Hurni, 1988b, 36.

12 Hurni, 1988b, 37.

13 Hurni, 1987, quoted in Hurni, 1993, 37.

14 Hurni, 1989, 13.

15 El Swaify & Hurni, 1996, quoted in Mountain Agenda, 1998, 9.

16 Including salinisation and alkalinisation (which, however, in the Ethiopian Highlands are less pronounced), leaching, acidification and build up of particular metals or salts to toxic levels. (Douglas, 1994, 12)

17 Deterioration of the soil structure through trampling by animals, rain splash, excessive ploughing, which breaks down soil aggregates. (Douglas, 1994, 13.

18 Declining biological processes, decline in organic matter, humus mineralisation, or declining beneficial soil fauna. (Douglas, 1994, 14)

19 Stoorvogel & Smaling, 1990, quoted in Drechsel & Gyiele, 1999, 5.

For Ethiopia, several studies are available where costs of soil erosion and nutrient depletion at the national level have been calculated (cf. Section 4.5). Estimates of annual productivity losses on cropland range between 0.12% and 2%.[20] Based on these productivity losses, economic losses in monetary terms can be calculated. The most simple indicator, the Gross Annual Immediate Loss (GAIL), would result in annual economic losses ranging between US$ 1.7 million and almost US$ 15 million (at 1994 prices) or between 0.005% and 0.45% of the 1992 agricultural GDP. Gross Discounted Cumulative Losses (GDCL), assuming a constant annual decline of production, a discount rate of 10%, and a time horizon of 25 years would result in economic costs of US$ 141 million to US$ 1,245 million or 4.3% to 37.7% of the agricultural GDP of 1992.[21] A recent study calculating annual nutrient (NPK) depletion on the basis of inputs and outputs of nutrients, calculates annual costs in the order of US$ 328 million to US$ 378 million or 10% to 11% of the 1998 agricultural GDP.[22]

***Deforestation***

Deforestation is a process as old as human land use. Land has been cleared to gain arable land and grazing land. With increasing population and diminishing forest resources, fuelwood requirements exceeded the natural regeneration capacities of the last remaining forests. Nowadays, forest resources are concentrated on only 4.6% of the total land area.[23]

An often-heard and ever again quoted statement is that the forest cover in Ethiopia was about 40% in 1900. In-depth studies of accounts and reports written by European travellers in Ethiopia from the 18th century onwards,[24] and analyses and dating of charcoal found in soil accumulations[25] clearly indicate that land use was much more widespread and forest cover much lower already at the turn of the last century.

Nevertheless, deforestation continues at alarming rates. It is estimated that between 1990 and 2000 the forest cover was reduced by 0.8%, and that each year slightly more than 400,000 ha forest disappear.[26] Larger areas of natural forest[27] exist mainly in the western and south-western parts of the country. In the Highlands, natural forests are very rare and restricted to inaccessible areas, church groves and graveyards. To overcome shortages of timber and fuelwood especially for the growing towns, Eucalyptus was introduced in 1894/95.[28] Nowadays in many areas the forest cover is increasing again slightly because of state, communal and private Eucalyptus plantations.

***Overgrazing***

Overgrazing is especially serious in the densely populated areas of the northern and central Ethiopian Highlands. Especially in rainfall-insecure areas livestock is very vulnerable because feed resources are extremely low. A scenario modelling[29] estimates that without major investments in land rehabilitation, agricultural and livestock development, education and family planning, a livestock crisis – the demand of grazing land and animal feed exceeds by far the available resources – is reached about 15 years earlier than the cropland crisis – the growing population can no longer be supported from the available cropland. Even

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20 Kappel, 1996, 1 quoting the Ethiopian Highlands Reclamation Study (1986), Hurni (1988), Sutcliffe (1993) and Bojö & Cassells (1994).

21 Kappel, 1996, 4.

22 Drechsel & Gyiele, 1999, 69.

23 World Bank, 2001, Data and Maps Dissemination Branch.

24 e.g. Ritler, 1997, 2001.

25 e.g. Hurni, 1982a, 1987.

26 World Bank, 2001, Data and Maps Dissemination Branch.

27 Definitions of forests are manifold and no commonly accepted definition exists. A common characteristic of forest is the height of trees (between 10 and 50 m) and the relation between the crown diameter and the distance between trees (i.e. the distance between trees is smaller than the canopy diameter). (Ritler, 2001, 8; Hurni & Ludi, 2000, 96)

28 Ritler, 2001, 4.

29 Hurni, 1993, 46.

with higher investments in the agricultural sector the livestock sector is much more under pressure because each household needs one pair of oxen to be able to plough, a cow to guarantee reproduction of draught animals, an animal for transporting goods, and some sheep and goats as a reserve.

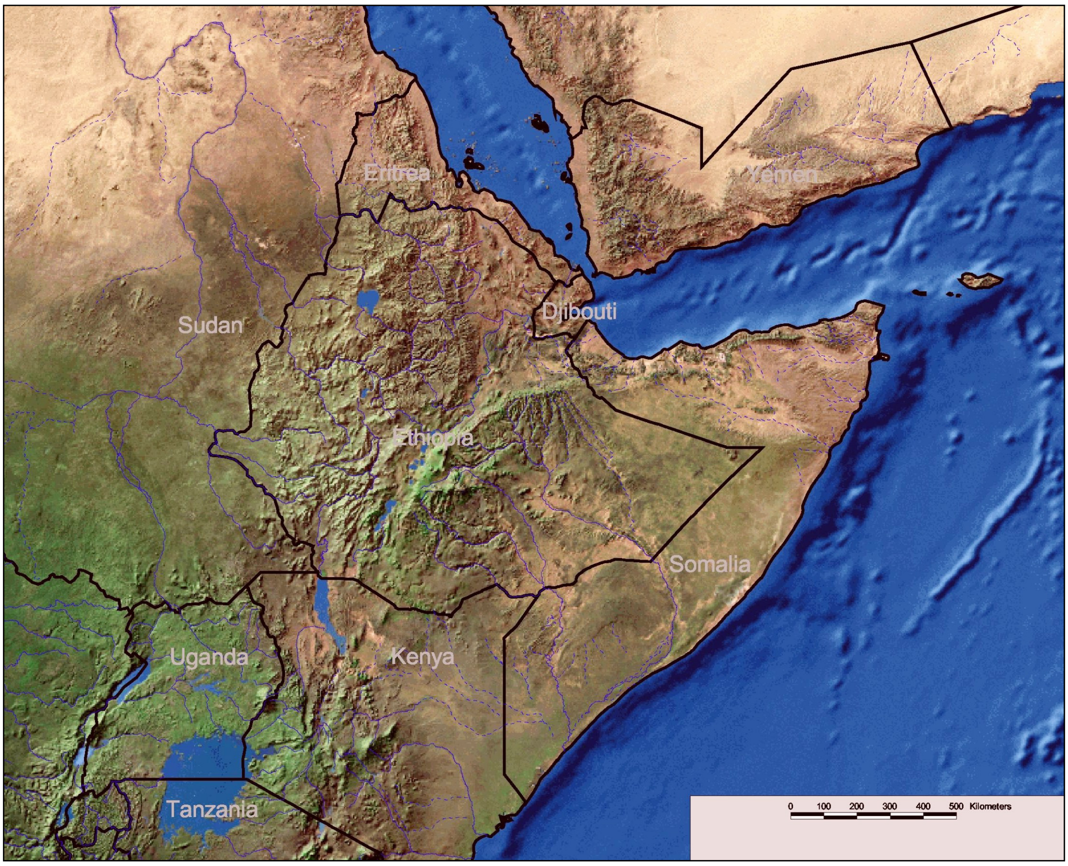


*Figure 2: The countries in the Horn of Africa. The highlands of Ethiopia and Eritrea can be clearly differentiated from the surrounding lowlands.*
*[Source: Digital Chart of the World, ESRI]*

### 1.1.2 Main development problems

Sub-Saharan Africa is considered by many concerned with development policy and co-operation to be a 'lost continent' because most development indicators show negative trends. National and international development activities in recent decades have been unable to halt these negative trends and concentrated more on combating symptoms.[30] Economic decline, falling per capita incomes and worsening social conditions have led many to characterise the 1980s as a 'lost decade' for Africa. In 1996, 48% of the population is estimated to live in absolute poverty,[31] and Africa is the only region in the world in which poverty is projected to increase over the next decade. The annual population growth rate of the African continent is the highest in the world, with serious negative implications for sustained economic growth and sustainable development of the region. 22 out of the 25 countries appearing in the UNDP's category of 'low human development' are on the African continent, as well as 33 out of the 47 Least Developed Countries (LDCs).[32] The proliferation of armed conflicts – between 1990 and 1995, 32 of the worldwide 97 armed conflicts were carried out in Sub-Saharan Africa,[33] and in 2000 it was 9 of 23[34] – and the human toll in terms of massive loss of human lives,

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30 Wiesmann, 1998, 23.

31 i.e. PPP is below US$ 1 per day. (DFID, 2000,12)

32 UNSIA, 1995. [http://www.undp.org/news/unsia01.htm#PartI.A]

33 Smith, 1997, quoted in Baechler, 1998, 7.

refugees and internally displaced persons have also strengthened the perception of Africa as a continent in turmoil and lacking in political stability.

However, this is only part of the African reality, and it is neither fair nor objective to label developments in the continent solely on the basis of these generalisations. Significant divergences in economic performance among countries are evident throughout the continent. In the past few years, growth rates in three countries have exceeded 8% p.a., 8 countries have reached between 6% and 8%; and a dozen countries have averaged between 3% and 6%. 35 African countries have been implementing structural adjustment programmes for more than a decade, and have succeeded in putting in place economic reform measures to correct fundamental economic imbalances and support private sector development.[35]

Many of the above-mentioned negative trends are also found in Ethiopia:

- Ethiopia is ranked 158 of the 162 countries for which the Human Development Index has been calculated in 1999. The per capita GNP is estimated at US$ 100 and the per capita GDP at purchasing power parity (PPP) at US$ 628. It is estimated that in 1995 31.3% of the total population had to live of less than US$ 1 per day.[36] Despite economic recovery during the past decade – between 1992/93 and 1995/96 the annual average growth rate of the GDP was 7.6%,[37] but for the whole decade 1990–1999 GDP growth on a per capita bases was only 2.4%,[38] which is below the population growth rate for this period – poverty is still widespread. An estimated 45.5% of the total population is living below the national poverty line, which is defined at 2,200 kcal food consumption per day.[39]
- The total population of Ethiopia is estimated at 64.4 million inhabitants in 1999 – the 16$^{th}$ biggest country worldwide with regard to population. Population projections estimate a total population of 88.1 million for the year 2015. The annual growth rate (1980-1999) is estimated at 2.7%. The dependency ratio is 1, implying that each adult person between 15 and 64 has to support one person either below the age of 15 or above 64.[40] 45.5% of the total population is below the age of 15. Life expectancy at birth is only 45.1 years. Of the total adult population between 15 and 49, 10.6% suffered from HIV/AIDS in 1999.[41] According to the Ministry of Health, the number of AIDS orphans has reached 1 million in 2001/2002. Ethiopia has the third largest population in the world with the HIV virus. Only India and South Africa have a greater number.[42]
- The dominant sector in Ethiopia is agriculture, which employs 83% of the labour force, contributes 53% to the GDP, and generates 90% of all exports.[43] Between 1992/93 and 1995/96, the agricultural sector grew by about 3.4% p.a.,[44] which was severely reduced between 1998/99 and 2000/2001 because of climatic irregularities and failing rain in some areas. Agricultural growth can barely meet the demand by a growing population. Self-sufficiency is a national goal, which will hardly be achievable under given conditions. Per hectare grain production is one of the lowest worldwide with around 1.2 tons.[45] Fertiliser consumption is with 16 kg per ha extremely low,[46] thus a potential still exists for raising production in future. The dominance of a subsistence orientated agricultural sector, no reserves, neither at the household nor at the national level, severe resource degradation, and many other factors make the rural economy highly

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34 SIPRI, 2001, 53.
35 UNSIA, 1995. [http://www.undp.org/news/unsia01.htm#PartI.A]
36 UNDP, 2001; World Bank, 2001, Data and Maps Dissemination Branch.
37 UNDP, 1997.
38 UNDP, 2001.
39 FDRE, 2000, 5.
40 World Bank, 2001.
41 UNDP, 2001.
42 IRIN News, UN Office for the Coordination of Humanitarian Affairs. [www.irinnews.org]
43 CIA World Factbook.
44 UNDP, 1997.
45 FAO, 2001.
46 WRI, 2000.

vulnerable to drought. Climatic irregularities such as the El Niño phenomenon can have serious impacts. Failing rains in 1999/2000 and 2000/2001 in south-eastern and eastern parts of the country led to more than 8 million people depending on food aid in 2001 and an estimated 5.2 million in 2002.[47] For the period 1984-99, 14% of the total cereal consumption was imported or constituted food aid.[48]

- The agricultural sector is not only of paramount importance for the national economy, but it is also the most important revenue source. The agricultural export sector is highly concentrated on a few commodities. Two-thirds of export revenues are generated by coffee alone. Coffee, hides and skins, *chat*, pulses and oilseeds generate more than 80% of the country's export earnings.[49] Worsening terms of trade, especially plummeting coffee prices on the world market[50] in comparison the growing import costs led to negative annual trade balances fluctuating between US$ 800 million and US$ 1 billion between 1994 and 1998.[51] Official external debt (excluding bilateral debt mainly owed to Russia for military purchases during the Soviet era)[52] amounted to US$ 5.5 billion in 1997. Its present value in 1999 corresponds to 374% of all exported goods and services. Annual debt service in 1999 amounted to 2.5% of the GDP or 17% of the exports of good and services.[53]
- Despite the overwhelming importance of the agricultural sector and the settlement area for over 80% of the Ethiopian population, rural areas are severely undersupplied with basic services and infrastructure. Only 24% of the rural population has access to safe drinking water. Access to health care is severely limited and biased towards hospital-based curative services in urban areas. Current levels of health are extremely low in rural areas. Infant and under-five mortality stands at 118 and 176 per 1,000, respectively. The adult literacy rate in Ethiopia is only 35%. Gross school enrolment ratios are 29% at primary level (less than half the Sub-Saharan average of 72%), 19% at junior secondary level, 9% at senior secondary level and less than 1% at tertiary level. Significant rural-urban differences exist, with Addis Ababa and other urban centres enjoying almost universal primary education while rural areas have an enrolment rate of only 18%.[54] It is estimated that about 75% of the rural population lives more than a half-day's walk from the nearest all-weather road away.[55] Spending on health and education has increased from 2.8% and 7% of the government budget in 1989 to 6.5% and 14% in 1998, respectively. Reforms in the fields of health and education are aimed at raising the level of service and coverage and at addressing rural-urban and regional disparities.[56] Since 1992, the government has taken several measures aimed at improving smallholders' productivity and livelihoods. They included removing government monopolies and restrictions on private trading and encouraging private sector participation in the agricultural input market. The Participatory Demonstration and Training Extension System (PADETES) was launched in 1994/95, mainly to increase farmers' use of fertilisers. Substantial resources for expanding rural credits were also made available. With the new policy, fertiliser consumption doubled between 1992 and 1999.[57] Despite all these measures and positive moves, rural poverty is widespread. Farmers lack alternative income sources. Positive impacts and a more sustainable management of resources is thus not expected in the short run considering the pressure under which rural households have to secure their livelihoods.
- Ethiopia's history of the 20th century is characterised by war and political struggles that affected the development of the country negatively. Italy occupied parts of today's Eritrea in the late 1880s, but was

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47 IRIN News, UN Office for the Coordination of Humanitarian Affairs. [www.irinnews.org]

48 FAO, 2001.

49 FAO, 2001.

50 Between 1998 and 2000, average coffee prices dropped from US$ 1.3 to US$ 0.8 per pound. (Charveriat, 2001,10, quoting the International Coffee Organisation ICO)

51 FAO, 2001.

52 Berhanu Abegaz, 2001, 184.

53 World Bank, 2001.

54 FAO, 2001.

55 UNCTAD, 2001, 27.

56 FAO, 2001.

57 FAO, 2001.

defeated in Adwa in 1896. In 1935 fascist Italy under Mussolini invaded Ethiopia again and occupied it until 1941, when the Emperor Haile Selassie returned from the exile in London. While Ethiopia became independent again, it was not until 1952 that the United Nations finally decided that Eritrea should be federated with Ethiopia. In November 1962, after intense pressure from Addis Ababa, the federation was ended, and Eritrea was absorbed into Ethiopia. Opposition in Eritrea grew, led at first by the Eritrean Liberation Front (ELF), later by the Eritrean People's Liberation Front (EPLF). Discontent inside the Ethiopian army and the handling of a devastating famine led to the overthrow of the emperor in 1974. Haile Selassie was replaced by a committee – the DERG – which became led by Mengistu Haile Mariam in 1977. After initial discussions with the Eritreans failed, the war continued and intensified. Mengistu's years in office were marked by a totalitarian-style government and the country's massive militarisation, financed by the Soviet Union and the Eastern Bloc, and assisted by Cuba. Communism was officially adopted during the late 1970s and early 1980s. Agricultural backwardness was the country's most urgent problem, and all attempts to reform the agricultural sector in a collective manner failed. Three years of severe drought, economic mismanagement and the mutual mistrust between the Government and Western aid agencies were the principal causes of the widely publicised famine in Ethiopia in 1984/85. The civil war mainly in northern parts of the country continued unabated until May 1991, when President Mengistu fled the country for Zimbabwe. Resistance from the remaining government forces crumbled and the Tigrinian-led Ethiopian People's Revolutionary Democratic Front (EPRDF) took control of the capital. In July 1991 the EPRDF leader, Meles Zenawi, was elected head of a transitional administration. Eritrea declared independence in May 1993. In Ethiopia, elections were held in 1994 to the new national Constituent Assembly. Fighting broke out in May 1998 between Ethiopia and Eritrea allegedly over land disputes and border violations. Underlying causes may include that Ethiopia was unhappy with Eritrea's introduction of its own currency in 1997, Eritrea still feared that its independence is under threat from Ethiopia, and the two leaders, despite having fought together against the DERG, grew apart over ideological issues. Just as the war resumed in 1999, reports emerged of serious food shortages in several regions of Ethiopia.[58] In 2000, a peace deal was signed, and UN peacekeepers were deployed along the disputed border. It is estimated that the war costs the two countries approximately US$ 1 billion. Military expenditures as a percentage of the GDP increased from 1997 to 1999 from 3.4% to 9% in Ethiopia, and from 13.5% to 23% in Eritrea, respectively. Besides costing 60,000 to 100,000 lives, between 800,000 and 1 million people were displaced within their countries.[59] At least two million landmines litter the countryside along the border. Some say there could be twice that number.[60] Both economies, which are fragile at best, and societies will suffer from the war for a long time.

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58 Historical summary based on US Department of State, 1998; Plaut & Gilkes, 1999.

59 SIPRI, 2001, 28.

60 IRIN News, UN Office for the Coordination of Humanitarian Affairs. [www.irinnews.org]

## 1.2 Development and Environment Interactions

> *"[...] natural resources, including agricultural (crop)land and especially pastures and forests, provide the main livelihood for most people in mountain regions world-wide. In recent decades, these resources have come under increasing pressure due to growing demands from mountain populations and from the surrounding lowland areas. There is a tendency towards increasingly unsustainable forms of use in many mountain areas [...]."*
> *(SDC, 2001,46)*

The above described environmental and development problems are not isolated but interact in various aspects. Although they cannot be separated, their valuation by different stakeholders differs greatly. For a small-scale farming household, declining productivity, ever growing pressure on land leading to declining farm sizes, and the need to produce enough to secure the survival of the household stand in the foreground. Lacking opportunities in other sectors of the economy forces farmers to gain their living from crop and livestock production. In order to secure their livelihoods and in absence of financial and human means which would allow farmers to take up alternative livelihood strategies or change their farming system, short-term needs have to be met which – with current technologies and management practices – overexploit the natural resource base which is the very foundation of the rural economy. This overexploitation of natural resources, which manifests itself in the form of soil degradation, declining forest cover, or reduced water availability, leads to declining crop and livestock productivity. From outside, the needs of small-scale farming households are not denied. However, because outsiders, be it government personnel, researcher, or development agencies, have a longer-term perspective, the conservation of the natural resource base gains more attention.

In an agrarian society like Ethiopia, interactions and dependencies between and among the environment and development become specifically obvious with regard to land and land degradation. Proximate causes for land degradation, especially soil erosion and nutrient depleting are manifold. They include soil characteristics (inherent erodibility and fertility), intensive and erosive rainfall especially early in the agricultural year where vegetation cover of the soil is low, the topographical characteristics of the highlands, overgrazing and deforestation, the cultivation of steep slopes, frequent ploughing, limited adoption of SWC measures, declining use of fallow, using crop residues as animal feed, using manure and crop residues as fuel substitute, and limited application of organic and inorganic fertilisers. Underlying causes for these problems include population pressure, poverty, limited market development, limited market access, land tenure insecurity and fragmented land holdings, lack of credit, short-term perspective of farmers, unavailability of appropriate and profitable technologies or inputs, lack of awareness on the side of farmers of such technologies, high costs for inputs and technologies, and difficulties to achieve collective action to manage natural resources.[61]

Because the interactions between the environment and development are so complex, solutions must necessarily also be complex. This makes it a specifically challenging task for government interventions as well as development cooperation, which are heavily involved in this field in rural areas of Africa. Technology promotion alone such as 'Green Revolution' technology packages or large-scale conservation campaigns such as those carried out in the Ethiopian Highlands between the early 1970s and late 1980s will not do. Although between 1976 and 1988 approximately 800,000 km of earth and stone bunds have been constructed on cultivated land, about 600,000 km of hillside terraces have been built for afforestations, 100,000 ha of land have been closed for natural revegetation, thousands of kilometres of check-dams have been built in gullies

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[61] Fitsum Hagos et al., 1999, 19.

and millions of tree seedlings have been raised,[62] the problem of soil degradation continues and still affects millions of rural households negatively. Today, only a fraction of these investments remains because of various reasons. Ethiopia is by far not the only place where past efforts of non-governmental, governmental and international interventions did not result in the desired growth of agricultural production, reduced poverty and improved environmental conditions. The realisation of this evoked reactions, which can be generalised into three general trends,[63] which can also be observed in Ethiopia:

- Concentration on humanitarian aid instead of development co-operation: Instead of continuing with rural development activities, many agencies concentrate on humanitarian aid. In the Ethiopian case this also has to do with the difficult political situation during the DERG era, when government control was strict and development agencies were not allowed to work in certain areas or fields that were considered as politically sensible. It is also an expression of the view that Africa is a lost continent and Ethiopia a lost case.
- Concentration on local initiatives to circumvent governmental institutions: Because government interventions in the field of soil conservation were considered a failure, a re-orientation towards the grass-root level has taken place with many development agencies. It is also mirrored in the Ethiopian policy of re-orientation of rural development and the concentration on the promotion of indigenous technologies and participatory approaches. It is argued that farmers have developed over centuries adapted technologies that fit the households' needs and assets and the agro-ecological circumstances much better than introduced technologies.
- Concentration of economic boundary conditions and governmental decision-making: This strategy is based on the conviction that poverty and resource degradation is a result of unfavourable economic and political structures. Remedy is seen in structural adjustment programs, privatisation and decentralisation, which is fostered by the World Bank, the International Monetary Fund, but also by bilateral co-operation agencies.

These above-mentioned trends in development are a reaction to the realisation that the linkages between environment and development are so complex. It must be postulated, however, that neither way alone will contribute enough to solve the major environment and development problems in Ethiopia. A comprehensive approach, whereby the various initiatives are co-ordinated to both address the development problems and the environmental problems will be necessary.

Although the present study, which was carried out within the framework of the Soil Conservation Research Programme (SCRP) can be seen as a reductionist approach in simply evaluating SWC technologies with regard to its economic performance, it is still believed that it contributes to the overall goal of environment and development. The evaluated technologies can be excellent with regard to their ecological performance, if they do not contribute enough to the farmer's well-being, they must be considered as insufficient.

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62 Hurni, 1988, 37; Hurni, 1993, 38.

63 Wiesmann, 1998, 30.

## 1.3 The Soil Conservation Research Programme (SCRP)[64]

*"Since the establishment of the first research site in 1981, the SCRP has built a huge resource database. Contrary to the size and quality of the database, the number and distribution of research sites is still too few for a large country with a rugged terrain like Ethiopia."*
*(Gete Zeleke, 2000, 29).*

As a reaction to increasing resource degradation and alarmed by the devastating effects of the drought in 1972/73, the Ethiopian government launched with the support of international and bilateral agencies a massive programme for afforestations and soil conservation. In the mid-1970s, the World Food Programme (WFP), and later FAO, the European Community and others became involved in the conservation and rehabilitation programme and contributed to the efforts undertaken by the government.[65]

Large campaigns were initiated and supported by the WFP, whereby few soil and water conservation (SWC) technologies were promoted. But the SWC technologies were applied too rigidly in this campaign and no consistent research activities existed with regard to soil erosion and soil conservation. The need to assess the efficiency of SWC technologies and elaborate possible improvements of SWC technologies and approaches was a major reason for the Ethiopian Government to invite the Swiss Agency for Development and Cooperation (SDC) to help establish a national research network through the University of Bern, which was founded in 1981. The main objective of the SCRP was

*"to support soil conservation efforts in Ethiopia by monitoring soil erosion and relevant factors of influence, by developing appropriate soil and water conservation measures, and by building local and international capacity in this field of research."*[66]

### 1.3.1 Concept and methodology of the SCRP

One main aim of the SCRP from the beginning in 1981 was to respond to urgent needs, such as the development of SWC technologies that are technically feasible, ecologically sound, economically viable and socially acceptable. The research concept of the SCRP involved the selection of benchmark sites with various socio-cultural settings in several different agro-climatic zones of the country. Accordingly, test catchments with traditional land use systems and a size between one and 7 $km^2$ were chosen. Soil erosion and other related variables were monitored in these catchments. The sites were observed without SWC for a period of one or more years, as well as for several years after SWC measures had been implemented by the WFP. The SCRP benchmark sites (cf. Figure 3) were selected in Maybar / Wello (1981), Hunde Lafto / Harerge (1982), Andit Tid / Shewa (1982), Anjeni / Gojam (1984), Afdeyu / Eritrea (1984), and Dizi / Illubabor (1988); another site was taken over from the Wolayta Agricultural Development Unit (WADU) in Gununo / Wolayta (1982).

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64 If not otherwise noted, the following Section is an excerpt from SCRP, 2000a.

65 Hurni, 1989, 6.

66 SCRP, 2000a, 3.

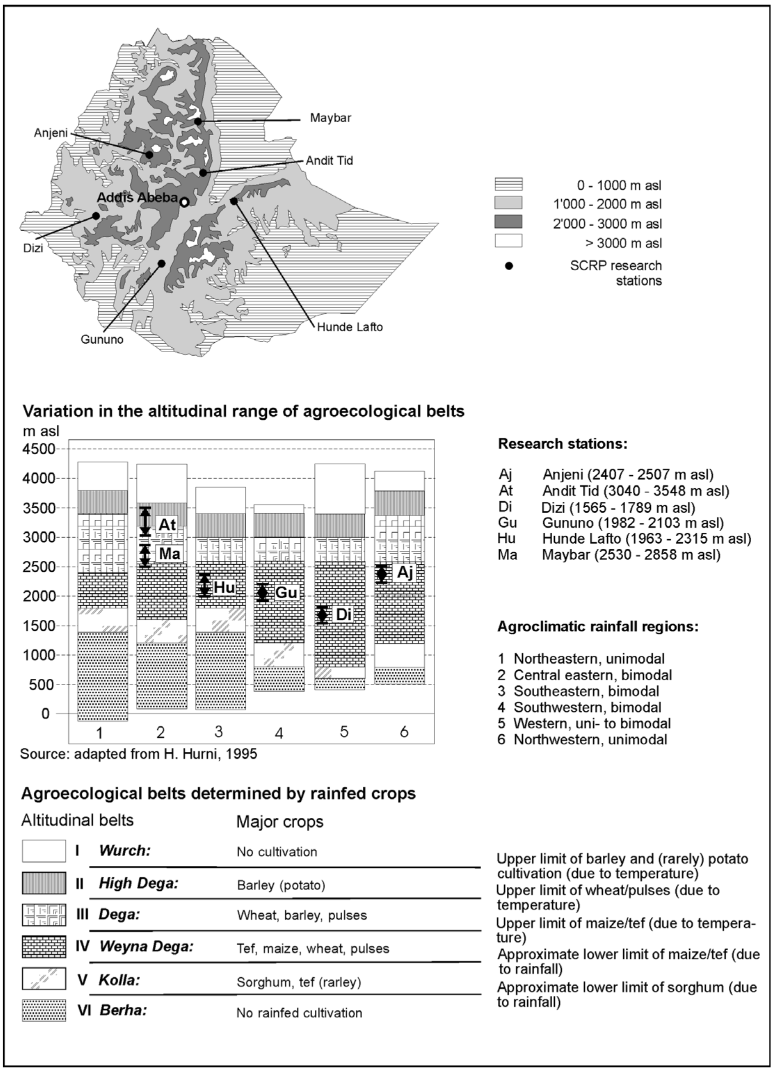


*Figure 3: Location of SCRP benchmark sites.*
*[Source: SCRP, 2000a, 6]*

The research programme was implemented with as little disturbance of the catchments and the farmers' fields as possible; all experiments were on-farm instead of on-station. The programme mainly monitored runoff / river discharge and soil loss / sediment yield at different scales, on different slopes and soils, under various land uses and crops, and under several SWC treatments. Parallelly, climatic data such as the amount, erosivity, intensity, inclination and direction of rainfall, air and soil surface temperature, wind direction, evaporation and duration of sunshine were recorded to interpret the erosion measurements. Land use was mapped for each cropping season. Throughout the catchment, crop yield and biomass samples were collected to monitor production of the major crops. The general status of soil degradation was determined through soil surveys. Current soil erosion was measured on test plots and at the hydrometric station. This allowed to determine the average patterns of soil erosion, for example by calculating mean annual and monthly results. Extreme patterns of erosion were determined by analysing the impact of the most severe rainstorms (critical times), and by mapping erosion rills at critical locations right after such extreme erosion periods.

In addition to the standard programme described above, the SCRP responded to site-specific research needs with a supplementary programme. Population and livestock dynamics, household land management strategies, attitudes towards and perceptions of SWC, as well as reactions to policy changes were documented specifically. Specific studies covered other relevant topics, such as agronomic SWC measures, indigenous SWC measures and strategies, soil fertility, erosion modelling, environmental education, and many more. The SCRP used a programme hierarchy with different research levels (cf. Figure 4):

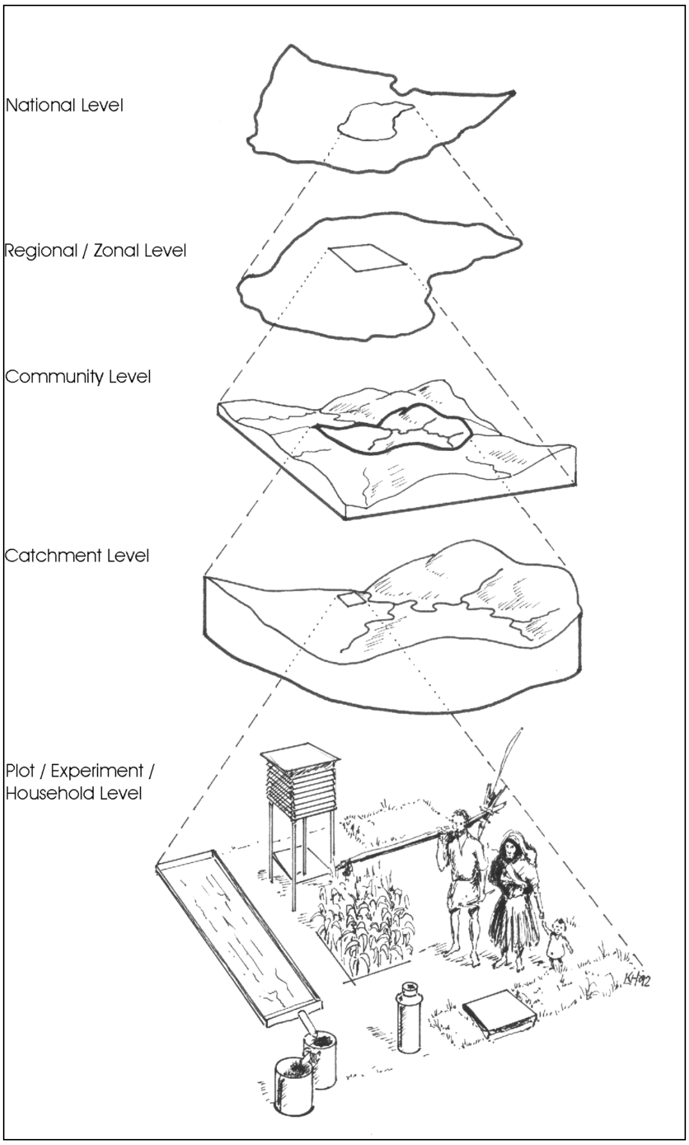


*Figure 4: SCRP research levels. [Source: SCRP, 2000a, 9, quoting Herweg & Hurni, 1993]*

- Outputs at the *national* and *regional / zonal* levels are for example an agro-ecological belt map at a scale of 1 : 1’000’000 and a study of rainfall erosivity. Climatic, land use/land cover, geomorphological, erosion, and demographic information are provided in a digital form as part of a Geographical Information System (GIS).
- Outputs at the *intermediate / community* level are for example topographic maps, soil maps, and demographic data. More detailed surveys were conducted to assess peasants’ perceptions of the environment, to study their response to environmental problems, and to determine social, economic, cultural and political limitations to SWC.
- At the *catchment* level, the SCRP monitored river discharge and sediment yield as well as land use, different parameters of vegetation, and production. Spatial patterns and immediate causes of soil erosion were documented after erosive rainstorms (assessment of current erosion damage: ACED).
- Climatic data are recorded at the *plot / experiment / household* level. The impact on soil erosion and production of land use, vegetation, slope gradient, soils, SWC measures and various agronomic parameters was measured on test plots, micro-plots and experimental plots. Socio-economic aspects such as land users’ SWC strategies and the range of technical options available to them were investigated at the household level.

At the lowest level of the plot or household, the research approach is based on the acknowledgement that ultimately it is the household deciding about the land use and management system, and therefore about the level of resource degradation. Farmers take these decisions under consideration of various frame conditions such as the physical environment and the socio-cultural and policy environment (cf. Figure 5).[67]

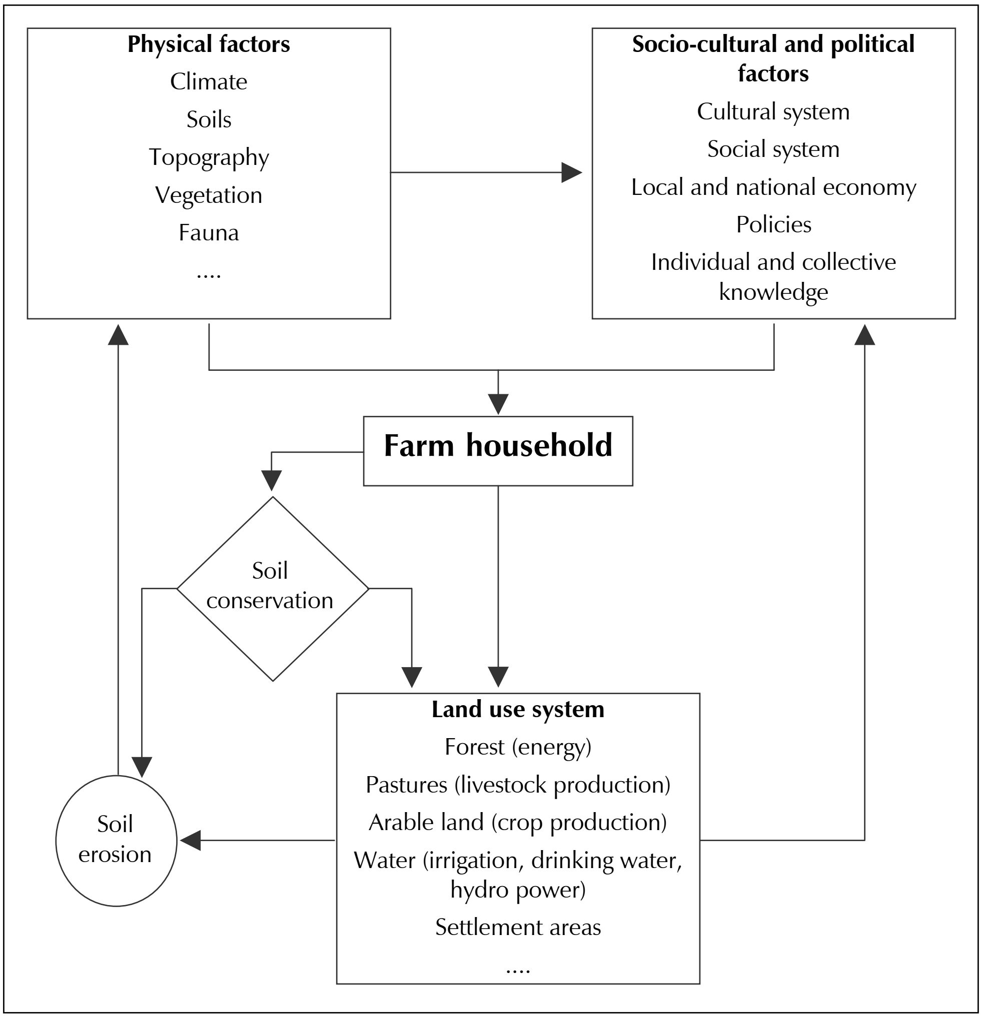


*Figure 5: The SCRP research approach at the local level.*
*[Source: Herweg & Hurni, 1993, 45, adapted]*

### 1.3.2 Development and improvement of SWC technologies

An important aspect of the SCRP was the testing of various conservation technologies with regard to their effect on soil loss and runoff and on yield and biomass production. In the 1970s and early 1980s, the large-scale conservation campaigns propagated a single technology for arable land all over the country irrespective of socio-economic and agro-climatic characteristics – contour soil and stone bunds. A goal of the SCRP was thus also to develop appropriate soil and water conservation measures.

Besides the development of guidelines with regard to the proper layout and construction of contour bunds, as well as guidelines for selecting the most appropriate SWC technology for various agro-ecological zones,[68] a major innovation of the SCRP was the introduction of the Fanya Juu type of bund. Instead of the typical design of bunds, whereby an embankment is made of soil and/or stones along the contour with a basin at its upper side, the Fanya Juu, ("throw uphill" in Swahili language) was propagated, whereby the soil is

[67] Herweg & Hurni, 1993, 42.

[68] SCRP, 1982, 33ff; Hurni, 1986a.

moved uphill so that the basin is below the embankment (cf. Figure 6). The major advantage of this SWC technology over the bund is that the development of sloping bench terraces is enhanced. Eroded material from upslope is deposited behind the embankment. Overflow is collected in the ditch below the embankment. Runoff in the ditch is either retained in the case of level structures, which are recommended for dry areas, or drained laterally in the case of graded structures, which are recommended for areas with higher rainfall. Whenever sediments are deposited in the ditch below the embankment, the embankment must be raised with the deposited material from the ditch. This new technology was first applied at a larger scale in Andit Tid research area as graded structures with a gradient of 1 to 5% leading to a natural or artificial waterway to safely drain the excess runoff.[69] Later, Fanya Juu bunds were also constructed in other high-rainfall areas such as Anjeni.

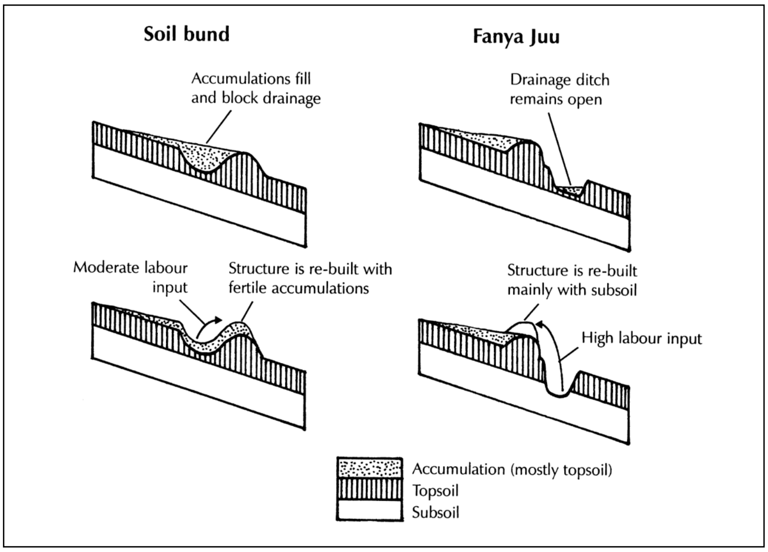


*Figure 6: Comparison of soil bund and Fanya Juu bund and the major differences in terrace development. [Source: Herweg & Ludi, 1999, 111, drawings by K. Herweg]*

### 1.3.3 Methods of measurement and observation

A vide variety of data was collected in each research station (cf. Appendix 3.1), of which only those which are relevant for this study will be briefly discussed (for further details refer to SCRP, 2000a).

***Land use and crop production***

The dynamics of land use and the approximate agricultural production within the research catchments were derived from seasonal land use mapping and harvest yield measurements. Production data (crop yield and biomass production, in t/ha) were collected after each cropping season for all major crops produced in the research catchments. Samples were taken on all runoff plots (harvesting the whole plot area) and on farmers' fields (harvesting a defined area of 4 to 9 $m^2$). When the crop was ready for harvest, it was cut and collected in the same way as the farmers in the respective catchment do it. All plants of each sample area were collected, including weeds. The samples were exposed for about 20 days to the sun, and the grain (including the cover) was separated from the rest by hand. The sundry weights of grain with cover on the one hand, and the straw on the other hand, were recorded. Then, the grain was separated from the cover by hand, and separately weighed and recorded. Finally, the grain and all of the biomass were returned to the respective farmers.

69 SCRP, 1984, 60; Hurni, 1986a, 44.

***Soil erosion and soil and water conservation***

Research on soil erosion and soil and water conservation (SWC) required a multi-level monitoring approach. Various devices (test plots, hydrometric stations, sediment troughs) or methods (assessment of current erosion damage – ACED) make it possible to examine soil erosion and SWC from different angles. Results gained with these methods eventually need to be interpreted together to get an overall idea of the order of magnitude, as well as of the temporal and spatial dimensions of soil erosion. The order of magnitude of this process is usually described by four main indicators. These are soil loss and runoff measured on plots, as well as sediment yield and river discharge measured at the hydrometric station. With sediment troughs and ACED only soil loss is determined.

By monitoring these indicators (variables) over a longer period of time in the SCRP sites, the impact on soil erosion of certain types of land management (on test plots, micro plots) or of SWC measures (on experimental plots) under specific situations (soil type, slope gradient, etc.) was evaluated. On the one hand, plot results generally refer to on-site erosion damage,[70] i.e. where soil erosion took place, and to the performance of protective measures.[71] In addition, rill mapping produced information about critical locations on-site.[72] On the other hand, hydrometric station data indicate the amount of water and sediment that left a highland catchment. This hints at the quality of land management including SWC on-site, as well as at potential off-site or downstream effects.[73]

***Soil loss*** and ***surface runoff*** were recorded on plots representing different land uses, soil types, slope lengths and gradients, and conservation measures. In their vicinity an automatic rainfall recorder (pluviometer) was established to be able to link the rainfall and runoff measurements. The SCRP standard programme involved 3 plot types:

- 4 Test plots (TP), 30 $m^2$ (2 x 15m)
- 2 Micro plots (MP), 3 $m^2$ (1 x 3m)
- 6 Experimental or soil conservation plots (EP): 180 $m^2$ (6 x 30 m)

The number of plots was different in Anjeni (4 TP, 2 x 4 EP). Corrugated iron borders defined the area under consideration for the measurement. They were inserted into the ground and could be removed when farmers performed fieldwork. Runoff and soil loss were collected in tanks at the lower end of the plot through an inlet tube. Activities related to the monitoring of test and micro plots were operated by the research assistants. Runoff and soil loss were measured (= tanks were emptied) when rainfall exceeded 12.5 mm, or when there was more than 20 cm of runoff water height in the collection tanks. Thus, it was not possible to collect runoff and soil loss for each storm. Instead, data was collected on storm periods that comprised one to four single storms.

***Soil conservation and water management***

The impact of selected soil conservation measures on soil loss, runoff, crop yield and biomass production was tested on experimental plots (EP) of 180 $m^2$ (6 x 30 m) each. In all stations, except Anjeni, the performances of level bund, level Fanya Juu, graded bund, graded Fanya Juu and grass strips were monitored against a control plot representing the prevailing farming practice. These measures represent those introduced SWC structures that are most widely used in the Ethiopian highlands. In Anjeni, a high rainfall area, only graded structures were tested. The EPs represent the standard SCRP conservation experiment. In addition, several other conservation trials adapted to the situations in selected SCRP research sites were conducted.

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70 Herweg & Stillhardt, 1999.

71 Herweg & Ludi, 1999.

72 Herweg & Stillhardt, 1999.

73 Bosshart 1996.

***Social and economic characteristics***

Under the SCRP standard programme, socio-economic information was gathered at irregular intervals using random sampling techniques. More detailed information was collected under the supplementary programme in detailed case studies. Data were generated using formal questionnaires supplemented by observations and informal discussions, both with individuals and with groups.

Between 1981 and 1990, demographic data (population size / age and sex structure / age and sex of household head) as well as data on livestock holdings (livestock type / herd size / number of oxen per family) were collected by research assistants. The basis was a list of households that farmed in the catchment. Additional information on relevant topics was collected in a supplementary programme. Quite a number of case studies exist that address socio-economic and cultural issues, land management systems, implementation of SWC measures and their acceptance by farmers, and their implications for SWC research and policy.

Following the severe droughts of 1972/73 and 1984/85, SWC measures in Ethiopia were broadly introduced by the government, mainly through mass Food-for-Work campaigns. Discussions as to how far the measures were truly accepted by farmers soon followed. The concept of 'acceptance' has never been clearly defined. The main reason for this may be that 'acceptance' – or its opposite 'rejection' – does not reflect reality. Farmers often took part in a process where new SWC measures were tested, in many cases they eventually merged the measures with their own traditional SWC techniques. But farmers did not simply accept or reject the measures, they rather 'modified' or 'adapted' them. Consequently, there was a need to move away from the too simplistic concept of adoption versus non-adoption. In the 1990s, the SCRP initiated studies on SWC 'adaptation', how and to what extent different communities and households manage soil erosion.[74] At the conceptual level, it was seen that:

- Farmers' use, maintenance and development of SWC must form the core of any new research activity.
- The adaptation of SWC measures, their modification and the reasons why they are modified must constitute the main focus of research.
- Besides the meso-level (catchment), more importance should be given to investigating at the 'micro-level' (household and plot).
- Potentials and limitations of SWC must be examined at different levels: community (addressing the question of awareness), household (addressing the question of means), and plot (addressing the question of technologies).
- Independent / indigenous variables must be separated from dependent / external variables to clarify how much SWC is the result of the communities' own histories, or of a government input instead.

Based on this conceptual development with regard to socio-economic aspects related to SWC, the present study has been formulated. It concentrates on farmer's incentives to either degrade or conserve the land. It is based on the realisation that even the best technology with regard to ecological performance must be also economically attractive to small-scale farmers. Further, it is assumed that the economic and institutional environment play an important role with regard to the economic behaviour of small-scale farming households whether or not to invest in SWC.

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[74] Yohannes G / Michael, 2000; Yohannes G / Michael & Herweg, 2000.

# 2 A Description of the Case Study Areas

## 2.1 Location of the Case Study Areas

The research areas are all located within the highlands of Amhara National Regional State (ANRS) (cf. Figure 7). ANRS is one of the constituent states of the Federal Democratic Republic of Ethiopia (FDRE) located in the central and northern part of the country bordering Tigray in the North, the Republic of Sudan in the West, Benishangul/Gumuz in the Southwest, Oromiya in the South, and Afar in the East. The state is divided in 11 administrative zones, including the capital city, Bahrdar. These zones are further divided in districts (105 Weredas, of which 48 are classified as drought prone and food-insecure). The Weredas are subdivided in rural and urban associations (5,300 Kebele Associations, KA). The total area of ARNS is 153,475 km$^2$, of which 73% is located above 1,500 m asl.[75] Of the total area of the region, 27.3% is under cultivation, 30% is under grazing, 14.7% is covered by forest and bush, and 18.9% is currently not used for productive purposes. The remaining 9.1% represents settlement areas, swampy areas, and lakes.[76] The population of the region was estimated to be 15 million in 1998/99. Of these, 90.3% live in rural areas. Mean population density is 91 persons/km$^2$ (ranging between 39 and 151 persons/km$^2$). Persons below the age of 25 years make up more than 65% of the total population.[77]

The majority of the population of Amhara Region depends upon crop and livestock farming. Cropping systems are predominantly rainfed. Farmers produce a combination of cereals, pulses and oilseeds. Cereals account for the largest percentage of cultivated area (84.3%) and total production (85%). About 28% of the livestock of Ethiopia, which is estimated at 29.8 million cattle, 11.5 million sheep, 9.6 million goats, and 3.9 million equines, are found in Amhara Region.[78]

Three of the five case study areas, namely Maybar, Andit Tid, and Anjeni are research sites of the Soil Conservation Research Programme (SCRP) (cf. Section 1.3, Figure 3). Andit Tid and Maybar are located on the mountain ridge between the eastern lowland and the Nile Gorge to the west. Anjeni is located on the slope of an isolated mountain massif, the Chocke Mountains in the central highlands. The study area of Simen is a bigger area in the northern part of Amhara Region inside and around the Simen Mountains National Park (SMNP). Simen forms a massif within the Highlands with the highest mountain of Ethiopia, Ras Dejen (4,533 m asl). Mesobit & Gedeba is the lowest site, located at about 1,800 m asl. on the footslopes of the eastern escarpment and bordering pastoralist areas of the Awash basin. Within the Highlands, the five study sites differ in various aspects, but also show similarities, as Table 1 shows.

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75 Ethio-GIS, 2002.

76 UNECA, 1996, quoted in Tesfaye Zegeye et al., 2001, 4.

77 BOPED, 1999, quoted in Tesfaye Zegeye et al., 2001, 4.

78 USAID, 2000, 3.

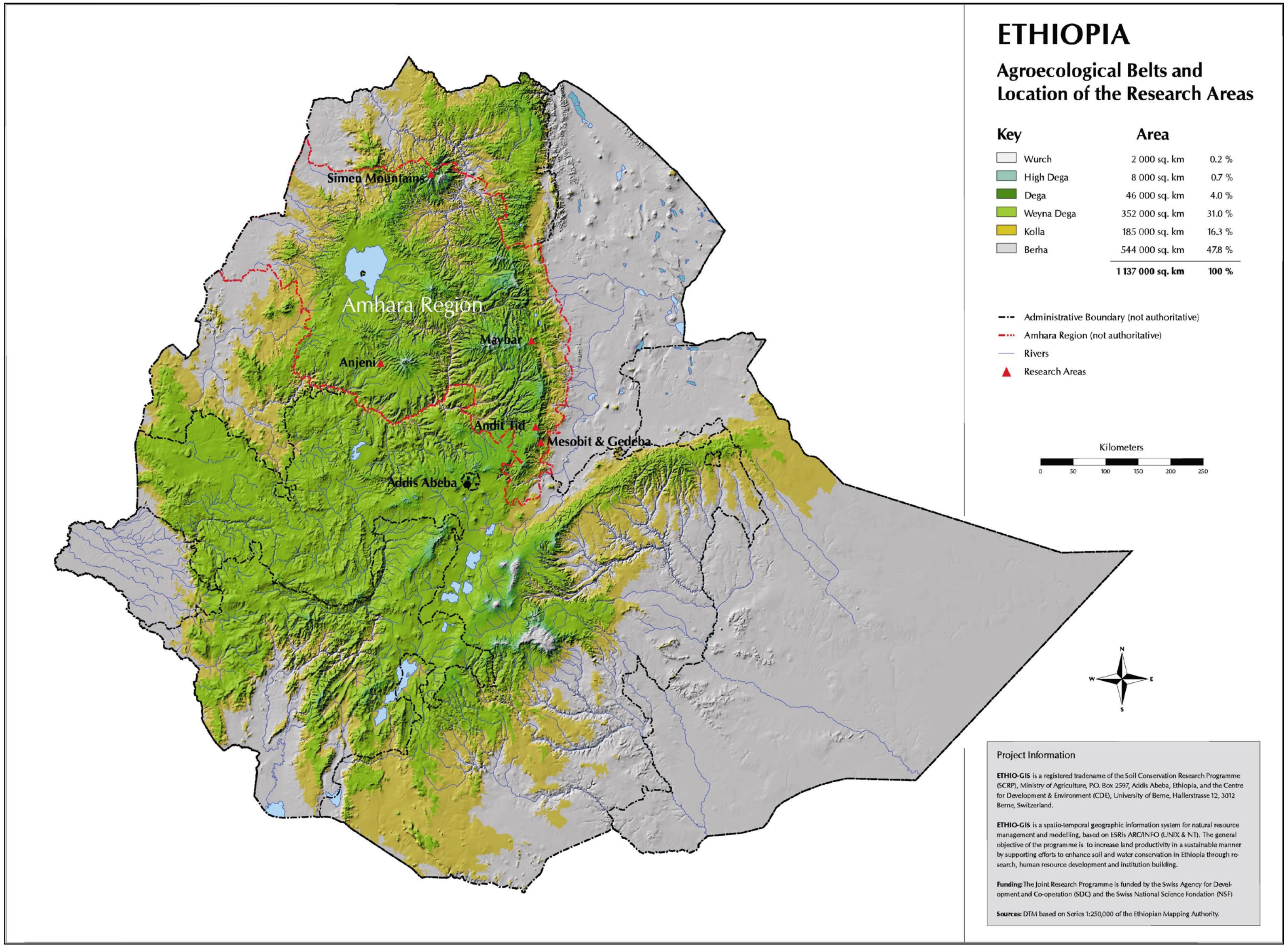


*Figure 7: Agro-ecological belts of Ethiopia and the location of the five research areas in Amhara Region. [Source: Ethio-GIS, CDE]*

## 2.2 General Characteristics of the Cases Study Areas

| | **Maybar** [1)] | **Andit Tid** [1)] | **Anjeni** [1)] | **Mesobit & Gedeba** [2)] | **Simen** [3)] |
|---|---|---|---|---|---|
| **Location** | Eastern Highland | Eastern Highland | Central Highland | Eastern Escarpment | Northern Escarpment |
| **Administrative Zone** | South Wello | North Shewa | West Gojam | North Shewa | North Gonder |
| **Altitude (m asl)** | 2,400–2,600 m | 3,000–3,600 m | 2,500–2,600 m | 1,800–2,600 m | 1,500–4,400 m |
| **Agro-climatic zone**[79] | moist Weyna Dega / moist Dega | wet Dega / wet high Dega | wet Weyna Dega | Kolla - Weyna Dega | Kolla – Wurch |
| **Climatic characteri-sation** | two rainy seasons (March-April, June-September) ∅ 1,150 mm/a | two rainy seasons (March-April, June-September) ∅ 1,340 mm/a | one rainy season (May-September) ∅ 1,650 mm/a | two rainy seasons (March-April, June-August) 900 – 1,200 mm/a | one rainy season (June-September) 900 - 1,600 mm/a |
| **Landscape** | flat plain around lake, steep slopes above 2,400 m asl, rolling topography | steep slopes below 3,300 m asl, relatively gentle slopes above 3,300 m asl | undulating hills | steep slopes above 2,000 m asl, relatively flat footslopes below 2,000 m asl | deep incised valleys below 2,000 m asl terrace like steps at 2,000 m asl steep escarpment undulating plains above 3,000 m asl |
| **Soils** | Phaeozem, Gleysol, Cambisol | Andosol, Lithosol, Regosol, Cambisol | Alisol, Nitosol, Cambisol, Regosol | no information available | Andosol, Leptosol/ Regosol, Phaeozem/ Regosol |
| **Soil erosion** [*)] | av.: 2 t/ha*a min: 1 t/ha*a max: 4 t/ha*a | av.: 48 t/ha*a min: 2 t/ha*a max: 140 t/ha*a | av.: 110 t/ha*a min: 59 t/ha*a max: 167 t/ha*a | no information available | av.: 70 t/ha*a min: 22 t/ha*a max: 123 t/ha*a |
| **Dominant ethnic group** | Amhara | Amhara | Amhara | Amhara, few Argoba | Amhara |
| **Religion** | Muslim | orthodox Christian | orthodox Christian | orthodox Christian | orthodox Christian and Muslim |
| **Dominant economic activity** | subsistence farming | subsistence farming | subsistence farming | subsistence farming | subsistence farming |
| **Market integration** | very low | very low | low | medium | extremely low |

*) Maybar, Andit Tid and Anjeni: Measured values on Experimental Plots (6 x 30 m), averages for 1986-89, 1987-91, and 1986-90, respectively, local cultivation practice (Herweg & Ludi, 1999, 105). Simen: Soil erosion rates calculated using the USLE Model adapted to Ethiopia (Hurni, 1985).

*Table 1: Characterisation of the five research areas.*
*[Sources: [1)] SCRP, 2000b, 2000c, 2000d; [2)] own survey data; [3)] Hurni & Ludi, 2000]*

[79] Hurni, 1986a.

### 2.2.1 Farming system and household economy

The dominant characteristics of the farming system in all research areas can be described as follows:

- subsistence oriented and family- or household-based;
- predominantly mixed cultivation of cereals, pulses and oil seeds;
- integration of livestock and crop cultivation;
- ox-drawn plough;
- use of highly adapted, low-cost technology;
- low integration in a larger economic system:

In all study areas, the predominant activity of the rural population is subsistence farming. The term 'subsistence-oriented farming system' means a farming system tailored mainly to meet the needs of household members. Needs not only comprise consumption for survival, but also include the production of surpluses (i) to meet social obligations, (ii) to sell in order to buy goods that cannot be produced on the farm, and (iii) to accumulate goods or capital which can be used as reserves for times of poverty and hardship. These needs are fulfilled almost entirely through crop cultivation and livestock production. Crop cultivation meets most food needs, while livestock is a possibility to accumulate reserves or wealth. However, crop cultivation and livestock keeping cannot be separated. Oxen are used as draught animals for ploughing, crop residues are used as fodder, manure is the only source of fertilizer, and animals are grazed on fallow fields, because in many villages almost no separate pastures exist. The combination of crop production and livestock keeping is an optimal strategy to diversify income and to spread risk. It is especially important at times of stress, e.g. if yields are inadequate.

The major part of the income of rural households in the research areas is generated on-farm and used to cover subsistence needs. Additional income is generated either on-farm (production of marketable products such as *gesho*, *chat*, specific oil-seeds, fuel wood and construction wood, etc.) or off-farm (e.g. trading, construction business, handicraft, tourism). The additional income gained from such sources is rarely more than 5 to 20% of a household's income. Households spend the majority of financial resources for consumption goods rather than production inputs.

The number of family members determines both the required minimal level of production, as well as the available amount of labour force. At community level various forms of collaborative work on a reciprocal exchange basis exist for certain activities (e.g. clearing fields, ploughing, harvesting). Otherwise, all tasks are fulfilled within the household. Unpaid family labour is the most common source of labour within a farm household. Only few farmers are in a position to hire farm labourers. A clear labour division exists based on gender. Men are usually responsible for fieldwork, whereas women are mainly responsible for childcare and house care, including the preparation of food, collection of firewood, and fetching of water. Besides these tasks, women are often also responsible for certain fieldwork such as weeding and transporting the harvested grain to the threshing ground. Usually men are engaged in off-farm activities as well as in local political and administrative activities. Many households depend on the help of their children. Boys are looking after animals and girls help their mother. Small families are often forced to keep their children at home and cannot send them to school as they depend on their labour force.

Farm technologies are simple but well adjusted. The ox-drawn plough (*maresha*) only scratches the surface but does not turn the soil. Fields are usually ploughed three to five times along the contour before sowing. This gives a fine seedbed and enhances water infiltration. However, this is also a cause of severe erosion. Ground cover is low after sowing, just at the same time the heaviest rainfall occurs. In very steep areas, fields are hacked by hoe. Whenever possible crop residues and grass are left on the field, which serves as ground cover and mulch to reduce soil loss. Mostly, however, crop residues are harvested as well and used as animal fodder. Maize and sorghum stalks are often used as fuel. Irrigation is not common in the research areas with the exception of Mesobit & Gedeba and Maybar.

### 2.2.2 Resource degradation

All research areas are characterised by considerable resource degradation. Simen is the only area where natural vegetation is still present in its original state. Of the research area, 11% is still covered with forest and an additional 8% with bush.[80] In the other areas, natural vegetation has mostly been cleared to gain grazing land and arable land. Remaining forests and bush areas are heavily utilised to collect fuelwood and construction wood and are often used as grazing areas, thus re-growth of trees is severely hampered.

Population increases during the past decades has increased the pressure on natural resources, especially arable land. People are thus forced to plough more and more areas unsuitable for crop cultivation[81] and arable land has to be used more intensively. Fallow periods are shortened, if not abandoned altogether. The consequences are various forms of soil degradation. On sloping arable land soil erosion is a severe threat to future crop production. Chemical degradation, i.e. nutrient mining is another characteristic. Crop residues are excessively used as fodder and cannot be used as soil conditioner, because former grazing land has been converted to cropland, but livestock numbers increased almost parallel to the increasing human population, thus reducing the availability of animal feed. Fuelwood demand can no longer be met from remaining small forests and bushland. People are forced to use animals dung as a fuel substitute. Soil organic matter content is decreasing alongside with other soil nutrients.

Reduced vegetation cover and decreasing soil depth lead to reduced water storage. Rainfall is lost excessively as runoff.[82] Reduced water storage is not only limiting biomass production, it also leads to drying up of springs and small streams, forcing women to walk longer distances to fetch water. Reduced water availability also increases the health risk both for people and for animals. And lastly, reduced water availability destroys the irrigation potential in many areas where it would be necessary to increase overall production.

Because people are forced to cultivate more land, a serious competition over grazing land emerges. In most instances grazing land is reduced in favour of cropland. As livestock numbers increase, pressure on remaining grazing land is tremendous. Degradation is of grazing land is widespread and vegetation cover is so low that it is no adequate soil protection anymore, thus leading to severe erosion damage as well. Grazing land is often the source of concentrated runoff, creating considerable damage downslope. Animal paths are often a starting point for rill and gully erosion because water is concentrated in a linear manner.

### 2.2.3 Organisational and institutional aspects

The research areas are all part of a Kebele Association (KA, former Peasant Association), the lowest administrative unit. Each KA has an elected executive body consisting usually of a chairman, a vice-chairman, a secretary, and 5 to 6 members representing various branches of the government administration (e.g. a member representing the Ministry of Agriculture, one for social affairs, and one for development and self-reliance). Each KA also has a local court, the *shengo,* consisting of 3 to 5 respected members, to solve minor disputes and a local militia responsible for policing and security. The KA structures are a more recent element introduced by the government on a low intensity level since 1976, and more intensively since 1992. A major responsibility of the KA besides normal tasks such as tax collection or maintaining law and order is to organise

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80 Hurni & Ludi, 2000, 50.

81 Whereby suitability is defined with regard to specific land use types (e.g. an area can be unsuitable for annual grain crop cultivation but suitable for grazing land). *"Highly suitable = Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level."* (Landon, 1991, 45). With regard to arable land, suitability can be limited by slope gradient (e.g. making high investments in SWC necessary, thereby reducing the benefit of crop cultivation) or soil type (e.g. poorly drained clay soils). There is no exact definition of suitability available, as it depends on topography, climate, vegetation, farming system and socio-economic features and their combinations.

82 Runoff can be as high as 80% of the rainfall, whereas well-covered soils under long grass or trees can retain as much as 90% of the rainfall. (Hurni, 1993, 37)

and regulate access to natural resources. The KA is responsible for land redistributions and the management of communal areas such as community forests or closed areas. The KA has unfortunately lost its character as self-administering body of the rural population, but has become more and more an organ to transmit decisions and orders decreed at higher administrative levels.

All research areas are characterised by a minimum of socio-economic infrastructure. Usually, a primary school is located in the vicinity. Higher education is only available in bigger centres, thus prohibiting many families from sending their children further to school. Possibilities for vocational training are absent in the areas. Health infrastructure is also only available in bigger centres, which are several hours, if not several days walk away. Market infrastructure is weak if not absent. Markets are of local character and demand and supply is limited. Transport infrastructure is good in Andit Tid, which is located on the main road linking Addis Abeba with the northern parts of the country. Anjeni and Mesobit & Gedeba are accessible all year round and are connected with the main road and bigger centres. The former dry-weather road linking Maybar with the main road and Dese is in such a bad condition that it is hardly passable with a 4WD. Accessibility in some villages in Simen has been improved since the road linking Debark, the nearest town, and Mekane Birhan, a Wereda capital in the South of the research area, has been built. Villages in the north of the National Park in the lowlands are not accessible by road.

The three SCRP research areas are comparably well served by agricultural extension workers thanks to the SCRP staff. In Mesobit & Gedeba the extension service is well staffed because the area is considered as having a high agricultural potential. Because the Simen Mountains are extremely remote even at Ethiopian standards, the extension system is extremely weak here.

The parish in Christian areas is a very important institution and plays a dominant role in rural society. Often, the church is the most stable institution, which promises a secure environment to the population in contrast to the ever-changing governmental institutions. Thus, the role of the church as a regulative institution remains strong. Important aspects are labour restrictions because of Saint's days, religiously sanctioned professions, which are affiliated with other faiths, and religious associations. Besides the ecclesiastical component of these associations they are also important as mutual self-help groups and in supporting poorer members of the society. Mutual aid is very strongly linked to these associations and respected by all members of the society. Thanks to this, a certain redistribution of wealth takes place and it helps resource-poor members or households to gain access to necessary production inputs (e.g. draught oxen, labour). In Muslim areas the *Kire* is an important institution. Although originally a burial association, it has taken over many more responsibilities. *Kire* members are usually involved in solving minor disputes and conflicts. In some areas the *Kire* has also been entrusted with the management of specific natural resources such as afforestations or closed areas.

Both religions, Orthodox Christianity and Islam are important in rural areas. Both support the sharing of goods and production factors among its members. This prevents on one side a strong differentiation of the rural society, which results in fewer social conflicts. On the other hand it also prevents the creation of specialisation and surplus accumulation, which could be invested in more productive spheres of the rural economy. Sharing is so deeply rooted in the rural society that resources are continuously distributed although the individual share will be ridiculously small. In the end not wealth is shared but scarcity is evenly distributed among all members of a society. This prohibits farmers from investing in innovations that might improve productivity, as additional production would only be distributed among poorer members of the rural society. The motivation of most farmers is thus to produce enough to cover household needs and social obligations, but not more.

## 2.3 Detailed Description of the Case Study Areas

### 2.3.1 Maybar[83]

Maybar is located in South Wello Zone at 2,500 m asl on 39°4′ E / 11°0′ N about 14 km SSE of Dese, the capital of South Wello Zone. The research site is part of the Kebele Association of Maybar. The research site in *Kori Sheleko* watershed was established in June 1981. Between March and July 1983 the catchment was conserved with level stone and soil bunds by the Ministry of Agriculture (MoA) through a Food-for-Wok campaign.

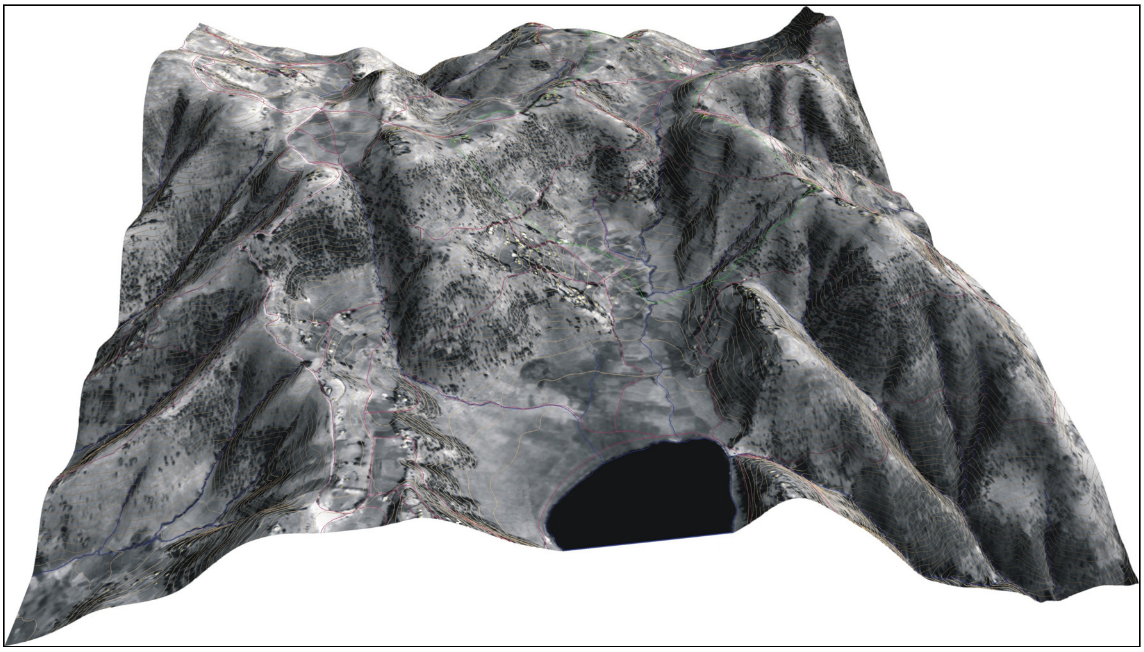

*Figure 8: 3D view of an orthophoto draped over the high-resolution Digital Terrain Model (DTM) of Maybar area.*
*[Source: Ethio-GIS]*

***Geologic underground and soils***

Soil properties and the soil genesis are mostly defined by topography, soil erosion and accumulation because the geological underground (constituted of alkali-olivin basalts of the Trapp series) is rather monotonous.

More than half of the catchment area is covered by shallow Phaeozems, associated with Lithosols, i.e. extremely shallow to shallow (soil depth 0-50 cm), stony dark brown clay loam soils, mostly excessively drained and well structured. Most of these soils are not suitable for permanent crop cultivation because of their very low soil moisture and nutrient storage capacity. Also, limited rooting depth and the fact that these soils mainly occur on steep slopes with high erosion hazards are severe limitations to crop cultivation.

The moderately deep to deep haplic Phaeozems, covering one fifth of the surveyed area are dark brown, stony clay loam soils. They have sufficient structure, are generally well drained, and occur mainly on concave, moderately steep slopes covered in some areas by natural woodland or forest. The haplic Phaeozems still have a high potential for crop cultivation but they also have only limited reserves in soil depth.

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83 The following Section is an excerpt from SCRP, 2000d.

The big colluvial and alluvial accumulation areas on less steep slopes and outer parts of valley bottoms are characterised by very deep haplic Phaeozems (7% of the survey area). These dark brown, sometimes greyish dark brown, stony clay loam soils have a moderate, in flatter areas even imperfect drainage. This can cause problems for crop cultivation during wet periods. In some places, these soils, which used to have a high original agricultural potential, now show severe signs of chemical degradation, i.e. organic matter and nutrient levels are very low.

Maybar also features hydromorphic soils, mostly in the central part of valley bottoms. These mollic Gleysols have a very high water table and are often waterlogged and swampy. Fluvisols and Regosols cover only 1% of the entire catchment area.

***Climate***

Maybar is located in the moist *Weyna Dega* / moist *Dega* agro-climatic zones. Figure 9 shows the standardised climate diagram for Maybar (according to Walter, 1964): a bimodal rainfall regime with one dryer month (June) between *Belg* (first, small rainy season) and *Kremt* (second, main rainy season). During 5 months (April to May and July to September), mean monthly rainfall exceeds 100 mm. November and June show arid conditions: the index of aridity[84] for these two months is below 20. In the Walter diagram, the rainfall curve drops below the temperature curve.

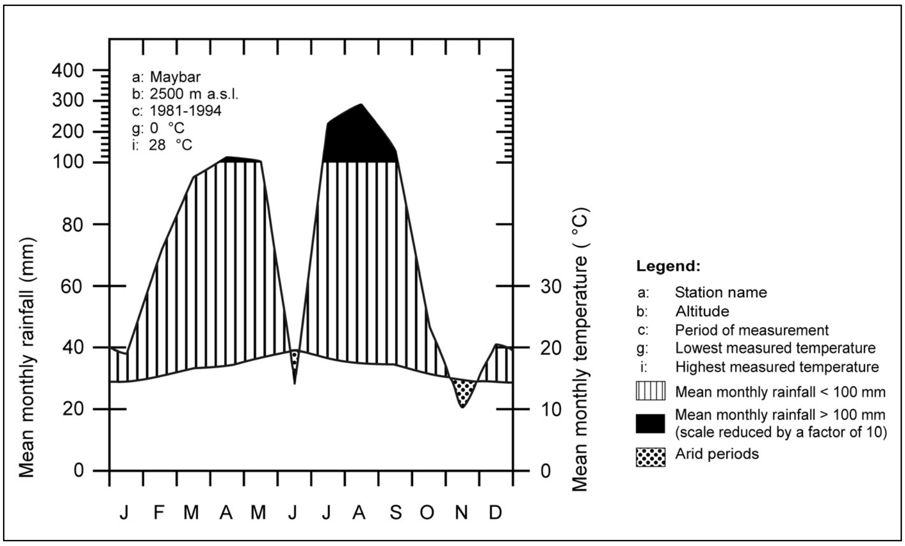


*Figure 9: Climate diagram for Maybar.*
*[Source: SCRP, 200d, 8]*

***Land use pattern in Maybar research catchment***

The total size of the Maybar catchment is 112.8 ha. Approximately 60% of the entire catchment is cultivated. Predominant crops are cereals and maize; they cover about 30% of the total catchment area. There are two cropping seasons in Maybar: the first, *Belg,* during the small rainy season in spring and the second, *Meher*, depending on the main rainy season during summer and autumn. With its smaller amounts of rainfall, the *Belg* season is predominantly used to plant cereals; in the *Meher* season pulses, which require more water, are dominant. Maize is planted during *Belg* and grows over both cropping seasons. The percentage of fallow land is generally low. It fluctuates between 1% and 15% during both cropping seasons.

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84 According to de Martonne and Lauer (1952), see SCRP, 2000a, 22.

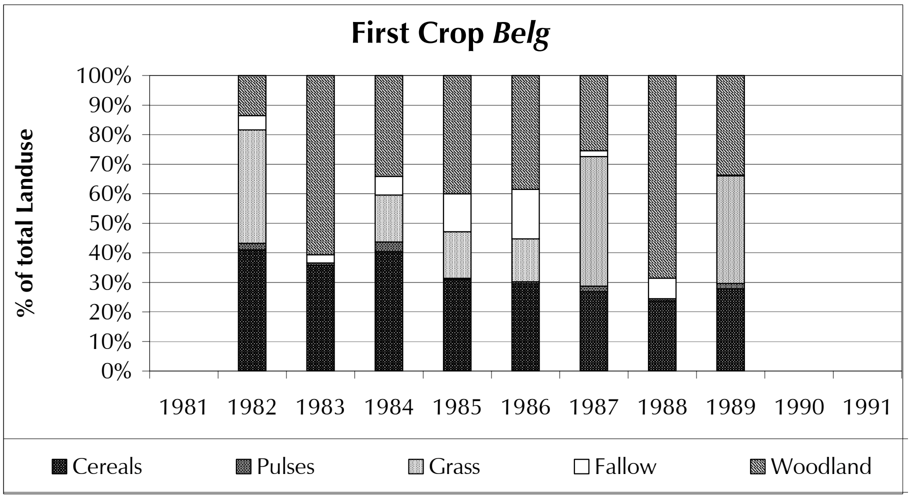


*Figure 10: Land use in % of total Maybar catchment area during Belg (1981 - 1991). No crop data for Belg season available in 1990 and 1991 due to political disturbances and war. In 1983 and 1988 grassland was measured together with woodland.*
*[Source: SCRP, 2000d, 24]*

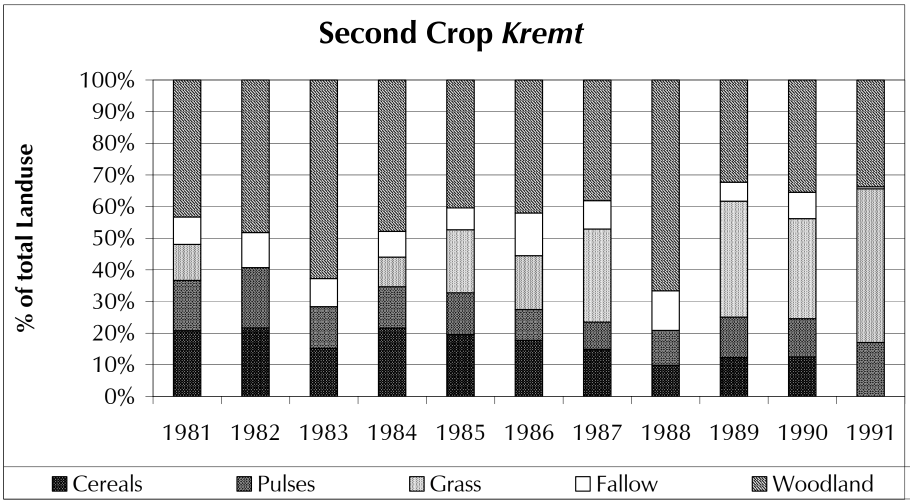


*Figure 11: Land use in % of total Maybar catchment area during Kremt (1981 - 1991). In 1983 and 1988 grassland was measured together with woodland.*
*[Source: SCRP, 2000d, 24]*

Major grain crops in Maybar are maize, barley, wheat, *emmer* wheat and *tef*, and major pulses are peas, beans, and lentils. Crop yields are relatively constant in both seasons, although *Kremt* is more reliable than *Belg*. Yields on the average were higher than 1 t/ha in most years (measurement period 1981-1993, except for 1984, the drought and famine year). The total cultivated area varied between 45 and 95 ha (40-84%) of the total catchment of 113 ha. In view of the steep topography over much of the area the latter is an extremely high proportion, indicating that the rates of soil erosion by water are likely to be very high.

***Soil erosion and soil and water conservation***

Four test plots at different slopes are used to monitor soil loss (cf. Table 2). Soil loss and runoff varies greatly from year to year according to rainfall erosivity and plant cover. Although 1984 was a drought year with the lowest annual rainfall, annual erosivity was highest of all measured years, leading to an extremely high annual soil loss of 118.7 t/ha on TP 4 (maize). In 1982 and 1987, TP 4 and TP 1 had very low soil loss values when cultivated with maize: 2.0 and 2.7 t/ha. If the cultivation of maize covers two rainy seasons, it is prone to erosion in its early stage in *Belg*. Thus, in March 1982 and 1987, with normal rainfall and rather low erosivity, soil loss was low as well.

On cultivated plots, highest rainfall, erosivity and runoff as well as second highest soil loss occurred in August. Erosion hazard was also high in March, but lower in April, May and July. The *Belg* months in particular – i.e. March, April and May – suffered relatively high soil loss, probably because protective vegetation growth was often limited due to high rainfall variability during the first rainy season.

| Year | Rainfall [mm] | Erosivity [J/mh] | **TP 1, 16% slope** | | | **TP 2, 64% slope** | | | **TP 3, 43% slope** | | | **TP 4, 37% slope** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Crop type | Runoff [mm] | Soil loss [t/ha] | Crop type | Runoff [mm] | Soil loss [t/ha] | Crop type | Runoff [mm] | Soil loss [t/ha] | Crop type | Runoff [mm] | Soil loss [t/ha] |
| 1982 | 1,431.5 | 479.4 | em/ho | 251.6 | 56.9 | fp/ho | 84.7 | 95.7 | fl | 79.9 | 70.1 | mz | 42.0 | 2.0 |
| 1983 | 1,122.4 | 459.3 | mz | 119.5 | 13.2 | fl | 96.7 | 20.6 | fl/fp | 103.9 | 55.2 | em/ho | 64.7 | 13.5 |
| 1984 | 720.9 | 592.2 | fl | 71.1 | 75.0 | gr | 36.7 | 6.1 | gr | 59.5 | 38.5 | mz | 41.0 | 118.7 |
| 1985 | 1,093.2 | 301.8 | fl | 158.0 | 90.1 | gr | 43.7 | 19.4 | gr | 132.4 | 39.0 | bl/ho | 81.1 | 32.8 |
| 1986 | 1,465.2 | 422.5 | bl/ho | 155.8 | 13.9 | gr | 23.4 | 0.1 | gr | 134.8 | 0.2 | bl/ho | 34.6 | 0.7 |
| 1987 | 915.4 | 250.2 | mz | 57.3 | 2.7 | gr | 14.5 | 0.1 | gr | 22.2 | 0.0 | b/ho | 50.4 | 11.8 |
| 1988 | 1,347.1 | 465.8 | bl/ho | 569.9 | 35.5 | gr | 21.3 | 0.1 | gr | 28.3 | 0.5 | em/ho | 374.4 | 54.1 |
| 1989 | 1,406.6 | 413.8 | mz | 152.4 | 15.4 | gr | 21.9 | 0.3 | gr | 23.6 | 0.0 | em/ho | 78.0 | 18.7 |
| 1992 | 1,118.2 | 333.1 | bl/ho | * | | gr | 145.8 | 12.1 | gr | 216.4 | 4.6 | em/ho | 181.5 | 41.3 |
| 1993 | 1,488.5 | 478.7 | mz | 180.9 | 19.6 | gr | 61.3 | 2.5 | gr | 99.0 | 4.6 | mz | 84.2 | 24.2 |
| **Mean** | **1,210.9** | **419.7** | | **190.7** | **35.8** | | **55.0** | **15.7** | | **90.0** | **21.3** | | **103.2** | **31.8** |
| **SD** | **247.4** | **98.2** | | **144.7** | **29.2** | | **40.3** | **27.7** | | **58.2** | **25.4** | | **98.9** | **33.1** |
| **CV** | **0.2** | **0.2** | | **0.8** | **0.8** | | **0.7** | **1.8** | | **0.6** | **1.2** | | **1.0** | **1.0** |
| **Mean Dev** | **216.9** | **76.0** | | **97.8** | **25.4** | | **33.7** | **17.7** | | **47.3** | **23.5** | | **69.9** | **23.9** |
| **Rel Dev** | **0.2** | **0.2** | | **0.5** | **0.7** | | **0.6** | **1.1** | | **0.5** | **1.1** | | **0.7** | **0.8** |
| **Median** | **1,234.8** | **440.9** | | **155.8** | **19.6** | | **40.2** | **4.3** | | **89.5** | **4.6** | | **71.4** | **21.5** |

Notes: In 1988 runoff was exceptionally high on TP 1 and TP 4. Values may be incorrect.
1990/91: April 1990 to July 1991 station closed due to war.
1992: TP 1 measurements of TP 1 excluded from analysis because of problems in determining runoff.

*Table 2: Annual rainfall, erosivity, runoff and soil loss on test plots (1982-1993) in Maybar. [Source: SCRP, 2000d, 41]*

On experimental plots the performance of different SWC technologies with regard to soil loss and runoff and yield and biomass production is monitored:

| **Mean annual soil loss (t/ha)** | | | | | | **Mean annual runoff (mm)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Local Cultivat. Practice | Graded Fanya Juu | Graded bund | Grass strip | Level Fanya Juu | Level bund | Local Cultivat. Practice | Graded Fanya Juu | Graded bund | Grass strip | Level Fanya Juu | Level bund |
| 1.9 | 1.8 | 3.3 | 0.9 | 0.5 | 1.2 | 24.7 | 26.7 | 36.1 | 16.7 | 12.8 | 18.5 |
| **Relative impact on crop yield production (%)*** | | | | | | **Relative impact on biomass production (%)*** | | | | | |
| | -22 | -27 | -24 | -28 | -30 | | -22 | -25 | -23 | -21 | -26 |

* The area for yield and biomass measurement is always the entire plot (180 $m^2$) irrespective of area occupied by conservation structures

*Table 3: Mean annual soil loss and runoff for different SWC measures and local cultivation practice and relative impact on crop yield and biomass compared to local cultivation practice. Period of observation: 1986-1989. [Source: Herweg & Ludi, 1999, 106, 107]*

The average values for crop yield and biomass production on the treated plots were below the values of the control plot. Except for a few years and crops, production on treated plots totalled 70% to 78% of the untreated plot. In the rather dry year 1987, production results on the treated plots were relatively better compared to the control plot, but still lower on most plots (*Belg*: barley 80% - 120%; *Kremt*: horse bean 80% - >90%). This was probably due to the effect of water conservation measures.

The experiment gives an idea of the effect of mainly mechanical SWC structures. Soil loss and runoff were generally reduced but production results remained lower than on the untreated plot, at least during the first years after construction. Since production needs to be at least maintained at the present level, or increased, in order to cover the costs of SWC or to convince peasants to conserve the land, the experiment shows that mechanical conservation has clear limitations if applied without accompanying measures. Ultimately, in order to be accepted, mechanical measures must be supported by agronomic and biological SWC.

On average graded structures show higher soil loss and runoff values than level structures because of the drainage ditch. This, however, by no means indicates that level structures are generally more recommendable. The decision whether level or graded structures should be implemented must take into account the rainfall regime. For example, areas with high rainfall need graded versions to drain excess water, whereas low rainfall areas require level structures to retain moisture.

During the *Belg* season, the high variability (and lack) of rainfall requires a treatment that focuses on water conservation. However, level structures that meet this goal might be fatal if intensive rain occurs. From the beginning, a drainage possibility has to be considered and included. Opportunities for biological SWC measures are limited due to the climate. Emphasis can thus only be put on the more expensive mechanical measures. During *Kremt*, the treatment must focus on soil conservation. Drainage problems are most likely to occur. From the climatic point of view, chances for an efficient use of biological SWC measures are better than in *Belg*, but they could not be tested in the field.

***Social and economic characteristics***

Maybar is located on the north-eastern escarpment of the Ethiopian Highlands. It has been settled for centuries by subsistence-oriented small-scale farmers.

The population consists of Amhara people and the main religion is Islam. Religious associations are traditionally highly respected and powerful. Apart from religious matters, the management of common properties and communal socio-economic activities are also in the hands of religious leaders. The local Peasant Association took over political control over almost all rural activities in 1974 and maintained it up to the 1990s. By law, land has belonged to the State since the Rural Land Proclamation in 1975. Farmers have the right to use land in proportion to the size of their families, and the Peasant Association could redistribute individual holdings at any time.

Up to the 1980s more than half the catchment was used for grazing. In 1984, area closure was introduced in Maybar in order to protect marginal land from animal and human interference and destruction. After that, a drastic reduction of sediment load was measured in the catchment. However, area closure severely reduced the households' agricultural resources – particularly their grazing land – even though these resources were already insufficient. The measure was therefore abandoned in the early 1990s.

In general, the situation in Maybar is characterised by poverty. Population pressure is high. Individual landholdings are very small and yield per unit area is low. Fallow periods have been reduced to almost nothing. The livestock population in the catchment is sufficient to cause overgrazing, although each household's livestock holdings are rather small. General poverty and overall limitations have forced households to over-cultivate and overgraze the land from which they earn a meagre living. No off-farm employment opportunities exist to supplement low incomes, and peasants are forced to follow short-term strategies of survival. Despite a very low availability of arable land, a large family is considered a great advantage. The economic strategy of diversification makes children the backbone of a family's economy: relatives easily adopt or employ them to increase their labour force.

### *Demographic features*

In 1981, 35 out of a total of 121 households in the community had their homestead inside the catchment; in 1982/83 the proportion was 35 out of 146 households. As families living inside the catchment also used land outside, and families living outside also cultivated land inside, it was not possible to assess the exact total production of the catchment.

| Year | Number of households | | | Number of people | | | Mean household size (persons) |
|---|---|---|---|---|---|---|---|
| | Inside catchment | Outside catchment | Total | Inside catchment | Outside catchment | Total | |
| **1981** | 35 | 86 | 121 | 159 | 371 | 530 | 4.4 |
| **1982** / **1983** | 35 | 111 | 146 | 163 | 458 | 621 | 4.3 |
| **1987** | 53 | n.a. | 53 | 264 | n.a. | 264 | 5.0 |

*Table 4: Number of households and people in Maybar and mean household size. [Source: SCRP, 2000d, 60]*

An average family in Maybar consists of 4 to 5 persons, and only few families have as many as 10 to 12 members. The population in Maybar is very young, as is the case in the whole country. 37% of the population in 1981 were under 16 years of age, in 1988 the percentage of under-16-year-olds was 45%. Economic problems are thus not caused so much by an overall high number of children per adult female or household, but by the fact that a large number of young people start a family at a very early age, thus accelerating the cycle of population growth.

About 39% of the population in Maybar are aged less than 15 years and about 8.4% are older than 65 years. In terms of the distinction usually made between the 'economically productive population' (between 15 and 65) and the 'dependent population' (under 15 and over 65), there is an equal share in each category (approximately 50%). However, within the Ethiopian context as well as in other developing countries such a standard classification is not relevant, since children as well as old people are of significant economic value.

### *Livestock holding*

Farm animals are important for Maybar's rural economy. Oxen are needed for ploughing; cattle, horses, mules and donkeys for threshing crops; horses, mules, and donkeys for transportation. Sheep and goats are raised mainly for sale to supplement income from crop production. In addition, farm animals are the only assets in case of crop failure or when extraordinary cash is needed for extraordinary events.

Because animals are highly desired, overstocking of the limited grazing area is the result. Nevertheless, the size of livestock holdings per household is low. Only a few farmers in the area (about 20%) own a well-balanced combination of species for the household economy. There is an acute shortage of fodder in the area; hence straw is the main component of animal feed. All crops are cut close to the soil during harvest to collect as much fodder as possible.

| Number of oxen per household | 1981 (121 households) | | 1982 (111 households) | | 1983 (35 households) | | 1987 (53 households) | | 1999 (16 households) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number of HH | % | Number of HH | % | Number of HH | % | Number of HH | % | Number of HH | % |
| **0** | 30 | 24.8 | 25 | 22.5 | 8 | 15.1 | 7 | 20.0 | 3 | 18.8 |
| **1** | 41 | 33.9 | 49 | 44.1 | 20 | 37.7 | 15 | 42.9 | 4 | 25.0 |
| **2** | 46 | 38.0 | 37 | 33.3 | 25 | 47.2 | 13 | 37.1 | 9 | 56.2 |
| **3** | 3 | 2.5 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| **4** | 1 | 0.8 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| **Mean** | 1.2 | | 1.1 | | 1.2 | | 1.4 | | 1.4 | |

*Table 5: Oxen holding per household in Maybar.*
*[Source: SCRP, 2000d, 64; data for 1999: own survey]*

***Landholdings***

After the land proclamation act of 1975 land was redistributed among the farmers. In 1984, area closure was introduced in order to allow for the land to regenerate; later on the area was gradually increased year by year. This was one of the main reasons for the gradual decrease of cultivated land from 45 ha (38%) to 25 ha (21%) of the catchment in 1988. By 1987, cultivation was limited to flat land and moderately steep slopes, and most of the very steep slopes and degraded areas were protected from human and animal interference. For the farmers, area closure meant a sharp reduction of access to land for cultivation and grazing. It further narrowed already limited and insufficient resources. In 1987, individual holdings of good land were about 0.5 ha for a family with two children or about 1 ha for a family with five children. After 1990, area closure had to be given up gradually and the land was used again more intensively.

***Organisational aspects***

Farmers in Maybar face the following major constraints:

- Shortage of farmland: as a result of both physical limitation and high population growth. Due to an acute shortage of land for cultivation and grazing, land use is intensive, fallow is not regularly practised, and crop and biomass yield are low.
- Rainfall variability: Untimely, excess or insufficient rainfall is the main natural hazard affecting crop production. Occasional hailstorms and frost should also be mentioned.
- Lack of fertiliser: Fertilisers are not available on time and are too expensive. All sources of organic fertilisers such as farm-yard manure, straw, crop residues, etc. are used for other, more basic and immediate needs (fodder, fuel, etc.).
- Shortage of labour: As a rule, households use an economic strategy of diversification. All farming activities, including weeding, protecting fields from birds and wild animals, cattle raising and tending, as well as other domestic and economic tasks are very time- and labour-consuming.
- Pests and diseases.

### 2.3.2 Andit Tid[85]

Andit Tid is located in North Shewa Zone at 3,040 m asl on 39°4′ E / 9°5′ N about 180 km ENE of Addis Abeba and 25 km NE of Debre Birhan, the capital of North Shewa Zone. The research site in *Hulet Wenz* watershed is part of the Kebele Association of Andit Tid. The research site was established in July 1982. Between December 1983 and February 1984 the catchment was conserved with graded Fanya Juu bund (cf.

85 The following Section is and excerpt from SCRP, 2000b.

Figure 6). This type of conservation measure was chosen for Andit Tid as the area is located in a high rainfall area and there is urgent need not only to control soil erosion but to safely drain excess water. Conservation in Andit Tid was implemented by the Ministry of Agriculture through a Food-for-Work campaign.

***Geologic underground and soils***

The geology of this area is characterised by volcanic rocks with rhyolites, trachytes, tuffs and basalts. The steep catchment is covered with deep gullies on almost all steep slopes, especially in the lower part of the research unit.

The soils with the highest area coverage are humic and ochric Andosols. In undisturbed locations over 3,000 m asl humic Andosols are the climax soils. Ochric Andosols have most probably developed through intensive agricultural use and soil erosion from humic Andosols.

Flat valley floors are covered by Fluvisols. They develop through the accumulation of eroded material from the surroundings. Soil depth on flatter slopes can reach more than two meters. The characteristics of these soils are strongly determined by their origin in the surroundings. Nutrient availability in Fluvisols is good, with only phosphorus lacking.

Lithosols occur on steep slopes. They are the result of long-term soil erosion, have a high stone content and can therefore not be ploughed. The average nutrient level is not bad, but as a consequence of the shallowness the overall amount of nutrients is low. Only the phosphorus content is relatively high.

Regosols are strongly influenced or even formed by erosion and accumulation. The profiles are usually not deeper than 50 - 60 cm but the underlying rock is strongly weathered, thus making tillage possible even on the shallowest soils. These soils have a very low organic matter content (in general <1%). The soils are slightly acidic and the amount of nutrients and plant available water is very low. In particular, the lack of plant available K, Mg and P is remarkable. In the catchment there are eutric and cambic Regosols. The latter are deeper, contain more nutrients and more plant available water. Also organic matter content is higher.

In the lower and most western parts of the research unit regosolic Cambisols occur. These soils are also strongly influenced by erosion and accumulation processes. In general, Cambisols reach a depth of at least 80 cm. The characteristics are strongly influenced by accumulated soil material coming from the upper parts of the catchment (Andosols). The content of plant available nutrients is high, the pH level is slightly acid.

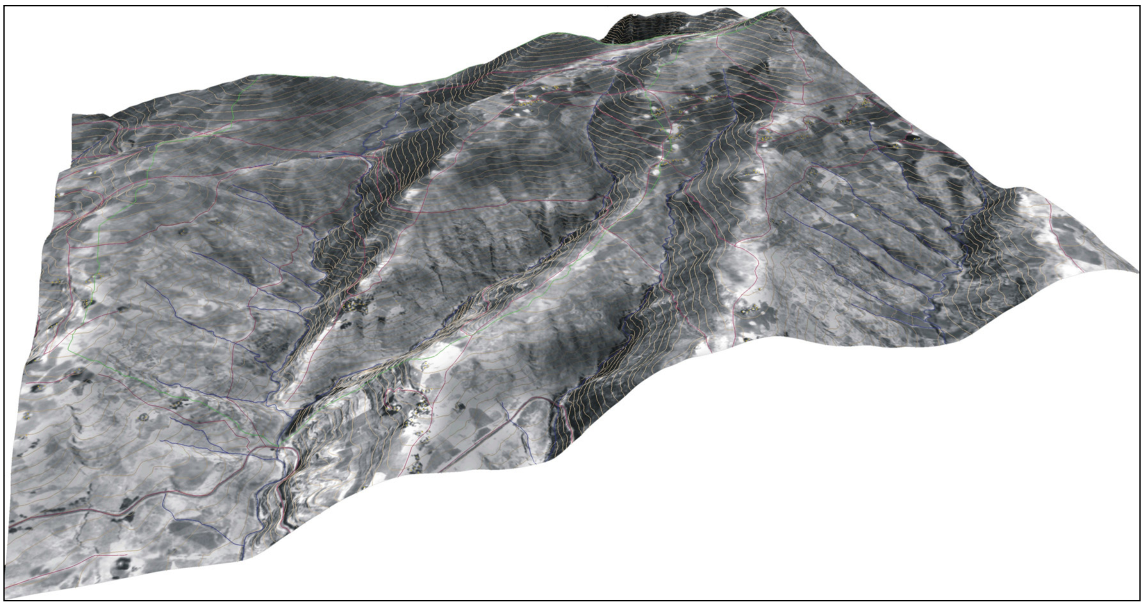

*Figure 12: 3D view of an orthophoto draped over the high-resolution Digital Terrain Model (DTM) of Andit Tid area.*
*[Source: Ethio-GIS]*

***Climate***

Andit Tid is located in the Wet *Dega* and Wet *High Dega* agro-climatic zones. Figure 13 shows the standardised climatic diagram of Andit Tid (according to Walter, 1964) which is characterised by a bimodal rainfall regime with one dryer month (June) between *Belg* (first, small rainy season) and *Kremt* (second, main rainy season). During 4 months (May and July to September) mean monthly rainfall exceeds 100 mm. The months from November to February show arid conditions. In the Walter diagram, the rainfall graph drops below the temperature graph.

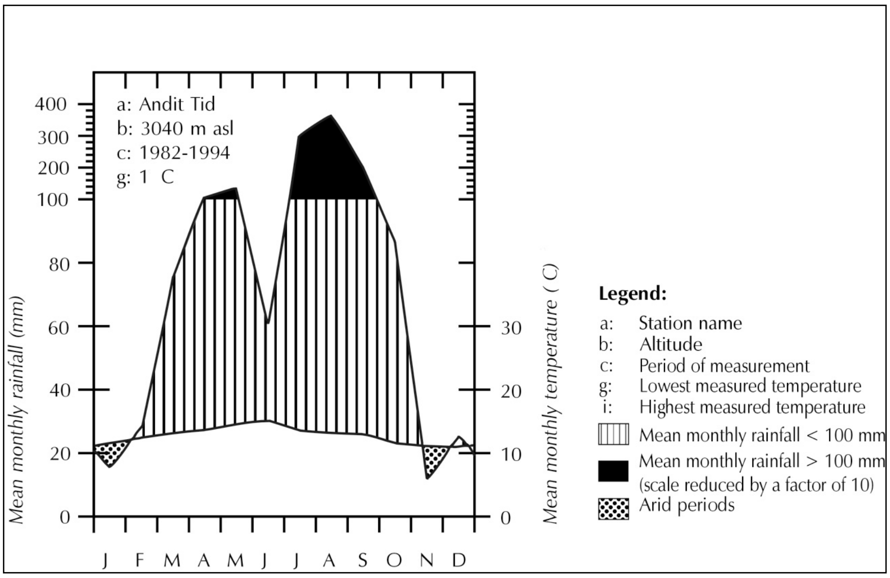


*Figure 13: Climate diagram for Andit Tid.*
*[Source: SCRP, 2000b, 8]*

***Land use pattern in Andit Tid research catchment***

The size of the hydrological catchment is 477.3 ha. The results shown below are in percent of the catchment area. The climatic conditions in the uppermost parts of the catchment (around 3,500 m asl) do not allow for two cropping seasons. Above this height the vegetation period is limited through temperature.

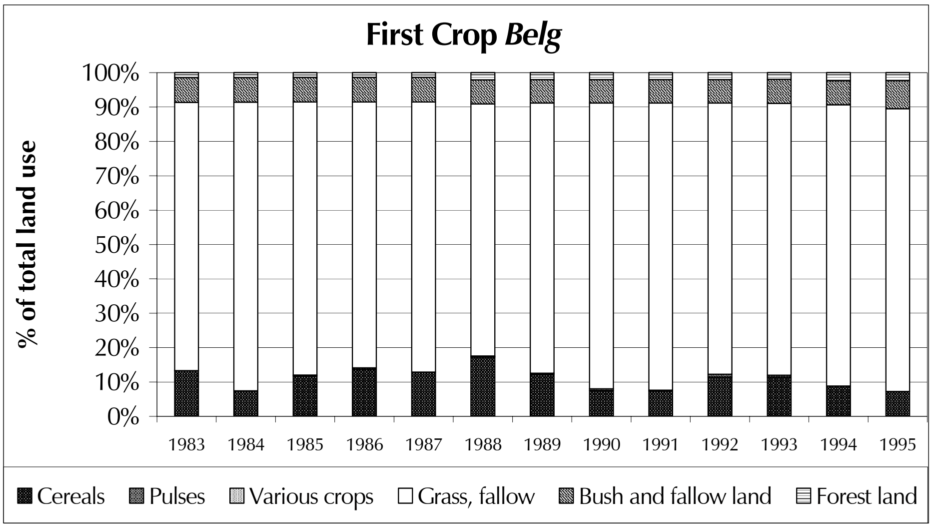


*Figure 14: Land use in Andit Tid during Belg (1983-1995).*
*[Source: Stuber, 1998, quoted in SCRP, 2000b, 26]*

The first cropping season, *Belg*, is during the small rainy season in spring. The second and main cropping season, *Meher*, lasts from summer to the end of autumn. The predominant crop in Andit Tid is barley; it normally covers more than 90% of the cropland (during *Belg* almost 100%). Because of the low temperatures that hamper crop growth, grassland is dominant in the catchment. It covers around 80% of the total area. Large parts of grassland plots are under rotation. The rotation cycle is very limited: barley alternates with grass and vice versa.

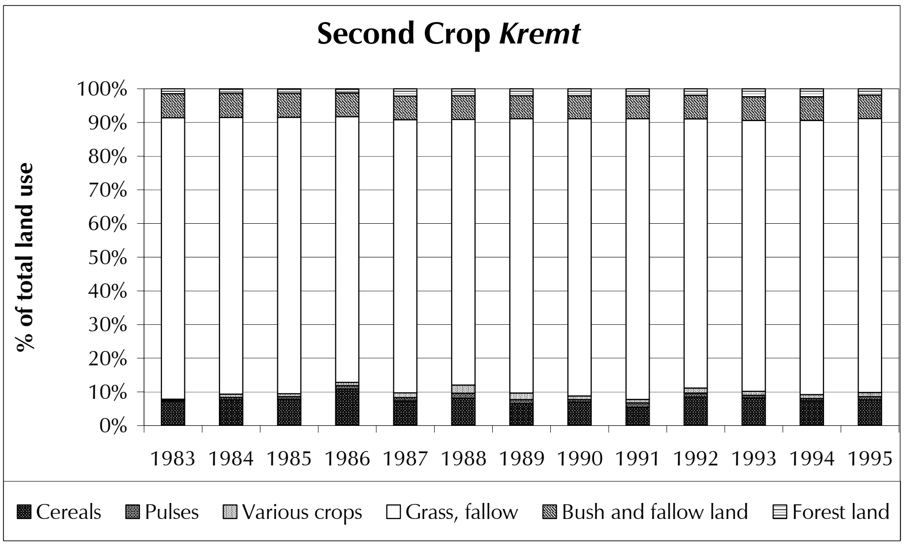


*Figure 15: Land use in Andit Tid during Kremt (1983-1995).*
*[Source: Stuber, 1998, quoted in SCRP, 2000b, 26]*

Main crops in Andit Tid are barley, which is grown during the *Belg* and during the *Kremt* season. In the lower part of the research catchment (below about 3,200 m asl) crop rotation is possible. Here, grain crops, mainly barley and to a smaller extent wheat are grown alternating with pulses (horse bean, field pea, lentil) or oilseeds (linseed).

***Soil erosion and soil and water conservation***

Four test plots at different slopes are used to monitor soil loss. Soil loss and runoff varies from year to year according to rainfall erosivity and plant cover. Table 6 presents and overview of annual soil loss and runoff on the different test plots. In Andit Tid, there is no grass plot as such. TP 3 with frequent fallow periods was subject to intensive grazing and therefore also to severe erosion. TP 2 was an exceptional plot indicating the erosion hazard under impact of interflow. Runoff values often exceeded rainfall values, because the interflow frequently reached the soil surface at this spot. It is surprising that the steepest cultivated plot, TP 4 on 48% slope showed the lowest mean soil loss. This seems to be related to a slightly different crop rotation and the agronomic practices specially adapted to steep slope cultivation. In addition, the relatively low runoff on both steep plots, TPs 3 and 4 (48%) suggests a better infiltration (on eutric Regosol and ochric Andosol, respectively).

Without considering differences in soil, slope, rainfall and erosivity, highest soil loss was measured on plots with wheat and lentil. But even fallow plots which normally have more ground cover suffered from high soil loss (>100 t/ha and year, which is far above any tolerable level).

Annual results show considerable variation. Some examples may therefore help to further interpret the results:

- 1987 was the year with the lowest erosivity and the second lowest rainfall. Correspondingly, soil loss on all TPs was low as well, although not the lowest measured. Still, the order of magnitude, ranging from 41 to 160 t/ha, was very high. Erosion could be observed throughout *Kremt*, but unlike other years, in October 1987 soil loss was unusually high, totalling up to one fifth of the annual values.
- 1991 had the highest erosivity and rainfall; this also caused very high soil loss on TPs 1 and 2 (both lentil). TPs 3 and 4 were left fallow and thus had slightly less erosion.
- In 1986, on TPs 1, 2 and 3 wheat was planted. The flatter TP 1 (23%) showed lower soil loss compared to the steeper TP 2 (39%). However, the steepest plot, TP 3 (48%) had the lowest value measured. Although TP 1 and TP 3 were both located on eutric Regosol, TP 3 had the higher infiltration capacity.

| | | | **TP 1, 23% slope** | | | **TP 2, 39% slope** | | | **TP 3, 48% slope** | | | **TP 4, 48% slope** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Rainfall [mm] | Erosivity [J/mh] | Crop type | Runoff [mm] | Soil loss [t/ha] | Crop type | Runoff [mm] | Soil loss [t/ha] | Crop type | Runoff [mm] | Soil loss [t/ha] | Crop type | Runoff [mm] | Soil loss [t/ha] |
| 1983 | 1,546.8 | 647.3 | fl | 672.2 | 242.1 | lt | 768.7 | 286.7 | fl | 503.0 | 204.5 | bl | 281.0 | 182.5 |
| 1984 | 979.5 | 281.8 | fl | 303.4 | 124.1 | wt | 270.7 | 149.7 | li | 135.7 | 64.7 | bl/fp | 128.9 | 40.9 |
| 1985 | 1,446.6 | 572.2 | lt | 409.4 | 144.9 | lt | 617.7 | 221.9 | lt | 385.6 | 151.8 | fp | 250.7 | 29.8 |
| 1986 | 1,659.9 | 388.8 | wt | 480.4 | 163.4 | wt | 659.3 | 183.1 | wt | 442.2 | 123.2 | bl | 237.4 | 58.3 |
| 1987 | 1,029.4 | 216.2 | lt | 273.0 | 121.3 | lt | 324.6 | 160.0 | fl | 222.8 | 68.8 | lt | 117.0 | 41.9 |
| 1988 | 1,388.0 | 605.3 | wt | 586.1 | 211.3 | bl | 705.8 | 199.2 | fl | 585.9 | 141.6 | bl | 389.7 | 154.5 |
| 1989 | 1,287.1 | 394.8 | lt | 437.1 | 168.3 | lt | 510.9 | 223.9 | wt | 370.8 | 171.2 | fl | 153.7 | 11.8 |
| 1990 | 1,072.4 | 476.7 | fl | 466.4 | 144.1 | wt | 596.3 | 293.9 | fl | 394.7 | 76.7 | bl | 248.2 | 155.5 |
| 1991 | 1,690.2 | 887.6 | lt | 750.1 | 239.7 | lt | 668.8 | 268.5 | fl | 533.3 | 73.4 | fl | 459.8 | 93.1 |
| 1992 | 1,472.0 | 403.5 | li | 614.5 | 127.8 | li | 691.6 | 137.6 | lt | 413.3 | 130.7 | bl | 252.9 | 96.7 |
| **Mean** | **1,357.2** | **506.0** | | **499.3** | **168.7** | | **581.4** | **212.4** | | **398.7** | **120.7** | | **251.9** | **86.5** |
| **SD** | **244.3** | **187.3** | | **147.2** | **44.0** | | **156.7** | **53.7** | | **129.3** | **45.9** | | **103.1** | **56.9** |
| **CV** | **0.2** | **0.4** | | **0.3** | **0.3** | | **0.3** | **0.3** | | **0.3** | **0.4** | | **0.4** | **0.7** |
| **Mean Dev** | **208.3** | **158.9** | | **125.2** | **37.4** | | **127.6** | **46.5** | | **96.8** | **39.8** | | **75.1** | **50.0** |
| **Rel Dev** | **0.2** | **0.3** | | **0.3** | **0.2** | | **0.2** | **0.2** | | **0.2** | **0.3** | | **0.3** | **0.6** |
| **Median** | **1,446.6** | **476.7** | | **473.4** | **154.2** | | **638.5** | **210.5** | | **404.0** | **127.0** | | **249.5** | **75.7** |

*Table 6: Annual rainfall, erosivity, runoff and sol loss on test plots (1983-1992) in Andit Tid. [Source: SCRP, 2000b, 41]*

In Andit Tid on average the Fanya Juu on Experimental Plots retained less water than the comparable soil bunds. Due to the waterlogging hazard in high rainfall areas like Andit Tid level structures cannot be recommended, even if they showed the best values for soil loss reduction. On graded structures a considerable amount of water was drained, particularly under fallow conditions. This helped to prevent waterlogging, but it does not reduce soil loss as much as needed. Absolute values were still above 10 – 20 t/ha and year. Grass strips and graded structures reduced soil loss by 40 to 73%. To further decrease soil loss, runoff velocity should be reduced.

| **Mean annual soil loss (t/ha)** | | | | | | **Mean annual runoff (mm)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Local Cultivat. Practice | Graded Fanya Juu | Graded bund | Grass strip | Level Fanya Juu | Level bund | Local Cultivat. Practice | Graded Fanya Juu | Graded bund | Grass strip | Level Fanya Juu | Level bund |
| 48.0 | 17.8 | 29.0 | 13.0 | 6.0 | 6.9 | 354 | 348 | 335 | 236 | 194 | 133 |
| **Relative impact on crop yield production (%)*** | | | | | | **Relative impact on biomass production (%)*** | | | | | |
| | -50 | -12 | -39 | -29 | -20 | | -45 | -11 | -37 | -29 | -21 |

* The area for yield and biomass measurement is always the entire plot (180 $m^2$) irrespective of area occupied by conservation structures

*Table 7: Mean annual soil loss and runoff for different SWC measures and local cultivation practice and relative impact on crop yield and biomass compared to local cultivation practice. Period of observation: 1987-1991.*
*[Source: Herweg & Ludi, 1999, 106, 107; SCRP, 2000b, 49]*

In most cases the production measured on plots with SWC structures remained lower than on the control plot. Increased production was measured mainly on plots with level structures, which are not recommended for the reasons given above. To a large extent low yield resulted from the reduction in cultivated land for crop production, since 10 to >20% of the area is occupied by the SWC structures. In addition, waterlogging above the structures, concentrated rodent population in the structures (habitats are no longer destroyed by ploughing), and weeds spreading from the SWC structures also affect production.

The experiment focuses on the performance of (mainly) mechanical SWC. EP results have shown that it is possible to reduce erosion by mechanical measures, but not sufficiently. Soil loss was still generally high. Drainage remained the critical factor, since in order to reduce soil loss it would have been necessary to further reduce runoff, but as a consequence waterlogging would have affected production. Moreover, waterways easily develop into gullies.

Soil loss and runoff were reduced but production remained mostly below the values in the untreated plot, at least during the first years after construction. But production needs to be at least maintained at the current level, or increased in order to cover the costs of SWC and to convince farmers of the efficiency of conservation measures. The results imply that the benefits of mechanical conservation are limited. Mechanical measures alone will not lead to immediate benefits in terms of increased production: they must be supported by agronomic and biological SWC. However, high altitude and low temperatures limit the variety of species and vegetation growth, particularly at the beginning of *Belg*.

***Social and economic characteristics***

Andit Tid is located on a volcanic ridge between the vast central plateau of Ethiopia and the eastern escarpment. It can be considered typical of all highly degraded central highlands above 3,000 m asl. The settlements in Andit Tid are usually situated in clusters on slopes, ridges and spurs.

The Andit Tid research unit consists of two valleys with a total area of 477.3 ha. It is mountainous with steep slopes in many parts, and high differences in altitude. Because of the high risk of frost during the *Belg* season, in the upper parts of the catchment (above 3,300 m asl) barley is cultivated as a staple crop. During the *Kremt* season mainly the lower parts are cultivated. The *Belg* fields lie fallow for a relatively long timespan and soil burning – locally known as *gay* – is practised.

Originally, the soils were quite favourable for cultivation. Depending on the area, cultivation seems to have started 530 to 1,140 years ago (as the results of an analysis of carbon deposits show). First settlers were presumably Oromo pastoralists from the lowlands. The names of several places still bear traces of the Oromo past. But today, the population is entirely Amharic (orthodox Christians). In Andit Tid religion strongly influences the organisation of agricultural work. Only on around 130 days per year are there no religious restrictions on farming activities. Despite this cultural situation, the community does not seem to face major shortage of labour supply.

The land reform in 1975 brought about a new distribution of land. Theoretically, each household should get land, including both fertile land and less productive land in relation to its size. In Andit Tid farmers should also get land in both cultivation zones, *Dega* and *High Dega*. In practice, this land allocation rule was not strongly followed. Since 1975, land holdings have been reallocated and split up due to the growing number of families entitled to land. Thus, families have had to survive with decreasing farm sizes and the regular redistribution caused an insecurity about tenure that has not encouraged for farmers' investments in resource conservation measures. From about 1988, villagisation was implemented in the catchment area.

In general, the situation in Andit Tid is a difficult one for peasants. It is characterised by relatively high population and livestock densities, a high degree of land degradation, low crop yield and production as well as drastically reduced fallow periods. Field resources are scarce and unevenly distributed among the farmers. Beside shortage of land, the lack of manure for fertiliser is a main problem for the farmers. Yields are further endangered by hailstorms, frost, pests (i.e. *wag*, *fake*) and rodents. Even though petty trade exists on a very low level, off-farm opportunities are lacking and pure subsistence production is the rule. Under impoverished conditions, keeping small animals like sheep and goats becomes a short-term alternative and the trend of land-use is to move up-slope to the remaining natural vegetation above 3,300 m.

In 1982/83 and in 1987, the SCRP standard programme on socio-economic aspects (demographic features and livestock holding) was conducted in the Andit Tid research unit. In 1982/83 only 26 out of a total of 73 households cultivating land inside the catchment were also living inside the catchment. In 1987, 48 of the households living inside the catchment were investigated. An in-depth study was conducted in 1986.[86] All 139 households cultivating land inside the research unit – out of which 89 households were actually living within the catchment – were thoroughly interviewed on demography, land holdings, and animals. Further, 30 farmers were questioned in informal interviews mainly on soil conservation topics. In a subsequent in-depth study in 1995[87] a total number of 151 households was differentiated according to landholdings whether they only had inside the catchment or were additionally cultivating parcels outside the research unit. Also, some information was collected of households exclusively dependent on land outside the research unit. Thus for 1994, data exist on 162 households in and around the research unit.

### *Demographic features*

In 1986, population density was estimated to be 145.5 persons per sq.km – a high figure compared with the national average of 31 persons and the average for the Ethiopian highlands of 61 persons per sq.km. The estimated population density for cultivated land was about 230 persons per sq.km.

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86 Yohannes G/Michael, 1989.

87 Stuber, 1998.

| **Number of family members** | **Frequency** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **1982** | **1983** | **Total 1982/ 1983** | **1986** | **1987** | **1995** | | |
| | 83 pers. | 228 pers | 311 pers | 700 pers. | 194 pers. | inside 164 pers. | outside 564 pers. | Total 728 pers |
| **Recorded households** | 19 | 54 | 73 | 139 | 48 | 34 | 117 | 151 |
| **Average fam. size** | 4.4 | 4.2 | 4.3 | 5.0 | 4.0 | 4.8 | 4.8 | 4.8 |

*Table 8: Size of families in the Hulet Wenz research catchment. [Source: SCRP, 2000b, 57]*

An average family consists of five members, while only few families count more than eight members. Singles as well as small households with only one or two members are frequent. Such figures indicate a break down of traditional social structures and a difficult economic situation.

Based on the data of the different studies carried out between 1982/83 and 1995, 42 to 47% of the sampled population was below 15 years. In general those figures reflect a situation typical of developing countries with their fast growing populations.

In 1982/83, 7 out of 74 (10%) households were headed by women, whereas in 1986, it was 16 households out of 139 (12%). Those are small households with either a single woman, or mother/daughter or mother/child. Households of bigger size consist of a mother with several children. In general, those households do not have enough labour force and resources and are under share cropping contracts. Thus they often are submitted to impoverishment.

***Livestock holding***

Sheep are the dominant species, in 1986 for example accounting for 47% of the animals, followed by oxen (12%) and goats (11%). The number of animals in the study area is very high in relation to the available pasture. In 1986, livestock density on the permanent grazing land was 11.83 TLU/ha. In consideration of fallow land (201.76 ha) livestock density was 1.48 TLU/ha compared to 0.36 TLU/ha for the highlands of Ethiopia as a whole.

| **Year** | **Sample No. HH** | **Number of oxen** 0 | 1 | 2 | 3 | 4 | 5 | **Total** | **Mean** |
|---|---|---|---|---|---|---|---|---|---|
| **1982/83** | 73 | 17 | 17 | 35 | 3 | 1 | 0 | 100 | 1.4 |
| **1986** | 139 | 18 | 33 | 84 | 3 | 1 | 0 | 214 | 1.5 |
| **1987** | 48 | 8 | 14 | 23 | 2 | 1 | 0 | 70 | 1.5 |
| **1995** | 34 inside catchment | 7 | 7 | 20 | 0 | 0 | 0 | 47 | 1.4 |
| | 117 outside catchment | 32 | 23 | 54 | 3 | 4 | 1 | 161 | 1.4 |
| | Total 151 | 39 | 30 | 64 | 3 | 4 | 1 | 208 | 1.4 |
| | 11 HH | Outside catchment border, not specified | | | | | | 18 | 1.6 |
| | | End sum 162 households | | | | | | 226 | 1.4 |
| **1999** | 15 HH | 4 | 2 | 7 | 1 | 0 | 0 | 19 | 1.3 |

*Table 9: Oxen holding per household in Andit Tid research area. [Source: SCRP, 2000b, 60; data for 1999: own survey]*

Families with only one ox accounted for about 22% in 1986, so that the importance of *Mekenajo*, a mutual aid agreement in order to join a team of oxen becomes obvious. Households headed by women often have to accept disadvantageous share cropping agreements since they do not possess oxen.

***Landholdings***

In 1986, 41% of the households owned less than 2 ha, and 55% of the households had 2-5 ha. Only 4% had larger holdings. The average land holding per family was about 2.95 ha.[88] According to elders and peasant association members, the minimum land requirement of an average household is estimated to range from 3 ha (in the case of fertile soils) to 5-6 ha if the land consists of both fertile and less fertile soil. Estimations even go higher, suggesting that 4 ha of grazing land are required to plough 1 ha of arable land.

With an average of 6 parcels per household in 1986 land fragmentation was quite high compared to the national average. Fragmentation of farmland goes up to 12 parcels per family mainly due to inheritance customs. The advantage of fragmentation is obvious: it is part of a diversification strategy which guarantees diverse yields over long periods of the year and reduces risks in production. Thus peasants have a positive attitude towards having scattered plots, with different types of soil and climate. Richer farmers dispose of more parcels and thus have a higher degree of insurance against natural hazards.

***Organisational Aspects***

Labour shortage is not reported to be a problem in Andit Tid. Nevertheless, informal work groups are necessary during agricultural peak times. The farmers of Andit Tid retain traditional work organisation such as *debo*, *wenfel* and *megazo*, which are mutual aid agreements between individual households.

- *Debo*: a group of individuals helps a household mainly during the harvesting and soil burning season and gets food as compensation,
- *Wendell*: mutual aid among relatives in performing tasks,
- *Mekenajo*: joint operation, usually involving two farmers who own one ox each, to make a team,
- *Megazo*: an arrangement that involves the renting of land, usually from a widow. The amount of crop payment depends on whether the widow also supplies the renter with seed and oxen in addition to the land.

### 2.3.3 Anjeni[89]

Anjeni is located in West Gojam Administrative Zone at 2,400 m asl on 37°3′ E / 10°4′ N about 15 km north of Dembecha and 40 km NNW of Debre Markos. The research site in *Minchet* catchment is part of the two Kebele Associations of Anjeni and Jenhala. The research site was established in March 1984. In 1985 first conservation measures were constructed outside the catchment and from February to April 1986 the catchment was conserved with graded Fanya Juu bunds, for which first experiences have been gained from Andit Tid area. In Anjeni the conservation was not carried out through a Food-for-Work campaign, but instead the local communities participating in conservation works were offered a clinic as an incentive.

88 The study conducted by the author in 1998/99 covering 15 households shows that poor households on the average cultivate only 1.5 ha and rich households only 2.5 ha. On the average, land holdings decreased from 2.95 ha in 1986 to 2.1 ha per household in 1998/99.

89 The following Section is an excerpt from SCRP, 2000c.

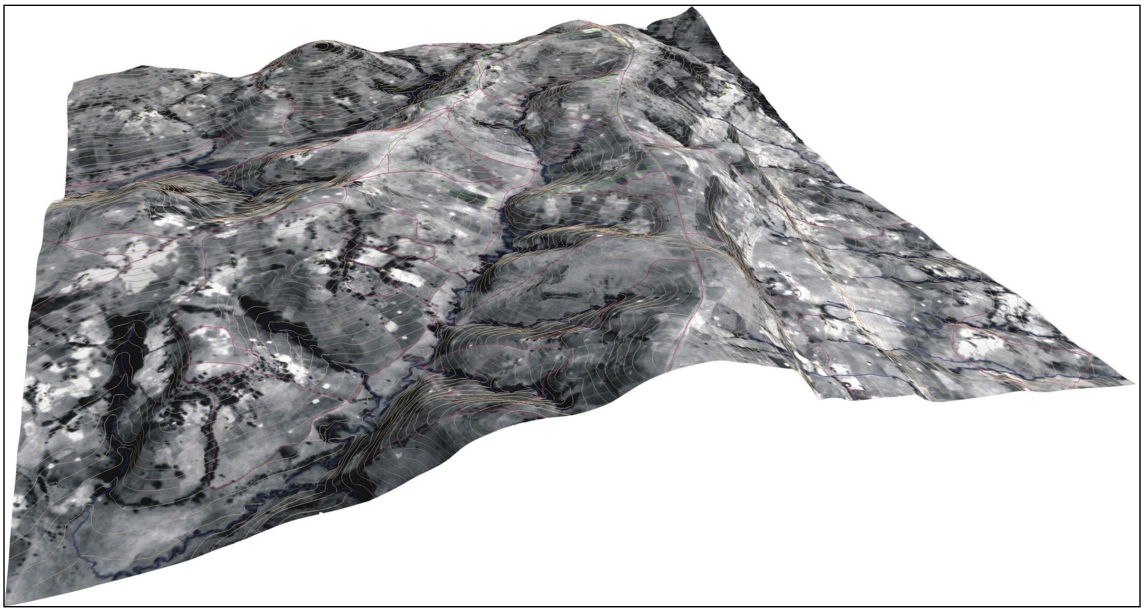

*Figure 16: 3D view of an orthophoto draped over the high-resolution Digital Terrain Model (DTM) of Anjeni area.*
*[Source: Ethio-GIS]*

***Geologic underground and soils***

Geologically speaking, the Anjeni research unit belongs to the basaltic Trapp series of Tertiary volcanic eruptions and is similar to most parts of central Ethiopia. The topography of Anjeni is typical of Tertiary volcanic landscapes; it has been deeply incised by streams, resulting in the current diversity of landforms. The soils have developed from a volcanic basement and reworked materials of Tertiary volcanic eruptions, and rarely from sedimentation processes.

A detailed soil survey was conducted by Gete Zeleke in 1997. The soils of Anjeni vary within short distances. About eight major soil units and ten sub-groups were identified. The valley floor and depressions of the foothills in the catchment are predominantly covered with deep, well-weathered Alisols (41% of the area). Moderately deep red Nitosols (23.8%) cover transitional, gently sloping (convex to linear) zones of the catchment. The high, steepest elevations, with mainly convex shapes, are covered with very shallow Regosols and Leptosols (12.4%). They are probably derived from Nitosols in the truncation process of soil erosion. The hilltop of the catchment and partially the medium steep area of the slope are covered with moderately deep young dystic Cambisols (19%). These soils are transitional soils with a less developed B-horizon, and again probably truncated by soil erosion in the recent past. Small pockets of Luvisols, Lixisols and Acrisols can also be found in the catchment.

The soils of Anjeni are generally acidic and low in organic carbon content, have low to medium total nitrogen and plant available phosphorus contents. This indicates overexploitation of soils and leaching processes. In contrast to these chemical properties, cation exchange capacity of most soils is high. This is probably related to the high clay content of all soils but does not indicate high soil fertility. Both the relatively broad extension of Cambisols and other shallow to very shallow soils (Regosols and Leptosols), as well as the poor chemical properties of all soils are clear signals of accelerated land degradation in the area.

***Climate***

Anjeni is located in the Wet *Weyna Dega* agro-climatic zone. Figure 17 shows the standardised climatic diagram of Anjeni (according to Walter, 1964): there is a unimodal rainfall regime with five months during which rainfall exceeds 100 mm. The months from November to March show arid conditions. In the Walter diagram, the rainfall curve drops below the temperature curve.

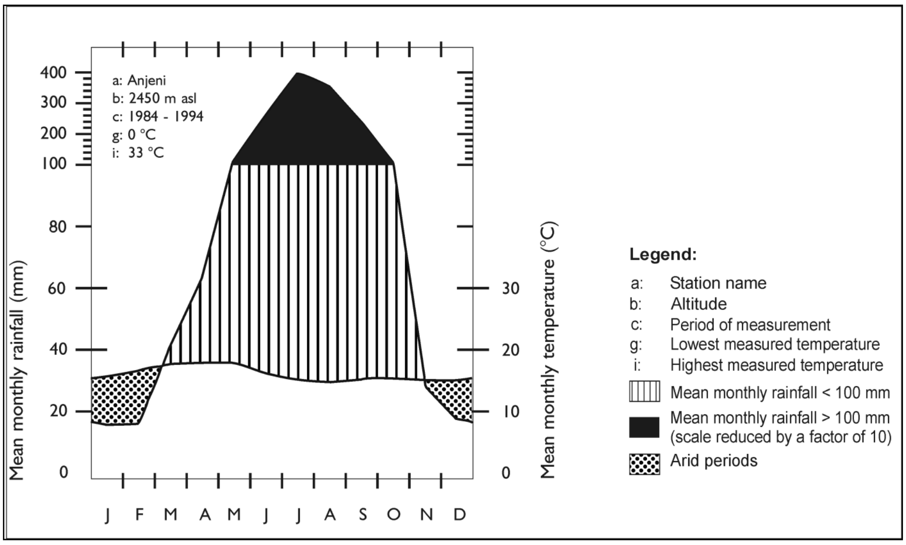


*Figure 17: Climate diagram for Anjeni.*
*[Source: SCRP, 2000c, 6]*

***Land use pattern in Anjeni research catchment***

The size of the hydrological catchment is 113.4 ha. Up to 80% of the entire catchment is arable land. Predominant crops are barley and tef; they cover around 50% of the total catchment area. Conditions in Anjeni usually do not allow two cropping seasons, except for barley.

Results of the land use distribution analysis over the years from 1984 to 1996 are given in Figure 18. The trend shows a marked increase of cereal crops at the expense of grass and fallow. The sector "various crops" contains mainly oil crops. Land use results are shown in percentage of the total catchment area.

In Anjeni, major crops grown are barley, tef, wheat and maize as grains, lupine *(gibbto)* and beans as pulses, plus linseed. In addition, minor parts of the cropped area are covered with oil seeds (*noug*). Average crop yield per hectare was between 0.6 and 0.9 t/ha, which is low considering that Gojam is known as the grain basket of Ethiopia. This low productivity may be explained to some extent by the relatively high share of tef, but also by the relatively high degree and extent of soil degradation.

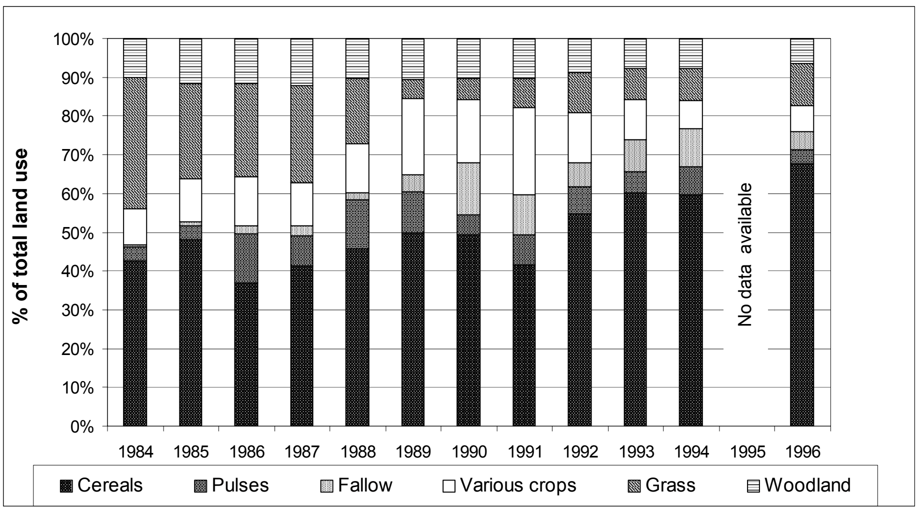


*Figure 18: Land use in % of total Minchet catchment area in 1984 – 1996.*
*[Source: SCRP, 2000c, 24 quoting Ludi, 1994 and Heinimann 1997]*

***Soil erosion and soil and water conservation***

Four test plots at different slopes are used to monitor soil loss. Soil loss and runoff varies from year to year according to rainfall erosivity and plant cover. Of all SCRP stations, Anjeni shows the highest annual runoff (up to 50% of rainfall) and soil loss values. Highest soil loss on cultivated plots occurred on the steepest slope (TP 1; 28% slope). The differences between gentler slopes on TP 2 and TP 4 (12% and 22% slope) were not significant. The runoff, by contrast, was significantly higher on the gentlest slope of TP 2, with eutric Nitosol.

Annual results show considerable variations. Examples may therefore help to further interpret the results:

- In 1986, soil loss on TPs was high although annual rainfall and erosivity was the lowest of all years. No month was registered with particularly high rainfall and erosivity. For all cultivated plots, though, several months with soil losses higher than the mean for these particular months were detected: on TP 1 (wheat) in September / October, on TP 2 (horse bean) in June, and on TP 4 (fallow) in May. Surprisingly, despite low erosivity values from June to August, soil loss generally was not lower than in other years.
- In 1989, relatively low soil loss correlated with low erosivity.
- The highest erosivity in 1990 caused average soil loss, except for TP 2 (highest soil loss measured). 60 - 85% of erosion was concentrated in the months of July and August.
- Erosivity in Anjeni was high compared to other stations. At this level, variability in annual erosivity seems not to have had a major impact on the amount of soil loss. Only TP 2 values corresponded with changes in annual erosivity.
- Wheat and tef seemed most susceptible to erosion. Under barley and horse bean, less soil loss was observed, but it was still above 100 t/ha.
- Soil loss from the grass plot (TP 3) amounted to 13 t/ha during the first years, but remained less than 1 t/ha from the fourth year onwards, once a permanent dense grass cover had developed.

| Year | Rainfall [mm] | Erosivity [J/mh] | **TP 1, 28% slope** | | | **TP 2, 12% slope** | | | **TP 3, 16% slope** | | | **TP 4, 22% slope** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Crop type | Runoff [mm] | Soil loss [t/ha] | Crop type | Runoff [mm] | Soil loss [t/ha] | Crop type | Runoff [mm] | Soil loss [t/ha] | Crop type | Runoff [mm] | Soil loss [t/ha] |
| 1985 | 1,556.2 | 552.1 | bl | 798.0 | 148.0 | te | 1,159.3 | 187.5 | gr | 757.9 | 11.9 | te | 734.4 | 263.2 |
| 1986 | 1,372.1 | 393.9 | wt | 646.0 | 182.9 | ho | 595.8 | 66.4 | gr | 570.6 | 11.4 | fl | 502.1 | 159.4 |
| 1987 | 1,811.4 | 731.2 | bl/lu | 863.1 | 202.5 | te | 857.9 | 176.6 | gr | 578.9 | 12.8 | wt | 535.5 | 166.0 |
| 1988 | 1,854.7 | 675.2 | wt | 728.0 | 191.0 | ho | 718.3 | 38.2 | gr | 562.9 | 0.9 | fl | 535.6 | 69.3 |
| 1989 | 1,647.9 | 531.2 | ne | 595.2 | 102.7 | bl/bl | 518.1 | 41.7 | gr | 306.2 | 0.0 | ho | 357.8 | 41.3 |
| 1990 | 1,668.4 | 874.3 | fp | 736.6 | 175.1 | ho | 1001.9 | 238.9 | gr | 386.6 | 0.6 | te | 551.6 | 131.5 |
| 1992 | 1,770.2 | 696.9 | wt | 744.1 | 223.6 | te | 874.4 | 154.5 | gr | 360.7 | 0.1 | te | 548.4 | 156.3 |
| 1993 | 1,839.3 | 612.2 | bl | 629.8 | 134.4 | bl | 898.4 | 147.5 | gr | 419.2 | 0.0 | bl | 498.6 | 87.7 |
| **Mean** | **1,690.0** | **633.4** | | **717.6** | **170.0** | | **828.0** | **131.4** | | **492.9** | **4.7** | | **533.0** | **134.3** |
| **SD** | **154.8** | **136.1** | | **84.1** | **36.8** | | **196.8** | **69.4** | | **140.4** | **5.7** | | **96.2** | **65.0** |
| **CV** | **0.1** | **0.2** | | **0.1** | **0.2** | | **0.2** | **0.5** | | **0.3** | **1.2** | | **0.2** | **0.5** |
| **Mean Dev** | **128.9** | **111.0** | | **70.5** | **31.2** | | **163.0** | **62.0** | | **124.7** | **5.5** | | **60.1** | **51.9** |
| **Rel Dev** | **0.1** | **0.2** | | **0.1** | **0.2** | | **0.2** | **0.5** | | **0.3** | **1.2** | | **0.1** | **0.4** |
| **Median** | **1,719.3** | **643.7** | | **732.3** | **179.0** | | **866.2** | **151.0** | | **491.1** | **0.8** | | **535.6** | **143.9** |

*Table 10: Annual rainfall, erosivity, runoff and sol loss on test plots (1983-1992) in Anjeni. [Source: SCRP, 2000c, 39]*

On experimental plots the performance of different SWC technologies with regard to soil loss and runoff and yield and biomass production is monitored. In Anjeni two sets of experimental plots (EP I, 28% slope, EP II, 12% slope) at different slopes with different expositions and different soil types are present. Because Anjeni is a high-rainfall area, only graded structures are present because besides soil conservation water drainage is equally important.

| Mean annual soil loss (t/ha) | | | | | Mean annual runoff (mm) | | | |
|---|---|---|---|---|---|---|---|---|
| | Local Cultivation Practice | Graded Fanya Juu | Graded bund | Grass strip | Local Cultivation Practice | Graded Fanya Juu | Graded bund | Grass strip |
| EP I | 110 | 36 | 38.0 | 30 | 487 | 325 | 331 | 275 |
| EP II | 90 | 17.1 | 34 | 36 | 482 | 239 | 290 | 401 |
| **Relative impact on crop yield production (%)*** | | | | | **Relative impact on biomass production (%)*** | | | |
| EP I | | +4 | -13 | 0 | | -5 | -13 | +8 |
| EP II | | +14 | -6 | +14 | | +5 | -12 | +11 |

* The area for yield and biomass measurement is always the entire plot (180 $m^2$) irrespective of area occupied by conservation structures

*Table 11: Mean annual soil loss and runoff for different SWC measures and local cultivation practice and relative impact on crop yield and biomass compared to local cultivation practice. Period of observation: 1986-1990. Mean soil loss and runoff for grass plot: observation period 1989 and-1990 and 1992.*
*[Source: Herweg & Ludi, 1999, 106, 107, SCRP, 2000c, 47]*

On EP set-up I Fanya Juu and bunds did not show significant differences in mean annual runoff and soil loss. In the last two years of recording, the bund seemed to retain slightly more water than the *Fanya Juu*, which increased the risk of waterlogging. On average, the grass strip reduced soil loss by 67% compared to the control plot. During the last two years of measurements, the bund seemed to perform slightly better in conservation than the Fanya Juu. On average both systems reduced soil loss by about 65%. Despite high erosivity in 1990, there seems to have been a tendency towards continuous decrease of soil loss, in both absolute and relative terms, although rainfall and erosivity showed high variability during the same period.

On EP set-up II both soil loss and runoff values were lower on the more gentle slope compared to set-up I. On set-up II, Fanya Juu showed the highest reduction of both soil loss (81%) and runoff. However, water retention was a severe obstacle to the production of certain crops. Unlike in set-up I, high erosivity in 1990 resulted in increasing soil loss on set-up II.

Vegetation cover on all cultivated plots (cereal, pulses) apparently failed to provide sufficient protection, particularly at the beginning of the rainy season. This shows the need for structural SWC. Nevertheless, absolute soil loss values were still above the tolerable level (>30 t/ha and year, on average), under any SWC treatment. The grass strip seems to be a recommendable option for several reasons. On one hand, compared to bunds and Fanya Juu it is less costly and requires less labour. The risk of waterlogging is not as big as under the other treatments on gentle slopes. Additionally, reduction of soil loss is considerable, although the grass strip does not show the highest reduction measured. With respect to erosion, other SWC structures may be more efficient than grass strips (Fanya Juu seems to be slightly better than bund), but construction and maintenance is expensive and problems of adaptation must also be considered.

EP results show the impact of structural conservation and the grass strip only, without considering additional yield improvement practices. Thus, the reduction of soil loss and the achievement of a stable production level must already be considered a success. However, it was not possible to increase crop yield production to an extent that could convince land users of the usefulness of SWC. Therefore, the goal of finding measures that are both protective and sufficiently productive has not yet been reached. Further research must aim to find a better compromise between biological, agronomic and mechanical SWC components. A solution is needed, particularly for tef which leads to pulverised and bare soil at the beginning of the rainy season.

***Social and economic characterisation***

The Anjeni research unit is located in the upper parts of Wet *Weyna Dega* and is a typical example of an intensively cultivated area in Gojam. It is an area with favourable natural conditions in relation to soils, precipitation, temperature and, in particular, due to the lack of pests and diseases such as malaria or tsetse flies. The Anjeni research catchment covers an area of 113.4 ha. Most of it belongs to the Anjeni peasant association (575 ha) with the exception of a small area that belongs to the Jenhala peasant association. The population density in 1991 in the area of the Anjeni peasant association was 193 inhabitants per sq.km.

The traditional system of land use was adapted to a natural environment with low human and animal population densities. It was characterised by lengthy fallow periods, extensive reliance on natural vegetation and minimal pressure on grazing land. However, in the last few decades, increasing human and livestock populations put natural resources under enormous pressure. Today the agricultural system in Anjeni has features typical of both the upland cereal-based system and the smallholder mixed system of agriculture. The upland cereal-based system is characterised by the fact that it reaches the highest possible degree of self-sufficiency with little market integration, which is also the case in Anjeni. Crop growing and livestock keeping are closely linked in Anjeni. The main emphasis in farming is clearly on cereals, pulses, and oil-seeds. Food security was reputedly satisfactory, surely also due to storage practices.

The entire Amhara population of the Anjeni research unit adheres to the Ethiopian Orthodox Christian faith. The church and religious beliefs have a considerable influence on peasants' activities: there are numerous religious associations that also serve as the social basis for dissemination of information. Numerous holidays, some with strict rules, are an integral part of the agricultural calendar, but may interfere with the organisation of urgent fieldwork.

The 1976 land reform programme implemented a redistribution of farm plots and an increase of the number of families entitled to cultivating farm plots. The commonly accepted socio-economic grouping appears to be the hamlet (*got).* From 1988 onwards villagisation was implemented in the catchment area, but is currently dissolving as farmers are moving their homes back to the old settlement locations. It is too early to assess the impact of the new policy introducing economic liberalisation as of 1990 – a policy aiming to strengthen farmers' roles and their contribution to the national economy and development.

In the past few decades, the general development in the area can be described as highly dynamic, and moreover, natural resources are greatly threatened. In terms of system theory the farming system in Anjeni tends to undermine itself through positive feedback-loops: An increasing number of persons and families have to share the same amount of land. Besides, cattle breeding and cultivation compete dramatically because no major technological change has occurred despite shrinking grassland resources. The average farm size today is too small to support a family. Cultivating steep slopes, using unfavourable cultivation practices, shortening fallow periods, removing biomass, and overexploiting grazing and bush land are widespread. Thus, processes of intensification and degradation drastically narrow down farmers' options. Affected by environmental degradation and land shortage, some farmers have already emigrated to join resettlement schemes in Wellega and elsewhere in western Ethiopia. In future, specialisation or new occupations, as well as changes in the farming system and market-orientation will be necessary.

In 1984 the SCRP standard survey was conducted, producing demographic and livestock data for all 85 households that had farmland, fully or partially, inside the research catchment. In 1987 a reduced sample of 31 households was selected by the Standard Survey, out of which 19 households were used to produce a complete data set. An in-depth social survey was conducted in 1992, concentrating on farmers' economic strategies and options.[90] This in-depth study cites 95 households (of which 76 belonged to Anjeni PA and 19 belonged to Jenhala PA) with a share of farmland inside the research catchment. Only few households depended entirely on land inside the catchment. Of the 95 households, 28 were selected for in-depth interviews according to wealth categories. The Anjeni research unit was also part of an informal social study covering Dizi, Anjeni and Gununo conducted by a social anthropologist in 1992.[91]

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90 Ludi, 1997.

91 Tsehai Berhane-Selassie, 1994.

### *Demographic features*

Most families consisted of three to six persons. Single persons or incomplete families headed by a female were rare. On the one hand, this indicates that there has been virtually no need, opportunity, or permission for men to leave the community in search of other employment. On the other hand, it indicates that the nuclear family – the most important economic and social unit in the Amharic culture – could still make a living in the area. Impoverishment so far was palliated within the community. But there were reports that some impoverished farmers who fell out of the agricultural production system had had to emigrate.

| | 1984 | 1987 | 1991, Anjeni PA | 1991, Jenhala PA |
|---|---|---|---|---|
| **Households recorded** | 85 | 19 | 76 | 19 |
| **Persons recorded** | 430 | 85 | 405 | 97 |
| **Average size of fam.** | 5 | 4.5 | 5.3 | 5.1 |

*Table 12: Number of households, people, and average family sizes in Anjeni research area. The samples of 1984 and 1991 include all households with a share of land inside the research catchment. [Source: SCRP, 2000c, 65]*

In 1984, 53.7% of the population were aged less than 15 (231 out of 430). In 1991 the under-15 age group constituted 50% (79 out of 158) and 58.6% of the population were younger than 18 years. Such high numbers of young people in a society are typical of countries with a high population growth rate

### *Livestock holding*

Livestock plays an important role in the land use system: it is a source of food, income, security, and status. Peasants argue that because the population is so high, the livestock number must also be high, as each family should have at least two oxen, one cow, one animal for transportation, as well as some sheep. While richer households show no tendency to increase their herd sizes, and concentrate more on the quality of their herd, average and poorer families want to increase herd sizes, and in some cases they are compelled to do so.

Providing fodder for livestock is one of the greatest problems faced by smallholders in Anjeni, and this limits the desire for more cattle. In addition to the shortage of fodder, people mention ticks (*alqet*) as a problem of cattle rearing. Between 1984 and 1991, the amount of pasture land decreased by approximately 3% annually, while the number of livestock – like the human population – grew by more than 3%.

| Number of oxen per household | 1984 | | 1987 | | 1991, Anjeni PA | | 1991, Jenhala PA | |
|---|---|---|---|---|---|---|---|---|
| **0** | 3 | 4% | 3 | 16% | 3 | 4% | 3 | 16% |
| **1** | 17 | 20% | 3 | 16% | 15 | 20% | 6 | 32% |
| **2** | 54 | 63% | 10 | 53% | 43 | 57% | 7 | 37% |
| **3** | 10 | 12% | 3 | 16% | 13 | 17% | 3 | 16% |
| **4** | 0 | 0% | 0 | 0% | 2 | 3% | 0 | 0% |
| **56** | 1 | 1% | 0 | 0% | 0 | 0% | 0 | 0% |
| **Total households** | 85 | | 19 | | 76 | | 19 | |
| **Total oxen** | 160 | | 32 | | 148 | | 29 | |
| **Average** | 1.9 | | 1.7 | | 1.9 | | 1.5 | |

*Table 13: Oxen holding per household in Anjeni research area. [Source: SCRP, 2000c, 70]*

One thing that prevents poor households from becoming self-sufficient is that they do not have enough oxen. With 27 households out of 95 in 1991, 28.4% did not have a pair of oxen, while 52.6% had two oxen and 18.9%, i.e. 1/5 of the households, had more than one pair. With an average of 1.9 oxen per household, the situation in Anjeni can be considered good compared to many other highland areas

***Landholdings***

In 1984, the sample households had fairly small holdings inside the Anjeni research unit, with 71% of the households cultivating only 1 ha or less inside this area. The average was significantly lower than 1 ha. It is not known how much additional land they cultivate outside the catchment. 85 households with a total of 430 persons had access to land inside the catchment in 1984. Out of the total area they had to share 58.5 ha, meaning that an average household had 0.7 ha, and each person had 0.14 ha of land inside the catchment (incl. grassland, village land, bush-land, bamboo, and fallow land). All families also cultivated land outside the catchment. Figures for 1991 show that most of the families had a total of 1 to 2.5 ha of farmland inside and outside the catchment. Fragmentation of land was high. Families had up to 8 parcels.

Despite continuing inequities with regard to land holdings, the situation had improved considerably compared to the pre-revolutionary period (1974). At that time, for example, 58% of the households were small farms with less than 1 ha of land; collectively they cultivated only 18% of the land, while the richest 5% of farmers controlled 29% of the land. In 1992, the richest 10% of the population controlled about 15% of the total arable land, the middle group accounting for 25% of all farms controlled 24% of the land, and the poorest groups, which make up 48% of the population, controlled only 38% of that arable area.[92]

Between 1986 and 1991 the total number of people engaged in agriculture increased by 176, or 19% in the Anjeni peasant association. In 1986, 208 peasant association members – each representing a family – were registered, whereas in 1991 this total had risen to 246. Over a period of 5 years, population growth amounted to 3.8% annually, while there was an 3.6% increase of the number of households.

According to PA data in 1986, the mean size of farmland per household was 2.2 ha. Based on the assumption that the total amount of cultivable land remained constant, this means that the mean farm size per household decreased to 1.9 ha until 1991. During this five year period the mean decrease in farmland per household was 0.3 ha, or 15%. With increasing pressure on the land use system, 80% of the total Anjeni PA was farmland. Only the grassland remained almost constant. The average farm size is now at the limit of subsistence farming.

### 2.3.4 Simen[93]

The Simen Mountains in northern Ethiopia (38° E / 13° N) symbolise an area which is typical of the Ethiopian highlands at their extremes: Simen has a topographic ruggedness with steep escarpments – and with a breath-taking beauty of high touristic value. Simen has a rich natural biodiversity with altitudinal successions of fauna and flora and many endemic species of which the Walya ibex has become a national symbol, although it is now threatened by extinction. Simen has been inhabited by human land users for more than two thousand years and thus provides an outstanding cultural heritage and an example of peaceful co-existence of religious groups. Simen has the highest peak in Ethiopia, Ras Dejen (4,533 m asl), where an alpine climate near 0°C persists all year round, sometimes even with a snow cover lasting a couple of days. However, this moist highland area is surrounded by dry lowland savannahs and deserts.

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92 Ludi, 1997, 61.

93 The following Section is an excerpt from Hurni & Ludi, 2000.

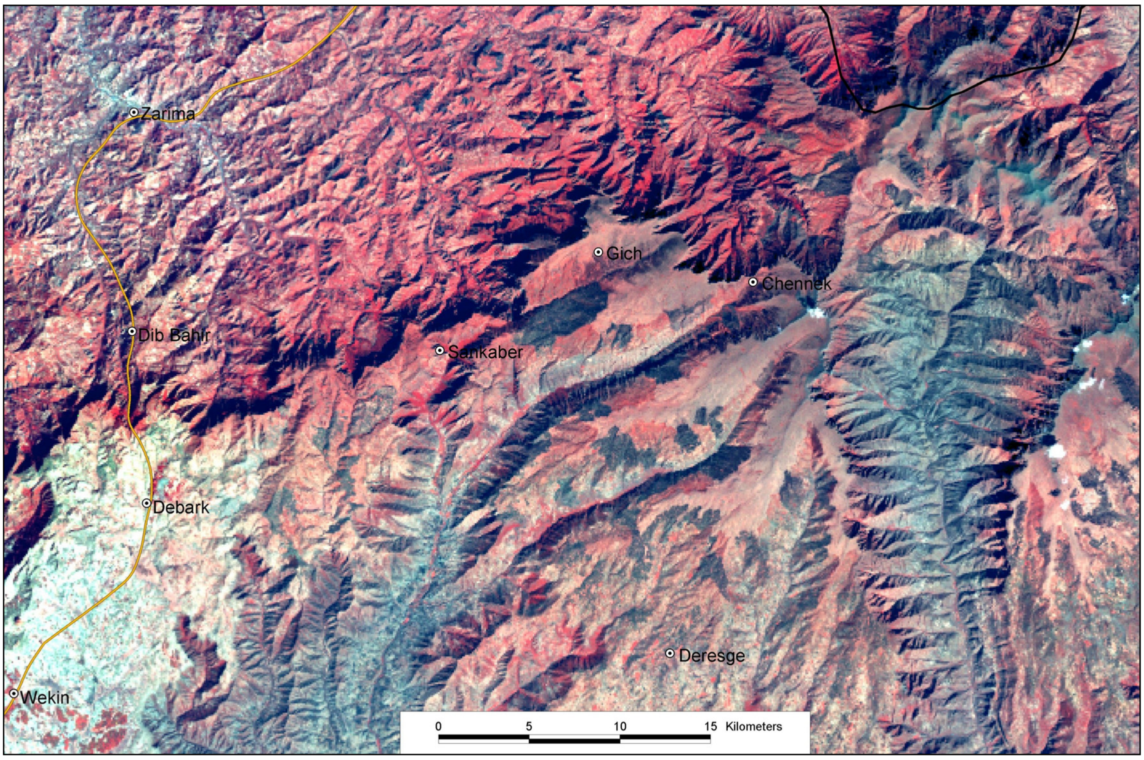


*Figure 19: Satellite image in false colour of the Simen Mountains. (Landsat TM5, January/ February 1987) [Source: Ethio-GIS]*

Unfortunately, Simen is also plagued with the typical features which have made Ethiopia world famous. Degradation of natural resources, particularly vegetation and soils, is widespread and leads to a chronic food deficit under present standards of mountain agriculture. Traditional farming, while preserving a high diversity of cultural plants, has very low standards of productivity. Contemporary technological, social and economic development is virtually absent in this remote area. Demographic trends since the 1950s show a doubling of the population every 25 years, resulting in scarcity of good land, shortening of fallow periods on shifting cultivation land, and deforestation even in the last remnants of natural forests.

Finally, Simen is blessed with outstanding wildlife in certain areas where some natural habitats remained. The Walya ibex in-migrated into Simen during the ice age,[94] only a few thousand years earlier than human land users. Because of this rare endemic animal, Simen received the attention of the global community, which called for its protection and survival. This external interest led to a national initiative to create a National Park in 1969, thus forming a protection area where nature should survive.

Safeguarding the survival of wildlife, however, soon conflicted with the interests of the human inhabitants of the area. It was argued that even without the National Park the sustainability of the mountain livelihood systems of the people would not be guaranteed, because the remaining natural resources of the Park area would soon be consumed. Hence, protection should be enforced by any means. However, this line of thinking was difficult to justify in view of human starvation, which has affected some villages year by year, especially since the 1990s, even in the absence of climatic drought. Moreover, experiences with Park enforcement during the 1970s and 1980s were mostly negative.

The research area covered by the Simen Mountains Baseline Study, from which the following information is derived, was carried out insider and around the Simen Mountains National Park (SMNP). It is located in North Gonder Zone (NGZ), an administrative subdivision of Amhara National Regional State (ANRS) in north-central Ethiopia. The Park, with a total area of 136 km$^2$, is embedded in 8 Kebele Associations (KA),

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94 Nievergelt, 1981, quoted in Hurni & Ludi, 2000, 4.

or communities, namely *Mindigebsa & Adisge, Abergina, Ambaras/Jona & Argin,* and *Lori* in the highlands, and *Adebabay, Agidamiya, Kabena & Sera Gudela, and Angwa & Kernejan* in the lowlands,[95] belonging to 3 different Weredas (*Adi Arkay, Janamora* and *Debark*). These 8 KA's cover a total area of 471 $km^2$ and consist of 30 villages.

### *Geology*

The Simen area was built up by plateau basalt (Trapp series). A 3,000–3,500 m thick sequence of basaltic volcanic layers was deposited on Mesozoic sandstone and limestone that form a 500 m thick cover over the Precambrian crystalline basement.[96] These layers are composed of numerous 5 to 50 m thick olivine-basalt lava flows, interbedded with tuff layers. The main part of the Simen area consists of remnants of a Hawaiian-type shield volcano, overlying the volcanic flows of the Trapp series. The shield volcano was mainly built up by augit-basalt flows several meters thick. The extreme escarpment appeared to be preconditioned by an extended uplift of the whole massif during the Tertiary, comprising major faults which can be attributed to the Rift system extending over most of East Africa to the Red Sea. Harder rocks on the foot of the escarpment preconditioned the development of the terrace-like steps which today form a favourable area for settlement and agriculture.[97]

### *Topography, geomorphology, and soils*

The study area extends from its lowest point at 1,350 m asl in the north-west to 4,430 m asl, the peak of Bwahit mountain. A very high relief energy is characteristic of the whole area. Four distinctive geomorphic units can be differentiated:[98]

- the deeply incised lowland valleys below 2,000 m asl;
- the lowland terrace-like steps (roughly at 2,000 m asl), which comprise the main cultivation and settlement area of this belt;
- the steep escarpment between 2,000 and 4,000 m asl, extending in a SW-NE direction, which forms the main wildlife habitat;
- the highland plains and valleys South of the escarpment, a densely settled and cultivated area.

As a function of the highly differentiated topography, climate, and land use system in the Simen area, many different soil associations can be found. One main distinction can be made between areas above roughly 3,000 m asl, and those areas below. In areas above 3,000 m asl, Andosol is the typical soil type on uncultivated or scarcely cultivated land, whereas in areas below 3,000 m asl and on cultivation land above 3,000 m asl, Phaeozem, Vertisol, Luvisol, Regosol and Leptosol are dominant. Soil degradation is very pronounced in the entire study area, but particularly on cultivation land. Average soil loss rates on arable land (including both actually cultivated as well as fallow land) are estimated at 70 t/ha and year. These figures are 70% higher than the 42 t/ha per year on arable land that have been estimated for the Ethiopian Highland in general.[99] Highland villages with an average of 85 t/ha per year, generally show higher annual erosion rates than lowland villages with 65 t/ha per year. One explanation of this latter feature is the topographic situation. All lowland villages are characterised by a more or less flat terrace which is the main cultivation area. Here,

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95 The terms 'highlands' and 'lowlands' do not directly correspond to the agro-ecological altitudinal zonation used in Ethiopia. Villages referred to as being in the highlands mostly lie above 2,800 m asl and would thus be in the *Dega* Zone. The 'lowlands' can be further divided into the 'upper' lowlands, between 2,200 and 2,800 m asl (still mainly *Dega*), and the 'lower' lowland below 2,200 m asl (*Weyna Dega* to *Kolla*). The distinction between highlands and lowlands is thus relative and specifically related to the Simen area.

96 Hurni, 1986b, 34.

97 Hurni, 1986b, 35.

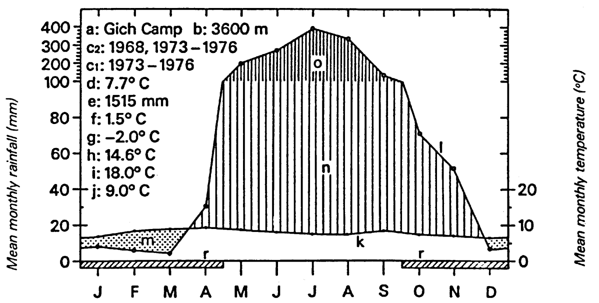
98 Hurni, 1986b, 28.

99 Hurni, 1989, 14.

erosion rates are generally lower. Secondly, fallow periods in lowland villages are generally longer than in highland villages, especially on sloping land, thus having more land under grass or bush vegetation, with lower average erosion rates

### *Climate*

The pattern of rainfall in the Simen Mountains is characterised by one single rainy season with high amounts between June and September. Daily temperatures vary between 27°C annual mean in the lowest parts of the study area at 1,350 m asl, and 2°C on the highest peak in Simen, Ras Dejen, at 4,533 m asl outside the study area. In the study area, rainfall varies between less than 1,000 mm in the lowlands and more than 1,500 mm in the highlands. In Gich Camp, a longer-term average of 1,515 mm was measured in 1968 and 1973–1976, with a mean annual temperature of 7.7°C at 3,600 m asl.[100]




*Legend:*

- *a: Climatic station*
- *b: Altitude (m asl.)*
- *$c_1$: Measuring period temperature*
- *$c_2$: Measuring period precipitation*
- *d: Mean annual temperature in °C*
- *e: Mean annual precipitation (rainfall)*
- *f: Mean daily minimum temperature of coldest month (NOV, DEC): 1.5° c*
- *g: Absolute minimum temperature (JAN 1974, NOV 1975, JAN 1976): –2.0° C*
- *h: Mean daily maximum temperature of warmest month (APR): 14.6° C*
- *i: Absolute maximum temperature (MAR 1975): 18.0° C*
- *j: Mean daily variance of temperature: 9.0° C*
- *k: Annual interpolation of mean monthly temperatures: Normally between 7 and 8° C*
- *l: Annual interpolation of mean monthly percipitation*
- *m: Arid months (dotted)*
- *n: Humid months (hatched widely)*
- *o: Mean monthly percipitation over 100 mm, reduced 10 times (hatched narrowly)*
- *r: Months with absolute minimum temperatures below 0° C (hatched)*

*Figure 20: Climate diagram for Gich Camp, Simen Mountains National Park.*
*[Source: Hurni, 1982, 53]*

### *Vegetation and wildlife*

Simen is a mountainous area where unique botanical and zoological combinations of species have been able to resist human interference because of the extreme topography and altitudinal range of the landscape. Particularly worth of mention are the Walya ibex endemic to Simen, the Simen fox (Ethiopian wolf) endemic to Ethiopia, and the vegetation belts typical of Ethiopia, which can be seen in their most extended altitudinal range in succession.

### *The Simen Mountains National Park (SMNP)*

Based on surveys supported by UNESCO in the 1960s, the Park was delimited and gazetted in 1969, with an assumed area of 225 $km^2$. This Simen Mountain Baseline Study's reassessment of the gazetted Park boundaries, however, showed that the Park area is actually only 136 $km^2$, much less than anticipated. The Park comprises part of the spectacular escarpment of Simen, with comparatively large areas of natural vegetation and a wide variety of animal species, and includes cultural landscapes both in the highlands as well as in the lowlands. These areas had been settled much before the establishment of the Park. Long-term user rights by local land users are in conflict with the national wildlife conservation policy, mainly because natural resources inside the Park are constantly being diminished despite the establishment of the Park.

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[100] Hurni, 1982, 54.

***Ethnic groups and demographic features***

The population of the Simen Mountains belongs to the Amhara ethnic group. Rural households play the major role in and around SMNP, both in number and regarding their influence on natural resources and ecology. At the end of 1994, an estimated 4,925 households were living in the area, which gives a population of about 27,750 people.[101] For 1964, 2,700 households were estimated from aerial photo interpretation and house counts.[102] This results in an increase of households of roughly 2.0% per year for the given 30-year period. For the whole area, an annual growth rate in the order of 1.5 to 2% can be assumed also for the next decades, which will result in a doubling of the population within the next 35 to 45 years.

The population structure in terms of gender and age is similar for the whole study area, and is typical of all least developed countries. Slightly more than 50% of the human population is below the age of 15, and only about 15% are more than 50 years old. In the three highland villages of Argin, Ambaras and Abergina it can be observed that there are less children in the age class of 1–5 years than in the age class of 6–10 years. It is uncertain whether this fact relates to reduced fertility due to the generally worsened livelihood condition in these villages, or if child mortality increased, or both. In these same villages, a significant deficit of men in the age class of 31–35 years could be observed. The most probable reason is the civil war.

***History and religion***

The Amhara and Tigrinya groups are sometimes considered synonymous with Ethiopian Orthodox Christianity. In Simen, however, a more complex situation is found. Until about 1990, three different religions co-existed: the Orthodox Christian, the Muslim, and the Felasha (Ethiopian Jews). After 1988, the Felasha of Simen were invited to migrate to Israel, probably based on a secret agreement between the two Governments at that time. It is assumed that the first settlers in the area were Felasha, practising the Jewish faith. Around the 12th century Christianisation took place, which may have originated from Lalibela, the political and cultural centre at that time. In the 16th century some Ethiopian Orthodox Christians were temporarily forced to convert to the Islamic faith in the course of the Muslim conquest of Ethiopia by Mohammed Gragn. However, the majority of the population in Simen reconverted between the 17th and 19th centuries under the influence of the Christian emperors of Gonder,[103] although a number of communities kept the Muslim faith, particularly in the less accessible areas of Simen. For example, in the study area, the ratio of Muslim to Christian people is about 30:70, which is a relatively high proportion of Muslims compared with the rest of Simen.

***Farming system***

Agriculture in Simen is the predominant occupational sector, with almost 100% of the population engaged (outside the towns). The farming system is characterised by complex linkages between the cropping subsystem and the livestock subsystem.

Main crops grown in the highlands are barley, horse bean, field pea, lentil, linseed and flax. In the upper lowlands, barley, wheat, tef, horse bean, field pea, linseed and noug are dominant, and in the lower lowlands (2,000 m asl and below), tef, sorghum, millet, maize and noug dominate. Homesteads are used to grow potato, maize, onion, pepper, and other spices. Areas above 3,200 m asl allow only the cultivation of barley and potato due to temperature limitations. To avoid diseases (*ergot*) and infestation with weeds, barley should not be grown in two consecutive years. Below 3,200 m asl, crops are grown in a rotation cycle, with cereals followed either by other cereals, or pulses. Areas between 2,000 and 2,800 m asl seem to be privileged when considering the variety of crops that can be grown. Neither temperature nor rainfall pose strict limitations.

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101 Based on a social survey carried out in 1994 by the North Gonder Planning and Economic Development Department and estimates for villages not covered by the survey. As an approximation, 5 persons per household were taken to estimate the number of people.

102 The number of houses for 1964 and 1975 are taken from Staehli, 1978, as far as available. Otherwise they were counted on aerial photographs dated from 1964.

103 Staehli, 1978, 39.

Below 2,000 m asl, mainly rainfall, and to a lesser extent also temperature, limit the choice of possible crops to sorghum, millet, maize, noug, and in some favourable places, tef.

Generally, fallow periods in the lowlands are much longer than in the highlands, mostly between 2 and 5 years, sometimes up to 8 years. However, both in the highlands as well as in the lowlands, fallow cycles are becoming shorter due to land scarcity. In the highlands, the intermediate fallow year is abandoned in many instances. In areas where different crops can be grown, the problems associated with continuous cropping are mainly its negative effect on soil fertility, i.e. mining of available soil nutrients without any measures to replenish the nutrient stock. However, in areas where only barley can be grown, the risk of *ergot* increases dramatically when barley is sown year after year.

***Institutional characteristics***

The study area is characterised by a minimum of socio-economic infrastructure and administrative institutions: Few schools, no clinics, few markets of only local character, an economy based mainly on subsistence agriculture, and almost no extension services. The religious systems provide the strongest institutional set-up in the villages, followed by the Kebele Associations (KA).

The most prominent institution in the study area is the Simen Mountains National Park (SMNP). While seen by the Government as a means to implement protection of the Park resources, local inhabitants consider the Park institution as a threat to their existence. Because the inhabitants of a number of villages inside or in the vicinity of the Park were expelled in 1978 and could only return after about 8 years, their attitude towards the Park as an institution remained critical.

Land titling is delegated to the KA, which has the mandate to redistribute land according to the needs of a growing population. As a result, on the one hand, there is no security in individual land holding, but on the other hand, this allows local reallocations that might be needed to achieve sustainable land use in the medium term. This insecurity should thus not only be seen as an impediment to development, but also as an opportunity for sustainable land management and protection of natural resources.

### 2.3.5 Mesobit & Gedeba

Like Simen, Mesobit & Gedeba does not belong to the research network of the SCRP. No previous studies were carried out in this area, therefore information with regard to major bio-physical and socio-economic characteristics are lacking. The following information is based on some impressions gained during a field study carried out in the field of household and communal strategies dealing with conflicts over natural resources.

Mesobit & Gedeba is located at 39°5′ E / 9°3′ N at an altitude of 1,800 to 2,600 m asl at the footslope of the central Ethiopian highland bordering the lowlands in the east. Mesobit & Gedeba is about 50 km ESE of Debre Birhan, the capital of North Shewa Zone. The small, but important market town of Aliyu Amba is about 3 km to the NE of Mesobit & Gedeba, and Ankober, the former imperial capital before it has moved to Entoto / Addis Abeba,[104] about 15 km to the NW. Mesobit & Gedeba with a population of about 1,300 inhabitants in 230 households is on of 6 villages (*got*) of Aliyu Amba Zuria KA.[105] Mesobit & Gedeba is located at the contact zone of different ethnic groups with different land use systems. The prevalent land use system in Mesobit & Gedeba is permanent crop cultivation combined with livestock production. Irrigation is comparably widespread. Only a few kilometres to the east, the area is inhabited by Afar pastoralists. Mesobit & Gedeba and surroundings have since generations been an area of intensive economic exchange between the two groups and production systems but also an area of conflict.

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104 McCann, 1995, 111.

105 Data from the KA administration, estimates for 1998.

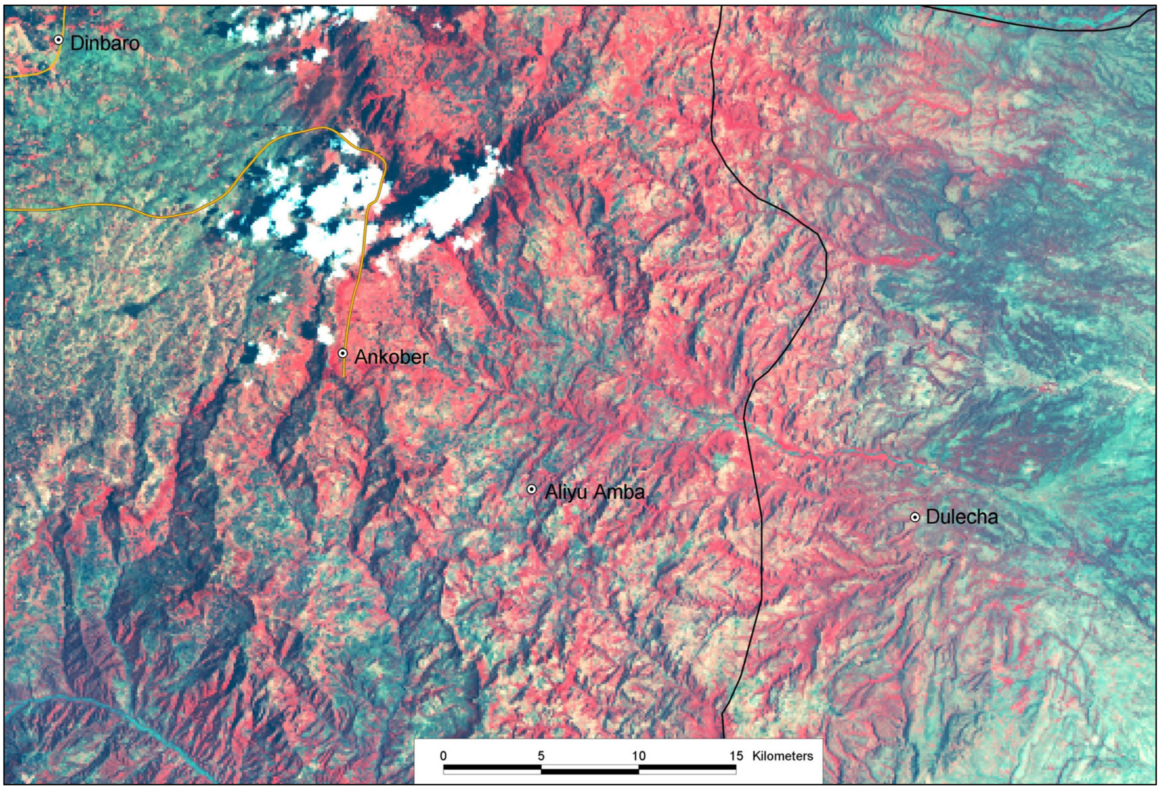


*Figure 21: Satellite image in false colour of the Mesobit & Gedeba area. To the east the Afar lowland is visible, to the west the highlands around Debre Birhan. (Landsat TM5, January/ February 1987) [Source: Ethio-GIS]*

With regard to the bio-physical environment Mesobit & Gedeba shows similarities to Maybar. However, no detailed information is available with regard to climate, soils and soil degradation. Due to its altitude at only 1,800 m asl, temperatures might be slightly higher and annual rainfall lower than in Maybar. Crops grown in the area and remnants of natural vegetation would indicate an annual rainfall in the order of 900 to 1,200 mm. The DA estimated that about 75% of the area is covered with brown to dark brown soils of medium fertility (in Maybar, dark brown soils are classified as Phaeozems).

A major difference of Mesobit & Gedeba compared to the other research areas is the widespread usage of conservation structures and small-scale irrigation. Both is a precondition as well as a result of a much more pronounced market integration of the population of Mesobit & Gedeba compared to the other research areas. Specific marketable goods such as vegetables and fruits are cultivated in irrigated gardens. Agricultural inputs such as artificial fertilisers are bough on the market and used for tef, which is sold. Terracing the land thus not only contributes to control soil erosion and runoff, but also improves water conservation and prevents fertilisers from being washed away.

Although the inhabitants of Mesobit & Gedeba are mainly orthodox Christians, they are much more liberal than their neighbours in the highlands. On the one hand religious rules are not obeyed as strict as in highland areas. It is quite common to see farmers doing fieldwork such as ploughing also on Saint's days. On the other hand artisans and other professionals do not have such a low social status as in highland communities. More often farmers mentioned that they depend on the skills of artisans and do therefore respect them.

# Part II

# Theory and Methodology

# 3 Conceptual Framework and Methodology

## 3.1 Economic Aspects in the Sustainability Discussion

> *"If environmental phenomena were independent of economic activity, there would be no need to trouble economic analysis. Environmental issues could be addressed by environmental policies, and economics could pursue its own objectives, without risk of impairing the achievements of its own and other domain's objectives. Environment and economy interact, however."*
> *(Bartelmus, 1997a, 324)*

> *"The loss of productivity due to erosion, though difficult to estimate in precise terms, is a major economic setback to the farming community around the world."*
> *(Olson et al., 1994, 586)*

The concept of sustainable development evolved from the "Limits to Growth" debate of the early 1970s, which discussed whether or not economic development would lead to environmental degradation and the collapse of societies.[106] This discussion can in turn be traced back to Malthusian considerations and the idea of a 'Spaceship Earth',[107] in which the natural resource base humankind has to survive on is assumed to be limited, whereas the demand is thought to be almost infinite.[108] Since these early debates, the concept of sustainable development has been refined and has become central to the way we think about environment and development, which is reflected in the 'Earth Summit' held 1992 in Rio de Janeiro.

Sustainable development as defined by the Brundtland Commission,[109] who said that

*"Economic development should be in such a way as to meet the needs of the present generation without compromising the ability of future generations",*

is to too vague for operational purposes at project level[110] and furthermore is primarily of normative nature.[111] This definition fails for three reasons: firstly, it does not specify what human needs are, secondly, it does not clarify the timeframe for the analysis of future generations' needs, and thirdly it does not mention the environment as a key concern in sustainability.[112] Bartelmus' (1997a, 338) definition would read as

*"[...] the set of development programmes that meets the targets of human needs satisfaction without violating long-term natural resource capacities and standards of environmental quality and social equity."*

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106 Pezzey, 1992, 1; Harris, 2000, 4.

107 Tisdell, 1993, 162. The closed system Earth stands in conflict with 'cowboy economy', the cowboy being symbolic of the illimitable plains and also associated with reckless, exploitative, romantic, and violent behaviour.

108 Leach & Mearns, 1996, 4.

109 WCED, 1987, 43.

110 e.g. Wiesmann, 1995; Bartelmus, 1997a.

111 Pagiola, 1993, 44.

112 Bartelmus, 1997a, 338.

Although it does not define them precisely, this definition includes standards, targets, and norms, leaving them open to societal negotiation. In a next step, sustainable development is broken down into its three key components, which are described separately:

*"**Economic**: An economically sustainable system must be able to produce goods and services on a continuing basis, to maintain manageable levels of government and external dept, and to avoid sectoral imbalances, which damage agricultural or industrial production.*

***Environmental**: An environmentally sustainable system must maintain a stable resource base, avoiding over-exploitation of renewable resource systems or environmental sink functions, and depleting non-renewable resources only to the extent that investment is made in adequate substitutes. This includes maintenance of biodiversity, atmospheric stability, and other ecosystem functions not ordinarily classed as economic resources.*

***Social**: A socially sustainable system must achieve distributional equity, adequate provision of social services including health and education, gender equity, and political accountability and participation."*[113]

There is ample evidence that current production and consumption patterns do not meet these criteria set forth in the above definition. Characteristically, reference is made to climate change and global warming, ozone layer depletion, water scarcity and pollution, land degradation and desertification, deforestation, or biodiversity loss.[114] The above definition also clearly shows that definitions of sustainable development are not free of conflict, as the goals expressed are often multi-dimensional and therefore raise the issue of how to balance the objectives and how to judge success or failure. Neither environmental problems nor problems of conflicting objectives will be solved by simply listing indicators. An operational definition of sustainability must be found, which is capable of linking the phenomena among each other, as well as with the costs and benefits of related economic activities.[115] Therefore, one branch of economics is mainly concerned with the social evaluation of economic activities, which have either immediate or long-term consequences for the natural environment. A second branch is mainly concerned with the proper valuation of environmental goods such as direct production inputs (e.g. fossil oil, wood) or services (e.g. sinks), in order to capture the different values of a resource properly and to give the right scarcity signals through price mechanisms.[116]

### 3.1.1 Environmental economics

Environmental economics in its broadest sense is concerned with

*"[...] economic interrelationships between mankind and the environment [..]. It involves, amongst other things, study of the impact of economic activity on the environment as well as the influence of the environment on economic activity and human welfare."*[117]

In a more restricted sense, environmental economics seeks to incorporate environmental goods and services into the economic system just like any other input, based on monetary values.[118] In neoclassical economics, on the other hand, the environment is seen as nothing more than natural resources, which are treated as production factors. Consequently, they are undervalued, as only direct use values are considered, while all other values are ignored.[119] This way of looking at the environment as a mere production factor is

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113 Harris, 2000, 6.

114 WBGU, 1996.

115 Bartelmus, 1997a, 325.

116 Dasgupta, 1996, 388.

117 Tisdell, 1993, 3.

118 Perich, 1993, 1.

119 Wiesmann (1998, 189) distinguishes four levels of concepts of 'nature' and 'resources': ***ecological systems***, i.e. all forms, attributes and relationships found in nature (also termed nature, environment, basic capital, natural capital), ***natural resources***, i.e. all components of nature that are considered valuable or can be used by man, ***natural potential***, i.e. all components of nature considered valuable or useful by a society at a given point in time, and ***utilised potential***, i.e. that part of the natural potential actually used at a specific time. In the following

considered responsible for externalities, since it implies that costs from the use of resources are paid for not by consumers or producers, but by society at large or by any other group of consumers or producers not involved in the production or consumption process.[120]

Environmental economists assume that the environment and all the various values of resources can be treated as a commodity, because consumers can reveal their preferences for environmental services or environmental deterioration, even though they generally have no market price. Economic valuation has thus been broadened to include natural resources, which are an input into the production system (direct use value, which is priced), as well as environmental functions such as waste and emission absorption capacities (indirect use values, which are usually not priced), or regulation of cycles (e.g. water, energy), and non-use values, such as option or existence values. This distinction is reflected in the two schools of ***resource economics*** and ***environmental economics***. While the former considers nature mainly as supplier of raw material, which is tradable, and is concerned with the inter-temporal allocation of resources, the latter considers natural resources as consumption goods such as clean air. External effects resulting from the consumption of natural resources are in the centre of the analysis. In resource economics it is assumed that the market can handle the distribution of resource consumption over time. Only if there is no market or if the market is not functioning properly, governmental regulations become necessary.[121]

When entering the production process as direct use values, natural resources can be valued and reveal their true scarcity. This, however, requires clear property rights. In the case of fodder or fuel, for example, property rights are often not clearly defined, which leads to overexploitation of the resource. Indirect use values such as resource functions are hardly ever valued, although they are considered as use values in the above figure. The figure also shows that non-use values are less tangible to the individual than use values. Existence values – the values people attribute to resources simply by knowing that they exist, even if they never directly consume them – are shown to the far right as the least tangible. For example, the value people from industrialised countries attribute to the snow leopard and its preservation is much higher than the value Afghan highland farmers, who suffer livestock losses, attribute to the animal.

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discussion, usually the second term is used, that of natural resources, meaning those components of nature which are considered valuable or usable by human populations in general. Neoclassical economics, however, have concentrated on the utilised potential of natural resources and thus considered only the direct use values.

120 Dinwiddy & Teal, 1996, 200.

121 Endres & Querner, 2000, ix.

The following Figure 22 presents the different economic values attributed to environmental assets:

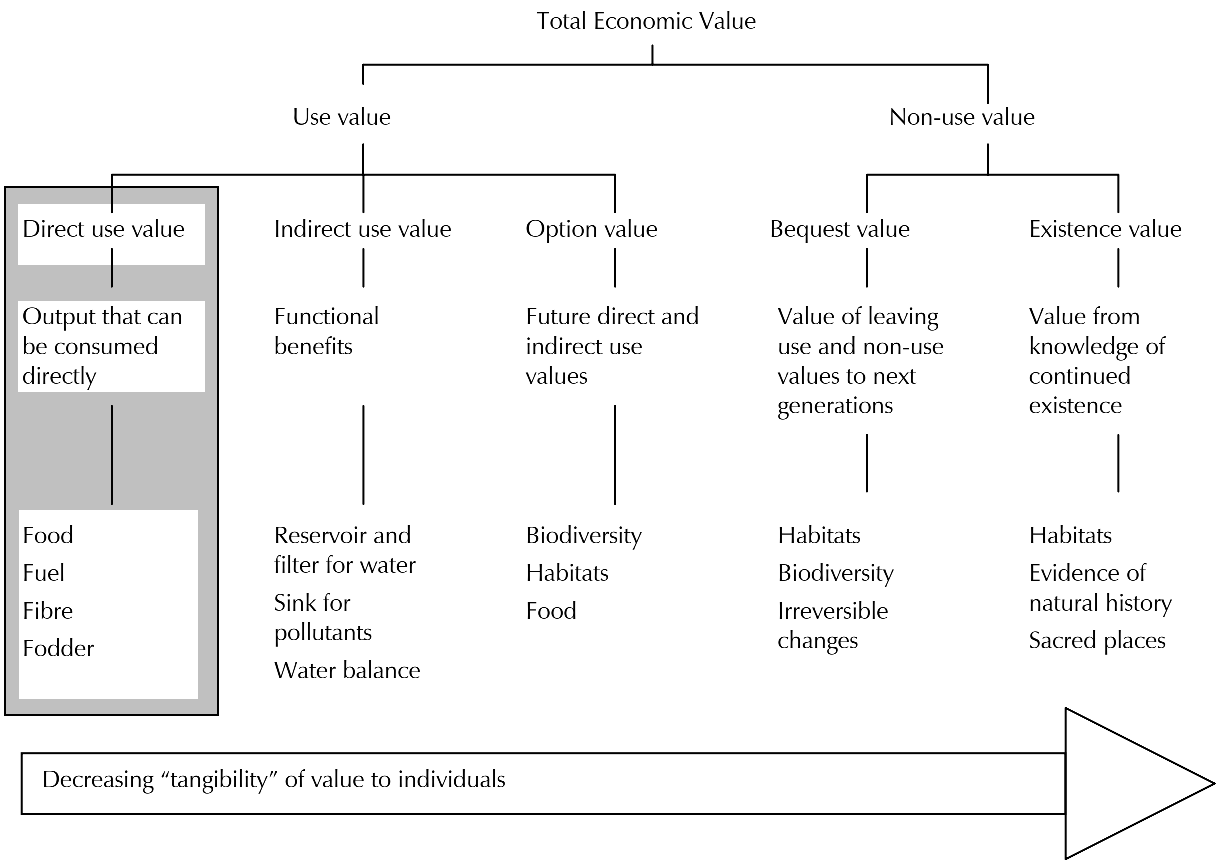


*Figure 22: Economic values attributed to environmental assets with reference to soil.*
*Focus of work* ▭
*[Source: Munasinghe, 1992, 22; Grohs, 1994, 15]*

***Techniques to value environmental assets***

In an attempt to put monetary values on non-marketed environmental goods and services, different techniques have been developed to capture their total economic value. The main purpose of the valuation of environmental goods and services is to assess the benefits or losses that a change in environmental quality would bring for individuals.[122] The basic principle underlying the different valuation techniques is to find out how much an individual would be willing to give up or pay for an environmental improvement or how much the individual would expect to gain in compensation for a deterioration of environmental quality. There are five broad categories of valuation techniques:[123]

- Experimentation
- Stated preferences
- Surrogate markets
- Damage functions
- Benefit transfer

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122 Environmental quality is understood as the sum of all values of an environmental asset, i.e. use and non-use values.

123 OECD, 1994, 80-1.

The first technique, ***experimentation***, involves offering the environmental good in question to the public, and observing how much people are willing to pay for it. While this technique is closest to economic theory, where people choose from different goods and reveal their preferences through their behaviour on the market, such large-scale experiments are difficult to design and usually politically impossible to implement.

The second technique asks people to ***state their preferences.*** Individuals are asked how much they would be willing to pay for an improvement of environmental quality (Willingness-to-Pay, WTP), or how much they would expect to gain in compensation for a deterioration of environmental quality (Willingness-to-Accept, WTA). This method is also known as 'Contingent Valuation Method' (CVM). Although it seems to be a straightforward method, several factors are known to influence the maximum amounts people state:[124] (i) Information bias: Information given to the respondents concerning the good to be valued, as well as the information they already have, may be biased and thus influence their answer. (ii) Way of payment: Answers depend on whether payment is to be direct (entrance fees) or indirect (tax), and to whom the payment is made (e.g. NGO vs. State). (iii) Aggregation level: Respondents stating their WTP for only one particular good (e.g. the forest to be preserved near their home) may answer differently from those stating their WTP for a wider set of the same type of good (e.g. all forests). (iv) Strategic answers: If the question concerns a public good, respondents might state a very low WTP, as they expect that one day they will actually have to pay for that good and that the price will depend on their answer. (v) Hypothetical bias: Respondents might not answer honestly and state a high WTP simply because the question is hypothetical, whereas if they actually had to pay for the amenity, their true willingness to pay would be much lower. (vi) Budget restriction: People state rather what they are able to pay, than what they are willing to pay. (vii) Current circumstances, public opinion, individual interests, and prejudice can have a strong influence on the stated WTP. (viii) Since only the current generation is asked to state its WTP, a bias against future generations is possible and probable. Despite these biases and possible errors, a substantial number of CV studies have been conducted in the USA and in Europe. Usually, valuation concerns goods such as air quality, water quality, recreational areas, wilderness sanctuaries, or national parks. In developing countries, CV studies are still uncommon and focus mostly on national parks and water supply.[125] The reason for the small number of CV studies conducted in developing countries is that they require a high level of knowledge from respondents. Furthermore, CV studies usually concern goods for which property rights are not clearly specified.[126] Protest bids are therefore frequent (e.g. the value of a national park derived from stated preferences might be heavily distorted because respondents claim ownership over this land). WTPs elicited based on CV studies must therefore be treated critically and should be supplemented with additional studies relying on other valuation techniques.

The third technique, based on ***surrogate markets***, is an indirect method where the behaviour of individuals is observed on markets for other goods than the ones to be valued. Usually, those goods are a complement to the environmental good to be valued. There are three methods based on surrogate markets: (i) The travel cost method, where the time and money spent by people to reach an environmental good, usually a recreational site, is valued and considered as the willingness to pay for this amenity. However, only direct use values are considered; existence or option values are not taken into account. (ii) The hedonic pricing method is based on markets for goods directly influenced by the environmental quality to be valued. Typically, it uses land and housing markets to value air and noise pollution. This method presumes freely functioning and efficient property markets as well as mobility and free choice, all of which are not necessarily given in developing countries. If a market for land existed, the value of SWC investments could be estimated with this method. If land with conservation structures were sold for a higher price than land without, the additional price paid would be equivalent to the value of prevented resource degradation. (iii) The wage risk method is similar to the hedonic pricing method but considers the labour market instead of the property market.[127]

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124 Tisdell, 1993, 102; Abelson, 1996, 78-9; Bartelmus, 1997b, 6.

125 OECD, 1994, 85-7.

126 OECD, 1994, 110; Abelson, 1996, 82.

127 OECD, 1994, 135ff.

The ***damage function*** technique is not directly based on individual willingness to pay for environmental benefits. It establishes a dose-response relation between environmental damage (response) and the cause of that damage (dose). This method is usually used to value effects of pollution on health, water, and vegetation. It is applicable only to environmental changes that have impacts on marketable goods, and is therefore not suitable for valuing non-use benefits. Basically, the damage function technique looks at environmental resources that lead to a marginal change in the output of a marketed good, and directly values the impact in terms of changes in output valued at market prices. This method is most often used to estimate environmental costs or benefits, in industrialised as well as in developing countries.[128] Although the method seems simple, it does present several difficulties: Firstly, the data needed to establish the dose-response function must be available, and all possible variables that might be involved must be known. Established functions based on data from other locations might not be accurate enough. Secondly, markets must be well-functioning to allow a proper valuation of the good. Especially in subsistence economies, where many goods are not traded and/or markets are highly distorted, the valuation of the response is not a simple task. Thirdly, since environmental damage is evaluated on the basis of marketed goods, only direct use values are considered. Thus, the result is an undervaluation of the actual damage. And fourthly, the isolation of the response to a given dose is often difficult, as it might be masked by other effects (e.g. technological progress).

The fifth technique, the ***benefit transfer*** approach, does not establish its own estimates of costs or benefits of environmental change, but rather transfers the estimates established in similar studies and projects elsewhere. The main advantage of this approach is that estimates of economic benefits or costs are available more quickly than if a specific study had to be carried out. Secondly, by relying on previous studies, the costs for the economic valuation can be significantly cut. However, it is difficult to find suitable estimates of costs and benefits of environmental change. It is often pointed out that most effects of environmental change are highly location specific both in ecological and socio-economic terms, and that therefore the WTP stated in one place cannot easily be transferred to another.

***The role of markets and prices in environmental valuation***

A basic principle in economic valuation is to assess scarcity, which determines the value of a good or service. When a market for that good or service exists, its scarcity is measured by its price. It has already been mentioned that externalities play an important part as an underlying cause for as well as an effect of environmental degradation. Externalities are generally attributed to market failures. In this context markets are defined as

*"[...] institutions that make available to interested parties the opportunity to negotiate mutually advantageous courses of action."*[129]

Market prices are established through the exchange of goods and/or services. Theoretically, an efficient market is one that is highly competitive, with many buyers and sellers, all of whom have perfect information about the market, i.e. about supply and demand, both in quantitative and qualitative terms and about their real interests. If one assumed such a perfect market, goods and services would be priced at their marginal cost and would reflect full opportunity costs of resource use, including direct costs but also externalities. Prices would be efficient and clear the market so that demand is equal to supply and benefits to society from resource use (through the good traded) would be maximised.[130] The functioning of markets is closely related to property rights and to the structure of information that people possess and/or have access to. A reason for lacking markets of environmental goods is that costs of negotiation – or transaction costs – are too high. This can be due to economic activities affected by ecological interactions (i) involving long geographical distances, e.g. deforestation in the upper course of a river leading to soil erosion damaging a hydroelectric power plant hundreds of kilometres away, or (ii) large temporal distances, e.g. carbon emission will have an effect on the global climate in future. Another reason for lacking markets is the nature of certain environmental goods such

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128 OECD, 1994, 159ff.

129 Dasgupta, 1996, 393.

130 Bann, 1997, 2.

as the deep sea or the atmosphere, which are also termed global commons, where private property rights are impractical and thus prevent markets from existing. And finally, there are resources such as biodiversity, for which ill-specified or unprotected property rights prevent the existence of markets.[131]

Even in the case where markets existed and the value of environmental goods could be estimated, environmental goods might either be not priced at all or incorrectly priced, and therefore lead to distortions in the economy with the effect of biasing investments and policy decisions against environmental concerns. Only if environmental resources are correctly priced, i.e. considering direct use values as well as non-use values, misallocations of resources in the economy can be avoided and social well-being maximised. ***Pricing*** can take three forms. Firstly, prices can be user charges for resources consumed directly (e.g. water, wood). Secondly, prices can be emission or waste charges for using resources as a receiving capacity for assimilating wastes from the consumption or production process. And thirdly, prices can include producer charges for resources that are embodied in an economic good, such as energy embodied in minerals (e.g. extraction costs), which again are embodied in a traded good (e.g. a car). The price for a natural resource would therefore be the costs for extraction or harvesting plus any external costs that the extraction or harvesting causes plus 'user costs'.[132] The pricing of a product that embodies resources that have so far not been priced would equal to marginal costs of production, include extraction or harvesting costs, and the value of externalities caused by the production and consumption of that good. This would result in a product price equal to the costs of production plus an emission or waste charge. The emission or waste charge should equal the marginal damage done to the environment. Non-renewable resources would thus be priced as the sum of marginal costs for extraction plus marginal external costs plus marginal user costs. If renewable resources were used in a sustainable manner, i.e. harvesting is equal to or smaller than regeneration, user costs are not applicable and proper pricing would equal to marginal harvesting costs plus marginal external costs. If the harvesting were bigger than the regeneration, then the pricing would also include user costs. If renewable resources are not only to be harvested but also to be enhanced trough investments, e.g. fuelwood plantations or water supply, then the price for these managed natural resources would be established based on stated or deduced WTP's for these resources.[133]

### 3.1.2 Renewable and non-renewable natural resources

Two broad categories of natural resources exist: renewable and non-renewable natural resources. However, there is no clear distinction between the two types. Whether a resource is considered renewable or non-renewable depends on the time of regeneration. In principle, also non-renewable resources such as fossil fuels, fossil water, and minerals are renewable, but the time of regeneration from a human point of view is far too long. Thus, a general distinction between the two types is that resources are considered renewable if regeneration is expected to take place within a human lifetime. Renewable natural resources, in contrast, are all those resources that are part of an ecological process. They are in equilibrium between consumption and regeneration. If this equilibrium is negatively disturbed, degradation will happen.[134]

Regarding the sustainability of resource an important issue is ***substitutability***.[135] It refers to the ease of substitution among inputs. Factor substitution shows how well inputs can be substituted to produce a specific level of output. This is especially important when resources are becoming scarce, since substitutability between different natural resources will be of relevance especially in the case of substituting non-renewable with renewable resources.

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131 Dasgupta, 1996, 393.

132 Basically user costs arise because for a non-renewable resource the use of a unit of this resource today means going without this resource in future. User costs are sometimes also termed 'depletion premium', 'rent' or 'royality'. (OECD, 1994, 294)

133 OECD, 1994, 239ff.

134 CDE, 1995, 15.

135 Hughes Popp, 1997, 1.

A second concept that is closely linked with resource use is ***reversibility*** with regard to change or damage. In the case of non-renewable resources, any use is non-reversible. In the case of renewable resource use, whether reversibility is given or not depends on the amount of use, preventive actions, and activities undertaken to restore the resource. Reversibility is of concern when substitution for an input is difficult. If natural resources as inputs in the production process are complementary, the exhaustion of one input will lead to an overall decrease in the production level. Applied to the case of use of soils, degradation happens if human use leads to a deterioration of soil functions.[136] This process can be slowed down, halted or even reversed by either changing the intensity of use to allow natural regeneration, by filling up natural pools, by artificially complement soil functions (e.g. fertilising, irrigation), or by technical measures such as soil conservation activities. However, the potential of a resource to change naturally or being changed back to its original state by human investments is limited. Soils can be degraded to a point where they can no longer be restored to their original state.

The third key issue in the use of natural resources is ***uncertainty***. Uncertainty concerns prices, input supply, outputs, and environmental impact. There is also uncertainty whether a resource is renewable or non-renewable, i.e. if the current use of a renewable resource is within the limits of regeneration or not.[137]

A forth issue is ***recycability,*** which is of special interest with regard to non-renewable natural resources. Most non-renewables, such as metals, can be recycled and used again. Recycability becomes then important when supplies of non-renewable resources are diminishing, their extraction costs increasing, the costs for waste management increasing, or their substitutability technically not easy or expensive. Also with regard to soil, recycability is important.

The fifth key issue is ***resilience***. Resilience refers to the ability of land, for example, to reproduce its capability after interference. Resilience is high if it requires a major disturbance to overcome the limits to qualitative change in a system. If resilience is limited, human activities become necessary to supplement natural resilience.[138]

### 3.1.3 Weak and strong sustainability

In economic terms sustainability can be defined as a situation in which the development vector, D, increases monotonically over time, i.e. $dD/dt > 0$. Which development characteristics are included in D remains a societal debate. For the sake of simplicity, it has usually been per capita income, which, however, captures only economic growth. In more recent times further factors, such as those included in the Human Development Index (HDI) have been included in order to give a better description of development.[139] This definition of sustainability, however, is not problem-free, as it implies an indefinite time horizon, which is normally not given. This formulation does also not imply whether $dD/dt$ must be positive in every time period – corresponding to the strong sustainability criterion, or whether only the trend of $dD/dt$ must be positive – corresponding to the weak sustainability criterion.[140]

In economic terms, sustainability has three meanings:[141] firstly, sustainability can be defined in terms of ***constant per capita consumption***. However, constant per capita consumption can be achieved by total depletion of one specific natural resource, which is substituted by man-made capital. The second meaning is defined in relation to a ***constant stock of natural capital***. The argument is that natural capital, especially non-

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136 Heiniger, 1994, 14.

137 Hughes Popp, 1997, 3.

138 Blakie & Brookfield, 1987, 10; Ludwig et al., 1997, 1.

139 e.g. increase in real income per capita, improvements in health and nutritional status, increasing life expectancy, educational achievements, access to resources, fair distribution of income, gender issues, and increases in basic freedoms. (Pearce et al., 1990, 2; Human Development Index: UNDP, 2001, 239)

140 e.g. Pearce et al., 1988; Pezzey, 1992; Kappel, 1994b.

141 Hughes Popp, 1997, 6ff.

renewable resources, is the limiting factor in the production process and must therefore be preserved. This argumentation is supported by: (i) uncertainty associated with lacking knowledge of the consequences of natural resource depletion. (ii) In the case of non-renewable resources, as any depletion is permanent, this permanent change should be approached carefully and slowly. (iii) As natural resources are not only an input into the production process but perform a multitude of different functions, resources should be preserved to ensure these other functions to be fulfilled. The third meaning of sustainability is that of ***intergenerational equity***. The needs of future generations define the level of resource use today. It is often argued that intertemporal efficiency requires the maximisation of the present value of net gains across generations. If a society agreed on this, intertemporal efficiency could lead to the extinction of non-renewable resources and 'excessive' use of renewable resources. This discounting of future benefits and costs will lead to what has been termed the 'dictatorship' of the present generation.[142] It is thus argued that intertemporal efficiency criteria conflict with intertemporal equity criteria.[143]

With regard to natural resource use constancy or a non-negative change of the natural capital stock is often considered a necessary condition for sustainability.[144] At any point in time the stock of natural resources will depend upon the initial natural endowment (and in the case of renewable natural resources upon previous rates of reproduction) and on the past use that has been made of these resources by human beings either as producers or as consumers.[145] A distinction can be made between the 'existing natural capital stock' and the 'optimal natural capital stock'.[146] The latter would be one for which any small increase in the stock would yield benefits that are equal to discounted costs of achieving this increase. In many instances the existing capital stock is below the optimal capital stock (e.g. forest cover is below the demand for wood and the remaining forests cannot maintain the necessary functions such as regulated water cycles). Moving from the existing capital stock to the optimal capital stock would therefore be a goal to achieve and would correspond with the notation of 'sustainable development'. Further, natural resources are multifunctional. This multi-functionality (e.g. vegetation has not only a direct use value as food or fodder but also plays an important role in carbon sequestration or the regulation of water cycles) can only be integrated in the concept of optimal capital stock, as the notion of 'existing capital stock' would only refer to the direct use value of a resource.

A constant natural capital stock can take on several meanings.[147] One is to consider a ***constant physical capital stock***. This is feasible for renewable resources, as any depletion of the stock (e.g. direct consumption or transformation of natural resources in the production process) can be compensated by investments in the same natural resource. Since any positive rate of use, however small, reduces the stock of non-renewable resources, other criteria, such as the ***Serafian quasi-sustainability rule***, are necessary.[148] This rule pertains not only to non-renewable resources, but also to renewable resources to the extent they are being mined. The rule states that owners of non-renewable resources may enjoy part of the profits from the liquidation as consumable income. The remainder, equivalent to the user costs, should be reinvested to produce income that continues after the resource has been exhausted. As a normative rule, the Serafian quasi-sustainability states that the user costs should not be invested in any asset that is going to produce future income, but that the investment should be designed specifically to produce renewable substitutes for the asset being depleted.[149] A second interpretation is in terms of a ***constant economic stock***. This allows a decline of the

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142 Page, 1977 quoted in Batie, 1989, 1092.

143 Batie, 1989, 1092.

144 Pearce et al, 1988, 6. This would also correspond to neo-classic theory and accounting in which income and capital are clearly distinguished to avoid consuming the capital base of income generation. The consumption of financial or produced capital without replacement or reproduction is clearly non-sustainable in the long run. (Bartelmus, 1997a, 328)

145 Dinwiddy & Teal, 1996, 242.

146 Pearce et al., 1988, 7.

147 Pearce et al., 1988, 9-11.

148 Goodland, [2002], 2.

149 e.g. BP (British Petroleum) is a major investor in photovoltaic technologies. Profits arising from the depletion of fossil fuels are invested to produce renewable substitutes (solar energy).

physical stock if prices reflect scarcity and therefore increase with decreasing physical stock. The challenge is to find the proper price that reflects scarcity, includes all other functions of that resource and is not distorted. The last interpretation is that the ***total capital stock*** remains constant, including natural capital as well as man-made capital. This corresponds to the idea that future generations should inherit a capital stock no smaller than the one in the previous generation. The problem is that there is no general rule whether natural and man-made capital are complements or substitutes. In the case where the two are substitutes, there is a bias towards the expansion of man-made capital at the cost of natural capital. This is because man-made capital tends to be a marketed product whereas part of the natural capital, such as clean air, tends to yield environmental benefits for which no market, hence no price, exists. For other components of the natural capital stock, such as mineral resources or oil, a market price exists. Because the price of some components of the natural capital is falsely zero, more of this capital is used to increase the amount of man-made capital. There is also no incentive to augment the natural capital stock, as many increments produce non-marketed outputs and services that are yet not priced. In many instances, especially in developing countries, the substitution of natural and man-made capital is often impossible or uneconomical,[150] such as the substitution of natural soil fertility by artificial fertiliser. Based on moral considerations there is also a strong argument against substituting man-made and natural capital.[151] If it were possible to substitute the two types, it would also be possible to totally sacrifice specific natural resources and produce man-made or human capital instead, and still achieve sustainable development. The idea of natural and man-made capital being complements is more prevalent in developing countries where a considerable part of the economic development is based on natural resources.[152]

Considering all of the above aspects, conditions for strong and weak sustainability can be derived as follows: strong sustainability is given if (i) the use of renewable natural resources is below or equal to the natural regeneration rate, (ii) the use of non-renewable natural resources is compensated through an equivalent increase of renewable natural resources, and (iii) the amount of wastes and emissions is smaller than the absorption capacity of the natural environment. Weak sustainability would be given in the case where a decrease in the natural capital stock was compensated by an equivalent man-made or human (e.g. knowledge) capital stock.[153]

### 3.1.4 Sustainable resource use with special reference to agriculture in developing countries

The topic of sustainable resource use is especially important in developing countries of the South, which depend heavily on natural resources for their economic development. Two types of countries can be distinguished: those that derive a considerable part of their income from the exploitation of non-renewable resources, such as fossil fuel or minerals, and those that mainly depend on renewable resources.[154] The former will not be further considered in this report.

In the context of sustainable use of natural resources, generally three dimensions are considered, which are highly interlinked:

- ecological sustainability
- economic viability
- socio-cultural compatibility.

150 Pagiola, 1993, 12.
151 Pezzey, 1992, 9.
152 Pearce et al., 1988.
153 Kappel, 1994b, 6.
154 Auty, 2000, 347ff.

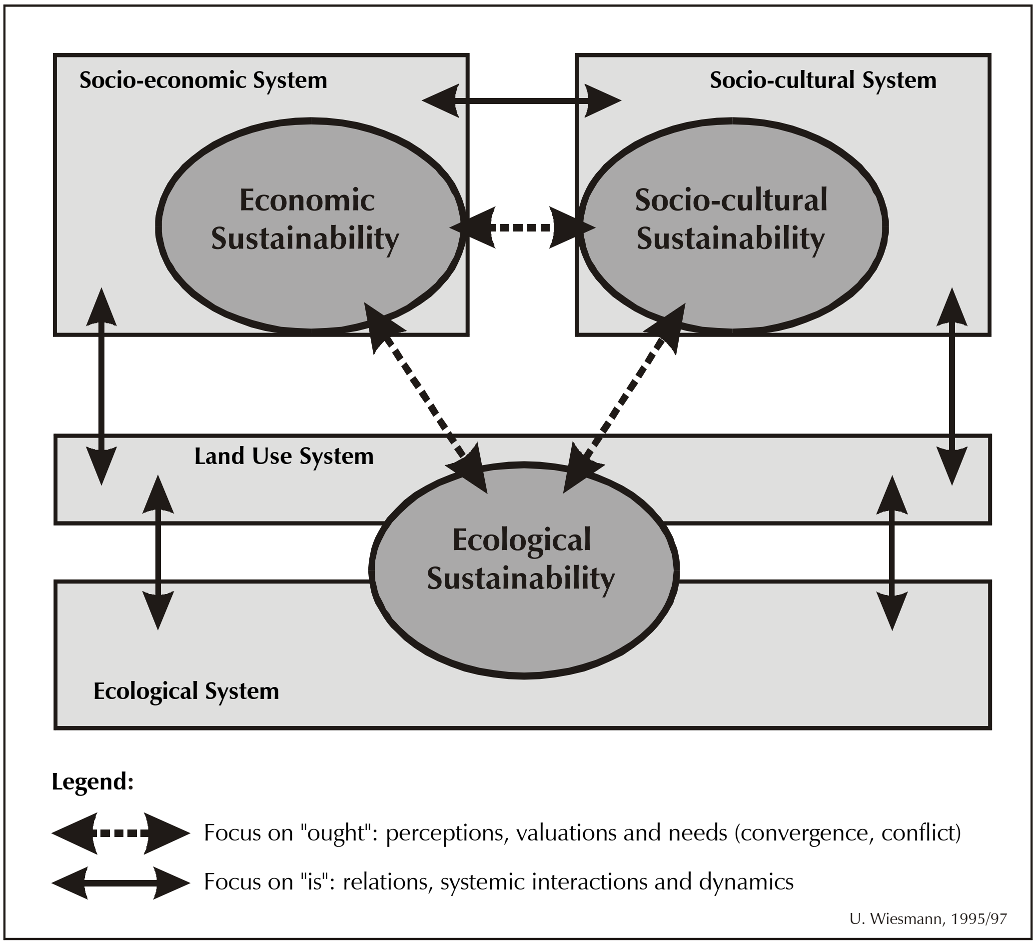


*Figure 23: The 'magic triangle' of sustainable development.*
*[Source: Wiesmann, 1998, 184]*

Figure 23 presents a simple model of the 'magic triangle' of sustainable resource use or sustainable development.[155] A general consensus exists that scales of values for sustainable development can be established in the three dimensions of the economic system, the socio-cultural system, and the ecological system. Figure 23 also shows that there are two types of interactions: those that are (positive perspective) and those that ought to be (normative perspective). ***Existing relations*** and systemic interactions between the three systems are in the context of this report linked through the land use system. ***Relations that ought to be*** are based on perceptions, valuations, and needs, and necessitate societal agreement. Although the three dimensions can partly be analysed separately, changes in one system will, through a complex series of interrelations, lead to changes in the other systems. Positive changes in the economic system, for example, historically often led and still lead to negative changes in the ecological system. Thus, sustainable development is not conflict-free, as positive changes in one system must often be weighed against negative changes in another system. From Figure 23, it also becomes apparent that through land use or other economic activities, the ecological system that contains the resources, which are an input in the production and consumption process, is subject to change. The use of natural, renewable resources[156] is therefore of special interest, as they are the main basis for economic development in most developing countries. Natural resources can be defined from two perspectives: from the ***local perspective*** – as specific natural potential or resources, and from the

155 If not otherwise stated, the following discussion is based on Wiesmann, 1998, 179ff.

156 Natural resources are understood as all components of nature considered valuable by a society at a particular time. A specific form of natural resources, the utilised potential, are those natural resources actually used by a society at a specific time. (cf. footnote 119; Wiesmann, 1998, 189)

***external, scientific perspective*** – as general natural potential or resources. The term 'specific' indicates that resources are valued in a particular socio-economic and cultural context, whereas 'general' denotes resources that are perceived by scientists, decision makers or any other outsider as valuable parts of nature. Although the two views of resources may overlap in part, each includes certain functions and elements not found in the other (e.g. deep groundwater is often not considered a resource by a rural society, whereas medicinal plants may have a high value at local level but are not considered to be part of the general natural resources). Natural potential, be it specific or general, can be grouped in four types:[157]

(i) production-oriented natural potential (e.g. natural soil fertility, genetic potential, raw materials that are an input in the production process),
(ii) physiological natural potential (e.g. quality of air and drinking water),
(iii) socio-cultural natural potential (e.g. religious and cultural significance of objects such as trees, monuments, aesthetic values of a landscape), and
(iv) the intrinsic ethical value of nature, which is not defined in terms of possibilities of human use.

These four types of natural potential can be compared to the various use values of environment as described in Section 3.1.1 (c.f. Figure 22). While (i) and (i) would refer to direct and indirect use values, (iii) and (iv) would correspond to existence values as a sub-category of non-use values of environmental assets.

***Temporal and spatial aspects*** play an important role in the valuation of resource use. Time aspects are important as the general natural potential, and even more so the specific natural potential, have a clear relation to society and culture. What is valued as a resource depends on the economic, technical, social, cultural and ethical characteristic of a particular society at a given time. What is currently valued a resource might be valued differently in future. In the context of resource use, sustainability is defined as a long-term, non-depreciating use, and this time factor must therefore be considered. However, from the current use it is not possible to predict what specific and general resources might be valuable to future generations. By including both the specific and the general natural potential into the definition of sustainable resource use, the chance that interests of future generations are taken care of is increased. The use of natural resources usually takes place in a delimited region, inhabited by a particular human society. In general, sustainable use of natural resources is thus also confined to this region. However, this raises the problem of transregional impacts of resource use such as air pollution or soil erosion. Resource use in one region can be responsible for negative changes of the natural potential in another region. By considering regional and transregional impacts, a specific resource use has to be related to a particular society in order to determine whether a resource use is sustainable or not.

As mentioned before, a positive change in one system might be accompanied by a negative change in another system (c.f. Figure 23). The question arises of ***balancing negative and positive fluctuations***. This question can be best answered by considering either the concept of 'weak' or 'strong' sustainability. In the case of weak sustainability, society has to value the sum of negative changes as being smaller than the sum of positive changes in other systems. Thus, to some extent, trade-off between a depreciation of a certain natural resource and the increase of economic well-being or socio-cultural improvement is possible. Strong sustainability implies that any negative change resulting from resource use in any of the three systems is to be considered non-sustainable, despite possible positive changes in other systems. As any use of natural resources leads to positive and negative fluctuations in the three systems, the strong sustainability criterion is hardly feasible. Weak sustainability is thus easier to attain and to make operational for evaluating resource use. It is important to consider, firstly, that the positive and negative changes are made visible and are going to be valued by the concerned societies, and secondly, that aspects of irreversibility are taken care of.

Summarising the above considerations, Wiesmann (1998, 197) proposes the following definition of the degree of sustainable resource use:

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[157] Wiesmann, 1998, 192. The classification of resources into the four types is not exclusive. A specific resource can have characteristics of more than one type.

*"The degree to which resource use is sustainable in a regional context is a function of the extent to which a society is willing to strike a balance between negative and positive fluctuations in the values of specific and general natural potential."*

This definition implies the following:

- Whether resource use is considered sustainable or not depends on social negotiation and valuation. Sustainability is thus no fixed target. It depends on time, the regional context, and the needs of a specific society. When evaluating a specific resource use with regard to its sustainability, a society has to find answers to the following questions: (i) For whom and in what sense is the resource use sustainable? E.g., a farmer might evaluate a given use with regard to its contribution towards optimising utility, even maximising profitability, whereas an ecologist might evaluate the resource use according to ecological principles. (ii) Where is the resource use sustainable? E.g., water use in the highlands might be sustainable there, but curtail water availability for downstream pastoralists. (iii) For how long is a given resource use sustainable? E.g., the current generation might consider a given resource use as sustainable, but production possibilities for future generations are reduced.[158]
- A positive change in one system can be valued as sustainable by society even if there is a negative change in another system. A certain amount of trade-off is possible, implying the notion of weak sustainability.
- There is a possibility of defining a minimal level of a given resource in a given regional context that must be preserved for future generations. In this case the total extinction of a resource can be prevented.
- There is no discrepancy of the above definition of the degree of sustainable resource use compared to the definitions of weak sustainability described in Section 3.1.3. Wiesmann's concept focuses on the concept of constancy of the 'total capital stock', which allows the substitution of natural capital with man-made or human capital. This substitution in Wiesmann's concept is reflected in the societal negotiation process whereby a balance between negative changes in one system (e.g. increased water demand for irrigation leads to drying up of swampy valley floors) and positive changes in the other systems (e.g. increased household income from the sale of high-value irrigated crops and increased spending on health and education) has to be found.

### 3.1.5 Soil as a natural resource

With regard to soil as a natural resource, the problem is that it contains both characteristics of a renewable and a non-renewable resource. It is ***renewable*** in the sense that (i) soil formation takes place, and (ii) it can be enhanced by human activities. It is ***non-renewable*** in the sense that under natural conditions and in the short time frame of a human life, soil formation is often far too small compared to soil degradation processes resulting from current human use. Thus, it can be depleted to the state where the original or desired use is no longer possible. This dual characteristic of soil as renewable and non-renewable resource can also be described by certain components of soils: Inorganic components such as clay minerals must be considered non-renewable, as they can be renewed only over centuries. Organic components, on the other hand, can be renewed quickly within months or cropping seasons.[159] In its simplest form, sustainable use of soil can be described with the principle of 'soil loss tolerance'. This would imply that the maximum level of soil erosion or soil nutrient depletion must be below the rate of soil and nutrient regeneration. Soil productivity, as the main direct use value of the soil, can be considered both natural capital and man-made capital.[160] As a natural capital, soil productivity offers services for human use, such as the cultivation of food crops or animal fodder. On the other hand, it is a man-made capital, since soil productivity can be regenerated by active measures, such as fallowing or manuring, or enhanced by inputs, such as artificial fertilisers.

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158 Hurni, Herweg & Ludi, 1998, 97.
159 Sutcliffe, 1991, 27; de Graaff, 1993, 96.
160 Grohs, 1994, 13.

Applying the sustainability criteria described above, which are slightly modified for valuing changes of soil productivity, the following options exist:[161]

- If ***strong sustainability*** is the goal, soil productivity cannot be substituted against any other natural resource. The natural capital must be fully conserved. Soil mining may therefore not be allowed and soils must regenerate naturally.
- If ***sensible sustainability*** is the goal, substitution between production inputs is allowed. This implies that nutrients lost through plant uptake or erosion can be replaced either on-farm with soil productivity enhancing technologies (e.g. manuring, fallowing), or through external inputs (e.g. artificial fertiliser). However, it has to be considered that not only nutrients, but also many other factors contribute to soil productivity. So, for example, it is possible to substitute nutrients, but soil erosion nevertheless might decrease soil depth to a level where plant growth is constrained.
- If ***weak sustainability*** is the goal, substitution between consumption streams of natural capital is possible. Natural capital can be depleted and substituted by similar goods. It is thus possible to substitute natural capital with man-made capital. The loss of soil productivity can be substituted by purchasing the services of the soil, such as food, fuel, fodder, and fibre, from other locations.

Usually, only strong and weak sustainability are differentiated (c.f. Section 3.1.3). The introduction of sensible sustainability is in principle a modification of the weak sustainability criterion. What is proposed is that substitution is required within a given subsystem or with regard to specific functions of a resource, e.g. natural and artificial nutrients can be substituted. Weak sustainability would allow the substitution of natural and man-made or human capital and it would allow substitution at a regional or even international scale. The major difference between sensible and weak sustainability in the above definition is thus the scale at which substitution is permitted. For the case of soil erosion affecting soil productivity negatively it would imply that in the case of sensible sustainability investments are necessary locally which would control soil erosion and maintain soil productivity. In the case of weak sustainability it would, in principle, be possible to let parts of the arable land degrade totally if the lost production can be substituted from other sources or localities. In this case, other constraints, such as financial means to purchase substitutes, must be considered.

In this study, the weak sustainability criterion, especially the sub-variant sensible sustainability will be the guiding principle. Substitution of production inputs is allowed at the local level. This means that soil productivity lost can be substituted at the field, farm or catchment level. This would imply, for example, that declining nutrient pools can be restored through increased fertiliser inputs, if they can be financed. It would also imply that soil erosion must be controlled at the field level. However, a balance must be found between investments in soil conservation locally and the positive effects of soil erosion on fields down-slope, which can profit from soil erosion up-slope. It would also imply that temporal substitution is possible, i.e. nutrients could be mined for a certain period of time if later natural regeneration of the nutrient pool is secured.

According to Wiesmann's definition, soils will be used in a sustainable manner if a specific use in a specific regional context, from the internal as well as from the external point of view, is considered sensible. A sensible use of soils is given if the long-term functions of the resource soil in the dimensions "production-oriented potential" (e.g. soil fertility), "physiological potential" (e.g. soil as a filter for improving water quality), and "socio-cultural potential" (e.g. sacred places) corresponds with the present and future needs of the affected population from the point of view of all concerned actors. Soils can thus degrade to a certain degree as long as it does not endanger the production level or the regulative functions and does not lead to damages outside the concerned region. Degradation levels may not exceed a threshold where costs for restoration are becoming prohibitively high. The regional context of soil use is mainly the level of watersheds, but can also be a farm or a field. Substitution between different systems is allowed (e.g. soil nutrients can be substituted with artificial fertiliser) if society agreed on this. Substitution necessitates an economic system, in which means can be freed to buy the fertiliser without compromising other economic or socio-cultural activities or needs.

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[161] Grohs, 1994, 14; Bartelmus, 1977a, 329.

### 3.1.6 Economic valuation of soil

Although use and non-use values of the soil should be valued and incorporated in an economic valuation of soil erosion and conservation, generally only direct use values – soil productivity and its changes – are included. The main reasons are conceptual difficulties in putting a price on non-use values and the limited knowledge of the benefits of resources for future generations.[162] Indirect use values, such as soils acting as a reservoir for water buffering peak runoff, are difficult to value in monetary terms.

There exist three different techniques to value the costs of soil erosion: Firstly, the change of productivity technique, secondly the replacement cost approach, and thirdly the property valuation method.[163]

The ***change of productivity*** technique is the most popular approach. Usually yields of an eroded soil are compared to yields of an uneroded soil and the difference is attributed to soil erosion. Erosion damage functions refer to the private economic benefits forgone when an erosive practice is adopted instead of a conservation practice. These damage functions are established for "with versus without soil conservation" evaluation and not for "before and after soil conservation" evaluation, as only this allows the separation of different impacts on yield levels. The opportunity costs of the erosion-induced decline in production are the costs of purchasing an equivalent amount of goods from another source. The change of productivity approach is based on the weak sustainability criteria when used to evaluate the costs of soil erosion as substitutes for the soil functions are used. The main problem of this approach is that yield levels are determined by the interaction of a number of factors such as soil type, climate, pests and diseases, and crop and land management, which make it difficult to isolate the effects of soil erosion on yields from all the other effects. Secondly, the impact of erosion can be masked by the use of fertiliser, irrigation, or improved management, such as weeding. Thirdly, a functioning market system is necessary to calculate the monetary losses resulting from soil erosion. A further factor complicating the calculation of soil erosion - crop yield functions is that the agricultural environment is highly dynamic. The demand for certain goods and market prices might force farmers to give up the cultivation of a specific, soil conserving product and switch to annual crops leading to high soil losses. Furthermore, farmers respond to long-term declines of yields by adjusting the level of inputs (e.g. seeding rate, labour input) and/or by adapting the farming system (e.g. switching from animal traction to hand cultivation). Not only the agricultural system of subsistence farmers, but the livelihood system as a whole is highly dynamic. It is thus difficult to attribute an observed change in household strategies to resource degradation and to value such changes properly.

The second method, the ***replacement cost*** approach, is usually applied to value the erosion-induced loss of soil nutrients.[164] This approach calculates costs that arise in order to replace the damaged asset. Costs of fertiliser are used as surrogates; labour required to apply the fertiliser can also be valued. The intertemporal value of soil erosion is equal to the capitalised annual costs of replacing lost nutrients over a defined period of time. By replacing lost nutrients through the substitute artificial fertiliser, the replacement costs approach follows the strong sustainability criterion. Soil functions are restored in situ with investments in fertiliser, which are a substitute at the production level for functions of the soil to provide nutrients to plants. However, replacing nutrients is not sufficient to restore all soil functions, because losses of organic matter, changes in soil texture and structure, rooting depth and water holding capacity equally reduce soil productivity. Consequently, the calculation of costs of soil erosion based on the replacement cost technique often undervalues the soil functions. In several studies, this approach has been applied. Many authors, however, note that the costs of erosion calculated in terms of nutrient loss are significantly lower than the costs of yield loss.[165] The replacement cost approach does also not consider the different forms in which nutrients are available in the soil, and does not consider whether the nutrients are, or will become, a limiting factor. Especially on deep and fertile soils, nutrient loss may be considerable, yet farmers may not experience any

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[162] Grohs, 1994, 16.

[163] Grohs, 1994, 16-7; Clark, 1996, 12ff.; Stocking & Lu, 2000, 127f; Section 3.1.1.

[164] Grohs, 1994, 17-8; Clark, 1996, 7ff.

[165] e.g. Grohs, 1994; Bishop, 1995, Annex A.

yield decline.[166] Soil erosion removes both plant available and fixed forms of nutrients, which are not available to plants. Calculating the total value of lost nutrients and replacing them with artificial fertiliser, which supplies nutrients only in an available form, overestimates the costs. Another aspect to consider are possible negative off-site effects of applying artificial fertiliser in large quantities, such as leaching of nutrients into water bodies with consequences on the water quality.[167]

The third method, the ***property valuation***, can be used to determine the implicit value of a non-traded characteristic of a certain good.[168] The value of agricultural land, for instance, depends on a variety of variables such as location, topography, or soil productivity. Controlling for all the other variables except soil erosion, and its impact on soil productivity, allows interpreting price differences as the costs of soil erosion damages. This method can be applied for owner farmed and rented land. In the Ethiopian context, similar to many other African countries, where there is no land market (land is in the ownership of the state or a kinship group and cannot be traded but is acquired through other mechanisms than the market), and institutional arrangements are not sufficient to ensure private property rights, this method cannot be used.

### 3.1.7 Limitations of the various valuation techniques

Several problems limit the use and reliability of the different valuation techniques. Both the change of productivity and the replacement cost approach rely on opportunity costs. It is thus necessary to find shadow prices for soil functions and reliable market prices for the soil. Secondly, the isolation of soil erosion on yield levels is not an easy task. Thirdly, with these two techniques, only use values are considered, while non-use values are ignored. Unknown or potential benefits of the soil are not valued, but even known soil functions are ignored because they do not result in benefits that can be translated to marketed values. Lastly, the time frame, for which changes in soil properties are valued, is of great importance, as soil erosion today also has consequences for future generations.[169]

As mentioned before, soil shows characteristics of both a renewable and a non-renewable resource. It is non-renewable in the sense that degradation can be irreversible if the original state cannot be restored at all, or only at prohibitively high costs. Decreased rooting depth can irreversibly degrade the soil. Other impacts of soil erosion, such as nutrient loss, can be compensated through technological progress. In the economic valuation of soil, the question is how to incorporate such irreversible degradation. This can be done by including either an option value or a safe minimum standard.[170] The option value equals to the extra payment to ensure future availability of the resource. How high such an option value should be is debatable, as we do not know the probability of taking a wrong decision that curtails possible choices for future generations. If, for instance, the current generation decided – willingly or unwillingly – to degrade the soil totally, future generations might be left to starve. The option value of soil degradation today must thus include possible costs for future generations (e.g. starvation, food aid, etc.), which are difficult to anticipate. The second possibility is to define safe minimum standards. In the context of soil degradation, such a safe minimum standard could be that soil erosion rates must not exceed soil formation rates. This allows – in principle – future generations to use the soil equally. The problem with the two concepts is that they are feasible if two alternatives are available – one degrading the soil irreversibly and one preserving it. The example of Ethiopia shows that the problem faced by many farmers in developing countries is that although soil degradation is progressing and that the danger of irreversible damage exists, or that irreversible damage has already taken place, there are only few, if any, feasible alternatives available.

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166 Enters, 1998b, 15.

167 Drechsel & Gyiele, 1999, 30.

168 Munasinghe, 1993, 28; Grohs, 1994, 19.

169 The question of finding appropriate discount rates and time horizons for analysing effects of soil erosion are discussed in more detail in Sections 5.3 and 5.4.

170 Grohs, 1994, 21.

### 3.1.8 Soil degradation and economics – underlying causes of excessive soil degradation and its economic significance

The link between economic development and environment is not simple. It is even mentioned that there is an underlying dilemma regarding the trade-offs between economic growth and environmental quality. Whether economic growth leads to more environmental degradation or vice versa depends on the type of economic development path and the dependency of the rural population on the countries' natural resource base.[171] There are policies that can have negative implications on both economic efficiency and on the environment. In many developing countries, for example, industrialisation in the 70's and 80's was protected by high tariffs. This so-called import-substitution strategy did not lead to the desired outcome of a growing national industrial sector. Often, it also created a bias against small-scale agriculture because large-scale export-oriented agriculture was promoted. A second problem complex concerns the link between poverty, population growth, and the environment.[172] The appreciation of environmental goods and services are not a 'luxury good' that is purchased only when the 'struggle for development' is won, on the contrary, environmental goods and services are essential forms of capital for the development process.[173] Poverty can be both a root cause and a consequence for environmental degradation. Similarly, policies and activities aiming at reducing poverty can be both decreasing or increasing environmental degradation. Moreover, there are those policies or interventions which improve economic efficiency and income growth, but which have negative environmental effects. The use of fertiliser and pesticide is an often-quoted example.[174] In highly developed economies, soil degradation is often even further accelerated by environmental impacts of industrialisation, urbanisation, and the growth of the tertiary sector.[175]

In developing countries – and Ethiopia is no exception – it can often be observed that

*"[...] many environmental problems [...] originate from the lack of economic development, that is from the struggle to overcome extreme conditions of poverty. Poor people often have no choice but opt for immediate economic benefit at the expense of the long-run sustainability of their livelihoods."*[176]

Because of a number of factors, people are often forced to use the soil much more intensively than what would be sustainable.[177] From the point of view of land users, a certain amount of soil erosion or soil degradation is justified because the value of fertile soil is not infinite relative to other needs. In other words, it is not worth preventing soil erosion unless the benefits gained by conservation activities exceed the costs of the same conservation activities.[178] The problem is that as long as the costs of soil erosion are not fully internalised, they appear to be considerably smaller than the costs that have to be borne to prevent soil erosion. Costs of soil erosion that are not internalised can be both on-site costs and off-site costs.[179]

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171 Reed, 1996, 300; Moseley, 2001.

172 e.g. Barbier & Bishop, 1995, 134; Ray, 1997, 215; Reardon & Vosti, 1997a; Pender, 1999; Heady, 2000, 241-2.

173 Pearce, 1997, 212.

174 Ray, 1997, 216.

175 Hurni et al., 1996, 37.

176 Barbier, 1998, 5.

177 Moseley, 2001, 318-9. There are counter-arguments showing that if population densities exceed a certain threshold, labour-intensive technologies become attractive which enhance the natural potential. (e.g. Tiffen et al., 1994) However, very special circumstances are necessary (e.g. market access, availability of credit, infrastructure, etc.) to achieve such a development path. Even in such positive cases deteriorating environmental conditions during a certain 'transition' period can still be observed. Having reviewed more than 70 studies in hilly and mountainous parts of the World, Templeteton & Sherr (quoted in Southgate, 2001, 50) conclude that the relationship between demographic change and land degradation is neither uniformly negative nor always positive. Instead, the relationship can best be captured by an U-shaped function relating land productivity and land value relative to labour value. This would result in a situation where rural population growth first results in land degradation, but later contributes to improve land productivity.

178 Barbier & Bishop, 1995, 133.

179 e.g. Clark, 1996; Lal, 1998, 150.

***On-site costs*** are the costs that arise at the same locality, i.e. on the field or farm and include:

(i) immediate effects on plant growth such as seeds being washed away, plant uprooting and loss of water and fertiliser through runoff and sediment;
(ii) long-term costs due to adverse effects of erosion on soil quality, such as a decrease in rooting depth, loss of plant-available water, decrease in nutrients and soil organic matter and in the longer run the exposure of unfavourable sub-soil.

***Off-site costs*** are the costs that occur when runoff and sediments from a field, a watershed or a waterway leaves one unit and flows into another. Such off-site effects involve three categories:

(i) damage to present and future crop growth through inundation, or through siltation and deposition of sediments;
(ii) adverse changes in the environment such as siltation and eutrophication of rivers, contamination of water bodies with agro-chemicals through runoff, or changed runoff patterns of rivers because of reduced water retention capacity of degraded soils;
(iii) damage to other enterprises and to civil structures such as water reservoirs and power plants, port facilities, or built-up areas and to arable land through flooding.

Whether on-site or off-site costs are more important depends on the agro-ecological situation. Based on results from several case studies, de Graaff (1996) concludes that in sub-humid mountainous zones off-site costs are considerable higher than aggregate on-site costs. Soils in such mountainous areas are often of volcanic origin. They show a high amount of available nutrients, thus nutrient mining and nutrient losses through erosion do not affect yield levels substantially, as the pool of nutrients is big. On the other hand, these soils often show a high erodibility and erosion rates can be considerable under torrential rainfalls. In contrast, downstream effects are less pronounced in semi-arid areas than on-site costs mainly resulting from nutrient mining and water losses.[180]

In the case of on-site costs of soil erosion, land users cover part of the costs themselves in the form of reduced crop and animal production. If production declines reach a critical threshold level, land users loose the ability to cover the costs themselves. If they have no opportunity to either acquire new land, change their land use practices, or change their occupation altogether, they become dependent on outside assistance such as food aid. Only if they are forced to prevent on-site costs by investing in soil conservation, these costs will be internalised. Such a constraint can be exerted through legislation or through market mechanisms. In the case of off-site costs, which cause loss in national income and decreasing environmental quality, usually land-users fully externalise these costs. For example, for 1986, replacement costs for lost storage capacities in reservoirs world-wide have been calculated for 1986 at US$ 130 billion and loss of electric power at US$ 6.7 billion.[181] The perpetrators do not come up for these costs.

### 3.1.9 Conclusions

The main objective of economics is the ***optimal allocation of scarce resources***, or in other words the production, distribution, and consumption of scarce resources in a most cost-efficient manner. As environmental goods become increasingly scarce, economists believe that economic instruments can also be applied to organise the optimal or even sustainable use of environmental goods. An important reason for environmental degradation from an economic point of view is market failure. Either there are no markets at all for certain environmental goods, or market prices reflect only the direct use value, without internalising external costs, and do therefore not reflect true scarcity and do not allow an efficient allocation. Without a

180 de Graaff, 1996, 260.
181 de Graaff, 1996, 120.

market to determine prices, two important aspects cannot be fulfilled: (i) the reflection of scarcity, and (ii) the mechanism of excluding certain users. Economists go one step further and argue that not only market failures are responsible for environmental degradation, but even more so policy or government failures, as political institutions do not intervene to correct market distortions,[182] or if they intervene, the capacities to enforce laws and regulations are not sufficient. Furthermore, the government does not always stand as a neutral arbitrator among competing political groups and is thus not necessarily interested in maximising net social welfare. On the contrary, specific interest groups often have an influence on governments,[183] the government and its employees are sometimes even an interest group of their own.

As markets for environmental goods do not exist, two main problems occur: external costs and open access resources. ***External costs*** are those costs which arise from the production or consumption of a good for which the perpetrator does not pay. Instead, these costs are transferred to the public. As not all costs of production or consumption appear, there is firstly a strong bias towards over-utilising certain resources, and secondly, environmental friendly goods and services are marginalized. The solution would be to internalise external costs, to correct prices to truly reflect the total economic value of an environmental good and to let the perpetrator pay for all costs that arise from the production or consumption of a good or service. This approach is, for example, embodied in the 'polluter-pays' principle.[184]

***Open access resources*** (cf. Section 8.2) exist because no property or use rights are defined. Because of this lacking attribution of property rights, markets cannot exist for these resources. Without a market, no prices exist, thus nobody can be excluded from the use of the resource. The non-exclusion of users can be explained by (i) technical reasons (e.g. atmosphere, breathable air, deep sea) or by (ii) normative considerations. The solution to problems arising because certain environmental goods are open access resources is to define property rights, use rights or access rights for clearly defined users or owners. This does not mean that open access resources must be privatised; it means rather that bodies with clear rights and duties must be defined. This allows the exclusion of other users and states clear responsibilities for the use and maintenance of the asset. The allocation of use rights can either take place through legislation or through tradable certificates. Often the elimination of legal insecurities can already contribute towards improved resource management. An example would be to legally recognise village territories, including private arable land but also communal lands such as forests or grazing areas. The user group in this case is clearly defined – those people residing inside the village territory. The village inhabitants or specific committees are responsible for monitoring the proper distribution, use and maintenance of the resources. Such a move would change a non-property or open access resource to a common property resource. On the other hand, the definition of ownership titles does not necessarily improve environmental management but can even lead to excess use of resources.[185]

With respect to sustainable use of agricultural soils, economic analysis should shed light on:

- a better approximation of the total value of the soil, including indirect use values, option values and non-use values;
- a quantification of on-site and off-site costs of soil erosion;
- an optimal intertemporal allocation of resources for various uses;
- the development of mechanisms to internalise external (off-site) costs.

Although there are different mechanisms to regulate the use of environmental goods through the market, environmental economics do not directly relate to questions of sustainable development. Firstly, questions of power or distributive problems between groups within a country, between North and South, and between different generations, are not necessarily addressed. Secondly, mechanisms developed to integrate

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182 Perich, 1993, 3ff.

183 Sanders et al., 1995, 38.

184 e.g. OECD, 1997, 17. Different forms are possible: environmental taxes, emission charges, user charges, and product charges.

185 Perich, 1993, 7. Cf. Section 8.2 for necessary conditions for common property regimes to be managed in a sustainable manner.

environmental goods in a market system and to use proper prices to indicate levels of scarcity are only practical if there is a market. In developing countries, for many environmental goods or surrogates, no market exists, or existing markets are not well developed. As long as, for instance, land is in state ownership and cannot be traded, the value of soil degradation cannot be reflected through decreasing land prices; as long as the biggest share of agricultural production is consumed directly by the producers, market mechanisms like emission or erosion taxes cannot be imposed and can therefore not provide the desired signal. The main purpose of environmental economics is to value resources and damages resulting from resource degradation as precisely as possible to show to decision makers – politicians, technical experts and households alike – the magnitude of possible costs or benefits of various actions. Environmental impacts of political and economic decisions should be made visible and open for societal debate. A goal of this report is to calculate costs of soil erosion and possible gains of soil conservation at the household level to illustrate what the costs of these alternative decisions could be. Only if the decision makers have the necessary information and can value the outcome of different decisions, environmental friendly management practices will become more attractive.

## 3.2 Methodology of the Study

*"In short, soil erosion 'facts' may be as hidebound with bias, error and prejudice as the outpourings of social science."*
*(Stocking, 1996, 141)*

*"We need to know much more about the conditions under which households choose to invest in building or maintaining SWC practices. This investment decision must be understood within the framework of the diverse and complex livelihood strategies adopted by the poor, together with the policies and structures which influence these strategies."*
*(Boyd, et. al. 2000, 1)*

Whether a specific natural resource is used in a sustainable manner or not is determined by influences from the ecological, economic, and socio-cultural environment. Any change in the use of a certain resource – in the case of this study soil – will also have influences – positive or negative – on these three systems. Soil conservation proposes such a change. Therefore, the effects of soil erosion and conservation must be addressed in these three dimensions. The present study concentrates on the economic dimension. However, information from the other two systems is essential as well for a meaningful evaluation of costs and benefits of soil erosion and soil conservation. To address the different dimensions, different methods from different scientific disciplines are used. It is assumed that by combining methods and information from the biophysical, economic, and socio-cultural sphere the question of sustainability, profitability, acceptability and feasibility of soil conservation at the household level in rural areas of the Ethiopian Highland can best be addressed.

### 3.2.1 General purpose

In Chapter 1 the seriousness of soil erosion in the Ethiopian Highlands has been mentioned. There is a general consensus that soil erosion and land degradation is a major problem and contributes to the extreme poverty of big parts of the rural population. The Ethiopian Highland is characterised by a pronounced shortage of suitable arable land, forcing farmers to cultivate marginal areas resulting in serious resource degradation.[186] Available cropland per 1,000 inhabitants has decreased from 299 ha in 1987 to 170 ha in 1997. The per capita index of agricultural production (1989-91 = 100) has decreased during this period from 103 (1986-88) to only 97 (1996-98). At the same time, fertiliser use has more than tripled, although at a very low level, from an average of 5 kg/ha cropland in 1985-87 to 16 kg/ha cropland in 1995-97,[187] yet it could not compensate declining per capita agricultural production.

Shortage of suitable cropland forces farmers to use marginal areas, which are generally erosion prone in the Ethiopian context. At the same time, land use has intensified. Fallow periods are shortened or totally abandoned. The expansion of cropland is often at the cost of grazing land or in marginal areas at the cost of remaining forest or shrub-land. This again intensifies the pressure on remaining grazing land, which is characterised by serious overgrazing. As fuelwood is becoming scarce, because remaining forest areas are cleared to gain additional arable land, people are forced to use more animal dung as a substitute. Organic fertiliser is thus in very short supply and can only be applied to homestead areas. People often lack the money to buy artificial fertiliser. High erosion rates in combination with nutrient mining lead to declining soil

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[186] e.g. Hurni, 1993.

[187] WRI, 2000.

productivity once the pool of naturally available nutrients can no longer match the demand. Decreasing yields are the result of this vicious circle.

Different strategies would exist to escape this vicious circle of resource degradation and poverty. One such strategy is sustainable land management, more specifically sustainable use of agricultural soils.[188] Therein, soil conservation is one technology, which is looked at in more detail in this study.

Soil conservation is one technology addressing declining soil productivity through the control of soil erosion. Results from the Soil Conservation Research Programme (SCRP) show that erosion rates can be reduced substantially with the implementation of SWC, but they also show that yield declines cannot be halted but only slowed down (cf. Section 5.1.4). In early years after establishing soil conservation structures, total production of a field is often smaller with than without soil conservation, as a considerable portion of the land is occupied by conservation structures. For poor farmers this decrease in production without compensation is not tolerable.

The draught in 1974-75 brought the dimension of resource degradation to the attention of both national and international organisations. Large-scale soil conservation efforts were launched sponsored by the World Food Programme (WFP) and carried out by the Ethiopian Ministry of Agriculture. However, site-specific agro-ecological and socio-economic considerations were lacking and the same technology was applied over the whole country. The need to assess the efficiency of applied technologies and the elaboration of possible improvements were major reasons why the Ethiopian Government invited the Swiss Agency for Development and Co-operation (SDC) to help establish a research network trough the University of Bern. The mandate of this *Soil Conservation Research Programme* (SCRP) was to support national efforts in soil conservation by providing necessary data from monitoring soil erosion and relevant factors of influence, by developing appropriate soil and water conservation (SWC) measures, and by building local and international capacity in this field of research.[189] The direct target group of the SCRP were not small-scale farmers but implementing agencies, soil conservation experts, planners, decision makers, agricultural extension staff, and researchers. Nevertheless, the SCRP attempted to respond to felt needs and to develop SWC technologies that are technically feasible, ecologically sound, socially acceptable, and economically viable from a farmer's point of view.

The present study aims at addressing the question of the economic viability of SWC by showing the stream of costs and benefits of soil erosion and soil conservation over an extended period of time. It can be observed, not only for soil conservation but also for other investments in resource conserving technologies, that costs are felt in early years whereas benefits accrue only after some time. A cost-benefit analysis should show whether the selected technologies are profitable under certain assumptions or not. Profitability of technologies is one necessary precondition for their acceptance by small-scale subsistence farmers. However, there might be other investment opportunities, which are even more profitable than soil conservation and thus offer better investment opportunities to farmers. Therefore, profitability alone does not yet guarantee that soil conservation is integrated in the farming system.

Soil is still the basis for agricultural production, and therefore for the household economy of the rural population. However, it is believed that unless there is soil in a satisfactory quantity and quality, other investment opportunities are meaningless, except for those which aim at changing the whole household economy and giving up farming. There is thus an urgent need to slow down or even to halt soil erosion processes, if agriculture is to be possible in future.

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188 Also termed ***land husbandry***, which refers to care, management and improvement of land resources as a positive approach, where control of erosion follows as a result of good management practices. ***'Sustainable land management'*** is defined as a system of technologies and/or planning that aims to integrate ecological with socio-economic and political principles in the management of land for agriculture and other purposes to achieve intra- and intergenerational equity. (Hurni et al., 1996, 27; Hurni, 2000a, 85, Herweg & Steiner, 2002, 12)

189 SCRP, 2000a, 3.

### 3.2.2 Objective of the study

The objective of this study is to contribute to a better understanding of the economic performance of selected mechanical SWC technologies in different parts of the Ethiopian Highland at the plot and household level. It is believed that mechanical soil conservation is a necessary technology contributing to reverse the vicious circle of land degradation and poverty. However, mechanical SWC alone does not solve the problem, as the technology itself does not address all degradation processes and does not contribute directly to enhance production. Mechanical SWC is a necessary precondition to improve the farming system in marginal areas of the Ethiopian Highland, provided that no major changes in the farming and management system occur at the same time (e.g. a change from annual crops to perennial crops or from the ox-plough to hoe cultivation). Soil conservation is also necessary to prevent irreversible damages to the soil, which would lessen alternatives for future generations. There is, however, a pronounced difference between outsiders, who consider physical soil conservation a must, and the concerned land users, who consider physical soil conservation a burden, as it does not contribute directly to their short-term well-being.

This study aims at addressing the question of costs and benefits of physical soil conservation in a temporal perspective to compare the immediately felt costs and the benefits accruing in future. It is believed that a better understanding of the profitability of physical soil conservation and the reasons why conservation is not in any case profitable would make it possible

- to improve the motivation of farmers to invest in their resource base, which is their environmental basis for survival;
- to improve the technology itself and adapt it to the local situation and to needs and opportunities of the land users;
- to change factors in the economic and institutional environment, which hinder soil conservation from being profitable at the household level.

***Research objectives***

- To evaluate the economic performance of soil and water conservation technologies from the farmer's point of view (financial cost-benefit analysis)
- To discuss other investment opportunities within the household strategies, which might compete with soil conservation with regard to scarce production factors
- To identify necessary conditions at the household and farm level for the adoption of SWC technologies
- To identify conditions in the economic environment that prevent farmers from adopting SWC technologies
- To identify conditions in the institutional environment that prevent farmers from adopting SWC technologies

***Development objectives***

- To identify possibilities of changing SWC technologies to make them profitable from a farmer's point of view
- To identify policy changes which might contribute to make SWC investments profitable from a farmer's point of view
- To develop a framework for an economic assessment of SWC technologies in other parts of Amhara Region

### 3.2.3 Why an analysis at the farm / household level?

A considerable body of literature exists discussing the threat of soil erosion at the national level,[190] although usually based on extrapolation of only locally validated data, on assumptions, on qualitative impressions in especially affected areas, or on subjective valuations to strengthen the point of necessary investments in soil conservation. Little empirical work has been carried out on the economics of soil conservation on small farms in developing countries.[191] However, it is at the micro, farm or household[192] level where decisions about which practices to adopt or not adopt are actually made. At the household level, land users or peasants[193] decide on whether or not to invest in SWC, according to their objectives and needs, their assets, their production possibilities, and the constraints they might face. It is thus the land users who, through their selection of farming systems, crops, inputs, technologies, animal stocking densities, etc.,[194] determine the rate at which soil resources are degraded. It is also at the farm-level that a considerable portion of the costs of soil erosion accrues – usually in the form of foregone production or increased costs to compensate production losses. The micro-level is usually also where data is available that allows an assessment of effects of soil erosion on crop production and of cost of either soil erosion or conservation. Therefore, the question of soil erosion and its related costs should also be addressed at this local and small-scale level. Many soil conservation programmes, not least the soil conservation activities undertaken by the Ministry of Agriculture in Ethiopia, were not very successful because of the lack of acceptance by farmers. It is thus necessary to focus on incentives for farmers to either degrade or conserve their resource base.

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190 The World Bank (1992) in its World Development Report, for example, highlights the problem of declining yields because of decreasing soil qualities and its effects on the national economy. Country studies from Costa Rica, Malawi, Mali, and Mexico are quoted, where between 0.5 and 1.5% of the Gross Domestic Product (GDP) was lost annually from agricultural production because of soil erosion. Barbier & Bishop (1995, 133) cite figures of environmental damage for selected years for various countries ranging between of 3 to 17% of Gross National Product (GNP). Kappel (1996) calculates for Ethiopia annual losses of the agricultural GDP between 0.005 and 0.5% on the basis of productivity declines estimated by various authors. These highly diverse figures point at the difficulty to find suitable estimates of costs of soil degradation at national level. Lal, 1998; Sherr, 1999.

191 Eaton, 1996, 34.

192 In the context of this report the focus of the analysis is on the household. A household usually is that human group sharing the same hearth for cooking. Households can be composed of family members only, but can also include non-family members. Households are in constant contact with other households to be able to fulfil material and immaterial household needs. Households are not static but change in composition according to family cycles. Members within households are not necessarily equal but hierarchies among members exist based on gender and age. Often the term subsistence household will be used. This should not be mistaken for autarky. Subsistence farmers are always integrated in a market system, however to a varying degree among different members within a household, different households, different regions, and different time periods. Whenever the term subsistence farmer or peasant is used in later chapters, it is always referred to small-scale farmers operating in the Ethiopian Highlands, mainly producing for home consumption but also being integrated into a market system, although at a low level. It is also always referred to farmers deriving their major part of income from crop cultivation. Livestock raising is an integral part of the farming system but not the main source of income

193 The debate over small-scale farmers or peasants is widely held and will not be discussed here in detail. The following considerations, however, are nevertheless mentioned as they are of importance for the Ethiopian context. ***Peasant households*** can be described as showing the following characteristics: (i) The household's livelihood is derived primarily, but not exclusively from farming, usually a combination of crop cultivation and livestock production; (ii) The households owns its own means of production, especially land, or has at least rights of access to land; (iii) Agricultural production is based primarily, but not exclusively, on household labour; (iv) Household activities are geared towards balancing production and consumption; and (v) Production reflects varying levels of subsistence. ***Peasant societies*** can be described as follows: (i) Peasant societies are subordinate societies and thus part of a larger, dominating social system; (ii) Peasant societies are in a continuous state of transformation to adapt to changing external conditions; (iii) Peasant societies are dependant on markets that exhibit a high degree of imperfection and exploitation; (iv) A parallel economy exists, which has been described as 'moral economy', where reciprocal trading and support systems are established as part of the social network; and (v) Peasant societies show varying degrees of internal social and economic differentiation and stratification. (Wiesmann, 1998, 48f) For further details see Ludi, 1994. The terms (small-scale subsistence) land user and farmer are used synonymously in this report and refer to the concept of peasants.

194 Pagiola, 1993, 3; Barbier & Bishop, 1995, 133.

Barbier & Bishop (1995, 133) list a number of economic factors that influence the decision of farmers to conserve or degrade the soil:

- The value farmers attach to future income in comparison to present income, which may reflect the farmer's attitude to risk and uncertainty, as well as the level of household poverty and access to credit and off-farm income.
- The costs of the current soil conservation efforts, which accrue to the farmer, reflect availability of labour, purchased inputs and credits for conservation efforts.
- Relative input and output prices which determine the current profitability of erosive versus less erosive land use systems.
- The future returns of the farming system, which are affected by technological improvements and by the current farming system (crops, cultivation techniques, animal stocking densities, etc.) on soil fertility and future yields.

There are strong ***economic incentives*** that determine farmers' decisions to invest or not to invest in SWC. Farmers will generally not change their farming system (e.g. from highly erosive annual grain crops to less erosive perennial crops) or management practices (e.g. repeated ploughing to obtain a fine seed bed) unless it is in their direct economic interest to do so. Such modifications of management practices or of the farming system can be expensive and may include risks, which are a result of price fluctuations or institutional changes. Or, unless soil erosion is perceived by farmers to pose a threat to farm profitability or current livelihood strategies, or unless changes in the farming system and land management lead to immediate economic gains, farmers may be unwilling to bear the costs of soil conservation.[195]

Land improvement investments are determined by three factors.[196] Firstly, ***household specific incentives*** and ***disincentives*** have to be considered, such as:

- net returns of the investment, which depend on yields and input requirements, and the prices for inputs and outputs;
- riskiness of the investment, with regard to both short-term risks associated with yields or prices and long-term risks associated with political instability;
- relative returns and risks compared to alternative farm and non-farm investments;
- the household-specific discount rate.

Secondly, households are equipped with varying ***capacities*** to invest, which depend on

- the categories of assets available and the flow of cash earned from them, and
- complementary on-farm assets that foster investments.

Thirdly, the ability of households to invest is influenced by ***external conditioning variables*** common to all households in a specific agro-ecological and political context. Among these are:

- available technologies for production and input or output processing;
- agricultural and macroeconomic policies, which influence prices;
- the economic and institutional environment;
- the physical environment;
- transport and communication infrastructure;
- community-level infrastructure.

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195 Barbier & Bishop, 1995, 134.

196 Reardon & Vosti, 1997a, 58.

In Ethiopia, land pressure is considerable. Labour availability is high, but off-farm income possibilities are minimal, and therefore cash for material or hiring additional labour force to carry out conservation work is not available. Net returns to the conservation investment are small, if not altogether negative, and short-term risks (fluctuating yields) as well as long-term risks (insecure land tenure) are considerable. There is not enough capital available to buy fertiliser to improve land productivity. Markets are thin both for inputs and for outputs, and exhibit a high risk. Lacking transport and communication infrastructure leads to increasing transaction costs. In these conditions, all the above-mentioned factors are detrimental to the households' motivation and ability to invest in soil conservation.

In the context of the ***livelihood strategies*** discussion,[197] three broad clusters of strategies are distinguished: (i) agricultural intensification or extensification, (ii) livelihood diversification, and (iii) migration. With respect to soil conservation investments, the household decides to choose the first strategy, to intensify the agricultural production through increased output per unit area either by investing capital or by increasing labour inputs. Thus, soil conservation brings about opportunity costs through demands on labour and often also on land. To justify soil conservation investments, i.e. to convince farmers to undertake such investments, it is often assumed that SWC investments are beneficial, without looking in detail at costs and benefits. Investments in soil conservation exemplify the inherent tension between resource conservation and resource exploitation. Usually costs of soil conservation are felt immediately whereas benefits usually only accrue in future.

Generally, the environment in which rural households operate is risky, in environmental, economic or political terms. Households have to consider whether an investment reduces or increases ***risks***. In the case of SWC, investments can reduce risk in areas with high rainfall variability, as soil conservation can contribute greatly to water conservation and thereby to more reliable yields. However, it can also be that other options offer even better chances of reducing risk, such as investments in irrigation. In cases where land security is not guaranteed, investments in land do not produce necessarily returns to those who bore the initial costs. Thus, the decision on whether or not investments are made, be it in soil conservation or in other enterprises, is based on anticipated benefits. Whether investments are made in soil conservation not only depends on the technology and its functions, but also on the household itself. There are ample examples where different households invest very differently, according to their needs, but also their abilities. In many case studies it could be shown that female headed households tend to invest less, both in SWC and in other enterprises, as their availability of family labour or access to credit and information is often restricted.[198] Other options such as off-farm employment or migration are more prevalent within this section of the rural population. Rich farmers, on the other hand, might have enough family labour, but also have other financial options that enable them to compensate decreasing soil productivity through the purchase of artificial fertiliser. Summarised, whether or not a household invests in SWC depends on the following factors:

(i) the household itself, its composition, its assets, needs, etc., which is to a large extent conditioned by the dual engagement in production and consumption;
(ii) the needs of the household and related strategies in different spheres (e.g. intensifying agriculture, changing to other occupations, migration);
(iii) whether or not the SWC technology or the basket of different technologies offered fulfils part of the needs and fits into the strategies pursued, and
(iv) the ecological and non-ecological environment (i.e. risks and uncertainties related to natural resources, policy environment, institutional arrangements, population pressure, access to new technologies, off-farm employment opportunities, etc.).[199]

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197 cf. Boyd, et al., 2000, 3. Sustainable livelihood is understood as follows: *"a livelihood comprises the capabilities, assets (stores, resources, claims, and access) and activities required for a means of living: a livelihood is sustainable which can cope with and recover from stress and shocks, maintain and enhance its capabilities and assets and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels and in the short and long term."* (Chambers & Conway, 1992, 6)

198 e.g. Holden & Bekele Shiferwa, 1999; Boyd, 2000.

199 Reardon & Vosti, 1992; Bekele Shiferaw & Holden, 1997; Wiesmann, 1998.

### 3.2.4 Research perspective – internal and external view

In research and development concerning the use of natural resources, two opposing, in certain instances even competing, points of view have to be differentiated. Different actors perceive the problem as well as possible solutions differently. These actors can be grouped broadly into local land users and external actors (e.g. agricultural extension personnel, policy makers, researchers), with their respective '***internal' and 'external' view of resource functions, problems and solutions***. The two viewpoints as well as the definition of what is considered a resource refer to and are connected with certain more or less precisely formulated interests of the two sides (e.g. securing a livelihood versus promoting a certain conservation technology).

Relating to soil erosion and soil conservation these two perspectives can be clearly differentiated. Whereas farmers tolerate a certain level of soil erosion and have a highly diversified system of location-specific conservation technologies, which minimise land occupied by conservation structures, the outsider's view is that the level of soil erosion tolerated by farmers is far too high. They have therefore promoted a uniform conservation technology that controls erosion to a considerable extent, but at high costs (e.g. high portion of land occupied by conservation structures). The two views also differ in their orientation. The external view is more problem oriented and seeks to find mainly technical solutions. The internal orientation is more optimistic and is mainly concerned with needs and opportunities.[200] Proposed solutions from outside which address a specific problem might not correspond with the needs and opportunities perceived by land users, and may therefore not be adopted by the actors concerned. It is therefore necessary to combine the two perspectives.[201]

In this study, the calculation of costs and benefits of soil erosion and soil conservation and the presentation of results of the CBA in Section 6.1 corresponds to the external perspective. Soil erosion is perceived to be a problem that threatens the livelihood of many households in future. As a solution, soil conservation is proposed to address soil erosion and to contribute to securing the livelihood of the concerned land users. Different constraints are considered such as labour or cash constraints. Both costs and benefits of the two courses of action are converted to monetary values to compare them with other monetary quantities. The internal perspective, however, considers soil erosion only as one of numerous problems and soil conservation as one possible solution in a basket of different options. The goal of a household might be to diversify the household economy corresponding to the needs, but also corresponding to the opportunities within as well as outside the household. Soil conservation might therefore be only one opportunity to avoid the costs of soil erosion. This internal perspective with a description of land users valuation of soil erosion and conservation and needs and opportunities faced by households is presented in Section 6.2.

The two sides differ in one central aspect: the external perspective is problem oriented and, because of its more scientific background, focuses mainly on environmental factors. The vision is that through sustainable land management, including investments in SWC, the livelihood of the concerned land users can be improved. The internal perspective, on the other hand, is focused on needs and opportunities, and centres around securing the livelihood. Environmental factors are only a means to reach this goal. The vision behind this point of view is that through secured livelihoods, also more opportunities exist for sustainable land management, because as long as the livelihood of the concerned land users is not secured, the concern for sustainable land management only comes second. Figure 24 presents the two lines of thought. If the external perspective is dominant, technical solutions to address the problem are proposed, which might not fit into the livelihood strategies of the concerned land users. If the internal perspective is dominant, strategies to secure the livelihood are pursued, which might endanger the environmental basis of these same strategies. Sustainable resource use can only be achieved by bringing the two perspectives and the two courses of action together. This requires that the problems and opportunities be identified jointly by the two groups and that

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200 This optimistic view corresponds to the livelihood concept, whereas the problem-oriented perception can be termed as 'professional pessimism'. (Chambers & Conway, 1992, 22)

201 e.g. CDE, 1995; Guinand, 1999b, 39.

possible solutions be developed, which address both aspects, that of securing and improving the livelihood and that of sustainable management of natural resources.

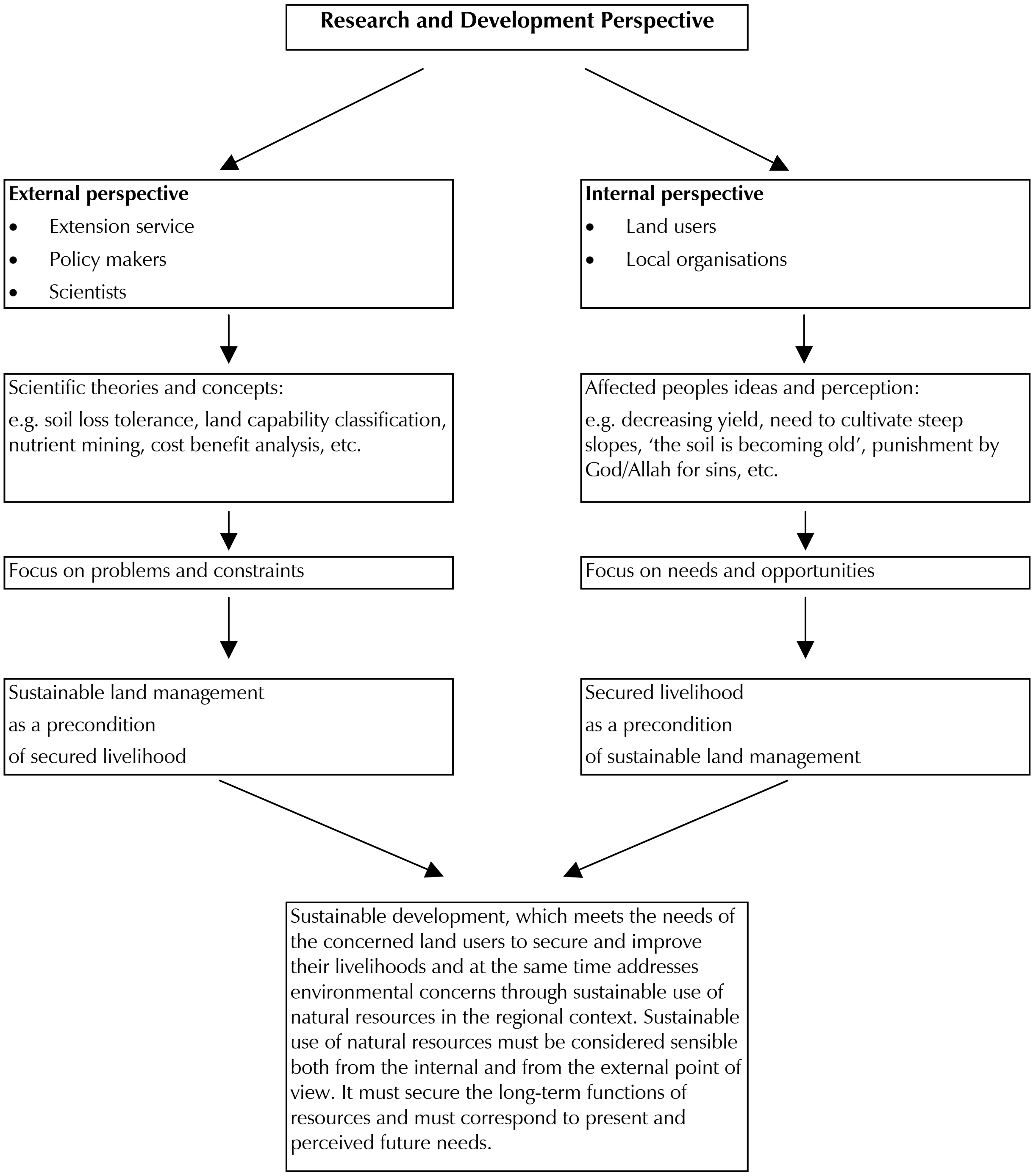


*Figure 24: The external and the internal perception of the problem of resource degradation. [Source: Own compilation; CDE, 1995; Guinand, 1999b, 42]*

### 3.2.5 Theoretical background and research approach

The theoretical background is based in parts on economic theories (cf. Section 3.1, Chapter 4, Section 5.3 and 8.1) and on concepts from natural science and human geography (cf. Section 3.1.8, 5.1, and 6.3.1). Soil erosion and its consequences on the household economy are in the centre of the analysis. Based on the idea of the 'sustainability triangle' and the complex interrelations between the components 'ecological system', 'economic system', and 'socio-cultural system', which come together in the concrete manifestation of a specific land use system (c.f. Figure 23), neither ecological nor economic considerations alone can address the problem of soil degradation and soil conservation in a satisfactory manner. Satisfactory in this context means by addressing both the internal and the external perspective and the reasons for and consequences of soil erosion and soil conservation in the three systems.

The research approach has been chosen in such a way as to combine the two perspectives and concepts from different scientific orientations. The approach is based on case studies, and assesses the profitability of soil conservation at the household level. Table 14 gives an overview of the different research levels:

| **Research level** | |
|---|---|
| Theory | Economic theory, natural science |
| Strategy | Sustainable development, sustainable use of renewable natural resources |
| Approach | - Case studies<br>- Household oriented<br>- Economic analysis (i.e. Cost-Benefit Analysis, analysis of the economic and institutional environment)) |
| Methods and instruments for data collection | - Analysis of secondary data<br>- Formal surveys (semi-structured household interviews)<br>- Key informants<br>- Wealth ranking<br>- Farm analysis<br>- Transect walks<br>- etc. |

*Table 14: Theoretical background and research approach. [Source: Own compilation]*

#### *Case studies*

The present study is based on various case studies (cf. Chapter 2). Only a case study approach could be applied because input variables in an economic analysis of soil erosion and soil conservation, such as the erosion process itself, effects of soil erosion on soil productivity, the reaction of different crops to different levels of soil erosion, the characteristics of the farming system, the reaction of different households to soil erosion and declining yields, livelihood strategies, the local economic environment, the institutional setting, etc., vary within a relatively small area. The case study approach concerns (i) the locations where the study has been carried out, and (ii) the households interviewed.

Case studies are studies in which specifically interesting cases concerning as many dimensions as possible and if possible over a longer time frame are observed (or interviewed), characterised and analysed.[202] Usually, the number of detailed studies is small, and the selection is as representative as possible for the issue under consideration, but not necessarily representative for the population as a whole. Case studies allow a deeper

[202] Lamnek, 1989, 5.

insight into relationships between people and institutions, allow the explanation of current attitudes, and show why certain behaviour occurs.[203]

The ***research locations*** are given in part by the location of the research stations, namely Maybar, Andit Tid, and Anjeni of the Soil Conservation Research Programme (SCRP) in Amhara National Regional State (cf. Figure 7). The selection of these benchmark sites was according to different socio-cultural settings and agro-climatic characterisations (cf. Chapter 2 and Figure 3). These case studies are supplemented by research carried out in other areas of Amhara Region, namely Simen and Mesobit & Gedeba.

The ***interviewed households*** have been selected on the basis of (i) wealth and (ii) whether or not they have kept, maintained or even expanded soil conservation on their land. In Maybar and Andit Tid, 16 and 15 households, respectively, have been selected according to these two main criteria. In Anjeni, the criterion to select the 5 case study households was wealth alone. In Maybar and Andit Tid the selection of households was made together with the Research Assistants who have been working for many years in the area as employees of the SCRP, Ministry of Agriculture (MoA). In Anjeni, the selection was based on a wealth ranking.[204]

### 3.2.6 Research steps

***Problem formulation and hypotheses***

In a first step, the problem and hypotheses were formulated based on the long-term experience of the SCRP. According to national and international experts involved in Ethiopia and the former general manager of the SCRP, one of the main problems was that the adoption of propagated conservation technologies (mainly physical soil conservation) by land users is unsatisfactory, despite their positive ecological performance. Different hypotheses can be derived from this problem analysis: (i) the technology itself does not fit into the strategies of households, (ii) the technology performs satisfactory with respect to certain aspects, but households face constraints that do not allow them to adopt it. The first hypothesis was addressed by Yohannes Gebre Michael (1999). He concentrates on strategies of adaptation of the propagated technologies by land users. The present study mainly concentrates on the second hypothesis in the sense that the technology is considered to address not all of the dimensions a technology has to fulfil – ecological sustainability, economic viability, socio-cultural acceptability and technical feasibility – in an equal and satisfactory manner, and that households therefore face certain constraints. The hypotheses formulated are:

1. Investments in resource conserving technologies are often not profitable from a farmer's point of view. They exhibit an unfavourable distribution of costs and benefits, and compete with other investments.

This first hypothesis assumes that although the technology is ecologically sustainable – meaning that it performs satisfactory in ecological terms, i.e. controls soil erosion sufficiently – and technically feasible – the technology is simple, it is an improvement of traditional technologies, and can be constructed and maintained by land users themselves – it is not profitable and does not necessarily fit in the livelihood strategies of the concerned land users. According to economic theory, if the technology were profitable, utility-optimising households would adopt it. Whether or not soil conservation technologies (introduced as well as adapted and traditional) are profitable, or under which conditions they are profitable, will be determined by a Cost-Benefit Analysis (CBA).

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203 Casley & Lury, 1982, quoted in Guinand, 1999, 61.

204 cf. Ludi, 1994 & 1997 for more details concerning the wealth ranking in Anjeni.

2. The considered conservation technologies might prove to be unprofitable from the farmers' point of view because the economic environment is unfavourable.

This second hypothesis is based on the analysis of profitability. Even if the conservation technology was unprofitable, the unfavourable economic environment could be a reason for it. The economic environment can be termed unfavourable if prices are distorted for political reasons (e.g. low producer prices favouring a small elite in towns, overvalued exchange rates, input subsidies favouring high-input and technology-based farming), if markets are absent, or if infrastructure is underdeveloped. An unfavourable economic environment results in high transaction costs that hinder farmers from participating in the market. Farmers are caught in the 'subsistence trap' and do not have the means or incentives to invest in resource-conserving technologies.

3. The considered conservation technologies might prove to be unprofitable from a farmers' point of view because the institutional environment is unfavourable. An unfavourable institutional environment might also hinder farmers from adopting conservation technologies even if they were profitable.

Institutions in the economic sense are written and unwritten rules that have an influence on the economic system and the behaviour of individuals and organisations. Institutions are based on values and norms and are implemented through a system of control and sanction mechanisms.[205] In the context of sustainable use of natural resources, institutions such as property and use rights are considered important. If, for example, use or property rights are not clearly defined, farmers have no incentive to invest in their land as the benefits might accrue to others than those bearing the investment costs. Other institutions such as the religious system, which imposes a variety of behavioural rules and sanctions on deviant behaviour can equally have an influence on the willingness of farmers to invest in SWC.

Based on the analysis of the profitability of conservation technologies at the farm level and the assessment of the economic and institutional environment, recommendations are made with regard to possible improvements of technology or changes in the economic and institutional environment with the intention to make soil conservation more attractive for small-scale subsistence farmers in the Ethiopian Highlands.

***Fieldwork***

Fieldwork for the Anjeni case study took place in 1992. Part of the results have been already published (Ludi, 1997) and will be further used in the context of this study. Fieldwork for the Andit Tid case study was conducted in 1998 and again in 1999, and for the Maybar case study in 1998/99. Fieldwork for the Simen case study was conducted in 1994. The purpose of this field research was not to collect data for the present study, but was a participatory research focusing on resource management and development options in the Simen Mountains National Park and surrounding rural areas. Main results have been published (Hurni & Ludi, 2000) and will be used in this context to supplement findings from Maybar, Andit Tid and Anjeni. Similarly, information in Mesobit & Gedeba (fieldwork carried out in 1998) has not been collected for the purpose of this study.[206] Results have been published (Ludi, 1999) and will also be used to supplement the information from the three main case studies.

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205 North, 1990.

206 This research has been carried out for the ECOMAN research project (Environmental Conflict Management in the Horn of Africa). ECOMAN was carried out in the framework of the Swiss Priority Program Environment of the Swiss National Science Foundation and the Swiss Agency for Development and Co-operation. The project was co-managed by the Centre for Security Studies and Conflict Research, ETH Zürich and the Swiss Peace Foundation, Bern.

***Analysis of data***

An important input into the Cost-Benefit Analysis is to determine the different costs and benefits involved in soil erosion and soil conservation. The present study can profit greatly from the long experience and the considerable database of the SCRP in Ethiopia. Starting in 1981, a wealth of data on different aspects in relation to soil erosion and soil conservation has been collected (cf. Section 1.3 and Appendix 3.1 for a list of collected variables). Data collected in the core research programme of the SCRP will be used to determine the effect of soil erosion on crop production and the effect of soil conservation on soil erosion rates. Other costs and benefits of soil erosion and conservation have been assessed during the fieldwork. Information on the economic and institutional environment has been collected through various interviews. This information will be the basis for the analysis of the household economy and characteristics of economic and the institutional environment.

***Compilation of data – cost-benefit analysis, analysis of the economic and institutional environment***

Data from different sources – secondary data from the SCRP and data collected during the different fieldwork phases – come together in the Cost-Benefit Analysis (CBA). This gives first hints at whether soil conservation under given assumptions is profitable or not. The CBA is complemented by further analyses of the household economy to show whether soil conservation investments can be carried out by the interviewed households. Other investment opportunities or household-specific constraints could be important reasons for households not to invest in SWC. Lastly, an analysis of the economic and institutional environment is carried out. This sheds light on constraints farmer households face and might help to explain why they do not invest in SWC.

### 3.2.7 Methods and instruments used for data collection

Methods and instruments used provide a combination of quantitative and qualitative data. This combination of methods, also referred to as triangulation, helps to overcome the limitations and weaknesses implicit in each type of method and contributes to validate research findings through different approaches.[207] Specific methods and difficulties encountered in the data collection and analysis are discussed in the respective Sections where the processed and analysed data is presented (e.g. Section 5.1.2 on data analysis to generate soil depth – soil productivity relationships, Section 5.3 on the individual discount rate). If nothing specific is mentioned in certain Chapters (e.g. Chapter 7 and Chapter 8), primary data has been collected through semi-formal interviews and from key informants.

***Secondary data***

The main source of secondary data is the database of the SCRP. The amount of data allowed statistical analyses. The present study applies the change of productivity approach to value the negative effects of soil erosion, despite the various known shortcomings (cf. Section 3.1.7), because of the amount and type of data available. The effect of soil erosion on yields is established using soil depth as a proxy indicator. Analyses of nutrients in eroded material were not made for the present study, which would allow the calculation of replacement costs. Such analyses were conducted in specific studies,[208] but they were not part of the long-term core programme of the SCRP and do thus not allow the assessment of changes over time.

Detailed discussions of methods and statistical tests are presented in the respective Sections.

***Semi-formal interviews***

The interviews can best be characterised as qualitative interviews. The structure of the interviews was semi-formal with leading questions (cf. Appendix 3.2). Whenever it seemed necessary to obtain detailed

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[207] Lamnek, 1998, 229.

[208] e.g. Kefeni Kejela, 1992.

information on specific topics, additional questions were asked. Although the respondents were selected as representative as possible (i.e. according to certain criteria and in consultation with Research Assistants who know the population well), the sample is not sufficiently big to allow valid statistical interpretations.

***Key informants – informal interviews***

Key informants are individuals who have a great knowledge concerning a specific aspect of interest. Various key informants were approached at different levels:

- Community level: community administrators, extension agents, project personnel, elders, young landless farmers, farmers with irrigated gardens, farmers with tree plantations, traders, priests
- Wereda level: employees of the Department of Agriculture, traders
- Regional level: employees of the Bureau of Agriculture, project personnel
- National level: employees of the Ministry of Agriculture, project personnel

Interviews conducted with key informants did not follow a pre-defined structure and a set of common questions but evolved freely according to the topic of interest.

***Focus group discussions***

Focus group discussions[209] were held on topics where a better knowledge about certain issues of interest was needed and collective perception of a given issue was the main focus, or where the perception of different groups within the population concerning a specific topic was of interest. The size of the focus groups varied but was mostly around 6 to 10. Focus groups often evolved from formal interviews or key informant interviews when neighbours joined in. The following specific focus groups were organised: young farmers on current problems, their future, and visions for development (Maybar), elder farmers on the role of religion (Andit Tid, Maybar), women on health problems (Mesobit & Gedeba), farmers on environmental conflicts (Mesobit & Gedeba), and farmers on irrigation and water sharing arrangements (Maybar).

***Farm analysis***

To obtain a better overview of prevailing farming systems, management practices and livelihood strategies, interviews were supplemented with observations on the fields cultivated by the selected households. Whenever possible not only own land but also leased land was considered. However, farmers were reluctant in indicating which fields they have leased. Usually, it was not possible to visit also these fields. The following main features of fields were assessed: size, location, slope gradient, soil depth, signs of degradation, and status of conservation structures.

***Participatory and other instruments***

A number of other instruments were used for the different studies:

- ***Wealth ranking***:[210] A wealth ranking was conducted in Anjeni, as households with different assets at their disposal show different strategies to secure their livelihood and have different possibilities with regard to carrying out SWC. Wealth was defined by the respondents as being more than access to or control over important economic resources: in their perception, it included social and political components. These were therefore taken into account in the ranking of the households.
- ***Farm walks***: whenever possible, the farm of the interview partners was visited to have the opportunity to listen to farmers' explanations of the farm layout, management practices, farm history, and problems. Farm walks also offered the author a visual impression of what the farmer was talking about and gave the possibility to discussed specific issues where a shared visual impression existed.

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209 cf. Guinand, 1999b, 62.

210 Grandin, 1988.

- ***Transect walks***: transect walks trough the research catchments and beyond gave a first impression of the ecological zones, general land use and land cover areas, and settlement patterns along the topo-sequence of the study area. They were conducted together with the RA's and two knowledgeable resource persons from the community. Trough intensive discussions during the transect walks a first impression on current problems in the ecological, social, economic and political sphere could be gained.
- ***Calendars***: Calendars were established by groups of farmers with regard to seasonal patterns of labour demand for on-farm and off-farm activities, crop production, food shortages, price fluctuations, rainfall patterns or religious holidays.

### 3.2.8 Major difficulties encountered during the fieldwork

The planning for this study was begun as early as 1995. At that time, the SCRP was still a national project with research sites in different regions and a General Manager in Addis Abeba. With him, a first draft of the research concept was discussed, and he approved it. When the Swiss National Science Foundation (SNSF) finally accepted the research proposal in 1997, the SCRP was in a process of decentralisation and main responsibilities were already handed over to the Regional authorities. It was thus decided to concentrate the study on Amhara Region, with which at that time the best communication was possible through the then research fellow Gete Zeleke, who worked in Bahrdar as well as in Bern. An agreement between the Bureau of Agriculture and the Centre for Development and Environment was signed, which allowed the research to be carried out. Despite this agreement, administrative obstacles were considerable, and much time had to be spent on obtaining the necessary research permissions at each administrative level.

In the intercultural context of this study, communication barriers showed to be substantial, not only as a with regard to language, but even more so with regard to understanding ideas and concepts and of how to approach farmers and how to work together. Research Assistants from the SCRP usually supported me during the fieldwork. They are familiar with the area and the population, as they have worked on the research stations for many years. Farmers, however, in part saw them as government employees who should not be trusted too much, especially concerning critical topics such as the household economy, ownership of capital (e.g. animals, trees), and perceptions relating to soil conservation. Research Assistants, on the other hand, were used to being the ones who knew more than the farmers, and therefore, the concept of listening to what farmers have to say and learning from them was new to them.

### 3.2.9 Limitations of the study

In the Ethiopian Highlands, farming is not simply a profession, but a way of life. It encompasses much more than the production of crops and livestock. Farming is highly interlinked with the local ecological, socio-cultural, economic and political system and shaped through deep-rooted norms and values. The attitude of farmers towards their way of life is clearly manifested through their valuation of other members of the society. The ecological environment can have a great influence on production possibilities of farmers, i.e. on an important part of their livelihoods, but on the other hand, the ecological environment is greatly influenced by the land use system. The attitude towards natural resources is on the one hand production related and oriented towards its direct or indirect usefulness (e.g. the disappearance of forests is made responsible for increased flooding of arable land, nevertheless big trees are felled to produce tools), but on the other hand, it is culturally shaped (e.g. wetlands or single trees are believed to host bad spirits bringing mishap, while stands of trees around churches or graveyards are holy sites). A change in one of the systems – ecological, economic, or social – can have far-reaching implications on the other systems. The reality land users live in is complex and influenced by local, regional, national and even international factors from the ecological, economic, technological, cultural, social and political sphere.[211] Livelihood strategies are shaped in such a way as to make best use of offered opportunities and at the same time minimise risks posed by the complex environment. Livelihood strategies themselves are highly complex and spatially and temporally variable. It would thus be arrogant to claim to have understood this complexity and variability, of either the livelihood strategies or the influencing factors, and even more so to judge it. It also seems arrogant to pick out one aspect from this complexity – soil erosion and soil conservation – and try to understand why farmers' actions lead to soil erosion, i.e. of valuing the effect of soil erosion and conservation with regard to one parameter – crop yield. Results presented in this report always have to be read with the necessary caution and in the knowledge that they represent but a mere attempt to shed some light on one detail of complex livelihood strategies – a detail which has furthermore been selected for study by outsiders. Nevertheless, also the view and perception of the concerned land users with regard to soil erosion and soil conservation is presented – or that what the author has understood and interpreted – and to try to understand certain actions not only in their direct meanings, origins and consequences, but to understand them in the wider context of complex livelihood strategies.

The present study has clear limitations with respect to generalisation of findings and possible bias of processed data. The studies were carried out as in-depth case studies covering a limited area and a limited number of interview partners. Neither study areas nor interview partners were selected randomly or according to criteria that allow up-scaling. An extrapolation of findings to other areas is thus difficult, as bio-physical, socio-economic and cultural factors differ within a small area. Much of the sampled data is of qualitative nature and therefore subjective. Often, ambiguous expressions such as 'big', 'small', 'much', 'far', 'in former times' etc. were used by the interview partners, which make a clear interpretation or conversion to metric units difficult, if not altogether impossible. Validation of conclusions based on this information is therefore difficult.

As in any qualitative research in the intercultural context, biased or even wrong interpretation of statements of the local population by the researcher is possible, particularly when working with translators. Being already farther away from farming, they tend to have difficulties in understanding farmers. On the other hand, farmers often specifically stress those points which they believe are of interest to the researcher. And lastly, the large cultural difference between the local population and the researcher makes a proper interpretation of observation and statements difficult. For any wrong interpretation I apologize to those affected.

Also quantitative data is not flawless. Especially the separation of the effect of soil erosion on yields from other impacts is problematic. The quantitative data from the SCRP database used in this report is of exceptional quantity and quality for conditions in developing countries. Nevertheless, their interpretation was often difficult. Sometimes data seemed implausible, but no explanations from those who have collected the data could be obtained. In other cases, the variation of data was so big that meaningful interpretation or statistical analyses posed difficult. The big variation of data (e.g. annual soil loss rates measured on erosion plots in Maybar can vary between 0.7 t/ha and 118 t/ha) points at the complex and unpredictable situation under which small-scale farmers in the Ethiopian Highlands operate.

Costs and benefits of soil erosion and conservation have been assessed as accurate as possible. However, errors are always possible. Should any flawed input parameters have been used in the CBA, they may have been multiplied and may distort results. The results of the CBA should thus not be taken literally but rather as an indication of the order of magnitude. Even small changes in input factors might change the considered technology from being profitable to not being profitable. A sensitivity analysis should help to identify those input factors that have an influence on the outcome of the analysis.

Findings are limited to a few soil and water conservation technologies. The calculation of costs and benefits is highly technology-dependent. If it proves that the considered SWC technologies are not profitable,

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211 Here, complexity is understood as a combination of phenomena and relationships, where phenomena can be used as criteria to separate and (non-linear) relationships as criteria to unite. Complexity should not be reduced to a sum of simple phenomena or relationships, but the integration of these latter in complexity. (Messerli, 1995, 18; Thompson Klein, 2001, 40)

this does not mean that any soil and water conservation technology is not profitable. Furthermore, the selected SWC technologies were analysed in three localities in different areas of the Ethiopian Highlands in a site-specific situation and with site-specific assumptions. If the technology proves to be unprofitable in some or even in all three places, this does not indicate that SWC in the other Highland areas is unprofitable as well.

The valuation techniques used to value the costs and benefits of soil degradation and soil conservation show a number of inherent limitations. They allow only the valuation of some soil functions – generally only direct use values such as soil productivity – and therefore undervalue soil as a whole resource. It is difficult to distinguish between reversible and irreversible damage and even more difficult to include possible costs of irreversible damage accruing to future generations. Thus, issues of intergenerational equity are inadequately addressed in any economic valuation. Despite these weaknesses of economic valuations of environmental goods and services, if the presented results are interpreted with awareness of those weaknesses,, such valuations nevertheless provide additional information regarding the costs of resource degradation and the benefits of resource conservation to decision makers, at the household level as well as at the regional or national level.

# 4 Cost-Benefit Analysis and Soil Conservation: Some Theoretical Reflections

*"In one sense, everyone making a decision of any consequence uses something very like benefit-cost analysis. That is, they weigh up the pros and cons of the options confronting them and decide between them accordingly."*
*(Arrow, 1997, 195)*

## 4.1 Basic Principles Underlying the Cost-Benefit Analysis

Cost-benefit analysis (CBA)[212] is essentially a social evaluation method based on applied welfare theory. It concerns decision-making with regard to the net social benefit of investments. Because society has limited resources to spend, cost-benefit analysis can help illuminate the trade-offs involved in making different kinds of investments.[213] CBA is not limited to evaluate investments that concern society as a whole. Like society, individuals face budget restrictions, and they have to evaluate the benefits and costs of a certain activity against other possibilities. It is thus also possible to conduct a CBA at the individual level.

CBA is one of several ***evaluation approaches*** used to determine whether an activity corresponds to the desired and envisaged aims (effectiveness), whether the overall benefits exceed the overall costs (efficiency), and whether they eventually have positive effects (impact) on the welfare of a community.[214] In contrast to multi-criteria analysis (MCA), CBA concentrates on costs and benefits and centres around the efficiency criterion to find out which is the 'best' alternative. MCA, on the other hand, pays much more attention to the process of ranking, but not necessarily selecting, various alternatives according to several criteria, and thus pays more attention to the criterion of effectiveness. CBA and MCA can further be distinguished by the fact that in a CBA, effects of an activity are expressed in monetary terms, whereas in an MCA, different criteria are weighed and compared without monetary values being assigned.[215] Thus, also non-market goods and intangible side effects of an activity can be included in the valuation without having to be assigned a price (cf. Section 3.1.1 for a description of different valuation methods). In the agricultural sector, and especially for subsistence farmers, it is usually not the maximisation of one goal, which is in the foreground, but rather the optimisation and meeting of several objectives (cf. Section 6.3.1). This optimisation process can be addressed in an MCA, but not in a CBA, as in the MCA, alternatives can be judged based on their contribution towards different criteria.[216] Although a CBA analyses only one objective –not necessarily the most important one for a subsistence household, and monetary quantification of costs and benefits is a necessary, but often difficult step, CBA provides a logical framework for the systematic collection, interpretation, and presentation of information from the perspective of trade-offs in decision making.[217] It is thus also useful for analysing costs and benefits of environmental investments and for demonstrating their contribution to the well-being of an individual or of society. Therefore, costs of soil degradation and benefits of soil conservation investments should not only be analysed in ecological terms, but also in economic terms. Cost-benefit analyses are not an

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212 Both terms cost-benefit analysis or benefit-cost analysis can be used.

213 Arrow et al., 1997, 198.

214 de Graaff (1998, 46) distinguishes efficiency, equity, and conservation principles (impact) that SWC investments should fulfil. Efficiency can be broken down in direct, on-site effects on production and income (e.g. production) and indirect, downstream effects on production and income (e.g. production loss, reservoir capacity). Equity concerns intra- and intergenerational equity. Conservation effects can be in the sphere of land, water, or vegetation.

215 de Graaff 1996, 551ff; Wiegand, 1995.

216 Drechsel & Gyiele, 1999, 41.

217 Enters, 1998a, 4; Ellis-Jones & Mason, 1999, 230.

end in itself, especially not when considering the multiple objectives of a small-scale subsistence household or when analysing environmental conservation activities, as environmental assets are composed of a variety of values (cf. Figure 22). With respect to soil conservation, a CBA would be sufficient only if farmers operated under perfect markets with the single objective of maximising profits.[218] Secondly, it could be that the CBA would produce a positive result for a specific SWC technology from the farmer's perspective. This does, however, not indicate whether the investment will be carried out or not. It could well be that other investments not considered in the CBA produce even higher benefits or fit better into the multiple strategies of a household, as other, equally important but not quantified issues, are addressed.

The basis of the CBA is, in principle, reflected in the ***consumers 'willingness to pay'*** for an increase in welfare. Dupuit (1844)[219] described the consumer surplus, which is defined by the demand curve (equal to the willingness to pay) and the price, as being the difference between the price actually paid when purchasing a commodity and the price the consumer would be willing to pay.[220] Because the marginal opportunity cost of a resource is the highest amount someone would pay for it in an alternative use, valuation in CBA is based on such willingness to pay (WTP) values.[221]

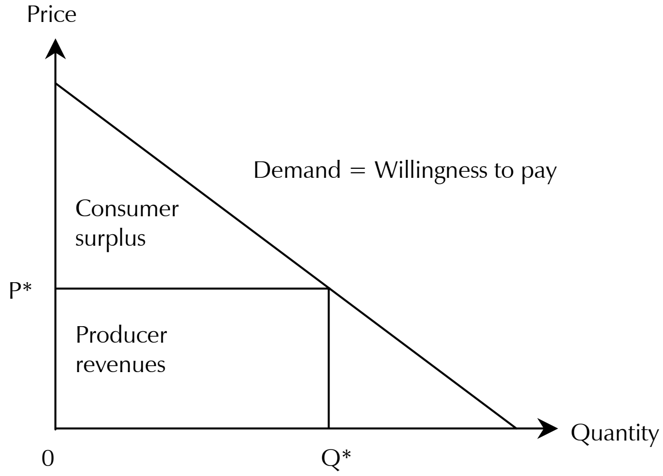


*Figure 25: Willingness to pay, consumer surplus, and producer revenues. [Source: Abelson, 1996, 23]*

The simple model presented in Figure 25 shows that the demand for a good or service decreases as the price increases. Producer's revenue is the quantity sold (Q*) multiplied by the price paid (P*). The consumer surplus is represented by the area above P* and below the demand curve. The lower the price P*, the bigger obviously the consumer surpluses are likely to be. In the case of non-marketed goods, such as many environmental goods or benefits, where P* is zero, all services can be considered consumer surpluses.

As mentioned in Section 3.1.1, a central aspect of environmental economics is to properly value environmental goods and services, to attribute a price P* which, considering a given demand curve for that environmental good, would result in a specific quantity Q* which is considered sustainable, either with respect to output or input.[222] Problematic is the fact that many of environmental assets do not have a market. Thus,

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218 Pagiola, 1994, 34.

219 quoted in Hanley & Spash, 1993, 27.

220 Hanley & Spash, 1993, 27.

221 Abelson, 1996, 22.

222 ***Output rule***: waste emissions from a project should be kept within the assimilative capacity of the local environment, without unacceptable degradation of its future waste absorptive capacity or other important services and functions. ***Input rule***: a) renewable resources: the harvest must be kept within regenerative capacities; b) non-renewable resources: depletion rate should be below the historical rate at which renewable substitutes by human invention and investments were developed. (Goodland, [2002, 1])

they are considered to have a zero price and are provided for free.[223] Since environmental goods are available to consumers at a zero price, they appear not to affect markets and they cannot be influenced through market regulations. A problem with using traditional CBA for the evaluation of investments or projects with an environmental component, be it related to input or output, is that they often fail to adequately capture environmental costs or benefits. Thus, if comparing different projects or investments based on a CBA, the selection is biased in favour of investments whose outputs have a market price and are therefore easily measured, and against investments in conservation projects whose benefits are not bought and sold in the market and are therefore more difficult to measure.[224]

If we assume that the value of an environmental good or service could be established, the following considerations would have to be taken into account:

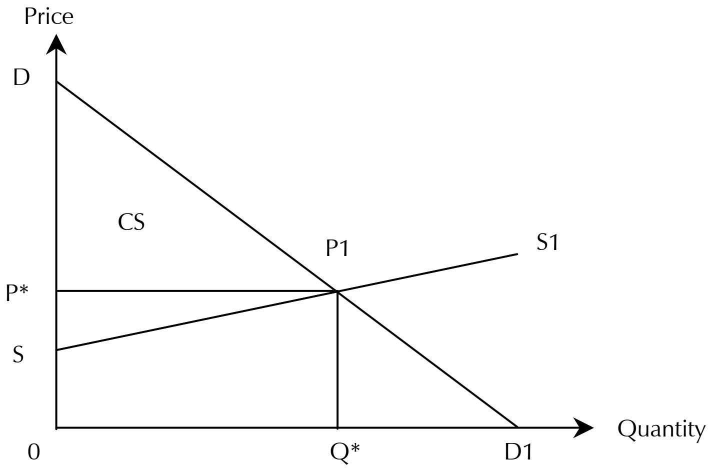


*Figure 26: Supply (S-S1), demand (D-D1), price, consumer surplus (CS), and the value of an environmental good or service. [Source: Bann, 1997, 3]*

The total value of an environmental good or service does not consists of the market value (P* *Q*) alone; it also includes the consumer surplus (CS, area D – P1 – P*). In a CBA, therefore, this total economic value should be used. This necessitates that the willingness to pay by consumers, which equals the demand curve (D-D1) can be established as a measure to capture the total value of the good or service.

One basic assumption in economics is that society's objective is to maximise the total welfare derived from goods and services that people consume.[225] Consumed goods and services include those that are produced as well as those that are provided by nature without transformation in a production process. As it is difficult to directly assess society's welfare, it is assumed that social welfare is an aggregate of individual welfare. Furthermore, social welfare is conceptualised in the form of potential compensation. This states that a policy or investment is socially beneficial if the 'winners' from a policy action or investment could, in principle, fully compensate the 'losers' and still be better off. Thus, the winners' maximum willingness to pay, and the losers' maximum willingness to accept must be established. The maximum willingness to pay or to accept can be traced back to the concept of indifference between two alternatives. Maximum willingness to pay would then be the amount of money that would make an individual as well off with the project as without the project.[226] The main difficulty is how to measure individual and aggregate willingness to pay for environmental goods. If goods are traded, the market value is an acceptable approximation of the willingness to pay. Environmental goods that are not exchanged on a market must be valued using survey methods as described in Section 3.1.1.

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223 Chichilnisky, 1997, 202

224 Bann, 1997, 1.

225 It remains to be decided whether maximisation of total welfare, which takes into account only the perspective of human users, is a suitable measurement and corresponds with notions of sustainability (cf. Section 3.1).

226 Poe, 1999, 572.

## 4.2 Cost-Benefit Analysis

Cost-benefit analyses establish a ***direct link between the environment and the economy***. They thus provide a framework for integrating the bio-physical and the socio-economic environments faced by farmers. Soil *per se* does not contribute to well-being directly, but it serves as an input e.g. in crop production.[227] Erosion affects crop yields through changes it causes in soil properties. Costs of soil degradation or soil improvement are thus derived indirectly through decreasing or increasing yields if considering on-site effects, or through abatement and restoration costs if considering negative off-site effects. Usually, only direct or on-site costs and benefits of soil degradation are included in the cost-benefit analysis, based on costs and benefits as accruing to the individual responsible for the damage, but not off-site costs and benefits affecting other individuals or parts of society.

Traditional project evaluation mainly considers direct costs and benefits. The expanded approach or 'social cost-benefit analysis' also includes the

"[...] *external and environmental improvement benefits (plus the benefits from environmental protection), as well as the costs of external and/or environmental damages and the environmental control measures*."[228]

A number of problems are encountered in extending cost-benefit analysis with environmental project impacts.[229] Firstly, the physical estimation of environmental effects of project impact is often difficult. Secondly, as most environmental resources are non-marketed (e.g. soil in situations where there is no market for arable land) and are sometimes even 'open access resources' (e.g. clean air), economic valuation of their services is not clear. Thirdly, the monetary valuation of intangible environmental goods and services, such as the need to preserve unknown species for their intrinsic value, is even less clear. And fourthly, as the value of environmental goods differs in time, the intertemporal choice is difficult to solve.

CBA and its implications for the environment are controversially discussed. Three main aspects evolve:

(i) It is difficult to place monetary values on intangible environmental resources.
(ii) It is difficult to place monetary values on environmental impacts.
(iii) There is controversy concerning the discounting of identified costs and benefits.[230]

It is often argued that environmental degradation is, at least in part, a result of market failures and lacking institutions (both at the local and at the national level), and government failures.[231] Institutions are a set of regulations concerning, *inter alia*, the use of resources. There are strong arguments for applying CBA not only with regard to physical investments, but also for the evaluation of new regulations.[232] Such regulations might improve free market outcomes – or they might correct economic behaviour when there is no market for a certain good. However, costs for new regulations need to be assessed against their possible benefits. In developing countries, the problem in relation to environmental regulation is that regulations are considered to be of minor importance with regard to preventing environmental degradation. It is argued that many of the immediate environmental problems, such as land degradation or deforestation, arise from population pressure and poverty. It is also claimed that because of the dispersed nature of the problem, regulations are extremely difficult and costly to enforce[233] and therefore more expensive that technical solutions.

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227 Enters, 1998a, 3.
228 Dixon and Hufschmidt, 1986, quoted in Barbier, 1998, 15.
229 Barbier, 1998, 15.
230 Lumley, 1997, 72.
231 e.g. Dasgupta, 1995, 395; OECD, 1995, 16; Barbier, 1997.
232 Arrow, 1997, 198.
233 Davies, 1997, 207.

### 4.2.1 Measures of project worth

The principle of the economic analysis of soil erosion and soil conservation is simple. It involves calculating the difference in the flows of costs and benefits between the case where the current erosive practice is continued and the case where a specific conservation practice is adopted. The CBA is therefore not to be confused with a 'before and after' analysis. Furthermore, a CBA is an analysis that takes into account one specific action or investment and compares it to a base case. If the results show that this one specific investment is not profitable, this does not imply that all other similar investments are not profitable either.[234]

The main difficulty in the economic analysis of soil degradation and soil conservation is to find a way of quantifying the impact of soil degradation, both on-site (e.g. decreasing yields) and off-site (e.g. siltation of dams), and to collect the required economic data to put a monetary value on these different impacts. However, the most critical question is not the cost of soil conservation, but rather whether the long-term benefits of reduced soil degradation justify the costs of conservation. Any assessment of the impact of introducing soil conservation measures thus requires an assessment of the rate of productivity decline and increase without and with investments in SWC.[235]

CBA is based on the principle of opportunity costs. Resources (e.g. land, labour, capital) invested in, for example, soil conservation, could also be invested in other enterprises. The value for these inputs is therefore assumed equal to the foregone benefit of investing these resources in an alternative enterprise.

***Net Present Value (NPV)***

The traditional project appraisal criterion is that discounted net benefits, the net present value (NPV),[236] should be non-negative:[237]

$$\sum_{t=1}^{t=T} \delta * [B_t - C_t] > 0 \tag{4.1}$$

where $B_t$ is the benefit of the project in time period $t$, $C_t$ are the costs of the project in time period $t$, $\delta$ is the discount factor, and $T$ is the time horizon.

Benefits $B_t$ can be written as:

$$B_t = \sum_{i=1}^{i=I} P_i * Q_i \tag{4.2}$$

where $P_i$ is the price of commodity $i$, and $Q_i$ the quantity of the output in time $t$.

Costs $C_t$ can accordingly be written as:

$$C_t = \sum_{j=1}^{j=J} P_j * R_j \tag{4.3}$$

where $P_j$ is the price of the commodity $j$, and $R_j$ the quantity of input in time $t$.

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[234] Pagiola, 1993, 27.
[235] Ellis-Jones & Mason, 1999, 230.
[236] also net present worth
[237] Pearce et al., 1990, 61.

The discount factor $\delta$ can be written as:

$$\delta = \frac{1}{(1+r)^t} \tag{4.4}$$

where $r$ is the discount rate and $t$ is time.

If, in addition to the normal costs of a project, also environmental degradation occurs, the appraisal criterion (Equation 4.1) is extended by $E_t$, the costs of the environmental damage by the project at time $t$:[238]

$$\sum_{t=1}^{t=T} \delta * \left[B_t - C_t - E_t\right] > 0 \tag{4.5}$$

When considering an investment proposal, always two questions can be asked: Firstly, does the project represent a good use of funds and is it worthwhile? And secondly, is the project under consideration to be preferred to other projects that could be carried out with the same funds available? The first question can be answered if the NPV as shown in Equation 4.1 above is positive. One project C (e.g. the case where SWC investments are carried out) is to be preferred to another project E (e.g. where the erosive practice is continued), if the NPV of C is higher than the NPV of E. When calculating the NPV, the returns from the investment project can be compared to returns from depositing the funds in a bank or to returns from lending the funds at an interest rate of $i$. If the NPV is zero or lower, then the money could have been invested elsewhere at least as profitable or in a more profitable way.[239]

A CBA of soil conservation should thus compare the two situations E 'uncontrolled erosion' on the one hand and C 'soil conservation' on the other hand. If the NPV of uncontrolled erosion – project E – is higher than the NPV, which can be achieved if investments in SWC are carried out – project C – then the investments in SWC are economically not worthwhile.

Before calculating the NPV, the returns of the two considered projects have to be estimated. In the case of soil erosion (E) and soil conservation (C), the following equations are used to calculate returns ($\pi$) under different practices. The returns, which can be obtained each year under the unsustainable practice, the practice with uncontrolled erosion, are:

$$\pi_t^E = py_t^E - c^E y_t^E \tag{4.6}$$

where

| | |
|---|---|
| $py_t^E$ | is the crop yield $y$ in year $t$ under the erosive practice multiplied by the price $p$ for the considered crop |
| $c^E y_t^E$ | the corresponding annual costs of production. |

The returns in the case of soil conservation would be:

$$\pi_t^C = py_t^C - c^C y_t^C - c_t^{SWC} + pz_t^{SWC} \tag{4.7}$$

238 Pearce et al., 1988, Annex.

239 Dinwiddy & Teal, 1996, 94. It is to be noted that the authors specifically mention that the NPV must be greater than zero for the investment to be profitable. Others, such as Pearce et al. (1990) assume that the discounted net benefits of each project i should be non-negative. In the situation where the NPV would equal zero, the investor would be indifferent about whether to invest the funds in the considered project or to use the funds for other purposes. This latter definition is hardly operational and would make choosing the more profitable project difficult.

where

$c_t^{SWC}$ are the costs for establishing and maintaining the conservation measures in year *t* and

$z_t^{SWC}$ any additional yield which can be realised on the conservation structures in any year *t*.

The net benefit obtained from adopting the conservation practice in any give period would thus be:

$$\pi_t^C - \pi_t^E, t = 1,2,3,....,T \quad (4.8)$$

The net benefit is discounted back to the current period and summed according to Equation 4.1 to arrive at the ***Discounted Net Gain DNG*** from switching from the erosive to the conserving cultivation practice.

$$DNG = NPV^C - NPV^E \quad (4.9)$$

where $NPV^C$ and $NPV^E$ are the discounted flows of net benefits with and without soil conservation.

In the case of soil conservation investments with relatively high costs at the beginning, the net benefits are usually negative in the first years and become positive only in later years, as uncontrolled erosion leads to declining yields. Thus, the length of the time span, in which the net benefits achieved with SWC are smaller than the net benefits achieved with the erosive practice, depends on

- the costs of the conservation technology, i.e. direct investment costs such as labour, expenses for tools, etc., and indirect costs such as the amount of arable land occupied by the conservation structures;
- the magnitude of the yield decline in the case of the erosive practice;
- the magnitude of the reduction of the yield decline achieved through conservation;
- the additional production on the conservation structures.

The following figure shows this in a schematic manner. It is assumed that uncontrolled soil erosion leads to declining net returns, as shown by path A in Figure 27. There might be a change in the management practice, i.e. horizontal instead of up-and-down ploughing, which does not necessitate initial investments but slows down the decline of net returns (path B). Investments in soil conservation let net returns in early years drop to low levels because of the considerably high initial investment costs. After some years, net returns might recover or even increase (path C and D, respectively), depending on the conservation technology, the specific situation in the area, and whether additional production is possible on the conservation structures, i.e. whether the area loss can be compensated.

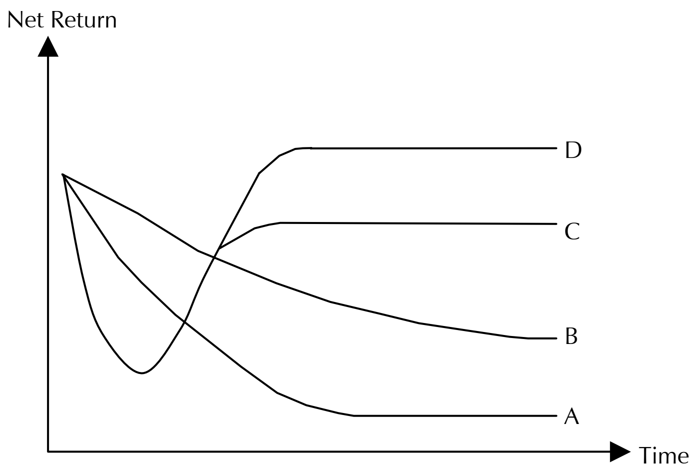


*Figure 27: Possible profiles of net returns over time with and without SWC investment. [Source: Own compilation]*

As in a CBA the stream of costs and benefits over time are considered, the discount rate and the time horizon of analysis are of paramount importance (cf. Section 5.3 and 5.4). The higher the discount rate the less weight is attributed to benefits in later years. If the discount rate is set to zero, immediate costs and future benefits are weighed equally. Thus, the sum of future benefits might be bigger than the immediate costs (DNG > 0). If the time frame of analysis is short, benefits in future might not be considered adequately.

In addition to the NPV, which is the most common criterion to judge the profitability of investments, three other measures also provide useful insights: the internal rate of return (IRR), the benefit-cost ratio (BCR), and the net benefit-investment ratio (N/K ratio). In the following equations $B_t$ and $C_t$ are benefits and costs of the investment according to Equation 4.2 and 4.3, $r$ is the discount rate, $T$ the time horizon, $N_t$ is the incremental net benefit in each year after the stream has turned positive, and $K_t$ the incremental benefit in initial years when the stream is negative.[240]

***IRR:***

$$\sum_{t=1}^{T} \frac{B_t}{(1+r)^t} = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} \tag{4.10}$$

IRR is the discount rate under which the discounted benefits are equal to the discounted costs, i.e. where the net present value is exactly zero. The IRR is the maximum interest that a project or investor could pay for the resources invested if the investment is to recover its initial investment costs and annual operation costs and still break even. Problematic is the fact that if net benefits of an investment are always positive or negative, the IRR cannot be calculated.

***BCR or B/C ratio:***

$$\frac{\sum_{t=1}^{T} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{T} \frac{C_t}{(1+r)^t}} \tag{4.11}$$

If the BCR were less than 1, present worth of costs at a specific discount rate would exceed present worth of benefits. Initial expenditures could thus not be recovered and the project would not be profitable.

***N/K ratio:***

$$\frac{\sum_{t=1}^{T} \frac{N_t}{(1+r)^t}}{\sum_{t=1}^{T} \frac{K_t}{(1+r)^t}} \tag{4.12}$$

The N/K ratio is useful when different investments, which are not mutually exclusive, should be ranked. Investments are profitable if the N/K-ration is greater than 1 when opportunity costs for capital are used.[241]

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240 Gittinger, 1982, 299 ff; Enters, 1998b, 20.

241 Gittinger, 1982, 343ff.

***Net Present Value Rate (NPVR):***

$$NPVR = \frac{NPV}{Present\ Value\ of\ \ Initial\ \ Investment} \tag{4.13}$$

The NPVR shows the relation between the expected NPV and the present value of the total initial investments.[242] It can thus be used to compare different projects that produce similar NPV's and select the one which minimises investment costs.

The four measures – NPV, IRR, BCR, and N/K ratio – are clearly interrelated. Taking opportunity costs for capital as the discount rate, the four measures would identify the same investment for implementation. Investments are profitable if either the NPV is positive with a discount rate equal to opportunity costs of capital, have an IRR above the opportunity costs of capital, or have a B/C ratio or N/K ratio greater than 1 at opportunity costs of capital.[243] IRR is the preferred measure if the discount rate that should be used is uncertain or disputed. However, to evaluate the resulting IRR, i.e. to be able to compare different investments, the IRR must be compared against a value, usually the opportunity costs for capital (i.e. lending rates of individuals or the state). The NPV is the preferred measure if mutually exclusive projects are evaluated. The B/C ratio, finally, shows how much the costs are allowed to increase before an investment has to be rejected. Instead of using the B/C ratio, which considers discounted costs and benefits, the benefit-cost ratio can also be calculated without discounting on an annual basis. It is argued that an undiscounted annual B/C ratio of 1.5 is necessary for small-scale farmers to accept a new technology.[244] An essential element the four measures have in common is that they allow costs and benefits to be presented as streams over time. The time aspect is especially important in cases where resource-conserving investments such as soil conservation are compared to exploitative practices.[245]

***Arguments against using CBA for evaluating environmental investments***

Several arguments are raised against using CBA and its measures such as the NPV for evaluating environmental investments such as soil conservation.[246] It is often argued that the NPV is not a meaningful evaluation criterion for environmental investments when long-term effects are involved. This point is specifically stressed by environmentalists who argue that environment has a non-negotiable value (i.e. an existence value) on its own. It is also mentioned that it is difficult to precisely describe in physical terms environmental degradation or the effect an investment has on degradation processes, especially if risks and uncertainties are big and if irreversible changes might occur. It is then even more difficult to convert such environmental degradation into monetary terms. It is also mentioned that different stakeholders value certain environmental attributes and damages differently, (i) depending on whether they are directly concerned or not and (ii) based on different ethics. A further argument against using CBA and its related evaluation criteria particularly concerns the case where the decision makers are small-scale subsistence farmers. Arguments raised are that subsistence farmers are only to a small part integrated into a market economy and that therefore it is difficult to valuate labour or to quantify parameters such as crops produced and consumed directly by the household. It is further argued that the conversion of such parameters to monetary values is even more challenging while it does not consider social aspects adequately. Moreover, markets – specifically capital markets – are often distorted or absent, and therefore the opportunity costs of capital discount rates based on them are difficult to determine. Lastly, it is argued that small-scale subsistence farmers have a different rationale when deciding whether or not to invest scarce resources than what is assumed in a CBA, which is

242 Kappel, 1996, 10.
243 Gittinger, 1982, 358.
244 Baum et al., 1999, 20.
245 Enters, 1998b, 20.
246 e.g. Bojö, 1992, 159; Abelson, 1996, 51; Enters, 1998b, 20; Harris, 2001, 20.

based on profit-maximisation. Achievement of subsistence requirements and minimisation of risks may have greater importance.

***Justification for using a CBA for the evaluation of the profitability of SWC in the Ethiopian Highlands***

Despite the criticism raised against using cost-benefit analyses, a CBA will be applied in the current study to determine the profitability of SWC investments. Not the absolute NPV of different technologies will be considered; rather the NPV resulting in the case where SWC investments are carried out will be set in relation to the NPV that is achieved if soil erosion continues uncontrolled. The evaluation criterion applied will thus be the discounted incremental net gain (DNG, cf. Equation 4.9) from switching from the erosive to the soil conserving practice. Since the analysis will consider local prices as paid to farmers, it will indicate whether the investment is profitable from a farmer's point of view, but not necessarily from society's point of view. Thus, local land users' criteria and perceptions are emphasised. The problem of soil erosion and soil conservation is complex; it affects different segments within a society differently and cannot be assessed according to a single factor or evaluation criterion. Despite this complex problem setting, not a holistic approach is taken, instead a reductionist scientific method is used[247] in an effort to shed some light on one aspect only – the profitability of SWC.

An evaluation of the profitability of soil conservation investments relying on a CBA can be justified on the grounds that

(i) a wealth of data from the physical and land use environment is available, which can be used to establish the necessary relations between soil erosion and yields as one of the most important inputs into the CBA,
(ii) data from long-term monitoring of the effect of different SWC technologies on soil loss rates is available, thus the effect of the considered investment on soil loss and crop yield can be determined,
(iii) economic data could be collected as part of the fieldwork in the research areas,
(iv) the CBA is done in three different locations within Amhara Region, for different situations in physical terms within the three research catchments (e.g. fields in different locations with different slope gradients, soil depth, and dominant land use system) and for different farmers, thus considering the heterogeneity of the physical as well as the socio-economic environment,
(v) different discount rates and time horizons are considered, and a sensitivity analysis of important parameters is carried out to test which input variables are specifically sensitive with regard to influencing the outcome of the analysis,
(vi) the valuation of resource degradation and the effectiveness of SWC from the point of view of outsiders (external view), based on results of the CBA, and from the point of view of the concerned land users (internal view) are compared and discussed,
(vii) the CBA is supplemented by an analysis of the economic and institutional environment, which points out important factors that have an influence on farmers' decisions and the general economic and institutional conditions.

## 4.3 Financial (Private) and Economic (Social) Analysis

Cost-benefit analyses can be made from two different points of view: from the individual's, in our case the farmer's point of view, and from the point of view of society as a whole. In the financial or private analysis, prices for inputs and outputs as faced by farmers are used for the calculation. With this type of analysis it should become possible to predict the likelihood of adoption of a proposed intervention, i.e. whether a farm household can afford to divert resources to soil conservation from other activities.[248] In the economic analysis, prices for inputs and outputs are corrected for market distortions such as regulations, market imperfections,

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247 Pretty, 1998, 845.
248 Stocking & Abel, 1993, 208.

taxes, subsidies, or overvalued currencies and inflation. World market prices would be used to determine the impact of the considered investment for society at the national level.[249] Such prices should reflect true scarcity of inputs and outputs.[250] Secondly, discount rates have to be adjusted accordingly. Individual discount rates reflect the marginal opportunity costs of funds as perceived by different individuals and groups in society (e.g. individuals, households, or firms)[251] and are usually considerably higher than the social rate of discount (cf. Section 5.3.5). A further important difference between the farmer's and society's perspective is the planning horizon. Although land users are usually aware of medium- and long-term negative impacts of soil erosion on soil productivity as well as monetary and non-monetary benefits of soil conservation, their planning horizon is normally relatively short, and decisions are made in view of immediate or medium-term needs with respect to securing the livelihood.[252] Finally, in the social analysis, external effects of soil erosion and soil conservation, which are irrelevant from a farmer's perspective, are also considered.[253] For society, the benefits of soil conservation may be expressed in terms of the value of increased future crop yield, relative to yields on degraded land plus the value of any avoided off-site costs (e.g. repair works at hydroelectric power plants, cleaning of water reservoir).[254] For the farmer the benefits of soil conservation would mainly constitute the monetary value of increased future crop yield, any other yield that can be harvested on the SWC structures, the non-monetary benefit of reduced risk, and increased factor productivity. Without market or government failures, the financial and the economic analysis would produce more or less same results, as input parameters would be equal.

Private investors, when deciding to embark on an investment project will have one central criterion – that of profitability or the question whether revenues from an investment exceed the costs over the lifetime of the project.[255] To answer this question evaluation criteria such as the above-discussed NPV are useful. For a society, the question is more complicated. Although also society faces budget restrictions and should invest available funds in the most promising enterprise, other criteria such as inter- and intra-generational equity or equitable distribution of resources among different regions within a country have also to be respected. Secondly, big national investment projects might alter the price structure of that commodity as well as possible substitutes and complementary goods. Thirdly, society is often involved in enterprises where neither private investors are engaged nor a market and prices exist to act as signals to producers and consumers. Thus, goods that have positive social benefits may not be provided, or may be provided in inadequate quantities or qualities, and goods (or rather 'bads') with adverse social consequences will not be discouraged. Thus, the problem is to devise mechanisms for incorporating these unpriced goods into the production and consumption decisions of the members of society.[256]

The distinction between the individual and the social perspective can also be explained by asking what farmers will do under certain conditions (positive question) and what society would like farmers to do under the same condition (normative question). Farmers decide on how to use their land in the light of their own objectives, production possibilities and constraints. Society, on the other hand, has social goals such as 'sustainable development' to achieve. Therefore, to answer the normative question calls for either an analysis of national benefits and costs arising from, for example, soil erosion and soil conservation valued in social terms using opportunity or shadow cost. Or farm-level benefits have to be re-evaluated at social prices, specifically also including any off-site costs and benefits. If farmers do the same what society would expect them to do, then no interventions are necessary. If, however, the privately optimal decision differs from the

249 Drechsel & Gyiele, 1999, 28.

250 Kappel, 1996, 12.

251 Aylward & Porras, 1998, 2.

252 Drechsel & Gyiele, 1999, 18.

253 Enters, 1998a, 5.

254 Barbier & Bishop, 1995, 133.

255 Although farmers can be considered in many respects as private investors, it should be remembered that small-scale subsistence farmers in the Ethiopian Highlands face many more constraints than simply finding the best possibility to allocate their resources in the most profitable way.

256 Dinwiddy & Teal, 1996, 87, 199.

socially optimal decision, i.e. farmers would tolerate a higher soil loss than society would consider optimal, then interventions in the economic or political system might become necessary to correct for distorted markets, price controls, taxation systems or subsidies.[257]

On-site costs of soil erosion are mainly borne by the land users in the form of reduced production or increased production costs. Off-site costs of soil erosion are transferred to society. Thus, costs of soil erosion and benefits of soil conservation are distinctively different for land users and society. Land users decide how much soil conservation to undertake, based on weighing the costs and benefits of the erosive practice compared to the conservation practice. This usually only includes on-site, but not off-site costs and benefits. Most probably, the result would be one where the individual farmer would tolerate a higher level of soil erosion than what society would. The following Figure 28 presents marginal damage (MD) and marginal abatement costs (MAC) of soil erosion from the two different perspectives:[258]

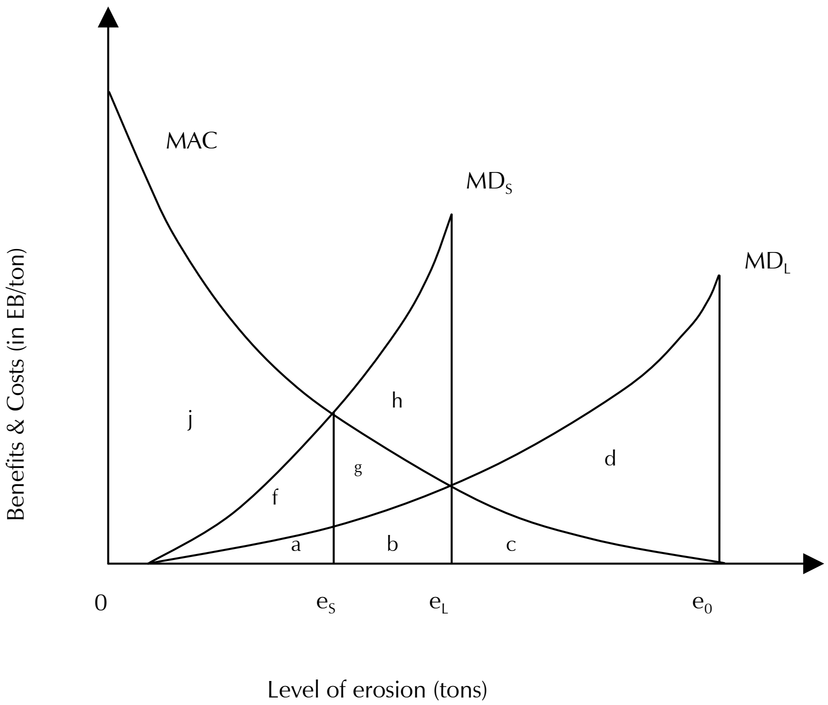


*Figure 28: Marginal damage (MD) and marginal abatement costs (MAC) of soil erosion from the land users' (L) and society's (S) point of view respectively.*
*[Source: Huszar, 1999, 59]*

With increasing soil erosion, the marginal damage to the land user increases. If no soil conservation is undertaken and soil erosion reaches $e_0$, the total damage to the land user would equal the area (a + b + c + d). If the land user considers this total damage to be too high, he can invest in SWC. This is shown in Figure 28 by the marginal abatement cost (MAC) curve. For each additional unit of soil erosion prevented, the costs for SWC rise. The area below this curve indicates the total costs of reducing soil erosion from the level $e_0$ to zero. The optimal level of erosion from a farmer's point of view would be $e_L$, where net benefits of reducing erosion are maximised, i.e. where marginal abatement costs (MAC) equal the marginal damage ($MD_L$) to the farmer resulting from soil erosion. If off-site costs of soil erosion are also considered, the marginal damage increases and the marginal damage society faces ($MD_S$) has to be considered. From the standpoint of society, the optimal level of soil erosion would be $e_S$, which is significantly lower than $e_L$. Social

257 Pagiola, 1999, 42, 49; Bekele Shiferaw & Holden, 2001, 352.

258 Huszar, 1999, 59f.

welfare increases if the area (h) is maximised, i.e. if the marginal abatement costs (MAC) are equal to the marginal damage inflicted to society ($MD_S$).

The problem is that $e_S$ is lower than $e_L$. A land user, if fully informed about the damage caused by erosion as well as the costs for preventing erosion and if acting following profit maximisation, would not reduce the level of erosion on his land below $e_L$, because additional benefits to the land user (b) are less than additional costs, represented by the area (b + g).

The damage inflicted to society and the damage inflicted to the individual land users is different because the external costs of soil erosion are not included in farmers' decisions. Two solutions are possible: either society provides an incentive equal to the area (g), which equals the amount by which the additional costs exceed the additional benefits to the land user of reducing soil erosion from $e_0$ to $e_S$. If the incentive were greater than (g) but smaller than (g + h), then both, society and the land user, would be better off. This fact is often used as an argument in favour of providing incentives for SWC, as both, society and land users, profit. It is also possible that society finds ways (through regulations or taxation) to motivate farmers to internalise the external costs of soil erosion, with the goal of bringing the two marginal damage curves together.

## 4.4 Steps Involved in a Financial Cost-Benefit Analysis

A CBA involves three major parts:[259]

(i) ***identification*** of all components relevant for the analysis, i.e. definition of the scope;
(ii) ***quantification*** of physical variables, i.e. environmental impacts of different actions;
(iii) ***valuation***, i.e. translation into monetary terms in the formal project analysis.

These three parts can be further broken down in 9 steps,[260] which are also reflected in Chapter 5 and 6. In Chapter 5 the main input parameters are developed and discussed (step 1 to 8). In Chapter 6.1 the results of the CBA and the sensitivity analysis are presented (Step 9). The results of the CBA are supplemented by an evaluation of soil degradation and of the merits and demerits of SWC from the point of view of the concerned land users. With the formal analysis resulting in one of the discussed measures of project worth (cf. Section 4.2.1) it is possible to assist decision makers – land users, project personnel, or agricultural extension agents – in evaluating different technologies as to how far one option is "better" than others. However, it has to be remembered that the CBA is not a means to an end, but simply a method of organising and presenting information expressed in monetary values.[261] With the CBA it can be shown whether a given technology is economically worthwhile of adopting. This assumes a decision based on the principle of profit-maximisation. Small-scale subsistence farmers in the Ethiopian Highlands, however, do not necessarily base all their decisions on the profit-maximisation criteria. Various strategies, which are embedded in the socio-cultural environment and partly shaped by the dynamic ecological and non-ecological environment, play an important role. Certain aspects of this non-ecological environment will be presented in Chapter 7 and 8, which will allow the reader to better evaluate the results of the CBA, on the one hand, and land users decisions in either adopting or not adopting certain conservation technologies, on the other hand.

***Step 1: Definition of the 'with' and the 'without' technology situation***

In the present study the situation 'with SWC' is compared to the 'without SWC' situation. In the 'with SWC' situation two cases are distinguished: introduced SWC and adapted SWC. These two technologies are in principle the same, either soil or stone bunds or Fanya Juu bunds (cf. Section 1.3.2 for a description of SWC technologies commonly applied in the Ethiopian Highlands). Introduced and adapted SWC differ from each other as in the case of introduced SWC the layout is according to the *'Guidelines for Development Agents on*

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259 Enters, 1998a, 8.

260 adapted from Stocking & Murnaghan, 2000, Appendix VI.

261 Enters, 1998b, 21.

*Soil Conservation in Ethiopia'*.[262] In order to achieve sloping bench terraces, the distance between two conservation structures depends on slope inclination and soil depth, as enough soil material is required to build up the terraces.[263] In the case of adapted SWC, it is assumed either that farmers have modified the original layout of introduced SWC, or that it concerns situations where indigenous conservation technologies are present. The layout of traditional or adapted SWC measures is more according to the needs of farmers or according to their analysis of specifically threatened areas within a plot (cf. Section 5.2.1).

Also for the situation without SWC, two cases are distinguished. In both cases, it is assumed that no conservation structures are present. The two cases differ insofar as in one case, only sheet erosion is considered, whereas in the other case, also rill erosion is modelled (cf. Section 5.1.4, 5.1.6).

An important part of the description of the situation with and without SWC is to model the effect of soil erosion on yield. For the current study, yields are expressed as a function of soil depth and slope gradient (cf. Section 5.1.3).

***Step 2: Conversion of data into common units***

Usually, data from interviews are in local units. In the Ethiopian Highlands, such local units mainly concern land (*timmad*)[264] and yield (*sahan*, *kunna*, *chinet*, *mezo*).[265] These units are converted to metric units to allow comparison. Monetary values are expressed in local currency – the Ethiopian Birr (EB), with an exchange rate of about EB 7.6 per US$ 1 in 2000. Crop revenues are calculated based on prices paid to farmers on the nearest local market. Family labour invested on the farm is expressed as opportunity costs.

***Step 3: Estimation of costs and benefits***

Costs and benefits are expressed in terms as they accrue to farmers (cf. Section 4.3). It is important to include only costs and benefits that occur as a result of adopting the technology. The different costs and benefits associated with SWC are further discussed in Section 5.2.

***Step 4: Monetary values of costs and benefits***

The different costs and benefits of adopting a technology are expressed in local currency. Whenever no direct monetary value is available, opportunity costs should be used. Production benefits and costs due to foregone opportunities are the principal monetary values. In the case with SWC, costs include labour costs for constructing and maintaining the conservation structures, foregone production because part of the arable land is occupied by the terraces, and costs for tools. Benefits include reduced yield decline and additional fodder grass production on the conservation structures. This case with SWC is compared to a 'base case' without SWC. Here, the main costs include yield reductions resulting from uncontrolled soil loss.

***Step 5: Identification of ranges in data to be used***

Crop yields in the three research areas fluctuate considerably from year to year. Mean values alone would mask this big difference. Therefore, minimum and maximum yield levels are also considered. An important characteristic of rural societies is that they are not homogenous. Various segments within the rural population face different constraints and opportunities and value therefore benefits and costs of SWC differently. Thus, to reflect these different circumstances, a sensitivity analysis is carried out. This is also done to test how sensitive the model reacts to changing input parameters.

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262 Hurni, 1986a.

263 SCRP, 1982, 33.

264 1 *timmad* is usually translated to 0.25 ha, depending on slope, stone cover, and perceived productivity. One *timmad* can be ploughed with a pair of oxen in one day. Mean (median) values for Maybar, Andit Tid, and Anjeni have been calculated at 3,420 $m^2$ (3,290 $m^2$), 2,900 $m^2$ (2,830 $m^2$), and 3,940 $m^2$ (3,530 $m^2$), respectively, and are thus considerably bigger than the commonly used 0.25 ha.

265 4 tins at 0.25 l = 1 *sahan*. 6-7 *sahan* = 1 *kunna*. 5 *kunna* = 1 *chinet*. ½ *chinet* = 1 *mezo*. 2 *mezo* = 1 donkey load or two bags at 25 kg.

***Step 6: Identifying the time period for appraisal***

An important part in a project analysis is the time period for the appraisal. Usually, the time period corresponds with the lifetime of the investment. In the case of SWC, in principle there is no limitation to the lifetime, as long as sufficient labour is dedicated to maintenance. When choosing a short time period for analysis, the slow improvement of land quality resulting from SWC does not become visible. When choosing a long time period, the benefits of SWC might be weighed accordingly, however planning horizons of small-scale subsistence farmers in the Ethiopian Highlands are usually rather short given the insecure environment in which they operate. Therefore, the present analysis considers different time periods for the calculation of costs and benefits.

***Step 7: Calculation of total costs and benefits, and the net cash flow per year***

In a first phase of the analysis, minimum and maximum yields are considered to calculate the net cash flow. In a second phase, mean yields are considered, while other input parameters are varied. The net cashflow is calculated for each year by subtracting total costs from total benefits.

***Step 8: Adjustment of the net cash flow for the time value of money***

Investments in resource conservation such as the considered SWC technologies are often characterised by an unfavourable distribution of costs and benefits over time. Main investment costs accrue in early years, whereas the benefits of SWC in the form of prevented soil loss, and prevented yield decline only become visible after some time. Future costs and benefits have to be adjusted to present values by multiplying them with the discount factor. Whether a given conservation technology is profitable or not compared to the situation without SWC depends to a great extent on the magnitude of the discount rate. Individual discount rates have been appraised (cf. Section 5.3). For the calculation of the present value of the net cashflow, different discount rates are applied which reflect different time preferences of rural households on the one hand and opportunity costs of capital on the other hand.

***Step 9: Calculation of the Net Present Value (NPV) of the considered technologies***

The NPV of a given technology is calculated by adding the present values of the net cash flow for each year of the appraisal. Whenever the NPV of a conservation technology is bigger than the NPV that is achievable without SWC (i.e. DNG > 0), the investment is economically worthwhile. Alternatively, whenever the difference between the NPV with SWC and the NPV without SWC is negative, the investment is economically not viable.

## 4.5 Review of Some Economic Analyses of Soil Conservation in the Ethiopian Highlands

Several economic analyses of soil erosion and soil conservation in Ethiopia have been carried out. The following presentation is not conclusive and will not provide a complete coverage, but gives an overview of different analyses based on varying assumptions. They generally apply the methodology of cost-benefit analyses. They differ mainly in the way the link between the soil erosion and yield is established, and in various assumptions concerning positive effects of SWC on crop yields.

### 4.5.1 Aggrey-Mensah, 1985 – Ethiopian Highlands Reclamation Study

Within the framework of the Ethiopian Highlands Reclamation Study (EHRS) already in 1985 a CBA was carried out on specific conservation technologies such as structural and vegetative measures, hillside terracing and hillside closures, zero tillage and crop intensification, irrigation development, economics of fertiliser application, and the use of a single ox-plough.[266] The authors stress that in the course of the analysis a number of problems were encountered. They especially mention the weak database and the lack of reliable information from natural scientists on the precise effects of conservation measures.

The analysis of structural and vegetative measures includes three cost influencing factors: (i) costs of the area lost to the structures, depending on slope gradient, (ii) costs for constructing the measures, and (iii) maintenance costs, which are a fixed percentage of the investment costs. The authors assumed that after 15 years maintenance would cease to be necessary, as the bunds would become part of the landscape and be totally consolidated. Two main benefits are identified: firstly, structural measures prevent further degradation costs. Secondly, in dryer areas increasing water retention capacity of the soil may enhance land productivity.

An important assumption in the CBA concerns the effect of SWC on yields. Yield declines in the case without SWC are assumed to be between 3 and 1.5%, depending on production zone.[267] With SWC it is assumed that these yield declines can be fully prevented. In particular, it is not only assumed that soil erosion can be completely prevented and that yields thus remain constant, but also that in dryer areas yields will increase by 7.5 to 15% thanks to increased water retention.

Soil bunds and grass strips are analysed for three different production zones and three different altitudinal belts within each zone over a time period of 25 and 50 years. No indication is given with regard to discount rates. Net benefits exceed net costs in the cereal / livestock zones already for a time period of 25 years. In the perennial crops / livestock zone, a time period of 50 years is necessary for net benefits to be higher than net costs. Economic rates of return are in the order of 4 to 14%. A sensitivity analysis carried out for the most important variables[268] shows in most cases positive results, i.e. net returns exceed net costs.

The positive outcome of this analysis can be explained by the following factors: Firstly, it is assumed that soil erosion can be controlled totally thanks to soil conservation and yields can at least be kept at a constant level. Secondly, it is even assumed that thanks to SWC and enhanced water retention yields increase after the structural measures are stabilised. Thirdly, without SWC it is assumed that yields decline at comparably high rates. As will be shown in Section 5.1, such positive assumptions are not very realistic. Neither can soil conservation fully control soil erosion – results show that yields continue to decline even if investments in SWC are made – nor is the yield decline without SWC as dramatic as assumed. Changing both these assumptions has a significant effect on net costs and benefits of SWC.

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266 Aggrey-Mensah, 1985.

267 Three different production regions are distinguished in the EHRS: HPC: high potential cereal / livestock zone, LPC: low potential cereal / livestock zone, and HPP: high potential perennial crops / livestock zone.

268 Price level, yield decline resulting from soil erosion, maintenance costs, labour input for initial construction, effectiveness of considered technology in controlling soil erosion, effect of water retention on yield, and area lost for crop production.

### 4.5.2 Sutcliffe, 1991 – National Conservation Strategy Secretariat

Based on the Ethiopian Highlands Reclamation Study stressing the importance of reduced soil water availability caused by declining soil depth, a study commissioned by the National Conservation Strategy Secretariat (Sutcliffe, 1991) models yield declines resulting from soil depth reductions. Sutcliffe evaluates critically different previous assumptions regarding to annual soil loss in different agro-ecological zones. He uses annual soil depth reductions of 3.5 mm and 8 mm. These soil depth declines are used to estimate the critical soil depth after which crop growth is negatively affected by reduced soil water availability.[269] Sutcliffe additionally includes the costs of reduced residue production, which he converts to tropical livestock unit equivalents. A third factor included in his study is the burning of dung and residues. Impacts of burning dung and crop residues are calculated in terms of plant nutrients (nitrogen and phosphorus) lost and the potential contribution to increase crop production.[270] Only on-site costs are considered. At a national level he estimates the yield loss for 1990 to be 0.4% (at annually 3.5 mm soil loss) or 1% (at annually 8 mm soil loss) of the Agricultural GDP of 1990.[271] Burning of dung and crop residues results in a much bigger loss of the Agricultural GDP of 5% in the case of lost grain production because of burning dung (reduced nutrient availability), and 4% in the case of lost livestock production because of burning crop residues. Taken the different losses together, the aggregate value of agricultural production lost amounts to an annual decline of the agricultural GDP of 0.46% (3.5 mm soil loss) or 0.65% (8 mm soil loss). Sutcliffe compares this hypothetical loss with the actually recorded decline of the agricultural GDP between 1983 and 1990, which amounted to 0.64% annually.

A second part of Sutcliffe's study includes the comparison of costs induced by soil erosion, decreasing plant water availability and reduced crop production resulting from the burning of dung with a number of soil conservation measures. He includes labour costs for constructing grass strips, soil bunds, Fanya Juu bunds, and bench terraces as well as for planting grass and tree legumes for forage and/or fuelwood. Additional costs arising from the loss of land for crop production due to the structures themselves as measured by the value of grain and crop residues forgone are also included. Benefits include increased production thanks to soil loss prevention. In dryer areas additional benefits result because of increased water retention. SWC structures are assumed to be efficient by 80% in reducing soil loss. The CBA uses market prices for the valuation of crops and livestock. Labour is valued at EB 1 and EB 0 per day. EB 1 is assumed for those situations where SWC structures are constructed during the slack period. To simulate the situation where Food-for-Work is offered opportunity costs for labour are assumed to be EB 0. For the calculation of net benefits Sutcliffe assumes two groups of farmers – poor and rich. He argues that poor farmers generally have a short planning horizon and high discount rates (10 years, 20%), whereas rich farmers with more secure income have a longer planning horizon and lower discount rates (25 years, 9%).

The calculation of NPV's for the different conservation technologies with different time periods and discount rates shows the following: if opportunity costs for labour are EB 1, only grass strips are profitable, both with a discount rate of 9% and 20%. Soil bunds, Fanya Juu bunds and bench terraces require too much labour for construction and occupy too much land to be economically viable. If labour costs are fully subsidised, grass strips, soil bunds and Fanya Juu bunds are profitable at a low discount rate and long time period; bench terraces are not. If additionally the benefits of increased water retention are considered, which is achieved

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269 Sutcliffe (1991, 11) mentions critical maximum (where crop yields start to be negatively affected by decreasing soil depth) and minimum (where crop cultivation is given up) soil depth for major crops: maize, wheat: max: 95 cm, min: 45 cm; sorghum, pulses: max: 80 cm, min: 35 cm; tef: max: 85 cm, min: 30 cm. The soil depth in the three research catchments of Maybar, Andit Tid, and Anjeni is generally below the critical maximum, with the exception of flat land, and in many parts already below the critical minimum. Nevertheless, crop cultivation is continued also on land with soil depths below the critical minimum with resulting low yields and increased insecurities.

270 Sutcliffe (1991, 20) also calculates the costs of replacing nutrients using the costs of artificial fertiliser. As replacement of lost nutrients with artificial fertiliser is rarely done in the Ethiopian Highlands, this calculation is not considered here.

271 Agricultural GDP in 1990: EB 4,021 million. EB 2.75=US$ 1.

after 5 years in the case of soil bunds, Fanya Juu bunds and bench terraces and after 10 years in the case of grass strips, grass strips show the highest NPV. Without subsidising labour, soil bunds and Fanya Juu bunds show a negative NPV at a short time horizon and a high discount rate, but a positive NPV at a long time horizon and a low discount rate.

Sutcliffe specifically mentions the importance of the costs of loss of land, which generally exceed the benefits of arresting soil loss (i.e. of maintaining the soil depth). Only if increased water retention leads to an increase of yields by 15%, the benefits of conservation exceed the costs. He also mentions that because in wetter areas the benefits of increased water retention are likely to be insignificant, the only way to make the considered technologies profitable is to increase the benefits resulting from fodder and fuelwood plantations on the conservation structures. Sutcliffe concludes that from the farmer's point of view (i) benefits from arresting soil loss and yield decline from decreasing soil depth take many years to increase to the point that they exceed the costs of the land lost, (ii) benefits from increased yields thanks to increased soil water availability equal or exceed yield decreases due to land lost for all technologies (except for bench terraces) in dryer areas, but not in wetter areas, and (iii) benefits from forage and fuelwood are essential in wetter areas to achieve positive benefits in the long run. He further concludes that the yields required to realise these benefits can only be achieved by high yielding carefully managed exotic forage species.

### 4.5.3 Bojö & Cassells, 1995 – The World Bank

Bojö & Cassells (1995) in their critical analysis of different estimates of economic losses induced by soil degradation[272] mention that double counting of costs in Sutcliffe's study occurs.[273] Without this double counting, the estimate of a decrease in the agricultural GDP of 0.46% to 0.65% must be reduced by 20% or more. They specifically mention that in all studies only gross soil loss has been considered, but not redeposition of soil to estimate net soil loss. Although they criticise others for their 'best guess' estimates,[274] they themselves estimate net soil loss to be only half of the gross figures used in the studies they analyse, or even less. On the assumption that productivity impacts are approximately linear, this would imply that the erosion damage estimates presented by Sutcliffe should be divided by two.[275] There is, however, no justification for this estimate and especially no discussion relating to gross and net soil loss, especially no spatial differentiation of areas loosing soil and areas gaining soil. They acknowledge that it could be that much of the detached soil is deposited on marginal areas, such as along grass strips and natural field boundaries, on grazing land or in depressions where soil depth is already sufficient to support unconstrained plant growth. Despite these observations, they argue that net soil loss from arable land should be lower than gross soil loss, and thus suggest to use net soil loss even below the rates Sutcliffe used.[276]

### 4.5.4 Kappel, 1996 – Soil Conservation Research Programme

Based on an example from a study by Ludi (1991), Kappel (1996) calculates costs and benefits for one specific conservation technology.[277] The technology analysed is a Fanya Juu bund with an embankment height of 40 cm. As the soil is only medium deep (60 cm) and the slope gradient big (45%), about 3,000 m of Fanya

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272 The following studies are included in the analysis: Ethiopian Highlands Reclamation Study (EHRS), 1986; SCRP, 1981-1991, Sutcliffe, 1991.

273 Opportunity costs of burned residues and dung in terms of lost crop production and livestock feed are added.

274 Bojö & Cassells, 1995, 39ff.

275 Bojö & Cassells, 1995, 12.

276 Bojö & Cassells, 1995, 40.

277 The analysis by Ludi (1991) includes a detailed assessment of two conservation technologies (Fanya Juu bunds and grass strips) at different slop gradients (0 to 45%), three different soil depths (40 cm, 60 cm, 80 cm), and two different embankment heights influencing the area where yield increases are possible (25 cm, 40 cm, yield increases between 3.75% and 12%). Net benefits are expressed as daily income.

Juu bunds are necessary for a one-hectare field. As per year only about 50 working days can be devoted for SWC without compromising fieldwork or without violating religious rules (e.g. holidays), it takes about 10 years to accomplish the conservation works, especially as part of the working days has to be devoted to maintaining existing structures, which is assumed to be 10% of the initial investment. A 'with' and 'without' SWC comparison is made. It is assumed that with SWC yields remain stable. Without SWC yields decrease linearly. In the example, a land loss of 25% of the arable area is considered for the case with SWC. The substantial loss of net returns because of decreased arable area can be compensated to a big part with grass, which is planted on the conservation structures. Nevertheless, in early years the yield loss, expressed in monetary terms, is much bigger than the grass yield, resulting in negative net returns for the first 10 years.

Costs in the example include labour costs for the construction and maintenance of the Fanya Juu bunds, which are valued at half the normal wage rate (i.e. EB 1.75 / day), labour costs for cutting the grass on the bunds, and costs for tools. Benefits comprise the returns from crop and grass. Crop returns are included in the CBA as the difference between the case with and without SWC.

Applying a discount rate of 10% and a time horizon for analysis of 40 years results in a negative NPV of EB -228/ha for this specific conservation technology. Negative net returns amount to about 50% of initial investment costs in terms of present value. The IRR, the discount rate at which the NPV is zero, is 7.15%.

### 4.5.5 Bekele Shiferaw & Holden, 1998, 2001

Bekele Shiferaw & Holden (1998, 2001) conduct a CBA based on data from the SCRP research stations of Andit Tid and Anjeni. Yield changes are modelled based on field plot data, using soil depth as a proxy indicator for soil quality. The estimated production functions are used to predict yields over time for each of the analysed conservation technology. The amount of land occupied by conservation structures is estimated at 10% for slopes with a gradient of 10% and 16% for slopes with a gradient of 24%. Modelling crop yields over time shows that yields with conservation are lower until a technology and slope specific threshold year, and tend to decrease at a slower rate as yields from unconserved land. A comparison of tef and barley for Anjeni shows that the threshold year is reached after 7 years in the case of tef and 23 years in the case of barley, both cases applying graded bunds. For graded Fanya Juu bunds and grass strips, the figures are 4 and 3 years for tef, and 18 and 14 years for barley, respectively. The shorter time to reach the break-even point in the case of tef compared to barley can be explained by higher erosion rates resulting in the case where tef is cultivated (75 t/ha*a compared to 53 t/ha*a, both with graded bund). In Andit Tid, the threshold year is reached under barley after 38 years for graded bund, 31 years for graded Fanya Juu, and 27 years for grass strip. Costs of conservation are mainly labour costs for construction and maintenance. Grass strips are the least expensive as per working day 100 m can be accomplished. Fanya Juu bunds are the most expensive with only 4 m bund to be accomplished per working day (WD). Soil and stone bunds lie in between with 14 m/WD and 7 m/WD, respectively. Daily wages in Andit Tid are estimated at EB 6 to 7 during the peak season, and EB 3 to 4 during the slack season. For Anjeni the respective figures are EB 5 and EB 2 to 3. For the CBA opportunity costs for labour as prevalent during the slack period are used. The time frame of analysis is variable, and crop and technology specific. It is determined by the farthest future time to which production remains profitable under alternative technologies. Different discount rates are applied varying between 0% and 50%. However, an assessment of consumption rates of discount for two groups of farmers (<2 oxen and ≥2 oxen) in Andit Tid in 1993/94 averaged in 85% and 70%.[278]

NPV's calculated using discount rates between 0% and 50%, and variable time frames show that unless future conservation benefits are discounted at very low rates (r < 5%), soil conservation in Andit Tid is not profitable. Net gains, which indicate the difference between the traditional practice without SWC and the conservation practice, are highest with a discount rate of 0% for the comparison of grass strip to traditional cultivation practice without SWC, and lowest for graded bund. This can be mainly explained with the impact

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278 Holden et al., 1998.

of erosion control resulting from the different SWC technologies and the technology-specific additional labour costs for construction and maintenance. In Anjeni, the comparison of the NPV as achievable in the case with and without SWC shows that grass strips are profitable in the case of tef cultivation even if discount rates are 50%. This can be mainly explained with the high erosion rate in the case of tef cultivation, leading to an abandonment of cultivation after 15 to 20 years. Graded bunds show a negative rate of return and Fanya Juu bunds show a rate of return of about 5%. As the soil erosion rate under barley is much lower than under tef, immediate costs of soil erosion are lower. The profitability of conservation technologies, therefore, drastically declines compared to tef.

The two authors conclude from their analysis that returns to conservation investments in Andit Tid and Anjeni are too low to convince farmers to invest scarce resources, even at very low discount rates. They conclude that the amount of land occupied by conservation structures is of great importance to this negative outcome. They therefore calculate NPV's for the same sets of data, however they assume that yields increase because of increased water retention, increased fertiliser efficiency, and the like, which is enough to compensate the land loss resulting from the physical structures. For both Andit Tid and Anjeni it shows that if yields increase enough to overcome the negative effect of area loss, grass strips become profitable even at high discount rates. Other conservation technologies, however, are only profitable at discount rates of less than 10%. Compensating area loss does therefore not seem to be sufficient to compensate the high investment costs in the case of structural measures such as soil and stone bunds or Fanya Juu bunds.

Their main conclusions are that economic gains to small-scale farmers by switching from traditional, erosive land management practices to soil conserving management practices under given production technologies are at best minimal. The reason for these rather disappointing results are seen in (i) the limited technical efficiency of the proposed SWC measures to reduce soil erosion, (ii) high initial labour costs for the construction of the SWC measures, and (iii) reduction of the effective arable area, thereby bringing negative returns to investments in the first years. Compensating the effect of area loss through increased yields does not seem to substantially improve returns to structural conservation measures. They further argue that the low returns to investments in SWC are a major reason for low adoption rates.

Although this study also has several shortcomings – continuous cropping of the same crop type is assumed to evaluate the performance of the technology, only one slope gradient per research area is used, despite the high dependency of both soil loss rates without SWC and area lost in case with SWC on slope gradient – compared to the previously discussed studies, the study by Bekele Shiferaw & Holden relies much more on effective data, either measured or derived from interviews, and less on assumptions. This leads to results that are distinctively different from the previous studies, with the exception of the one by Kappel, who also relies on actually measured and assessed data.

### 4.5.6 Berhanu Gebremedhin, 1998

The last study to be presented concerns an economic analysis of soil conservation in Tigray.[279] Based on field plots, yield differences between 'with SWC' and 'without SWC' are calculated. On terraced land two plots of 8 m$^2$ each were marked, one just above the terrace ('accumulation zone'), and one just below the next upper terrace ('loss zone'). Plots on unconserved land are designated as control plots. The experiment was carried out as an on-farm experiment, with farmers deciding on management practices and farm activities. Land lost to conservation structures is estimated to be 5% in the minimum and 15% in the maximum. Wheat yields are significantly higher (at the 5% level) in the accumulation zone than in the loss zone. Mean yields from the accumulation zone are up to twice the mean yields from control plots even when adjusted for 15% land loss. Wheat yields from the accumulation zone also show much smaller coefficients of variation than yields from the loss zone or from control plots, indicating more stable yields. Bean yields show similar tendencies like wheat, however the difference between yields from the accumulation zone and the loss zone

279 Berhanu Gebremedhin, 1998 & 1999.

is less pronounced. The difference between yields from the accumulation zone and from control plots is not significant at the 5% level if yields are adjusted for a land loss of 15%.

A profitability analysis is carried out based on the above yield data of investments in stone terraces. The average length of stone terraces in the study area is 700 m/ha. Based on regional campaign work for SWC assigning a target of 7 to 8 m stone terraces constructed per working day, this would result in 100 days labour input for the initial construction. Additionally, 5 working days per year have to be devoted for maintaining the terraces.

Mean wheat yields from the accumulation zone are roughly doubled and bean yields increased by about 50% compared to the control plot. Thus, in the CBA these higher crop yields need additional days for harvesting and threshing. Daily wages range between EB 6 and 8, depending on the season. Additional costs accrue in the case of SWC for shovels, axes, and spades. In the CBA it is assumed that 5% of the arable land is occupied by conservation structures, and yields are adjusted accordingly. Yield differences between the case with SWC and the case without SWC are assumed to be the yield difference between the yield measured from the accumulation zone and the yield measured from the control plots. It is further assumed that in the first three years yields from the conserved fields do not yet increase and that from the fourth year yield differences remain constant. For the calculation of the NPV two discount rates are used: one of 15% and one of 50%. The discount rate of 15% would correspond to the interest rate paid in the area for agricultural inputs. 50% corresponds to the estimated individual time preference. With a discount rate of 15%, the NPV of investments in stone terraces for a wheat – wheat – bean rotation over a time period of 30 years is EB 3,907. Discounted benefits exceed discounted costs in the fifth year. With a discount rate of 50%, corresponding to the individual time preference, the NPV would drop to EB 12. Incremental benefits exceed incremental costs in this case in the fourteenth year.

The main problem of the analysis by Berhanu Gebremedhin is his assumption of yield differences on the one hand and no consideration of effects of soil erosion on yields over time on the other hand. The latter problem is not solved, despite his mentioning that

*"[...] soil erosion is the most serious environmental problem in Ethiopia and cultivation land is the major contributor to soil loss"*[280]

and the observation that soil erosion reduces crop yields significantly.[281] The problem concerning the first aspect is that although he clearly demonstrates that yields from the accumulation zone are significantly higher than yields from the loss zone within a conserved field,[282] in the CBA he uses only yields from the accumulation zone to represent the case with SWC, and the yield from the control plot for the case without SWC. However, the accumulation zone represents only a small area between two conservation structures. If one assumed that half of the area between two conservation structures showed characteristics of the accumulation zone and the other half showed characteristics of the loss zone, then the wheat yield would decrease to 1,170 kg and the yield difference to be used in the CBA would only be 500 kg instead of 870 kg. Similarly, for beans the yield difference would drop from 250 kg to 100 kg. With these still positive assumptions concerning the yield between two conservation structures and same costs, the NPV with a discount rate of 15% would drop to EB 1,370 – one third of the NPV based on the higher yield estimate. The NPV with a discount rate of 50% would be negative with EB -470. Concerning the second problematic assumption – constant yields over a time period of 30 years without considering the negative effect of soil erosion – one could assume that yields decrease annually by 0.5% in the case without SWC and 0.25% in the case with SWC. This taken into account would result in an NPV of EB 1,440 with a discount rate of 15%, and an NPV of EB –460 with a discount rate of 50%. In this latter case the IRR would be 31%, which is still considerably high.

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280 Berhanu Gebremedhin, 1998, 77.

281 Berhanu Gebremedhin, 1999, 568.

282 Wheat, grain yield: accumulation zone: 1,530 kg/ha, loss zone: 810 kg/ha, control plot: 665 kg/ha. Bean, grain yield: accumulation zone: 760 kg/ha, loss zone: 520 kg/ha, control plot: 535 kg/ha.

### 4.5.7 Conclusion

From the above discussion, it becomes evident how important the underlying assumptions are in a CBA. The most critical of them concern the following variables:

- Decreases of yields due to soil erosion over time
- The efficiency of conservation technologies with regard to soil loss reduction
- The magnitude of possible positive effects of soil conservation on yields
- Costs for SWC, which are composed of (i) land lost for crop production because it is occupied by conservation structures and (ii) investment costs in the form of labour input and costs for tools
- Whether or not the conservation structures themselves can be used in a productive manner (e.g. for growing fodder grass or trees)
- The time horizon of the analysis
- The magnitude of the discount rate

The positive result of the CBA in the study by Aggrey-Mensah (1985) can be explained by the very high yield decrease resulting from soil erosion, and the also very high positive effect of soil conservation trough water retention on yields. The assumption that a total reduction of soil loss in the case with SWC is possible also contributes to this positive result. Only with such optimistic assumptions net benefits exceed net costs despite the high investment costs necessary for the establishment of most considered conservation structures considered. Sutcliffe (1991) takes into account not only soil loss, but also nutrient breaches. He assumes soil loss rates to be about half the values used in Aggrey-Mensah's study. With these reduced soil loss rates, yield declines in the case without SWC are much smaller than Aggrey-Mensah assumed. This leads to results whereby only grass strips with limited labour costs for their establishment show a positive NPV. Sutcliffe concludes that the amount of arable land lost and the high labour input for the construction of soil and stone bunds and Fanya Juu bunds are only justifiable in dryer areas, where water conservation plays an important role and yields can be increased substantially. In wetter areas, SWC is only profitable if bunds themselves can be used in a productive manner as a cultivation area for fodder grass or trees. Kappel's study (1996) considers an example that is based on data collected within the framework of the SCRP. He analyses a concrete technology under site-specific circumstances. The analysed technology results in a negative NPV mainly because of high investment costs, which are dependent on physical factors (slope gradient, soil depth). Similarly, Bekele Shiferaw & Holden (1998) rely on quantitative data collected by the SCRP and data collected through interviews from the concerned land users. In addition, their analysis results in mainly negative NPV's of the considered technologies. Only if discount rates are below 5%, grass strips become profitable. All other technologies (graded and level soil bund, graded Fanya Juu bund) need too much labour for the construction and maintenance and the amount of arable land occupied by the conservation structures is too big. They further conclude that the technical efficiency of the considered technologies is not good enough (e.g. soil loss cannot be reduced sufficiently). Berhanu Gebremedhin (1998) in principle also bases his analysis on measured quantitative data. However, his assumptions regarding yields in the case with and the case without SWC are not realistic. If corrections are made, i.e. the additional yield that can be achieved on a field with SWC is corrected downwards, it shows that the NPV at a low discount rate is reduced to about one third of his estimates. If using a discount rate similar to the farmers' time preference, the considered technology shows a negative NPV. His results with more realistic assumptions would then be similar to the ones of Kappel and Bekele Shiferaw & Holden.

Especially the authors of the early studies mentioned that the database for assessing yield impacts induced by soil erosion is extremely weak, that not enough data concerning the costs for the establishment of different conservation technologies is available, and that site-specific ecological and economic data is lacking. They therefore had to mainly rely on assumptions. This is one reason why their evaluation of benefits of SWC is very optimistic. Another reason for these optimistic results could be that at that time, there was still the perception that mechanical SWC could contribute in a much more economically efficient way to prevent further land degradation. These analyses were thus also used to support further investments in large conservation schemes, as it was shown – rightly or not – that in the medium to long term, the effect of SWC is also profitable from a farmer's point of view.[283] Only later, when it became evident that farmers did not adopt soil conservation technologies as expected, more detailed economic analyses were carried out in an effort to find out why adoption rates were so low. There was a strong argument that unless profitability is given from a household's point of view, small-scale subsistence farmers would act irrational if investing scarce resources in SWC, even if ecological effects were positive. It became clear in later analyses that the considered mechanical technologies did in most situations not contribute enough to make the high investments economically viable. This was taken as the starting point to discuss possible changes of the technologies themselves to (i) reduce the direct and indirect costs and (ii) to increase the benefits. Secondly, the economic and institutional environment in which farmers operate was more critically evaluated as it was realised that this might have an influence on (i) either the performance of SWC technology directly or (ii) the investment behaviour of the land users.

283 This is especially the case when there is a danger that land degrades totally, becomes badlands and has to be given up for crop production. In a situation where enough land reserves are available this is not very dramatic as long as it concerns only small areas. In densely populated regions, however, which make up the majority of the Ethiopian Highlands, the loss of arable land can have very dramatic consequences. If assuming a very long time horizon of several decades if not centuries, depending on the rate of soil loss, SWC will become profitable just because the land is protected from becoming badlands, but can be further used to produce crops. Such a long time horizon, however, cannot be expected from small-scale farming households under given circumstances in the Ethiopian Highlands. Secondly, to model soil erosion and soil conservation based on a CBA for such a long period of time under given volatile conditions and possible far-reaching changes in the economic, social, technological and even ecological environment would be very difficult.

# Part III

# Analysis

# 5 Analysis of Input Parameters and Variables for the Cost-Benefit Analysis of Soil Conservation

## 5.1 The Relationship between Soil Erosion, Soil Productivity, and Soil Conservation

*"The erosion-productivity linkage is exceptionally complex."*
*(Stocking, 1996, 149)*

The relation between soil erosion and soil productivity[284] is complex and involves numerous and various factors, which furthermore often depend on each other. As a general hypothesis, it can be assumed that soil erosion alters soil properties and thus has an effect on actual and potential productivity. Soil erosion generally decreases the soil depth. It can have a negative influence on the nutrient content of the soil and thus on soil fertility, it can decrease the organic matter content in the soil, and it can have an influence on physical soil properties (structure and texture) and plant-available water capacity.[285] Erosion can also have a direct effect on production through the formation of rills and subsequent washing out of seeds, or through accumulation of eroded material on germinated crop.

Impacts of soil erosion on crop productivity have been a major research objective especially in the USA.[286] For developing countries, however, little empirical and systematic evidence is available, and long-term monitoring on erosion and its effect on crop productivity is scarce.[287]

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284 Soil productivity is the inherent potential of a land system, expressed by factors such as soil quality and health, or physical, chemical and biological properties as a potential for biomass production. Production, in contrast, is the actual yield achieved by farmers under a given input system. Production can be maintained by technological inputs – at least to a certain degree – even while the soil degrades, but only at economic costs and with much uncertainty and risk. (Hurni, et al., 1996, 11; Stocking & Murnaghan, 2000, 11) Soil quality is a broader concept including *"the capacity of a soil to promote growth of plant, protect watersheds by regulating the infiltration and partitioning of precipitation, and prevent water and air pollution by buffering potential pollutants such as agricultural chemicals, organic wastes and industrial chemicals."* (National Research Council, 1993, quoted in Hughes Popp, 1997, 45) Such definitions make measurement problematic, because the interest lies in heterogeneous functions of soil quality and aggregate measures of the capacity of the soil to contribute to these outcomes. Therefore, usually soil quality or soil productivity is defined through *"the actual yield of usable vegetation [...] controlling for input use."* (Kim et al., 2000, 239)

285 Ponzi, 1993, 36; Enters, 1998b, 8. Clark (1996, 13) lists ten factors of soil erosion which alter soil properties and thus have a negative effect on crop yields: (i) reduction in soil nutrient content, (ii) reduction in soil moisture holding capacity, (iii) reduction in available soil water due to increased runoff, (iv) reduced rooting depth, (v) reduction in soil water transmission, (vi) reduction in soil fauna populations, (vii) reduction in seed germination due to degradation of the soil's physical structure, (viii) increase in the washing away of seeds and fertiliser, (ix) reduction in the timeliness of farming operations, and (x) increase in the risk of soil acidification and toxicity. Soil erosion, however, can also lead to the opposite effects in accumulation areas, whereby soil and nutrients are deposited and can increase rooting depth or nutrient contents. However, areas suffering from erosion are much more widespread and also more important for crop cultivation than areas profiting from soil accumulation. For example, in the three considered SCRP research catchments in the Amhara Region, Ethiopia, areas with slopes below 5% account for only 1.3% of the overall catchment area in Maybar, 1.7% in Andit Tid, and 3.5% in Anjeni (cf. Table 31).

286 e.g. Olson et al., 1994, 586; Weesies et al., 1994; Larney et al., 1995.

287 Enters, 1998b, 10. de Graaff quotes Stocking who even mentions that 85% of all studies on the impact of soil erosion on crop productivity have been conducted in the United States.

### 5.1.1 Impacts of soil erosion on soil productivity – a review of some modelling approaches

Different approaches have been taken to model the relation between soil erosion and soil productivity. Two broad categories are distinguished: Micro- and macro-studies.[288] Micro-studies include all experimental methods at plot level where yields on eroded and uneroded plots are compared or relations linking topsoil depth with crop yield are developed. Macro-studies, on the other hand, attempt to assess the erosion – productivity linkage at regional or national level, usually based on statistical methods or simulation models. Grohs (1994), Lutz et al. (1994), and Ananda (1998) quote several micro-studies conducted in the USA and a few conducted in developing countries (India, Nigeria, Zimbabwe, Sierra Leone, Kenya, Sri Lanka, and several countries in Central America and the Caribbean). Macro-studies at a national level have been conducted for Zimbabwe, Mali, Malawi and Leshoto.[289] Macro-studies are usually based on trend analyses of yields for different regions and soil losses estimated with the Universal Soil Loss Equation USLE (and its updated versions such as RUSLE). These macro-studies have the big disadvantage that the requirements regarding data quality are high and the impact of soil erosion on yield decline is difficult to separate from other impact factors, such as management changes (e.g. changes in weeding frequencies or tillage practices), technology changes (e.g. changes in fertiliser application), or changes in crop varieties.[290]

General conclusions valid both for macro- and micro-studies are that (i) the impact of erosion in a given geographical area on productivity is highly complex, being both soil- and plant-specific, and (ii) physical soil loss is only a rough proxy indicator for soil-fertility decline,[291] showing that even high erosion rates may affect crop yield only marginally on deep soils with favourable subsoil characteristics (e.g. Nitosol),[292] but can have serious consequences on fragile tropical soils,[293] and may even have a positive effect on yields (e.g. erosion leading to greater exposure of favourable clays with high nutrient contents).[294]

Olson et al. (1994) present an overview of different methods to determine erosion – productivity relations:

(i) ***Topsoil removal***: Studies relying on artificial topsoil removal have been used to create various topsoil depth in a randomised statistical design. Different studies have used this approach also in the tropics; one of them is a study by Belay Tegene conducted in southern Ethiopia.[295] In such experiments, soil layers are artificially removed to reduce topsoil depth to various levels. The remaining soil depth should simulate different erosion phases. As Olson et al. (1994, 586) point out, it is problematic that results from such experiments are merely of relative quality. They argue that natural soil erosion is a selective process involving preferential removal of organic matter, clay, and other fine soil fractions, while coarser material is left behind. Pagiola (1993, 118) reports of research undertaken in Kenya, where enrichment ratios (the ratio of nutrients in eroded soil to nutrients in parent soil) range from 1.05 to 3. This would lead to an underestimation of the severity of the productivity decline. On the other hand, with the total removal of topsoil layers, all organic matter, which is essential for crop growth and which, during a natural process of erosion and crop cultivation, would be continuously formed, is removed. Thus, the effects of soil erosion on productivity might be overestimated. The

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288 Crosson, 1983, quoted in Grohs, 1994, 9.

289 Grohs, 1994; Bishop, 1995.

290 Barbier & Bishop, 1995, 134.

291 Bishop, 1995.

292 Pagiola, 1994, quoted in Enters, 1998b, 9.

293 Grohs, 1994, 9, quoting two studies (Lal in Nigeria and Stocking in Zimbabwe) conducted on newly opened land on fragile soils, where yield losses were in the range of 3-4% per year for an annual soil loss of 10 t/ha, and 75% yield reduction per 1 cm topsoil decrease, respectively.

294 Stocking, 1996; Scherr, 1999.

295 Belay Tegene, 1992.

artificial one-time removal of soil layers cannot simulate such selective natural processes and therefore offers only a rough approximation of the complex and selective erosion process.

(ii) ***Paired comparisons***: Different locations are selected according to their past erosion phases. This requires detailed knowledge of the erosion history on the sites, which is not always easy to acquire. The main difficulty in such experiments is that although different sites may be found and past erosion history reconstructed, results may be compounded by other factors such as differences in soil properties due to different management practices or different landscape components (e.g. slope inclination, exposition, etc.). The above-mentioned study by Belay Tegene (1992) also selected field samples representing past history of erosion. This was to help in validating the results from the desurfacing experiments, as plots were selected with a soil depth comparable to that of the experimental plots where topsoil was removed artificially. One method within this broad category of paired comparisons is to relate topsoil depth to crop yields as an indirect assessment of the erosion-productivity relation, whereby it is assumed that shallow soils have suffered from stronger and/or longer erosion than deep soils. Hurni (1985) conducted such a study in Ethiopia, relating topsoil depth to barley yields.

(iii) ***Geostatistic analyses***: This method is based on multivariate factor analysis. Different variables are analysed and their relation to yield established within a given area. This procedure allows the analysis of spatial variabilities in soil and crop parameters. However, especially in developing countries, data for such analyses is usually not available in the necessary quality.

(iv) ***Simulation modelling***: Different models exist. Enters (1998, 11f) lists the following in an overview: the PI (Productivity Index) and CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems) models, which assume that erosion alters crucial soil parameters with subsequent productivity effects, CERES (Crop Estimation Through Resource and Environment Synthesis), a model simulating the impact of reduced rooting depth on yields, or EPIC (Erosion Productivity Impact Calculator), a model composed of physically based components for simulating erosion, plant growth and related processes, and economic components for assessing the costs of erosion and determining optimal strategies.[296] The main problem with the above-mentioned models is that they are all data consuming[297] and that the outputs of simulation models heavily depend on the quality of the input data. Furthermore, most models have been developed and calibrated in temperate climates and are therefore difficult to apply under tropical conditions without major modifications.[298]

After evaluating different models (see above), Olson et al. (1994) propose the following approach to determining the effects of erosion on soil properties and crop yield: (i) the location of at least 3 plots on slightly, moderately, and severely eroded phases of a soil series in a cultivated field, and (ii) the comparison of crop yields under uniform management for each of the plots.

Since many researchers in African countries suffer from a lack of data for sophisticated simulation models, usually the *productivity change* approach is applied. This method estimates the value of lost production associated with soil erosion. The main problem with this approach is to separate the effect of soil erosion on yields from other factors affecting crop yields. Such factors can be the variety of crop, management practices, climatic factors, pests and diseases, and soil fertility. Soil fertility again depends on various biological, physical and chemical properties of the soil, and it is not always clear, which of these factors are affected to what extent by soil erosion.[299] A number of studies have set crop yields in relation to topsoil depth or cumulative soil loss, since the above-mentioned complex soil – yield interactions are neither fully understood,

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296 Williams et al., 1990, 462.

297 EPIC for example requires input data for the following model components: daily weather data, soil data per analytical soil horizon (depth, sand, silt, and organic N content, organic carbon, CEC, bulk density and saturated conductivity), management information (tillage practice, dates of operation, kind and amount of fertiliser applied), and crop parameters (growing period, crop height, seeding rate, seed costs, price of output, harvest index). (Francisco, 1998, 72f; Sanders et al., 1995, 57)

298 Pagiola, 1993, 113; Ten[g]berg et al., 1998a, 56.

299 Gunatilake & Vieth, 2000, 197.

nor is all necessary data available. Such models are usually linear regressions,[300] or are based on exponential[301] or logarithmic functions.[302] However, such approaches underestimate the impact of nutrient depletion through leaching, volatilisation, or nutrient mining.[303]

Linear regressions, where crop yield is the dependent factor and different physical and/or management factors are taken as independent factors, are the most common, because all required data is usually available. Hurni (1985) estimated a linear relation between reworkable soil depth and barley yield for his study in Andit Tid, based on data from one year. He observed that on the specific soil (humic Andosol with little variations in properties through the A horizon and favourable water holding capacity, bulk density, and soil pH for root development), barley yield correlates well with soil depth (r=0.66). He estimated that a reduction of topsoil depth of 10 cm might result in a reduction of barley yields by almost 320 kg/ha.[304] Considering observed soil erosion rates for the area, he concluded that this reduction would occur after about 12 years of continuous cultivation, and on newly opened land with good soil profiles it would take as long as 4 generations to reach a critical soil depth. However, he mentions that crop yield may not only differ due to soil characteristics and depth, but may be even more dependent on management factors. A study carried out in Harerge[305] (south eastern Ethiopian Highlands) supports these findings by showing a weak positive, but not significant correlation of sorghum/maize/haricot bean inter-cropping yields with soil depth and a weak negative, but not significant correlation with slope gradient. Soil fertility (derived from a soil map and classified into four classes from low to high) and plant available water capacity in the top 50 cm were also not significant in determining the yield of sorghum/maize/haricot beans. The only factor with a significant influence seemed to be phosphorus content. The conclusion drawn from these calculations is that in addition to the considered natural factors, other factors such as the availability of production inputs (especially oxen for ploughing) and land management aspects are important in determining crop yields.

An econometric modelling using a Cobb-Douglas[306] function estimated a yield function, assuming that soil quality is related to topsoil depth and thus has an influence on crop yields. Based on data from Andit Tid, a reduction of the soil depth by one percent resulted in a reduction of barley, horse bean and linseed yields of about -0.5%, -1.5%, and -0.5%, respectively.[307]

Belay Tegene (1992) found a strong correlation of grain yield (maize and haricot bean, actual yields are converted to a percentage of maximum attainable yields for each crop under the management conditions specified for the experiment) and topsoil depth (r=0.96) on eutric Nitosols[308] in Gununo (Southern Ethiopian Highlands) on experimental plots where topsoil was removed artificially to simulate the situation where erosion has reduced the soil depth to various levels. The topsoil of the plots designed for the desurfacing experiment was removed artificially to varying depths. Four different levels of topsoil were removed (0 cm to simulate the slightly eroded phase, 20 cm and 40 cm to simulate the moderately eroded phase, and 60 cm to simulate the severely eroded phase) to simulate erosion phases as observed in the research catchment.[309] He

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300 e.g. Hurni, 1985, 660; Gachene, quoted in Lal et al., 1998, 25.

301 e.g. Belay Tegene, 1992, 89; Lal, quoted in Bishop, 1995, 40.

302 e.g. Ten[g]berg et al., 1998a, 60.

303 Enters, 1998b, 5.

304 Hurni, 1985, 660, calculated according to the linear regression presented in the Figure. Maximum yields measured are slightly above 5 t/ha, mean yields slightly below 2 t/ha.

305 Schläfli, 1985, 14ff.

306 A Cobb-Douglas function is a simple production function in the form of $Q = L^a * K^b$, with Q being an output, which is a function of labour (L) and capital (K) inputs. The parameters are estimated from empirical data. If a+b=1, constant returns to scale result; if a+b>1, the production function will show increasing returns to scale. The Cobb-Douglas function thus permits non-linear relationships between inputs and outputs.

307 Bayou Demeke & van Ierland, 1998.

308 Untruncated Nitosols can have topsoil horizons (Ah and AB) with a depth of 80 cm, which are nutrient rich and physically very favourable, and subsoil (Bt) horizons which are at least suitable in terms of chemistry and physical conditions. (Belay Tegene, 1992, 123)

309 Belay Tegene, 1992, 14.

calculated yields on shallow soils (20 cm) to be only 33% of the potential maximum yield, which is reached on soils with a depth of 65 cm and more.

Other similar studies have been carried out by Ten[g]berg et al. (1997) in Brazil. Their set-up is based on experimental plots that are cleared of vegetation and allowed to erode naturally, as opposed to artificial topsoil removal (such as in the experiment by Belay Tegene). Different levels of erosion are achieved by covering the plots with artificial mesh, simulating varying degrees of vegetation cover. The plots are left fallow for some years (between 3 and 7) and later cultivated for one or two years. Ten[g]berg et al. found a strong correlation (either linear or logarithmic) for the soil loss – time relation ($R^2$ between 0.79 and 0.99) and also strong relations (logarithmic) for the soil loss – yield relation ($R^2$=0.8). Similar studies as the one undertaken by Ten[g]berg et al. are conducted within an erosion – productivity network and include the study by Belay Tegene (quoted above) and studies in Thailand and Kenya. The set-up is to compare plots that erode naturally (control plots), plots that are artificially desurfaced, and plots where soil erosion is controlled. After an initial phase of erosion, plots are planted with a standard crop, and differences in productivity are assessed in relation to the amount of prior erosion. Different variables are monitored throughout the experiment: runoff and soil loss, physical and chemical characteristics of the remaining soil, chemistry of eroded sediment and enrichment ratio, chemistry of runoff water, biological activity of the soil, climatic variables (rainfall and temperature), plant and crop management, and indicators of growth stress.[310]

***Discussion***

Usually, research on the erosion-productivity relation was conducted on research stations over a limited period of time. The clear advantage of on-station research is that different factors (i) can be studied in detail, and (ii) can be kept constant (e.g. soil type, slope inclination, exposition, management, etc.), and that (iii) generally it allows continuous monitoring and thus the assessment also of irregularities such as damages to crops. Such controlled experiments are necessary to study certain variables and their impact on the erosion process or to compare different factors and their role on productivity.[311] The weakness of these on-station experimental plots certainly is that they represent farm conditions only to a very limited degree, especially land users' management practices. Secondly, most studies relied on data from a few years of research only, e.g. Ten[g]berg et al. (1998) calculate their relation on the basis of one or two cropping seasons, and Belay Tegene (1992) used data from 3 years of research. Thirdly, results from on-station erosion plots can give a false accuracy due to boundaries introduced, to limited observations, and to dissection of the erosion process and its effects on productivity into single variables, whereas the reality would be dominated by interactions.[312]

In experiments carried out in the erosion-productivity network, the approach has been adjusted insofar as the topsoil is no longer removed artificially. Instead, the experimental plots are left fallow for some years before cropping and monitoring of yield is taken up. This allows a better approximation of the natural erosion process. However, as the plots are kept bare and covered with meshes, which are supposed to simulate different degrees of ground cover. Consequently, there is no input of organic matter, which, under natural vegetation, would constantly be added to the soil. Thus, organic matter content is deliberately kept low, which has a significant influence on the erosion rates as well as the soil fertility. Another problematic aspect of covering the plots with artificial mesh is that meshes produce a constant cover over the whole year, whereas natural vegetation differs considerably in its cover over the vegetation period. After sowing, generally at a time of high and erosive rainfall, fields are usually completely bare and crop cover develops – if undisturbed – continuously over the year. Thus, meshes probably protect the bare soil too well at the beginning of the agricultural year and might therefore lead to underestimation of the annual soil loss.[313]

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310 Ten[g]berg et al., 1997, 96f.

311 Turkelboom, 1999, 5.

312 Turkelboom, 1999, 6.

313 A study carried out on the temporal and spatial variability of soil erosion in Andit Tid and Anjeni shows that the period of highest soil loss in Anjeni is between June and August, with crops being sown in early June (*Belg* Barley) and end of June / July (tef, horse beans). In Andit Tid, the period of highest soil loss is from July through August.

A problem related with regressions linking soil erosion to soil productivity is which function to choose – linear, exponential or logarithmic. All have their advantages and disadvantages. Linear relations are usually chosen for reasons of simplicity. Exponential functions might represent the relation more accurately on fragile tropical soils, where a very big initial productivity decline could be shown.[314] Logarithmic functions could be justified on the ground that on less fragile soils, productivity declines resulting from soil erosion might be small as long as soils are still relatively deep, and only increase when the soil depth reaches a critical threshold level, while they finally lead to a drop of yields to zero once soil depth has reached a critical minimal level.

The problem of linking soil productivity to soil depth is that implicitly physical soil loss is assumed to be the major factor in declining productivity. This might be the case on steep slopes and/or shallow soils, but on gently sloping land, nutrients lost through soil erosion may represent only a fraction of the nutrients extracted by crops or lost through leaching.[315] Another problem of methods linking yields with soil depth is the assumption, that once soil conservation has been established, soil depth will no longer diminish and therefore yields will stabilise. This, however, is not necessarily the case. Yields can diminish after the establishment of conservation measures due to soil disturbances or negative effects directly linked with terraces, such as water logging in the area behind the structures or the spreading of pests and weeds.[316] On the other hand, it is also possible that after some time, yields increase in the area immediately behind the conservation structures as soil conditions become more favourable, e.g. as soil depth and water storage capacity or nutrient availability increase due to the accumulation of soil from upper parts of the field behind the structure (cf. Figure 32).

Productivity change methods linking crop yield with soil depth or cumulative soil erosion assume that soil conservation would reduce soil erosion to zero. Analyses of data from the SCRP however show that even on conserved land, there is still a negative trend of crop yields as soil erosion continues, albeit to a much smaller degree than on unconserved land. It must also be noted that it would be uneconomical to reduce soil erosion to zero, as marginal costs of conservation would be far greater than marginal benefits from preventing further erosion and damages to the crop yield (cf. Figure 28). The fact that yields decrease despite soil conservation also emphasises the comment by de Graaff that nutrients lost through extraction by crops (e.g. nutrient mining) might be much more important than nutrients lost through erosion – at least in a system where hardly any inputs are made to maintain soil fertility.

***Hypothetical yield development over time***

Considering the complex interactions between soil productivity and soil erosion, between soil productivity and crop yields, and between technological changes[317] and crop yields, yield curves are most probably not static over time, as the regression equations would suggest. The following sketch (Figure 29) presents a hypothetical yield curve. It can be assumed – and has been shown by research carried out on fragile tropical soils in Africa[318] – that in the first years after land is newly opened and cropped, yield declines can be considerable (section A).[319] In a latter stage, yield declines could be more of a linear form (section B). Once soil depth, water retention capacity, and nutrient stocks have reached a critical level, it could be that yields decline more rapidly again and drop to zero or farmers stop cultivating the land as returns are no longer sufficient to compensate investments (e.g. labour, seed, animal traction) (section C). If such a course were assumed over the lifetime of a soil, the main question would then be where to locate the current situation. As it is usually not known how long or how intensively soils have been used in the past, it is impossible to precisely reconstruct

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For both areas, the highest susceptibility to soil erosion is the time between sowing and about two months after germination. (Hänggi, 1997, 82)

314 e.g. Lal in Nigeria on newly opened land, quoted in de Graaff, 1996, 101.

315 de Graaff, 1996, 101.

316 Herweg & Ludi, 1999, 109.

317 Irrespective of whether technological changes are a reaction of farmers to negative effects of soil erosion or exogenous, i.e. independent of erosion effects.

318 e.g. Lal in Nigeria, quoted in de Graaff, 1996, 101; Ponzi, 1993, 39; Francisco, 1998, 38.

319 This first section would also correspond to the yield curve Belay Tegene (1992) has found on Nitosol in Southern Ethiopia.

the erosion history. Thus, the location of the current situation on the curve and the type of yield curve to be applied can only be guessed at.

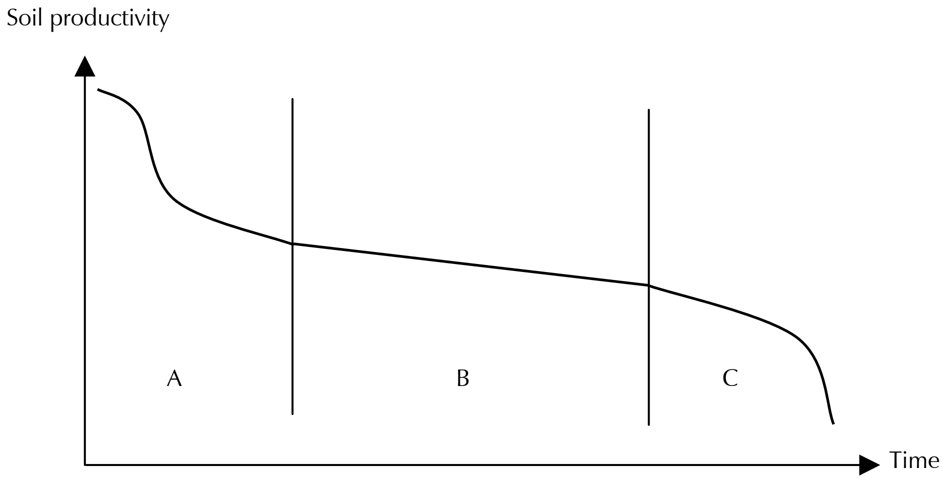


*Figure 29: Hypothetical yield curve over the total lifetime of a soil, where no investments (e.g. soil conservation) or technological changes (e.g. application of fertiliser, adjustment of farming system) are made. Section A would refer to an exponential yield decline immediately after the land is newly opened, section B would refer to linear yield declines resulting from soil degradation, and section C indicates dramatic yield declines once a certain threshold of soil depth / soil quality is reached.*
*[Source: Own compilation]*

Since the farming and erosion history of the three research sites considered in this study is not known, and therefore their exact location on the sketched yield curve cannot be defined, linear regressions will be used for further analyses. A reason for not using exponential functions is that the soils in the three research sites are not extremely fragile tropical soils but can – in their natural state – be considered as nutrient rich, deep soils formed on volcanic basement. These soils (mainly Andosols in Andit Tid, Phaeozem-Lithosol and Phaeozem in Maybar, and Alisols, Nitosols, and Cambisols in Anjeni) have developed from volcanic ashes and reworked material from Tertiary and Quaternary volcanic eruptions. They usually show favourable growing conditions (soil structure, nutrient content, CEC, soil pH) and little variations in properties throughout the A horizon.[320] Also throughout the B horizon they usually show high levels of nutrients and can still be considered rather favourable for crop cultivation. Thus, most nutrients and organic material are well distributed over the soil profile and not concentrated in the few top centimetres as in tropical soils.[321] Exponential functions are therefore not very plausible, as the first centimetres of soil loss do not have the devastating effect on crop yields suggested by an exponential curve. As yields decrease over time, farmers try to adjust their farming system as much as possible to prolong the productive 'life' of the soil. This is done through crop rotation, fallowing, sediment harvesting, manuring, physical soil conservation, or other changes in the management system. However, if inputs are limited, soil erosion is not totally controlled, and nutrient uptake by plants remains greater than nutrient input, yields show a negative trend. Although a linear function relating crop yields to soil depth will be applied in the present analysis, the reader must bear in mind that the turning point from small linear decreases to drastic yield declines towards zero will be reached at some time in the future – on shallow soils most probably in the near future.

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320 Hurni, 1985, 660; Sutcliffe, 1991, 10; Gete Zeleke, 2000, 21f.

321 Ponzi, 1993, 37.

### 5.1.2 The relation between soil depth and soil productivity – the situation in Maybar, Andit Tid, and Anjeni

In Section 5.1.1, different approaches to modelling the relation between soil erosion and soil productivity have been presented. For the cases of Maybar, Andit Tid, and Anjeni, the following approach has been chosen: current soil depth is taken as an indicator of past erosion. It is hypothesised that soil depth is a proxy indicator for soil productivity, although other factors such as available water capacity, bulk density, organic matter content, and pH would also be important indicators.[322] It is assumed that soil depth represents rooting depth, plant available water storage capacity, and to a certain degree storage capacity of nutrients, factors which have an influence on plant growth and production. It is further hypothesised that past erosion has not only decreased soil depth, but has also led to an alteration of soil texture, mainly the proportion of clay, silt, sand and stone contents, and composition and amount of plant-available nutrients. In other words, it is assumed that the effects of erosion on the productive capacity of the soil depend on the depth and quality of the remaining soil and not on the soil lost.[323] The selection of soil depth as proxy indicator should also capture an other effect, which is not reflected when considering only absolute soil loss values from erosion plots: soil is not only detached and transported, but also redeposited. Especially diffuse accumulations on adjacent fields can be a positive contribution to soil depth and nutrient content. There are numerous examples where soil loss from up-slope areas is used as a free input in adjacent lower lying fields.[324] However, it must be kept in mind that relying on soil depth as an indicator of soil productivity underestimates the impacts of nutrient depletion. Nutrients are not only lost through erosion processes but, in the context of the three research sites probably more important, through nutrient mining. Crops are grown almost every year without inputs, be it organic or inorganic fertiliser, and biomass is almost totally removed.

A further reason for this approach is that once soil is lost due to soil erosion, it is not – or only under prohibitively high costs – possible to bring it back within a reasonable time span. Although nutrients play an important role in determining crop production, if nutrients are excessively withdrawn, the nutrient stock can be at least partially restored through fertilising. Fertiliser, however, has only an effect on yield if there is enough soil left. The slope gradient was included as a variable in the regression analysis, because slope inclination has an influence on runoff and erosion processes. Furthermore, the land use system (e.g. choice of crops and land management practices) depends in part on slope gradients, and land use history differs considerably on different slope classes. Gentle slopes have generally been cultivated for much longer than steep slopes. Thus, steep slopes, despite their shallower soils, often produce higher crop yields, which can only be explained by the fact that they are less exhausted and less susceptible to waterlogging. And lastly, soil conservation measures such as earth and stone bunds aim at changing two main factors influencing the erosion process: slope gradient and slope length. Slope inclination, in combination with the reworkable topsoil depth, determines directly the number of conservation structures and thus the amount of productive land occupied.

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322 Sutcliffe, 1991, 10ff; Hughes Popp, 1997, 48.

323 Sherr & Yadav, 1996, quoted in Enters, 1998b, 10.

324 Farmers from Mesobit & Gedeba mentioned the positive aspect of erosion from up-slope forest and bush areas and stressed the importance of constructing terraces to capture sediments on their private fields. Stocking & Clark (1999) report on Sri Lankan farmers profiting from erosion on slopes by capturing eroded sediments in rice paddies downhill.

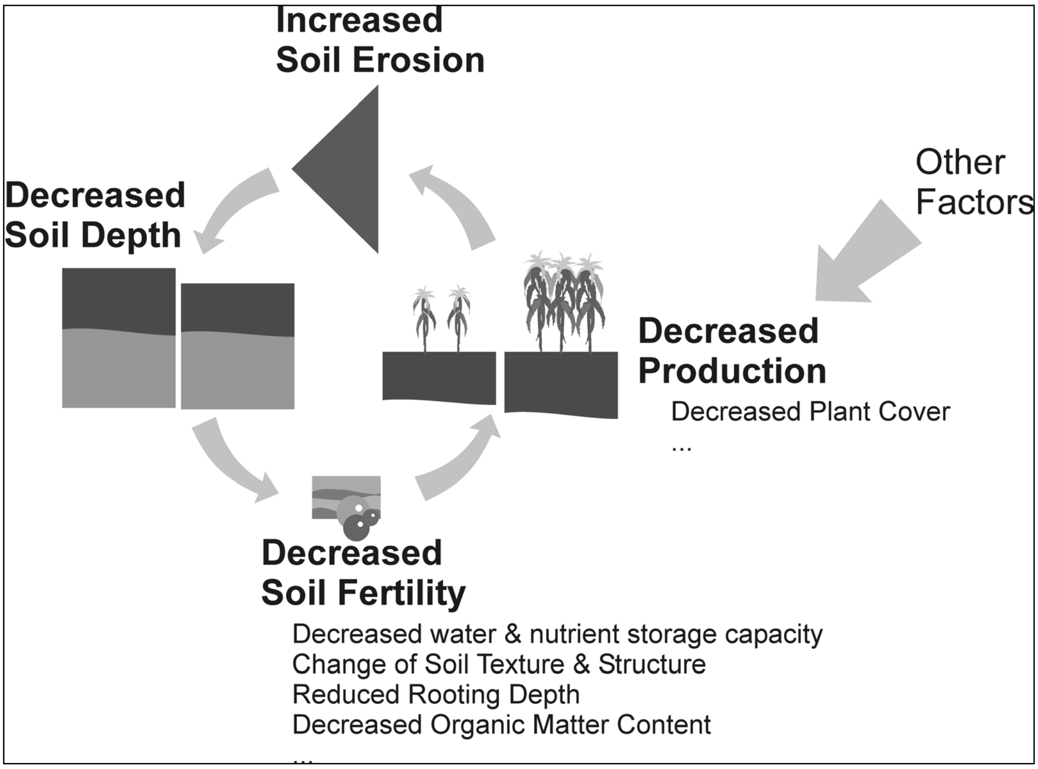


*Figure 30: Soil depth as a proxy indicator for soil productivity.*
*[Source: Own compilation, drawings by K. Herweg]*

Soil erosion and runoff in the three localities has been monitored on different erosion plots: test plots (TP, 2x15 m), micro plots (MP, 1x3 m) and experimental plots (EP, 6x30 m). Yield data has been collected on erosion plots and on farmers' fields throughout the catchment. Soil depth data is available from these yield sampling points. A relation between soil depth and soil productivity is established in a linear form, taking grain and straw yield as proxy indicators of soil productivity.

As the three locations differ considerably in various aspects (cf. Chapter 2), the following analysis of the relation between soil erosion and soil productivity has been carried out separately for the three sites to capture the many differences. The following section is structured as follows: First, some general remarks on data collection and data reliability, which are valid for all locations, are presented. The second part of the section describes the soil erosion – soil productivity relations individually for each location as well as the relation between soil depth and sampling location, the relation between yield and sampling location within a field in relation to conservation structures, and the time – yield relations.

***Data***[325]

The standard programme of data collection started right after the research stations were selected and established (cf. Appendix 3.1). Usually, during the first one ore two years after the sites were established, observations were carried out without soil conservation. In general, the data used for this study was collected during the following years:

- Maybar: 1986 – 1998
- Andit Tid: 1988 – 1997
- Anjeni: 1986 – 1995 (1991)

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325 For further details on data collection and analysis refer to SCRP, 2000a.

Crop yield data was in most cases used starting from the year when yield samples were collected in a series of 3 samples between two conservation structures, e.g. from 1986 onwards for Maybar and Anjeni, and from 1988 onwards for Andit Tid. Although in Andit Tid the sampling procedure of 3 samples between two conservation structures was also taken up in 1986, in the database, the specification of where the yield sample was taken from is missing for the year 1986. 1987 was not included in certain calculations because of missing information on the soil depth of the sample location. For Anjeni, in certain cases, data had to be excluded from 1992 onwards because of methodological problems (see below). It was also not possible to get access to yield data from 1996 onwards.

(i) ***Crop yield***[326] samples were collected from erosion plots (harvesting the whole area) and on cultivated land between the existing conservation structures (terraces). The sampling procedure was a random sampling for each cropping season. Samples were taken from cultivated fields of various farmers in the entire catchment. Starting in 1986, three sequential samples per terrace were taken from different locations: one immediately above (A), one in between (B), and one immediately below (C) the conservation structures (c.f. Figure 32). Before 1986, samples were randomly collected and are denoted with "N" in the database. They cannot be set in relation to a conservation structure. For most of the following analyses, only samples from location A, B, and C will be used. Samples taken between the conservation structures (B) represent a larger area, while those taken immediately above (A) or below (C) the structures represent only a narrow strip (c.f. Figure 32). Yield samples were taken on a 2x2 m plot (until 1987 3x3 m). Two different types of samples were collected from 1990 onwards: fixed and non-fixed. On "fixed" locations, samples were collected every year, supplemented by "non-fixed" samples that were randomly selected from the entire catchment. The number of non-fixed samples per crop type should represent the proportional area coverage by the respective crop inside the research catchment. Research Assistants (RA) were responsible for collecting yield samples during normal harvest time. Plants on the sampling location were cut and taken to the research station for drying (about 20 days) and weighing. Grain was weighed with and without the husk as well as straw and palatable weeds for indications of biomass production.

(ii) ***Reworkable soil depth*** was estimated at each sampling location using a soil auger, which was hammered into the soil until a harder sub-soil layer was reached.

(iii) The ***slope gradient*** was measured at each sampling location with an inclinometer.

(iv) ***Additional information*** was collected at each sampling location: how many times the field was ploughed before and after sowing, how many times the field was weeded, whether fertiliser was applied or not (artificial fertiliser, manure, and in Andit Tid 'soil burning'), and which crop had been planted in the preceding two cropping seasons in the same field. In some of the following analyses, only the information on whether fertiliser was applied or not will be used.

(v) ***Soil loss*** rates used in later calculations are derived from TPs and EPs. Plots have been established on farmers' fields and delimited with removable corrugated iron borders. The plots differ from conventional on-station erosion plots in that the farmer decides about the crop rotation, and farm operations (especially ploughing and weeding) are performed by the owners of the plots in their traditional way. This research set-up therefore allows a closer approximation to the actual conditions in the catchment. Runoff and sediments are collected in tanks at the end of the plots and used to calculate runoff and soil loss rates.[327] EPs were used to measure the impact of different conservation techniques on soil loss, runoff, crop yield and biomass.

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326 In the following, also the term 'grain yield' will be used. Whenever reference is made to crop or grain yield, it concerns yield without the husk.

327 For further details on the research programme and methods of the SCRP: Hurni, 1982; Herweg & Stillhardt, 1999; SCRP 2000a.

***Methodological difficulties***

Although the database offers good quality and exceptionally long time-series of primary data, certain problems related to data collection have to be mentioned to allow the reader to properly interpret the following results:

(i) Usually, data collection was carried out by RA's specifically trained for the different tasks to be performed at SCRP stations. Problematic is the fact that the RA's were responsible for data collection, but were not involved in the process of data analysis or interpretation. It was not their personal research interest, and in some cases, they did not know exactly for what purpose they were collecting all the data.

(ii) Although a training in mapping was conducted for RA's, their ability to locate sample points on topographical maps or aerial photos was limited. The reliability of land use maps and maps indicating fixed sample plots is considered insufficient for further analysis.[328] The information from maps could not be used.

(iii) The location of fixed sampling points was determined in 1986 by experts of the SCRP. However, no marks were set in the fields, and RA's had to remember from year to year where these fixed sampling points were located. Thus, sampling locations can vary from year to year. Unfortunately, this variation of fixed sampling locations was too high, both with regard to soil depth and to slope gradient, as to allow calculations of soil depth changes over the years.

(iv) The method of determining soil depth with an auger and a hammer was chosen as the best practice for handling the great number of samples involved, and furthermore, it minimises the disturbance of the soil profile. However, depending on the soil moisture, the soil's stone content, and even the strength of the RA, measurements of soil depth can differ considerably. In slightly moist soils with a small stone content, the soil depth measured was generally deeper than in dry and/or stony soils.[329] It could not be established, to which extent such factors distorted the measurements of soil depth, so somewhat implausible results could only partially be corrected. All soil depth measurements greater than 100 cm were corrected and reduced to 100 cm. This is justified by the fact that the auger is only 100 cm long, although the soil depth can be greater than 100 cm, especially in accumulation areas along streams, in depressions, and in the lower and flatter parts of the research catchments. Secondly, it can be expected that crop growth is not negatively affected as long as the soil depth is 85 to 95 cm and above (cf. footnote 269).

(v) Different experts of the SCRP had different objectives of data collection and gave special emphasis on the collection of certain data, depending on needs for specific analyses. This problem possibly occurred in Anjeni, where suddenly the soil depth increased considerably in 1993 and even more so in 1994 and 1995 compared to preceding years due to higher accuracy of depth measurement. The reason for this change and the magnitude of the difference could no longer be established, so data had to be excluded from the analysis.

(vi) A further problem occurred, as RA's often indicated missing data or measurements with a 0 in the field forms. Thus, it was not possible to conclude whether the true value was 0 or simply lacking.

(vii) So many years after the data was collected, it was no longer possible to correct all implausible data. Two modifications were made in addition to the above-mentioned correction of soil depth: firstly, some yield data that seemed implausible was excluded, such as yield values above 300% of the annual mean. Secondly, when both grain and straw yield was zero, these values were excluded, since yields were probably not measured, but falsely indicated as zero in the field forms. In cases where the grain yield was zero, but a straw yield was measured, it was assumed that the crop was damaged by pests, diseases or drought, and the data was used for further analysis.

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328 cf. Stuber, 1998, for a discussion of methodological problems related to numerical / GIS analysis of land use maps from several seasons in Andit Tid. Similar problems have to be expected also for Anjeni and Maybar.

329 Personal observation in the Andit Tid research area, where soil depth measurements in different periods on the same field resulted in different values.

(viii) Soil loss rates derived from experimental plots suffer from experimental interferences, whereby the measurement itself has an influence on the process being measured.[330] Impermeable boundaries around TPs and EPs, from which the soil loss data is derived, prevent overland flow from up-slope as well as import and redistribution of sediments within the plot, can cause the formation of rills along plot boundaries, and alter the balance between detachment and transport processes, primarily through the limited length of plots.[331] Thus, soil loss results measured on erosion plots resemble those on farmers' fields only to a limited extent.

(ix) The above-mentioned methodological problems make it difficult to extrapolate soil loss rates measured on plots to entire fields or even whole catchments. However, it is assumed that conditions as found in TPs offer the best approximation to soil loss on farmers' fields. It is further assumed that the TP length of 15 m offers the best possible simulation of erosion processes between two conservation structures. Because of the limited length of the TP, only sheet and, to a small extent, prerill erosion is assessed. The length of 15 m does usually not allow the formation of rills and, in particular, does not give any indication concerning damages created by run-on from up-slope bordering fields. Such events, which can cause extreme soil losses, have been assessed using the method of 'rill mapping'.[332]

(x) Soil loss and runoff are not measured directly, but are computed by measuring other variables such as water depth and sediment concentration in collection tanks of erosion plots or river gauging stations. Herweg & Ostrowski (1997) list a number of errors that can occur in the process of collecting input data (e.g. measurement of water depth or sediment concentration) and calculating output data (e.g. soil loss and runoff). Sensitivity analyses of parameters used in determining soil loss and runoff estimate errors in a range as high as –65% to +45%. Overall estimated errors for soil loss and runoff from erosion plots are in the order of ±3% and ±0.1% for annual soil loss and runoff data, and ±6% - 16% and ±2% - 5% for soil loss and runoff data on a storm basis, respectively.[333]

### 5.1.3 Results

***The relation between grain yield, slope gradient, and soil depth***

The relation between grain yield and soil depth and slope gradient was estimated using a ***linear function***. Although logarithmic functions generally exhibited slightly better $R^2$ than linear functions, the difference is small and cannot be separated from mathematical artefacts. To allow comparisons (i) over the years, thus excluding yield variations due to climatic irregularities, pests or diseases, and (ii) between crops, not the effective yield in tons per hectare for each crop was used, but the effective yields were converted to a percentage of the mean yield of the observation year.

Linear functions are estimated for all those crops used in further calculations according to the crop rotation cycle applied. Independent factors included in the function are soil depth and slope gradient. It can be expected that generally grain yield is ***positively related to soil depth*** as deeper soils offer a larger water store, a bigger pool of available nutrients, and better rooting conditions than shallow soils. Grain yield ***negatively correlate with slope gradient*** because soils are generally shallower on steep slopes than on gentle slopes (cf. Table 31), gravity supports erosion processes, and farm operations on steep slopes are more difficult and farmers often devote less time to farm operations than on flatter land.

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[330] Stocking, 1996, 150.

[331] An analysis by Herweg & Stillhardt (1999, 13) shows that the relationship between slope length and soil loss is not linear. Two types could be distinguished: soil loss increasing with slope length, indicating an increase of erosion due to entrainment and prerill erosion, and soil loss decreasing or remaining constant with increasing slope length, indicating that there is no significant entrainment effect, thus soil loss mainly originates from rainsplash or redeposition and diffuse accumulation within the plot is enhanced because of the longer slope.

[332] Herweg, 1996.

[333] SCRP, 2000a, 27.

The aim of the following functions representing the relation between crop yield, soil depth and slope gradient is to give a picture as close as possible to the situation in which farmers operate. Therefore, outliers have not been deleted, except for some few cases (cf. methodological difficulties above). Problematic with this approach is that outliers usually have a distorting effect on linear regressions. Thus, weak correlation coefficients and non-significant coefficients for soil depth and slope gradient could be a result of a few outliers (e.g. a big yield on a shallow soil or a big yield on a steep slope). A methodological problem related to linear functions is that even with a soil depth of only a few centimetres, grain yields are still considerably big. From the data, however, it must be concluded that farmers in general stop cultivating fields with a soil depth of less than about 10 cm.

Because actual yields have been converted to a percentage of the yield of the observation period, climatic factors such as rainfall or erosivity have been omitted in the regression function. Other factors such as land management practices (e.g. frequency of ploughing) have also not been considered because the variation for individual crops is not big, hence their explanatory power limited.

Linear regression functions in the following form are used:

$$\text{Grain yield [\%]} = \text{constant} + \alpha(\text{slope gradient [\%]}) + \beta(\text{soil depth [cm]}) \quad (5.1)$$

The notion aa/b as used below can be read as follows:

aa Crop: BL = barley, EM = emmer wheat, FP = field pea, HO = horse bean, LI = linseed, LT = lentil, MZ = maize, NE = noug, TE = tef, WT = wheat

b Season: 1= *Belg*, 2 = *Meher*

**Maybar**

Maybar is characterised by a complex cropping system. Often, two crops are sown per year, a shorter-growing and less water-demanding cereal crop during the *Belg* rainy season, and a more water-demanding and longer maturing pulse crop during the *Kremt* rainy season. Two different areas within the research catchment are distinguished: the upper part where maize is not cultivated due to climatic limitations, and the lower part, where maize is grown in every other year. Maize is sown in March, at the beginning of the *Belg* rainy season, and carried over through the *Kremt* rainy season. Table 15 gives an overview of possible crop rotation cycles:[334]

| Season | 1 (*Belg*) | 2 (*Meher*) | 3 (*Belg*) | 4 (*Meher*) | 5 (*Belg*) | 6 (*Meher*) | 7 (*Belg*) | 8 (*Meher*) | 9 (*Belg*) | 10 (*Meher*) | 11 (*Belg*) | 12 (*Meher*) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Upper part of catchment** | Barley | Field pea | Emmer wheat | Fallow | Wheat | Field pea | Emmer wheat | Horse bean | Fallow | Tef | | |
| **Lower part of catchment** | Barley | Horse bean | Maize | | Emmer wheat | Fallow | Maize | | Wheat | Tef | Maize | |

*Table 15: Possible crop rotation cycles in Maybar area according to altitude. [Source: Own compilation]*

334 Based on (i) interviews with farmers from Maybar area, (ii) SCRP Primary Database, crop rotation on fixed sample points, and (iii) Kassaye Goshu, 1997, 12.

| Crop/Season | Constant | α (Slope) | β (Soil Depth) | n | $R^2$ | F-Ratio |
|---|---|---|---|---|---|---|
| **Sampling location A (above bund)** | | | | | | |
| BL/1 | 142.13*** | -1.11*** | 0.03 | 280 | 0.05 | 6.70*** |
| EM/1 | 142.98*** | -1.06*** | 0.07 | 155 | 0.05 | 4.20** |
| WT/1 | 112.67*** | 0.26 | 0.11 | 49 | <0.01 | 0.07 |
| FP/2 | 137.96*** | -1.21** | 0.38 | 76 | 0.07 | 2.73* |
| HO/2 | 129.26*** | -0.47 | 0.01 | 218 | <0.01 | 0.70 |
| MZ/2 | 139.10*** | -0.88** | 0.13 | 236 | 0.02 | 2.25 |
| TE/2 | 121.71*** | 0.47 | -0.17 | 109 | <0.01 | 0.44 |
| **Sampling location B (between bunds)** | | | | | | |
| BL/1 | 113.41*** | -0.73*** | 0.10 | 295 | 0.04 | 6.21*** |
| EM/1 | 86.72*** | -0.33 | 0.55*** | 158 | 0.07 | 5.92*** |
| WT/1 | 120.68*** | -1.03 | 0.32 | 51 | 0.01 | 0.34 |
| FP/2 | 91.84*** | -0.04 | 0.41 | 111 | <0.01 | 0.49 |
| HO/2 | 107.42*** | -0.53 | 0.20 | 220 | 0.02 | 2.26 |
| MZ/2 | 100.60*** | -0.23 | 0.17 | 254 | <0.01 | 0.91 |
| TE/2 | 107.06*** | -0.39 | -0.08 | 104 | <0.01 | 0.20 |
| **Sampling location C (below bund)** | | | | | | |
| BL/1 | 81.43*** | -0.52** | 0.33** | 272 | 0.04 | 5.90*** |
| EM/1 | 71.88*** | -0.24 | 0.39* | 154 | 0.03 | 2.43* |
| WT/1 | 82.28*** | -0.20 | 0.11 | 50 | <0.01 | 0.04 |
| FP/2 | 108.98*** | -0.99** | -0.07 | 80 | 0.07 | 2.81* |
| HO/2 | 75.94*** | -0.04 | 0.44*** | 210 | 0.04 | 3.72** |
| MZ/2 | 96.64*** | -0.45 | 0.11 | 227 | <0.01 | 0.81 |
| TE/2 | 74.76*** | 1.23 | -0.09 | 109 | 0.02 | 1.15 |

*Table 16: Parameters for the linear regression grain yield (%) = f(slope gradient, soil depth) for different crops according to sampling locations in Maybar, 1986 - 1998.*
*(* significant at 10%, ** significant at 5%, *** significant at 1%)*
*[Data source: SCRP Primary Database]*

With the exception of wheat and field pea, the constant is highest on location A and smallest on location C. This gives an indication that terracing has – through various relations – a positive effect on yield. Field pea on location C and tef on all locations are negatively correlated with soil depth, whereas all other crops are positively correlated with soil depth and thus follow the expected signs (+ for soil depth, - for slope gradient). With the exception of wheat on location A and tef on location A and C, grain yield is negatively correlated with slope gradient. However, it has to be noted that (i) $R^2$ is extremely small, thus the two independent variables soil depth and slope gradient explain only a small portion of the total variance, and (ii) only few coefficients are significant. The same can be observed for the entire model; only for few crops, the model is significant. Looking at the two independent variables soil depth and slope gradient, it seems that slope gradient is slightly more important for predicting grain yields than soil depth. This will be an important conclusion to consider when designing further soil conservation measures. The fact that slope gradients play a comparably more important role can be interpreted in two ways: In Maybar, soils are generally very shallow. Based on a soil map (1985), about 53% of the survey area is covered with shallow (25 – 50 cm) and very shallow (10 – 25 cm) haplic Phaeozems, associated with Lithosols.[335] Thus, it could be that the soil depth has already reached critical levels, and that very shallow soils have been taken out of production. The second interpretation could be that after 1991 very steep areas formerly put aside as closed areas are more often cultivated. These steep slopes probably show comparably favourable soil conditions because they could regenerate over a period of several years and might show deeper soils than comparable slopes. Slope gradient might be the critical factor here. Despite the standardisation of yields, the variability is still very big.

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335 Weigel, 1986; Kassaye Goshu, 1997, 9f.

Taking all crops and sampling locations together, the following parameters result:

| Grain yield (%) | Constant | α (Slope) | β (Soil Depth) | n | $R^2$ | F-Ratio |
|---|---|---|---|---|---|---|
| All crops, all locations | 104.04*** | -0.48*** | 0.25*** | 3,418 | 0.02 | 35.27*** |

*Table 17: Parameters for the linear regression grain yield (%) = f(soil depth, slope gradient), all sampling locations (A/B/C, but not N) and all crops taken together in Maybar, 1986 - 1998.*
*(* significant at 10%, ** significant at 5%, *** significant at 1%)*
*[Data source: SCRP Primary Database]*

If all crops and all sampling locations are considered together, the model is highly significant. Also, individual coefficients are significant at the 1% level and show the expected sign. If the variable slope gradient were constant, each centimetre of soil depth decrease would lead to a yield decrease in the order of -0.25%. However, $R^2$ is very low and explains only about 2% of the total yield variation by the two variables soil depth and slope gradient. Other factors must therefore have a substantial influence on yield variations.

**Andit Tid**

There are two different cropping seasons in Andit Tid, which are clearly separated also spatially. Areas above about 3,200 m asl can only be cultivated with barley during the *Belg* season. Areas below 3,200 m asl are cropped with different crops during the *Meher* season; generally, only one crop is grown per year. Highland areas (*Dega*), which are cultivated with *Belg* barley, still show fallow periods of several years in between two cultivations. This fallow period is necessary to control pests and diseases and to partially recover soil fertility, as no crop rotation is possible due to climatic limitations. Table 18 gives an overview of possible crop rotation cycles.[336]

| Season | 1 (*Belg*) | 2 (*Meher*) | 3 (*Belg*) | 4 (*Meher*) | 5 (*Belg*) | 6 (*Meher*) | 7 (*Belg*) | 8 (*Meher*) | 9 (*Belg*) | 10 (*Meher*) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Upper part of catchment** | Barley | Fallow | Fallow | Fallow | Fallow | Fallow | | | | |
| **Lower part of catchment** | Fallow | Lentil | Fallow | Wheat | Barley | Linseed | Fallow | Horse bean | Fallow | Barley |

*Table 18: Possible crop rotation cycles in Andit Tid area according to altitude.*
*[Source: Own compilation]*

With the exception of wheat (horse bean is not considered as n is very small), all crop yields show the biggest constant on location A. This indicates that soil conservation has a positive effect on yields through its creation of more favourable growing conditions above the conservation structure. With the exception of wheat and linseed, the smallest constant is found on location C. A hypothesis was that crop yields would diminish with decreasing soil depth and increasing slope gradients. The results of the regression analysis do not confirm this hypothesis in all cases. *Belg* barley on location A shows opposing signs of coefficients for soil depth and slope gradient. This could be due to waterlogging problems above the conservation structures affecting the crop negatively in this high rainfall area. On steeper slopes, more water could be drained.

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336 According to (i) interviews with farmers from Andit Tid area, (ii) SCRP Primary Database, crop rotation on fixed sample points, and (iii) Yohannes G/Michael, 1989, 54.

| Crop/Season | Constant | α (Slope) | β (Soil Depth) | n | $R^2$ | F-Ratio |
|---|---|---|---|---|---|---|
| **Sampling location A (above bund)** | | | | | | |
| BL/1 | 107.26*** | 0.95 | -0.09 | 161 | 0.02 | 1.32 |
| BL/2 | 101.06*** | -0.89 | 1.03** | 133 | 0.06 | 3.91** |
| LT/2 | 111.70** | -0.60 | -0.09 | 14 | 0.01 | 0.07 |
| HO/2 | 88.94 | 1.37 | 1.19 | 10 | 0.16 | 0.67 |
| LI/2 | 79.45* | -0.21 | 1.18 | 52 | 0.04 | 1.08 |
| WT/2 | 81.27*** | -1.10 | 1.22*** | 36 | 0.25 | 5.35** |
| **Sampling location B (between bunds)** | | | | | | |
| BL/1 | 79.04*** | 0.10 | 0.46 | 163 | 0.02 | 1.37 |
| BL/2 | 71.28*** | -0.59 | 1.10** | 122 | 0.06 | 3.90** |
| LT/2 | 106.79** | -3.15 | 0.85 | 14 | 0.23 | 1.65 |
| HO/2 | 14.57 | -1.15 | 3.24 | 11 | 0.21 | 1.08 |
| LI/2 | 61.67*** | 0.54 | 0.53 | 53 | 0.04 | 1.10 |
| WT/2 | 101.40*** | -2.01** | 0.56 | 36 | 0.20 | 4.09** |
| **Sampling location C (below bund)** | | | | | | |
| BL/1 | 61.83*** | 0.98* | 0.04 | 159 | 0.02 | 1.53 |
| BL/2 | 58.34*** | -0.59 | 0.87** | 123 | 0.06 | 3.77** |
| LT/2 | 68.36 | -3.53 | 2.00** | 14 | 0.43 | 4.19** |
| HO/2 | 110.29 | -2.21 | 0.13 | 9 | 0.13 | 0.44 |
| LI/2 | 76.83*** | -0.28 | 0.27 | 51 | 0.01 | 0.32 |
| WT/2 | 122.56*** | -1.72* | -0.78 | 36 | 0.11 | 2.03 |

*Table 19: Parameters for the linear regression grain yield (%) = f(slope gradient, soil depth) for different crops according to sampling locations in Andit Tid, 1988 - 1997.*
*(* significant at 10%, ** significant at 5%, *** significant at 1%)*
*[Data source: SCRP Primary Database]*

Similar to Maybar, also for Andit Tid, the regression functions (i) show very small $R^2$ and (ii) are seldom significant. This could be explained with the comparably large number of samples and the high variability of yield, even if standardised. The latter shows one of the major problems farmers face – crop yields differ significantly from one year to the other due to a number of factors which are beyond human control, such as climatic variability (rainfall, temperature), pests, or diseases.

| Grain yield (%) | Constant | α (Slope) | β (Soil Depth) | n | $R^2$ | F-Ratio |
|---|---|---|---|---|---|---|
| All crops, all locations | 78.32*** | -0.18 | 0.62*** | 1,197 | 0.03 | 18.83*** |

*Table 20: Parameters for the linear regression grain yield (%) = f(soil depth, slope gradient), all sampling locations (A/B/C, but not N) and all crops taken together in Andit Tid, 1988 - 1997.*
*(* significant at 10%, ** significant at 5%, *** significant at 1%)*
*[Data source: SCRP Primary Database]*

When all crops and all locations are taken together, the variable soil depth, which is highly significant, explains yield variations better than the variable slope gradient, which is not significant. If slope gradients were held constant, each centimetre of soil depth reduction would decrease yields by -0.62%. Similar to Maybar, $R^2$ is still very low, only about 3% of the total yield variation can be explained by the two independent variables soil depth and slope gradient. Other factors must therefore have a substantial influence on yield variations.

**Anjeni**

In Anjeni, in contrast to Maybar and Andit Tid, considerable amounts of artificial fertiliser are applied. Therefore, grain yield data had to be corrected for the influence of fertiliser. Artificial fertiliser is mainly applied for barley (first and second crop), wheat, and tef. Unfortunately, it is not known how much fertiliser was applied per field. It is thus not possible to calculate response functions for fertiliser application (i.e. additional yield per kg fertiliser applied). The following Table 21 gives an overview of yields depending on whether fertiliser has been applied or not. It is interesting to note that for barley, the number of unfertilised samples is much bigger than the number of fertilised samples, whereas for wheat, the two are almost the same and for tef many more samples are from fertilised fields. This can be partially explained by the fact that tef seems to be reacting well to fertiliser, as the yield increase is more than 50%. Probably a more important aspect is that tef is not only consumed locally, but is also an important cash crop. Thus, if fertiliser is used for tef, which is sold on the market, costs for fertiliser can be recovered.

| | **Yield [kg/ha]** | | | | **F-Ratio** | **% Change** |
|---|---|---|---|---|---|---|
| | **Non-fertilised** | **(n)** | **Fertilised** | **(n)** | | |
| *Belg* Barley | 478.1 | (133) | 606.4 | (63) | 8.438*** | +26.8 |
| *Meher* Barley | 514.9 | (160) | 956.4 | (43) | 63.306*** | +85.7 |
| Wheat | 799.6 | (120) | 919.7 | (110) | 5.382** | +15.0 |
| Tef | 650.3 | (26) | 1,021.7 | (213) | 16.149*** | +57.1 |

*Table 21: Crop yields [kg/ha] without and with fertiliser application in Anjeni, 1986-1995. (Means difference: ** significant at 5%, *** significant at 1%, n: number of samples) [Data source: SCRP Primary Database]*

From Figure 31 (below), it becomes apparent that with the exception of wheat, the variance of yields with fertiliser (F) is considerably bigger (distance between 25% and 75% quartile) than the variance of yields without fertiliser (NF). It also shows that the median and the 25% quartile of fertilised yields are always higher than the ones of unfertilised yields. However, the 10% border of fertilised wheat and tef yield is lower than the one of non-fertilised yield. This means that the bigger variance of fertilised crops indicates a considerable number of very low yields. Thus, for these two crops, fertiliser application is riskier than for barley.

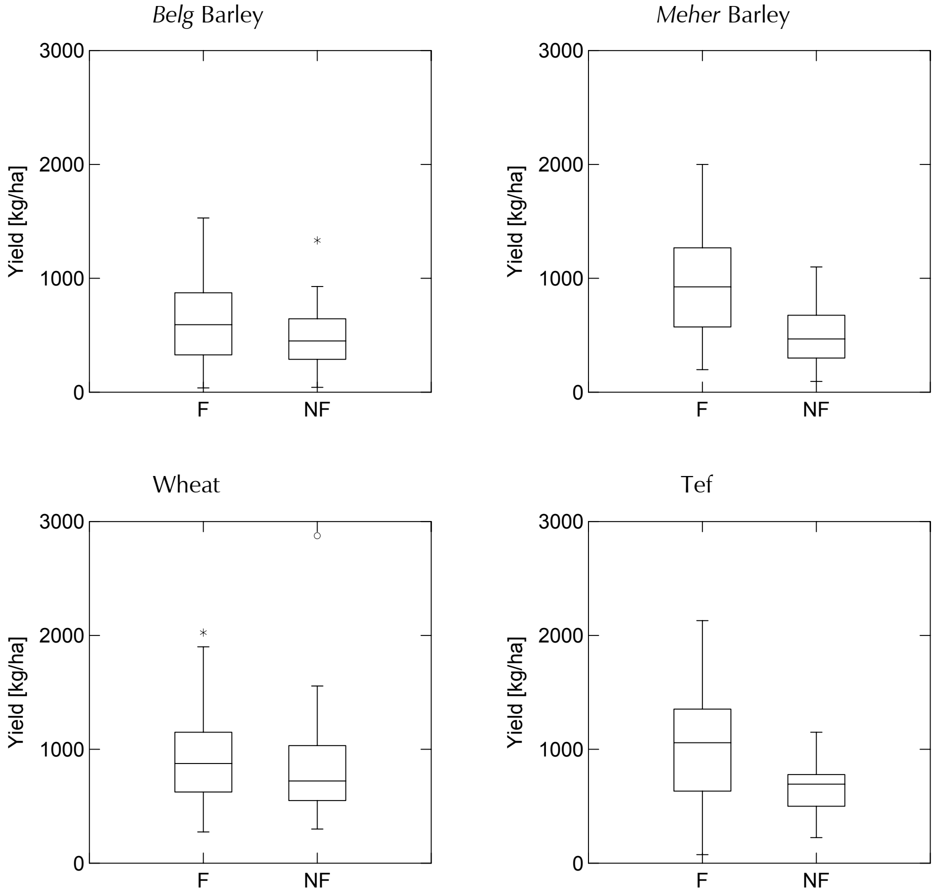


*Figure 31: Crop yields [kg/ha] with (F) and without (NF) fertiliser application in Anjeni, 1986-1995. [Data source: SCRP Primary Database]*

Most of the differences of fertilised and not fertilised yields from the different sampling locations are significant (cf. Table 22). With the exception of wheat on location C fertilised yields are higher compared to not fertilised yields. An observation frequently made and an argument used by Development Agents in convincing farmers to construct conservation measures is that – besides preventing soil from being washed away – also inputs such as fertiliser are kept on the field if soil erosion and runoff is controlled. In the case of Anjeni this argument can be clearly supported: Not only are highest yields found on location A, but the absolute differences between yield with and without fertiliser is also highest here. Relative differences are highest on location B in the case of *Belg* barley and wheat, which could be an indication that these two crops are affected by waterlogging, whereas tef shows the highest relative difference on location A, supporting the observation that this crop is not susceptible to waterlogging. *Meher* barley shows a completely different picture with highest relative differences on location C and lowest relative differences on location A. How far this can be related to the late sowing in September when erosive rainstorms are less frequent[337] and soil erosion reduced cannot be assessed conclusively. Highest yields on location A could be explained by the fact that (i) fertiliser is not washed away, and (ii) fertiliser might even be accumulated here. However, the positive effect of fertiliser on yields cannot be separated from the effect of accumulated soil or seeds, which might as well be transported from upper parts of the field and accumulated just above the bund.

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[337] Erosivity [J/mh]: June: 103.9, July: 173.3, August: 140.0, September: 66.2 (SCRP, 2000c, 42)

| | Sampling location A | | | | | Sampling location B | | | | | Sampling location C | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NF | (n) | F | (n) | F-Ratio | NF | (n) | F | (n) | F-Ratio | NF | (n) | F | (n) | F-Ratio |
| ***Belg* Barley** | 549 | (38) | 754 | (20) | 6.13** | 442 | (38) | 628 | (20) | 7.60*** | 425 | (37) | 495 | (21) | 1.05 |
| Diff. | 205 (+37.3%) | | | | | 186 (+42.1%) | | | | | 70 (+16.5%) | | | | |
| ***Meher* Barley** | 596 | (48) | 1,098 | (15) | 32.83*** | 530 | (48) | 1,011 | (14) | 27.91*** | 356 | (48) | 750 | (14) | 28.43*** |
| Diff. | 502 (+84.3%) | | | | | 481 (+90.8%) | | | | | 394 (+110.7%) | | | | |
| **Wheat** | 865 | (34) | 1,062 | (36) | 4.76** | 742 | (34) | 914 | (37) | 4.38** | 839 | (34) | 785 | (36) | 0.29 |
| Diff. | 197 (+22.8%) | | | | | 172 (+23.2%) | | | | | -54 (-7.6%) | | | | |
| **Tef** | 782 | (6) | 1,265 | (69) | 7.32*** | 690 | (6) | 992 | (72) | 2.67 | 582 | (6) | 837 | (68) | 2.41 |
| Diff. | 483 (+61.8%) | | | | | 302 (+43.8%) | | | | | 255 (+43.8%) | | | | |

*Table 22: Crop yields [kg/ha] without (NF) and with (F) artificial fertiliser in Anjeni, 1986-95, according to sampling location (A / B / C).*
*(Means difference: ** significant at 5%, *** significant at 1%, n: number of samples, Diff.: Difference (kg/ha) and % between fertilised and not fertilised yield)*
*[Data source: SCRP Primary Database]*

For the calculation of the regression functions relating yield to soil depth and slope gradient presented below in Table 24, fertilised yields (individual samples) were first corrected by the percentage indicated in Table 21 to arrive at unfertilised yields, as the difference between fertilised and not fertilised yields is considerable and significant at the 5% level at least.

Anjeni is characterised by one cropping season per year. Only barley can be sown twice. However, the rainfall pattern is not very favourable for two barley crops. *Belg* barley is sown in March, when rainfall is small and unreliable, and harvested in September. Immediately after the harvest of the *Belg* barley, the *Meher* barley is sown to make use of the remaining rainfall and soil moisture. Both crops are characterised by comparably low mean yields, as climatic conditions as well as soil characteristics are limiting. All other crops are cultivated during the *Kremt* rainy season only. Table 23 gives an overview of a possible crop rotation cycle.[338]

| **Season** | **1 (*Belg*)** | **2 (*Meher*)** | **3 (*Belg*)** | **4 (*Meher*)** | **5 (*Belg*)** | **6 (*Meher*)** | **7 (*Belg*)** | **8 (*Meher*)** | **9 (*Belg*)** | **10 (*Meher*)** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Horse bean | Tef | | | Noug | Barley | Barley | | Wheat |

*Table 23: Possible crop rotation cycle in Anjeni area.*
*[Source: Own compilation]*

338 According to (i) interviews with farmers from Anjeni area, (ii) SCRP Primary Database, crop rotation on fixed sample points, and (iii) Ludi, 1997.

| Crop/Season | Constant | α (Slope) | β (Soil Depth) | n | $R^2$ | F-Ratio |
|---|---|---|---|---|---|---|
| **Sampling location A (above bund)** | | | | | | |
| BL/1 | 125.91*** | 1.17 | -0.18 | 45 | 0.03 | 0.75 |
| BL/2 | 225.50*** | -1.11 | -1.17* | 39 | 0.10 | 1.88 |
| HO/2 | 184.85*** | 1.28 | -0.80 | 34 | 0.07 | 1.19 |
| NE/2 | 148.20*** | -0.32 | -0.44 | 34 | 0.05 | 0.74 |
| WT/2 | 142.21*** | -1.81* | -0.18 | 64 | 0.06 | 2.04 |
| TE/2 | 108.09*** | -0.28 | 0.33 | 38 | 0.03 | 0.56 |
| LI/2 | 136.85*** | -0.77 | -0.02 | 26 | 0.02 | 0.2 |
| **Sampling location B (between bunds)** | | | | | | |
| BL/1 | 88.18*** | 1.33 | 0.07 | 45 | 0.02 | 0.42 |
| BL/2 | 100.21*** | 0.09 | -0.07 | 39 | <0.01 | 0.03 |
| HO/2 | 122.5** | 2.65 | -0.46 | 34 | 0.08 | 1.25 |
| NE/2 | 56.21* | 2.60 | 0.39 | 36 | 0.07 | 1.22 |
| WT/2 | 128.42*** | -1.42* | -0.29 | 64 | 0.07 | 2.37 |
| TE/2 | 69.41** | -0.59 | 0.72** | 43 | 0.12 | 2.79* |
| LI/2 | 99.23*** | -3.02*** | 0.93** | 26 | 0.41 | 7.98*** |
| **Sampling location C (below bund)** | | | | | | |
| BL/1 | 99.24*** | 0.44 | -0.12 | 45 | <0.01 | 0.20 |
| BL/2 | 67.53*** | -0.18 | 0.17 | 39 | 0.01 | 0.22 |
| HO/2 | 77.04* | 6.12*** | -0.54 | 34 | 0.25 | 5.08** |
| NE/2 | 63.91** | 0.98 | 0.31 | 34 | 0.03 | 0.41 |
| WT/2 | 116.88*** | -0.37 | -0.43 | 64 | 0.03 | 0.78 |
| TE/2 | 23.20 | 2.01 | 0.88*** | 38 | 0.20 | 4.46** |
| LI/2 | 79.02*** | -1.41* | 0.58 | 28 | 0.25 | 4.06** |

*Table 24: Parameters for the linear regression grain yield (%) = f(slope gradient, soil depth) for different crops according to sampling location in Anjeni, 1986 - 1992. Yields are corrected for fertiliser influence. (* significant at 10%, ** significant at 5%, *** significant at 1%) [Data source: SCRP Primary Database]*

For further interpretations it is important to consider the fact that – like in the other two research stations – $R^2$ is extremely low, i.e. the dependent variable grain yield (%) shows a weak linear dependency from the independent variables soil depth and slope gradient. This can be mainly explained with the big variation of yields. Compared to Maybar and Andit Tid, where only few coefficients did not show the expected sign, in Anjeni the variables soil depth and slope gradient have an influence on crop yields that is more often contrary to expectations. It seems that in Anjeni, the variable slope gradient plays a more important role in determining crop yields than in the other two research sites. This could be related to the already mentioned problem of waterlogging, which especially affects horse bean[339] – which can be seen in the big to very big positive coefficient for the variable slope gradient, indicating that with increasing slope gradient crop yields increase. However, why the variable slope gradient has such a big influence on crop yields of horse bean on location C, where no waterlogging is to be expected, cannot be said conclusively. A further explanation for this seemingly contradictory picture could be the observed expansion of cultivated land into steeper areas. Gete Zeleke (2000, p. 56) observed from aerial photographs from 1957 that most of the cultivated land was on gentler slopes (below 20%). Cultivation was expanded to steeper areas only recently. It can be hypothesised that steep cultivation land is less exhausted than flat land because of a much shorter land use history. This could explain the seemingly contradictory effect of increasing slope gradients having a positive effect on yields: soil qualities on this newly opened land are still better than on flatter, but 'old' land. Because of the shorter land use history, Anjeni differs from Maybar and Andit Tid insofar as here, soils are generally much deeper and less degraded, and thus, soil depth is not yet a production-limiting factor. As Anjeni is a high rainfall area and dominant soil

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339 Acland (1971, 21) mentions that beans in general are very susceptible to waterlogging.

types seem to suffer from waterlogging, slope inclination plays an important role in determining runoff. The steeper the slope gradient, the more water can be drained, and the less damage to crops occurs due to stagnant water.

| **Grain yield** (%) | **Constant** | α (Slope) | β (Soil Depth) | **n** | **$R^2$** | **F-Ratio** |
|---|---|---|---|---|---|---|
| All crops, all locations | 98.15*** | -0.23 | 0.16** | 849 | <0.01 | 3.31** |

*Table 25: Parameters for the linear regression grain yield (%) = f(soil depth, slope gradient), all sampling locations (A/B/C, but not N) and all crops taken together in Anjeni, 1986 - 1992.*
*(* significant at 10%, ** significant at 5%, *** significant at 1%)*
*[Data source: SCRP Primary Database]*

If all crops are taken together, the linear regression presents the expected picture – grain yields decrease with increasing slope inclination and decreasing soil depth. However, the coefficients are comparably low with –0.23 for slope gradient and 0.16 for soil depth. Considering also the very low $R^2$ of less than 0.01, thus explaining less than 1% of the total yield variation by the two independent variables, other factors than the two are dominant in explaining differences in crop yields.

### *The relation between soil depth and sampling location*

| **Sampling location** | **Mean soil depth** | **Standard deviation (SD)** | **Standard error of mean (SEM)** | **n** | **$R^2$** | **F-Ratio** |
|---|---|---|---|---|---|---|
| **Maybar (1986-1998)** | | | | | | |
| A | 42.34 cm | 22.40 | 0.67 | 1,136 | | |
| B | 37.46 cm | 20.61 | 0.59 | 1,205 | 0.02 | 37.77*** |
| C | 34.71 cm | 20.38 | 0.61 | 1,120 | | |
| **Andit Tid (1988-1997)** | | | | | | |
| A | 40.90 cm | 19.01 | 0.93 | 419 | | |
| B | 37.22 cm | 17.34 | 0.86 | 410 | 0.02 | 12.43*** |
| C | 34.49 cm | 19.19 | 0.95 | 406 | | |
| **Andit Tid (1988-1997), upper part of the catchment (*Dega*)** | | | | | | |
| A | 47.90 cm | 20.75 | 1.63 | 163 | | |
| B | 44.56 cm | 18.67 | 1.46 | 164 | 0.03 | 2.14 |
| C | 43.34 cm | 22.18 | 1.75 | 160 | | |
| **Andit Tid (1988-1997), lower part of the catchment (*Weyna Dega*)** | | | | | | |
| A | 38.43 cm | 24.68 | 1.54 | 256 | | |
| B | 33.49 cm | 20.50 | 1.31 | 246 | <0.01 | 6.69*** |
| C | 29.85 cm | 20.21 | 1.29 | 246 | | |
| **Anjeni (1986-1991)** | | | | | | |
| A | 67.26 cm | 24.06 | 1.44 | 280 | | |
| B | 58.08 cm | 24.39 | 1.44 | 287 | 0.06 | 26.48*** |
| C | 52.44 cm | 24.64 | 1.47 | 282 | | |

*Table 26: Mean soil depth [cm], standard deviation (SD) and standard error of mean (SEM) according to sampling location A / B / C.*
*(* significant at 10%, ** significant at 5%, *** significant at 1%)*
*[Data source: SCRP Primary Database]*

In all research sites, soil depth according to sampling locations A / B / C shows significant differences, except for Andit Tid, *Dega* part of the catchment. Standard Errors of Mean (SEM) are small, indicating that the estimate of the mean is fairly accurate. Mean ± 1 SEM never overlap, with the exception of Andit Tid, upper part of catchment, giving a further indication that the means are well estimated and significantly different from each other. Standard deviations are comparably big, indicating a rather big variation of soil depth within the sampling location. Comparing the soil depth of the three sampling locations A, B, and C in a farmer's field, the positive aspect of soil conservation becomes clearly visible. In all three research locations, soil depth is highest in location A and lowest in location C.

**A comparison of soil depth differences between two conservation structures and annual soil erosion rates**

If one assumes that before conservation measures were constructed, soil depth was homogenous over a field, in Maybar, after 13 years of conservation (1986-98), soil depth between areas of high erosion (location C) and areas of mainly accumulation (location A) differ by almost 8 cm. In Andit Tid, a duration of conservation of 10 years (1988-97) leads to a difference in soil depth between locations A and C of 6 cm. In Anjeni, the difference in soil depth between locations A and C after 6 years of conservation (1986-91) is almost 15 cm. In other words, during the 13 years since conservation measures were constructed in Maybar, soil depth decreased by about 0.3 cm each year on location C, and increased by the same amount on location A. In Andit Tid, soil depth decreases on location C and increases on location A are around 0.6 cm per year for the period 1988-97, and in Anjeni, almost 1.3 cm of soil is dislocated annually from C to A during the period 1986-91. However, these figures are only in that range if all soil eroded in the upper part of a field is deposited above the bund and there is no net soil loss from a field. It is interesting to note that the 3 mm of soil dislocated annually from location C to location A in Maybar correspond well with the measured mean annual soil erosion rates of 30 t/ha on test plots (cf. Table 28). A similar situation is presented in Anjeni, with 13 mm soil dislocated annually from location C to location A and measured mean annual soil loss rates of a bit more than 140 t/ha on test plots. In Andit Tid, mean annual soil loss rates measured on test plots range between 97 t/ha and 138 t/ha, which can be converted to roughly 9 to 14 mm, and is above the amount of soil dislocated from C to A, which is about 6 mm annually for the whole catchment. If the upper and lower part are analysed separately, the amounts of dislocated soil are about 5 mm in the upper part and 9 mm in the lower part. This can be explained by the fact that in the upper part of the catchment, fields are only cultivated once every two to four years, thus cumulative soil loss is much lower than the estimates from test plots.

***The relation between crop yield and sampling location***

Since 1986, yield samples were collected in a succession of three samples: A – just above the conservation structure, B – in between two conservation structures, and C – below the next structure (cf. Figure 32).

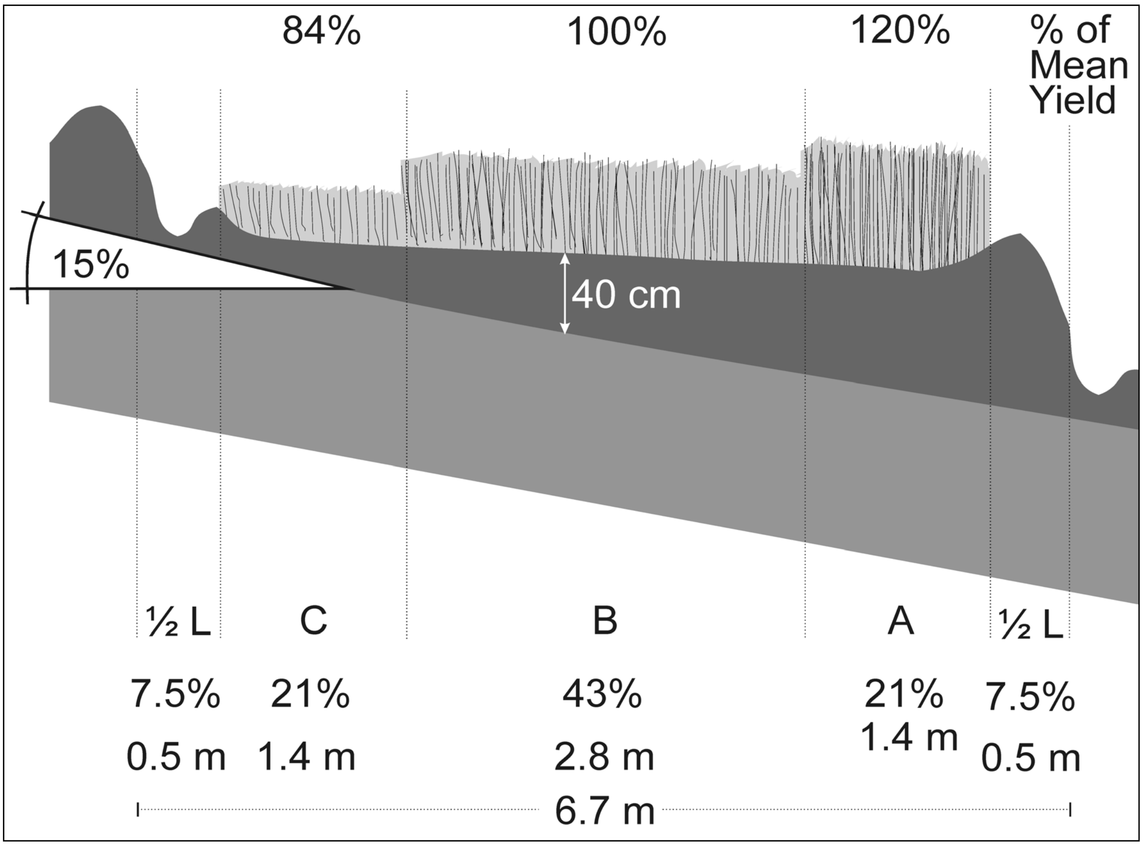


*Figure 32: Sampling locations between two conservation structures. The height of crops shown in the figure roughly represents the observed yield differences between locations A, B, and C. The approximate area coverage of A, B, C, and the land occupied by the conservation structures (L), is shown for an example with a slope gradient of 15% and an approximate top soil depth of 40 cm at location B. [Source: Own compilation, drawings by K. Herweg]*

The analysis of mean yields (in kg/ha) and yields expressed in percentage of their respective annual mean (%) are presented in Figure 33 and Table 27. Usually, a series of three samples was taken between two conservation structures. In some cases, not all three samples were collected, but sampling locations in relation to conservation structures have been indicated in the database. Also, these samples are considered in the analysis below and explain differing numbers of samples per sampling location.

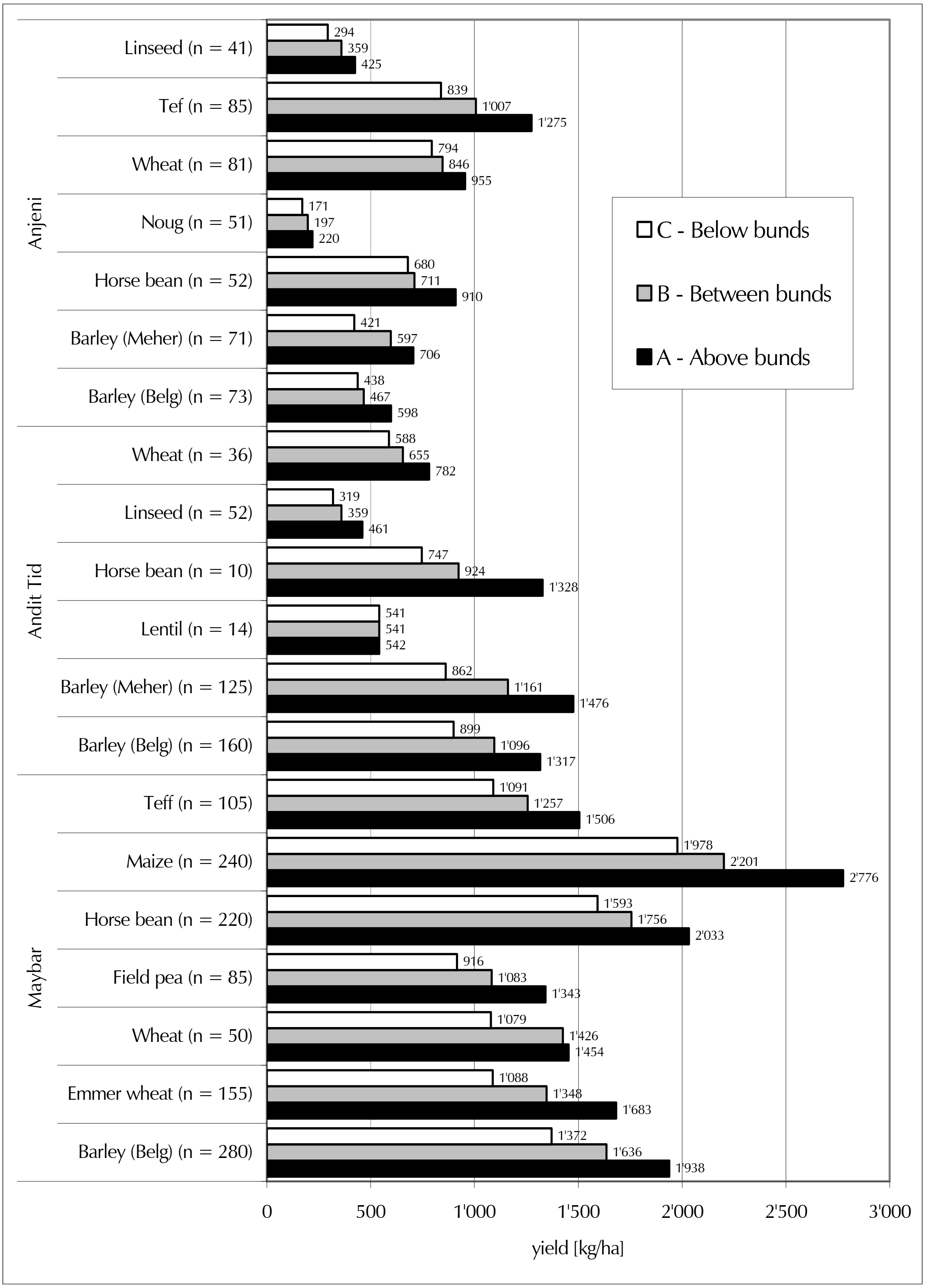


*Figure 33: Mean yield [kg/ha] of different crops depending on sampling location A, B and C. (In parenthesis n. Sampling period: Maybar: 1986-98, Andit Tid: 1988-97, Anjeni: 1986-95 [Data source: SCRP Primary Database]*

| **Maybar** | **Barley,** ***Belg*** [%] | **Emmer wheat,** ***Belg*** [%] | **Wheat,** ***Belg*** [%] | **Field pea,** ***Meher*** [%] | **Horse bean,** ***Meher*** [%] | **Maize,** ***Meher*** [%] | **Tef,** ***Meher*** [%] |
|---|---|---|---|---|---|---|---|
| A | 122.2 (280) | 123.8 (155) | 121.1 (49) | 122.5 (76) | 120.1 (218) | 129.7 (238) | 120.2 (109) |
| B | 101.9 (295) | 98.7 (158) | 117.8 (51) | 102.6 (111) | 104.6 (220) | 102.8 (254) | 99.4 (104) |
| C | 83.1 (272) | 79.2 (154) | 83.0 (50) | 83.4 (80) | 91.5 (210) | 92.9 (227) | 86.9 (109) |
| F-ratio | 40.80*** | 42.22*** | 6.22*** | 8.47*** | 12.75*** | 26.07*** | 11.24*** |
| **Andit Tid** | **Barley,** ***Belg*** [%] | **Barley,** ***Meher*** [%] | **Lentil,** ***Meher*** [%] | **Horse bean,** ***Meher*** [%] | **Linseed,** ***Meher*** [%] | **Wheat,** ***Meher*** [%] | |
| A | 122.9 (161) | 118.6 (133) | 99.4 (14) | 112.9 (10) | 117.7 (52) | 112.0 (36) | |
| B | 101.5 (163) | 93.9 (122) | 96.1 (11) | 83.7 (11) | 87.5 (53) | 90.9 (36) | |
| C | 84.3 (159) | 70.9 (123) | 92.6 (14) | 71.8 (9) | 79.5 (51) | 76.6 (36) | |
| F-ratio | 14.63*** | 16.9*** | 0.02 | 0.9 | 4.67** | 5.09*** | |
| **Anjeni – Fertilised** | **Barley,** ***Belg*** [%] | **Barley,** ***Meher*** [%] | **Horse bean,** ***Meher*** [%] | **Noug,** ***Meher*** [%] | **Wheat,** ***Meher*** [%] | **Tef,** ***Meher*** [%] | **Linseed,** ***Meher*** [%] |
| A | 121.4 (73) | 126.6 (72) | 124.8 (52) | 117.8 (51) | 112.8 (81) | 126.5 (85) | 124.2 (41) |
| B | 103.1 (73) | 102.7 (71) | 106.9 (53) | 104.1 (53) | 99.5 (81) | 101.1 (91) | 103.9 (41) |
| C | 90.8 (73) | 73.4 (71) | 91.7 (52) | 86.9 (51) | 93.9 (81) | 86.8 (85) | 83.7 (43) |
| F-ratio | 9.84*** | 18.23*** | 5.51*** | 6.25*** | 4.00** | 17.31*** | 12.17*** |
| **Anjeni – non-fertilised** | **Barley,** ***Belg*** [%] | **Barley,** ***Meher*** [%] | **Horse bean,** ***Meher*** [%] | **Noug,** ***Meher*** [%] | **Wheat,** ***Meher*** [%] | **Tef,** ***Meher*** [%] | **Linseed,** ***Meher*** [%] |
| A | 122.1 (73) | 126.7 (72) | . | . | 112.6 (81) | 125.9 (85) | . |
| B | 103.5 (73) | 103.8 (71) | . | . | 99.4 (81) | 100.3 (91) | . |
| C | 91.7 (73) | 72.1 (71) | . | . | 93.9 (81) | 86.0 (85) | . |
| F-ratio | 9.18*** | 21.51*** | | | 3.97** | 16.85*** | |

*Table 27: Mean yield [%] (in percent of annual mean yield) of different crops in different seasons (Belg, Meher) depending on sampling location A, B and C.*
*(In parenthesis n. Sampling period: Maybar: 1986-98, Andit Tid: 1988-97, Anjeni: 1986-95*
*F-ratio testing means difference: *** significant at 1%, ** significant at 5%, * significant at 10%)*
*[Data source: SCRP Primary Database]*

In Maybar, all crops show significantly different means depending on the sampling location. Also in the case where individual measurements are expressed as a percentage of the annual mean of this crop, thus levelling out extreme values influenced by climatic irregularities, diseases, or pests, the difference between the means remains highly significant for all crops. In Andit Tid, means for lentil, horse bean, and wheat are not significant if considering actual yields in kg/ha. In Anjeni, mean yields in kg/ha per sampling location are non-significant only for noug. Looking at absolute yields per sampling location, yields on location A are always higher than on location B, and yields on location B are always higher than on location C. This can be interpreted as a positive effect of soil conservation on yields. Especially in Maybar, where annual rainfall amounts are normally sufficient, but variability, both from year to year and throughout the various rainy seasons, is rather high, the positive effect of terracing with regard to water conservation can by postulated. In Andit Tid, only lentil shows a divergent picture compared to the rest of the crops, as the mean yield is the same on all three locations. However, only 14 cases are analysed, which is too small a number to produce clear results. The same is true for horse bean, with only 9 to 11 measurements per sampling location. In Anjeni, the difference of means for all crops is significant, irrespective of fertiliser inputs.

***The time – yield relation***

From the long-term data, it can be concluded that the average yield loss due to decreasing soil depth is in the order of -0.16% to -0.62% per each centimetre of soil lost at a constant slope gradient. This is a small value that can hardly be noticed from one year to the next, especially when considering the big variation of mean annual yields. The following Figure 34 to 37 and Appendix 5.2 give an overview of mean annual yields [in kg/ha] for the observation period for the three sites. Mean annual yields are expressed as a percentage of the mean yield over the whole observation period. Important to consider is that for some crops in certain years, only few samples have been collected. Thus, the calculation of mean annual yields might be distorted by (i) biased selection of sampling location (e.g. locations were selected either where crop stand was excellent or extremely bad), or (ii) outliers.

**Maybar**

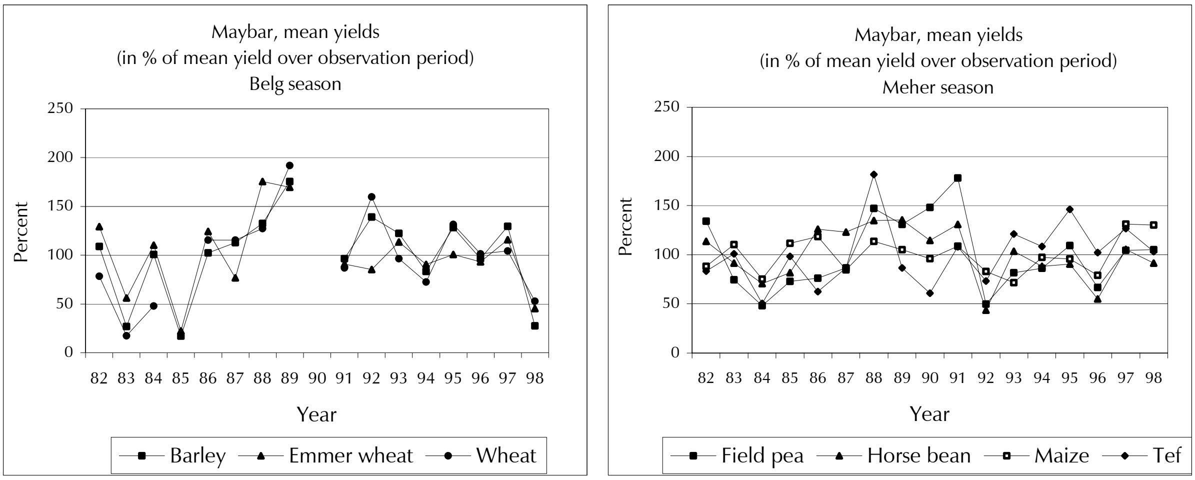


*Figure 34: Yield variations of Belg (left) and Meher (right) crops in Maybar. Yields are expressed as a percentage of the mean yield over the observation period 1982 – 1998.*
*[Data source: SCRP Primary Database]*

In Maybar, *Belg* season, yields can vary from only 20% to almost 200% of the long-term average. Different periods can be distinguished: until 1986, yields were fluctuating from year to year, only rarely reaching the long-term average. The time between 1986 and 1989 was a good period with yields generally above the long-term average. The period from 1991 to 1997 does not show a clear trend, but yields were mainly around or slightly above the long-term average. In 1998, yields fall to similar levels as during the drought year of 1985. This was also indicated by farmers interviewed, who mentioned that the first crop in 1998 was one of the worst they can remember. The yield level of the *Meher* crop does not fluctuate as much as that of the *Belg* crop. With few exceptions, yields lie within a range of ±50% around the average. In 1984/85, Maybar was heavily affected by drought, which is reflected also in very low yields for the second season crop. In 1992, yield levels were similarly low, although rainfall was not significantly lower than the long-term average. From the main crops cultivated during the second season, tef shows the biggest differences between minimum (50% of long-term average) and maximum (182% of long-term average) yields, followed by field pea (45% and 178%).

Long-term trends (1982-98) of mean yields show a mixed picture, however most of the yields seem to slightly increase, with the exception of emmer wheat and horse bean. Postulated annual increases for wheat and tef are biggest with +3.9% and +3.1%, respectively. The influence of artificial fertiliser can be neglected, as it was applied only in 49 out of 5,300 cases. What other influences played a role is difficult to say, as also the use of improved seeds is very limited. Postulated yield trends for horse bean are -1.2% annually and for emmer wheat -0.6% annually. The average over all crops (mean of all yields as a percentage of their long-term average) postulates an increase of +0.65% per year. This positive trend of yields seems rather surprising for a location like Maybar, which has always been characterised as highly degraded and drought-prone. However, climatic conditions in a 'normal' year with two rainy seasons are favourable, because two cropping seasons are possible, and the altitude allows the cultivation of a wide range of food crops. The main problem in Maybar, as for the whole area of the eastern Escarpment, is that drought is comparably frequent; i.e. the onset of the rains can be very late, leading to considerable or even total damage to the crops. It is interesting to note that the general trend of rainfall over a period of 12 years[340] is positive in Maybar (Appendix 5.3). However, annual variability is very big, with mean annual rainfall ranging from 720 mm (1984) to 1,548 mm (1982). Contrary to the perception that *Belg* rains fail more often than *Kremt* rains, the fluctuation of the *Belg* rains is much smaller than that of *Kremt* rains. The general positive trend of rainfall might have a strong influence also on the positive trend of yields. These long-term trends have to be interpreted with great care, as correlation coefficients are extremely small. One year more or less considered could change the trend from slightly positive to slightly negative very easily. This again points at the fact that many different factors play a role in determining yield levels, factors that cannot be captured by simply calculating yield trends. The big variation of annual yields also makes it difficult to isolate factors that could be improved, as (i) it is not clear which factors exactly play what role, and (ii) as some of the influences, such as climatic variations, can hardly be changed.

**Andit Tid**

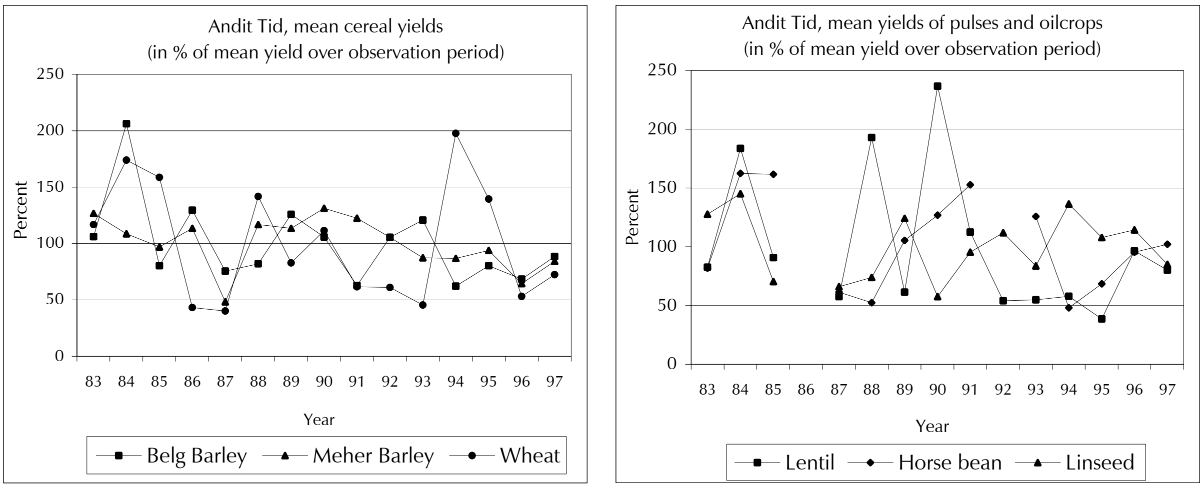


*Figure 35: Yield variations of cereal crops (left) and pulses and oilseeds (right) in Andit Tid. Yields are expressed as a percentage of the mean yield over the observation period 1983 – 1997. [Data source: SCRP Primary Database]*

In Andit Tid, only one cropping season per year is possible, due to climatic limitations leading to a long maturing period of most crops. Cereal crops fluctuate around the long-term average without showing a clear pattern. Only in 1995 to 1997 they all show similar levels and a same trend. Pulses and oilseeds show even bigger variations, with lentil having the biggest difference between the minimum (44% of long term average) and the maximum (238% of long-term average) yield. These results, however, could be distorted, because the number of observations is very small (around 10 per year). The same is true for horse bean.

For the two barley crops, where enough samples are available, the yield - time relation shows a pronounced negative trend: annually –3.0% for *Belg* barley, and –1.8% for *Meher* barley. Especially for *Belg* barley, a possible reason for declining yields could be that fallow periods are becoming too short. *Belg* barley is

340 1990/91 are not included as the research station was closed for part of these years due to war.

grown at very high altitudes. No other crops are cultivated there, hence crop rotation, which could improve or at least maintain soil qualities and would help to control weeds,[341] pests and diseases (mainly ergot), cannot be practised. It can be hypothesised, and it has been confirmed in interviews with land users from Andit Tid, that fallow periods in this *Dega* area are becoming shorter. One reason always mentioned was that land reserves are exhausted and farmers are forced to cultivate the land more often. The negative trend for the *Meher* barley crop can be associated with high soil losses and other forms of soil degradation, as crop cultivation is more intensive also in the lower part of the catchment, and fallow periods are reduced as a result of land scarcity. Furthermore, fertiliser is more or less absent in this area, crop residues are used almost completely as animal fodder, and animal manure is collected as a source of fuel.

In how far climatic factors such as rainfall play a role is difficult to state. *Belg* rains show a slightly negative trend of annually -0.2% over the observation period 1983 – 96. *Kremt* rains and annual total rainfall both show positive annual trends of +2.5% and +1.7%, respectively (cf. Appendix 5.3). However, it has to be kept in mind that these trends are based on a limited observation period of 14 years. One more year with an exceptionally low rainfall might suffice to change the trend. Increasing rainfall in Andit Tid could also be a reason for declining yields, as annual rainfall is already high, and increasing amounts might aggravate the problem of waterlogging, diseases, and vertical leaching of nutrients. A conclusive reason for the postulated increase of annual rainfall cannot be given. Whether global climatic change plays a role, whether more regionally observable fluctuations (e.g. ENSO) in the rainfall pattern are the reason, or whether factors influencing the micro-climate (e.g. denser forest cover in the vicinity of the climatic station in the late 90s as compared to 1983) play a role, and if so, to what degree, is not known and would require further research.

**Anjeni**

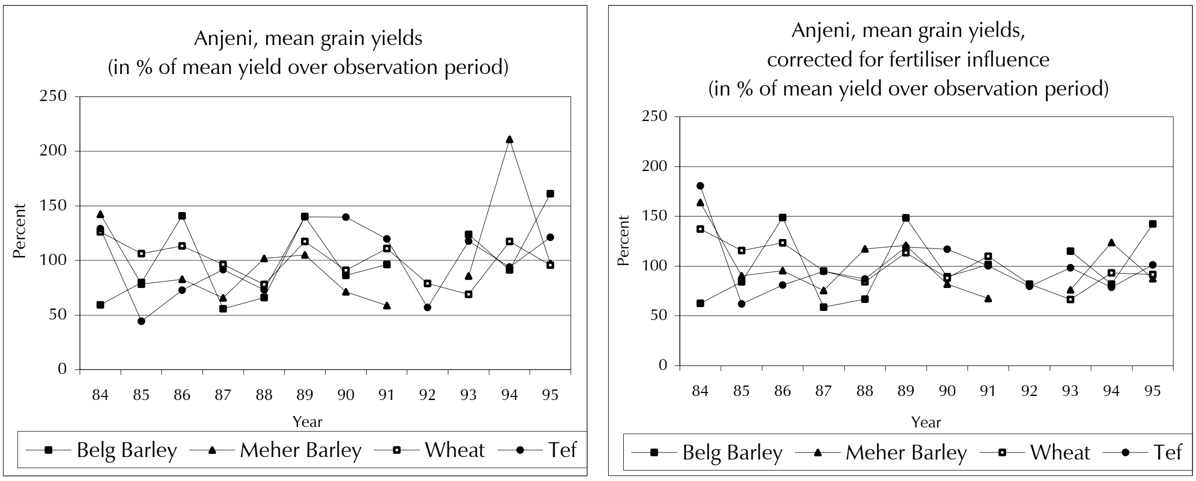


*Figure 36: Yield variations of cereal crops with fertiliser application (left) and cereal yields corrected for fertiliser application (right) in Anjeni. Yields are expressed as a percentage of the mean yield over the observation period 1984 – 1995.*
*[Data source: SCRP Primary Database]*

In Anjeni, mean yields of barley (*Belg* and *Meher* crop), wheat, and tef are significantly influenced by the application of artificial fertiliser (cf. Table 21). In Figure 36, 'uncorrected' and 'corrected' yields are presented.

341 In a similar highland area in the Simen Mountains, farmers mentioned a weed (*ginch*) growing so fast, that they cannot cope with weeding anymore (Hurni & Ludi, 2000, 76). In Andit Tid, highland barley fields are not weeded, thus if fields are infested by weeds, the competition between barley and weeds over nutrients, light, water, and space is very intense. Most probably, the weed is stronger than the barley, thus leading to decreased barley yields.

Artificial fertiliser is comparably widespread; of the roughly 1,600 samples, 480 (30%) were fertilised. Starting in 1990, when the DERG regime had to announce market liberalisations under national and international pressure, more and more farmers were able to buy fertiliser. For the first time, fertiliser was available on the "free" market, and grain prices were liberalised. Farmers thus had an incentive to produce more and to sell possible surplus.[342] In 1991 and 1992, fewer fields were fertilised. This could be explained with the tense security situation and hampered marketing activities during these years. When security was restored, markets could function normally again, and fertiliser was more readily available. This could be an explanation for the growing number of fertilised fields from 1993 onwards. It could also be, that increased fertiliser inputs are a strategy farmers have to apply to overcome decreasing yields resulting from accelerated soil erosion and other degradation processes. Thus, increased fertiliser use could also be interpreted as a sign of decreasing production and a necessary strategy to at least keep yields at a medium level.

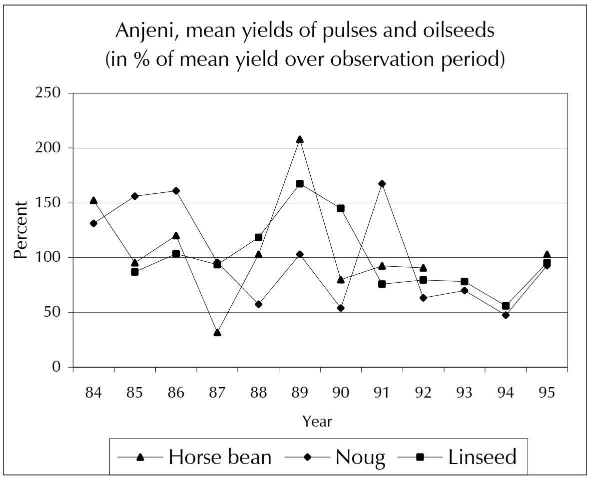


*Figure 37: Yield variations of pulses and oilseeds in Anjeni. Yields are expressed as a percentage of the mean yield over the observation period 1984 – 1995 [Data source: SCRP Primary Database]*

Yield trends for *Belg* and *Meher* barley, tef, and wheat differ considerably, depending on whether fertilised or non-fertilised yields are considered. *Belg* barley shows an annual positive trend of +7.3% for fertilised yields, but only an annual positive trend of +4% for unfertilised yields. *Meher* barley and tef show an annual positive trend of +3.2% and +2.6%, respectively, for fertilised yield. If considering unfertilised yields, for both crops the trend is negative with annually -2.3% for *Meher* barley and -1.9% for tef. Wheat shows a negative trend in both cases. If wheat is fertilised, the negative trend is -1.7% per year. With no fertiliser applied, the negative trend must be assumed to be –2.5% per year. All other crops show negative trends of annually –2.8% for linseed, -3.2% for horse bean, and –4.7% for noug. All crops taken together, the annual trend of yields can be postulated to be in the order of -0.8%. If yield increases resulting from the application of fertiliser are deducted, the annual overall trend must be estimated to be in the order of –2.7%. It can thus be postulated, that farmers have to invest more in artificial fertiliser to counterbalance the pronounced negative yield trend, which could be a result of overall nutrient decline because of high erosion rates, plant uptake, and leaching.

In the case of Anjeni, positive trends in rainfall do probably not play a major role, as rainfall is not a limiting factor in this area (cf. Appendix 5.3). On the contrary, too much rainfall might even be leading to crop damages through rust or waterlogging and leaching of nutrients. It can be hypothesised that negative yield trends are a result of soil degradation, and that to some extent also increasing rainfall might contribute.

[342] Ludi, 1997, 39.

### 5.1.4 The assessment of soil erosion in the three SCRP research areas

Postulated yield declines are calculated on the basis of different soil depth, which was taken as a proxy indicator for all the functions of a given soil in relation to crop growth. Decreasing soil depth was further taken as an approximation to the erosion process, and current soil depth measurements as an approximation to past erosion. It must be stressed again that soil depth only partially represents the relation between soil and yield. With soil depth alone, important factors such as nutrient content, organic matter content, plant available water capacity, soil structure, etc., which all have an influence on crop yields, are not well represented. Likewise, decreasing soil depth only partially represents the damages inflicted by soil erosion. There is ample evidence that eroded material shows higher concentrations of plant-available nutrients and organic matter than the soil of origin.[343] Soil erosion can further alter the soil structure, as finer particles are more easily entrained and transported than coarser particles, and can have a negative influence on the water retention capacity of the soil. Soil erosion therefore comprises many more processes than merely the decrease of soil depth, as assumed in the above-mentioned regressions; it degrades soils in various physical, chemical, and biological terms. Unfortunately, not enough information was available to relate other factors such as nutrient content, organic matter content, or soil structure to yield levels. Especially the dynamic change of these factors was not studied as part of the SCRP's core research programme. Therefore, it was not possible to further refine the regression functions linking crop yield with soil characteristics. The fact that crop yields were set in relation only with soil depth, and with no other soil factors having an influence on productivity, might explain the weak correlations of the regression functions presented in Table 17, 20, and 25.

Since there are no observations available concerning annual soil loss rates on the fields from the catchment where the samples were collected, whereas measurements of the soil depth (generally, the uppermost horizon Ap) are available, soil depth was taken as a proxy indicator for past erosion. However, the measurements of soil depth varied considerably from year to year. Thus, a tendency of decreasing soil depth could not be inferred from the measurements collected at the sample locations.[344] Instead, soil loss from test plots (TP) is taken as an approximation. As the length of a TP is 15 m, which is roughly the distance between two bunds in a field, ***soil loss from test plots*** is considered. In Maybar, only two of the four TPs were cultivated, and in Anjeni three, while the others were covered with grass or continuously hacked. This allowed the monitoring of soil loss from permanently covered plots as well as from bare plots without vegetation cover. The following Table 28 shows the measured soil loss from the cultivated TPs.

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343 Kefeni Kejela (1992, 223) calculated enrichment ratios based on experimental plots in Anjeni averaging 1.9 for total N, 1.6 for total P, 1.3, 1.1, 1.3, and 1.2 for exchangeable Na, K, Ca, and Mg respectively, and 2.1 for organic matter. He also cites studies conducted on tropical soils elsewhere in Africa, where enrichment ratios in the order of 1.7 for K, 1.5 for Ca, and 1.2 for Mg were calculated. Belay Tegene (1992, 41) calculated enrichment ratios in Gununo to be on the average 1.04 for organic matter and 1.2 for plant-available P from a cropped control plot.

344 cf. remarks on methodological difficulties p. 129.

| | **Maybar** | | **Andit Tid** | | | | **Anjeni** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Soil loss [t/ha]** | | **Soil loss [t/ha]** | | | | **Soil loss [t/ha]** | | |
| | **TP 1** | **TP 4** | **TP 1** | **TP 2** | **TP 3** | **TP 4** | **TP 1** | **TP 2** | **TP 4** |
| Slope / Year | 16% | 37% | 23% | 39% | 48% | 48% | 28% | 12% | 22% |
| 1982 | 56.9 | 2.0 | . | . | . | . | . | . | . |
| 1983 | 13.2 | 13.5 | 242.1 | 286.7 | 204.5 | 182.5 | . | . | . |
| 1984 | (75.0) | 118.7 | 124.1 | 149.7 | 64.7 | 40.9 | . | . | . |
| 1985 | (90.1) | 32.8 | 144.9 | 221.9 | 151.8 | 29.8 | 148.0 | 187.5 | 263.2 |
| 1986 | 13.9 | 0.7 | 163.4 | 183.1 | 123.2 | 58.3 | 182.9 | 66.4 | 159.4 |
| 1987 | 2.7 | 11.8 | 121.3 | 160.0 | 68.8 | 41.9 | 202.5 | 176.6 | 166.0 |
| 1988 | 35.5 | 54.1 | 211.3 | 199.2 | 141.6 | 154.5 | 191.0 | 38.2 | 69.3 |
| 1989 | 15.4 | 18.7 | 168.3 | 223.9 | 171.2 | 11.8 | 102.7 | 41.7 | 41.3 |
| 1990 | . | . | 144.1 | 293.9 | 76.7 | 155.5 | 175.1 | 238.9 | 131.5 |
| 1991 | . | . | 239.7 | 268.5 | 73.4 | 93.1 | . | . | . |
| 1992 | . | 41.3 | 127.8 | 137.6 | 130.7 | 96.7 | 223.6 | 154.5 | 156.3 |
| 1993 | 19.6 | 24.2 | . | . | . | . | 134.4 | 147.5 | 87.7 |
| | | | | | | | | | |
| Mean | 22.5 | 31.8 | 168.7 | 212.5 | 120.7 | 86.5 | 170.0 | 131.4 | 134.3 |
| Standard deviation | 18.1 | 34.9 | 44.0 | 53.7 | 45.9 | 56.9 | 36.8 | 69.4 | 65.0 |
| CV | 0.8 | 1.1 | 0.25 | 0.25 | 0.38 | 0.66 | 0.22 | 0.53 | 0.48 |
| | | | | | | | | | |
| **Mean** | **27.9** | | **147.1** | | | | **145.3** | | |
| **Standard deviation** | **28.8** | | **70.3** | | | | **62.7** | | |
| **CV** | **1.03** | | **0.48** | | | | **0.43** | | |

Remarks: **Maybar**: The research station was not operational from 04/1990 to 07/1991 due to civil war. Soil loss on TP1 in 1984 and 1985 was measured on hacked fallow and is thus not considered. In 1992 problems were encountered in determining runoff and soil loss from TP 1.
**Anjeni**: The research station was closed for several months in 1991 due to civil war.
**Andit Tid**: Test plots were removed at the end of 1992 after 10 years of measurement.

*Table 28: Annual soil loss [t/ha] on cultivated test plots in Maybar, Andit Tid and Anjeni. [Data source: SCRP, 2000b, 2000c, 2000d]*

For the two cultivated TPs in Maybar taken together, a mean soil loss of 27.9 tons per hectare and year and a standard deviation of 28.8 tons per hectare and year results. Taken a mean bulk density of roughly 1 $g/cm^3$,[345] a soil loss of 27.9 t/ha and year translates to about 2.8 mm soil depth reduction per year. Andit Tid and Anjeni both have similar mean annual soil loss rates of 147.1 t/ha and 145.4 t/ha respectively. The standard deviations are similar as well, and considerably lower than in Maybar. Thus, the coefficient of variation (CV) for Andit Tid is 0.48, and for Anjeni 0.43. Similar to Maybar, bulk densities of the dominant soils in Andit Tid and Anjeni are in the order of 1 $g/cm^3$.[346] Thus, mean annual soil depth reduction is in the order of 14.7 mm in Andit Tid, and 14.5 mm in Anjeni.

345 Weigel (1986) measured bulk densities mainly on haplic Phaeozems in Maybar. They ranged between 0.83 and 1.37 $g/cm^3$.

346 Bono & Seiler (1984) measured bulk densities of dominant soil types in Andit Tid. Andosols usually have bulk densities of 0.54 to 1.27 $g/cm^3$ in the Ah or Ap horizon, and in lower horizons, bulk densities ranged from 0.93 to 1.34 $g/cm^3$. Cambisols showed bulk densities ranging from 1.04 to 1.22 $g/cm^3$. For the main soil types of Anjeni (Nitosols, Luvisols, Regosols), Kefeni Kejela (1995) estimated bulk densities in the range of 0.95 to 1.20 $g/cm^3$. Especially Nitosols show bulk densities of slightly more than 1 $g/cm^3$ in the uppermost horizon. For further calculations, a mean bulk density of 1 $g/cm^3$ is assumed for all three localities.

Andit Tid and Anjeni suffer from mean soil losses about 5 times as big as the ones in Maybar. Possible reasons can be that in Andit Tid, which is situated close to the limit of agriculture at 3,000 m asl and above, vegetation growth is limited by temperature, which leads to comparably low vegetation covers. Furthermore, the catchment is characterised by steep slopes. In Anjeni, cropland covers almost the entire catchment, leaving hardly any grassland or forest in between. This intensive cultivation, in combination with high and erosive rainfall and high erodibility of the dominant soil types, can lead to these very high soil losses. In Maybar, many of the soils are stony to very stony, which reduces the erosive power of rainfall and slows down runoff. This reduces soil loss considerably, and encourages diffuse accumulation. However, the high coefficient of variation greater than 1 points to the fact that soil losses can be extremely high and vary considerably from year to year. The highest soil loss ever measured on a TP in Maybar occurred in 1984, and amounted to almost 119 t/ha. Even though that year was a drought year and has the lowest annual rainfall of the whole observation period, it showed the highest erosivity, which, in combination with very low vegetation cover, led to such a high soil loss. The variability of soil loss in Andit Tid and Anjeni is smaller, which is reflected in the smaller coefficient of variation.

Soil loss from test plots is taken as the basis for the approximation of unconserved land. If looking at soil loss rates measured on experimental plots, where different conservation measures and the local cultivation practice without conservation are compared, ***soil loss reductions on plots with conservation measures*** are in the order of 55% in Maybar, 59% in Andit Tid, and 68% in Anjeni over an observation period of 4 years in Maybar and Anjeni and 3 years in Andit Tid.[347]

| | **Mean soil loss, unconserved TPs** | **Soil loss reduction based on results from EPs (%)** | **Postulated mean soil loss, conserved land** |
|---|---|---|---|
| **Maybar** | 28 t/ha p.a. | 55% | 13 t/ha p.a. |
| **Andit Tid** | 147 t/ha p.a. | 59% | 60 t/ha p.a. |
| **Anjeni** | 145 t/ha p.a. | 68% | 46 t/ha p.a. |

*Table 29: Estimated annual soil loss from untreated plots and reductions of soil loss on treated plots. [Source: Own compilation based on data from the SCRP Primary Database]*

If the measured and estimated amounts of soil loss per hectare and year are translated into mm of soil depth lost, a mean annual soil depth reduction of 2.8 mm on unconserved land and 1.3 mm on conserved land can be expected in Maybar. In Andit Tid and Anjeni, the soil depth decrease would amount to 14.7 mm and 14,5 mm on unconserved land and to 6 mm and 4.6 mm on conserved land, respectively.

***Soil loss with and without conservation and its effects on soil productivity***

Considering mean soil loss rates as measured on TPs in Maybar (28 t/ha p.a. or 2.8 mm), on unconserved land, it would take about three years to reach one centimetre of soil loss, which would lead to a yield reduction of 0.25%. If the land were conserved, the same soil loss would be reached only after 7 years. In Andit Tid and Anjeni, there is even more than 1 cm of soil loss per year on unconserved land. On conserved plots, in Andit Tid, it would take about 1.5 years to reach a soil loss of 1 cm with an associated yield decline of 0.62%; in Anjeni, it would take about 2 years. In Maybar, annual yield declines would thus be about 0.07% if the land were not conserved and 0.04% if the land were conserved. In Andit Tid, with an annual soil loss of about 1.47 cm, yield reductions would be as high as 0.91% annually without SWC. Also in Anjeni more than 1 cm of soil is lost per year if the land is not treated, which leads to annual yield declines in the order of 0.23%. If the land were conserved, yield reductions would decrease to 0.37% annually in Andit Tid, and 0.07% annually in Anjeni.

[347] Herweg & Ludi, 1999, 107.

| | Mean annual soil loss [mm], unconserved land | Mean annual soil loss [mm], conserved land | Yield change [%] per 1 cm soil depth reduction | Annual yield change [%], unconserved land | Annual yield change [%], conserved land | Annual yield change, derived from regression analysis of mean yields |
|---|---|---|---|---|---|---|
| | (Table 29) | | (Table 17, 20, 25) | | | (Appendix 5.2) |
| | (a) | (b) | (c) | (c)/(1 cm/(a)) | (c)/(1 cm/(b)) | |
| **Maybar** | 2.8 mm | 1.3 mm | -0.25% | -0.07% | -0.04% | -1.5% |
| **Andit Tid** | 14.7 mm | 6.0 mm | -0.62% | -0.91% | -0.37% | -2.4% |
| **Anjeni** | 14.5 mm | 4.6 mm | -0.16% | -0.23% | -0.07% | +0.6% |

*Table 30: Mean soil loss [mm] on unconserved and conserved land, yield declines per 1 cm soil loss as calculated on the basis of the regression functions (yield = f(soil depth, slope gradient)), annual yield declines taking into account annual soil loss on unconserved and conserved land; and annual yield change based on a regression analysis of mean annual yields.*
*[Source: Own compilation, based on data from the SCRP Primary Database]*

Maybar is characterised by two rainy seasons, *Belg*, in spring, and *Kremt*, in summer. The two rainy seasons are separated by one dry month in June. According to the rainfall pattern, soil loss can also be distinguished between *Belg* and *Kremt*. From the mean annual soil loss of 27.9 t/ha measured on two test plots (cf. Table 28), about 53% can be attributed to the *Belg* season and 47% to the *Kremt* season. Andit Tid is also characterised by two rainy seasons, which are separated by a dryer month in June. Here, the relative amounts of soil loss are 24% for the *Belg* rainy season and 76% for *Kremt* rainy season. Anjeni has only one rainy season, lasting from around May to end of September. Therefore, soil loss cannot be further distinguished.

A comparison of yield changes over time and of yield declines as a function of decreasing soil depth shows the following picture: In Maybar, postulated yield declines are in the order of -0.25% per one centimetre soil lost or -0.04% annually on conserved land and -0.07% on unconserved land. Annual mean yields for the same period (1986-98) decrease by -1.5% annually on conserved land.[348] In Andit Tid, yield declines per one centimetre of soil loss are in the range of -0.62%, and annual yield declines taking into account mean annual erosion rates are in the order of -0.37% on conserved land and -0.91% on unconserved land. The average annual yield decrease as calculated on the basis of mean yields over the observation period (1988-97) is -2.4%.[349] In Anjeni, yield declines per one centimetre of soil loss are -0.16% or annually about -0.07% on conserved land and –0.23% on unconserved land. Different from Maybar and Andit Tid, yields in Anjeni increase over the observation period (1986-91) by +2.9% if considering fertilised yields, and by +0.6% if considering yields that have been corrected for the influence of fertiliser.[350] However, it has to be stressed that the observation period in Anjeni is very short and does not include 1992, 1993, 1996, and 1998, years where yields were comparably low in Maybar and Andit Tid. The estimated yield decline, or, in the case of

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348 Annual yield changes, Maybar, 1986-98: barley: -2.1%, emmer wheat: -3.3%, wheat: -3.1%, tef: +2.6%, maize: +0.6%, horse bean: -3.4%, field pea: -1.6%.
With regard to conserved land, it must be kept in mind that although the major part of the catchment has been conserved during the campaigns in the mid-80s, farmers have in the meantime expanded the arable area considerably. They have also significantly modified the original layout by dismantling some or all conservation structures on their land. Because remnants of these structures are still visible, RA's continued to collect harvest samples in a series of three between two conservation structures. Nevertheless, one must assume that this also includes unconserved fields. This observation is also valid for Andit Tid and Anjeni.

349 Annual yield changes, Andit Tid, 1988-97: *Belg* barley: -2.6%, *Meher* barley: -4.4%, lentil: -7.2%, horse bean: -1.0%, linseed: +2.7%, wheat: -1.7%.

350 Annual yield changes, Anjeni, 1986-91, with fertiliser application: *Belg* barley: -1.6%, *Meher* barley: -3.2%, horse bean: +3.3%, noug: -1.2%, wheat: 0.3%, tef: +20.8%, linseed: +1.7%.
Annual yield changes, Anjeni, 1986-91, corrected for fertiliser influence: *Belg* barley: -1.7%, *Meher* barley: -3.2%, horse bean: +3.3%, noug: -1.2%, wheat: -1.6%, tef: +6.9%, linseed: +1.7%.

Anjeni, yield increase, over the years is certainly influenced by climatic factors. However, it has also been shown that rainfall did rather increase than decrease during this period of time (cf. Appendix 5.3). Thus, a marked negative trend of climatic conditions on yield levels cannot be postulated, especially since the drought years of 1984/85 are not considered.[351] It can therefore be hypothesised that a major part of the postulated yield decrease is a consequence of soil degradation – physical, chemical, and biological. A certain percentage can be related to decreasing soil depth as a result of soil erosion, as has been shown in the yield – soil depth relation. Annual yield decrease in Maybar is around -1.5%, of which -0.04% can be attributed to decreasing soil depth. The remaining decline of -1.46% must originate from other degradation processes, such as decreasing nutrient contents, decreasing organic matter content, or decreasing water storage capacity of the soil. In Andit Tid, the annual negative yield trend is big with -2.4% over the considered observation period. Thereof, almost 16% or -0.37% can be attributed to decreasing soil depth. The rest must be attributed to other degradation processes, which were not captured by the proxy indicator 'soil depth'. In Anjeni, yields increase annually by 0.6% if no fertiliser is applied. Annual yield decreases as a result of decreasing soil depth are estimated to be in the order of -0.07%. Thus, effects of soil erosion through decreasing soil depth and other degradation effects must be offset by other factors such as climate, improved seeds, or changed farming practices.

### 5.1.5 An appraisal of soil life

A critical aspect to consider when interpreting soil loss rates is the relation between annual soil erosion rates and the given soil depth in an area. A great soil loss might have little impact on deep soils, but can be devastating on an already shallow soil. One way of comparing the two is to estimate the life span of a given soil. From the soil depths measured where crop yield samples were taken, it can be concluded that soils shallower than 10 cm are usually no longer cultivated. Also soils shallower than 20 cm are rarely cultivated.[352] Soils shallower than 10 cm are considered degraded and are given up, as from a farmer's point of view, seed and labour input are no longer economical. If soil loss rates on unconserved land and soil loss reductions thanks to conservation are assumed to correspond to the figures presented in Table 29 and to remain the same for the whole observation period, then the following life span of soils can be expected:

$$T = (100 * (Sd_0 - Sd_{crit})) / (E - F) \qquad (5.2)$$

with T = time (number of years) required to reach a critical soil depth (here 10 cm and 20 cm), $Sd_0$ = soil depth in the reference year (in cm), $Sd_{crit}$ = critical soil depth (in cm) beyond which crop production will not be economically profitable, E = mean annual soil loss rate (in t/ha * year) and F = mean annual soil formation rate (in t/ha * year).

The mean soil depth indicated in Table 31 does not describe the soil depth that could be expected on newly cleared land. The actual soil depth values are calculated on the basis of available measurements, which means that the soils considered have already suffered from substantial soil losses before reaching these values.

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351 It has to be mentioned, however, that this argumentation considers total annual rainfall, but not rainfall distribution, which might play a decisive role in determining yields.

352 In Maybar, out of 4,064 samples, 21 (0.5%) were collected on soils with a depth of 10 cm or below, and 387 samples (9.5%) on soils between 11 and 20 cm deep. In Andit Tid, the figures are 13 (0.6%) (<10 cm) and 295 (13.3%) (11-20 cm) from a total of 2,224 samples, and in Anjeni, 6 (0.4%) (<10 cm) and 58 (3.4%) (11-20 cm) from a total of 1,620 samples.

| Slope class | Slope gradient [%] | Mean soil depth [cm], location B, only cultivated land [1)] | n | Life span (cultivation years) without conservation | | Life span (cultivation years) with conservation | | % of total catchment area per slope class (both cultivated land and other land categories) |
|---|---|---|---|---|---|---|---|---|
| | | | | $Sd_{crit}$ = 20 cm | $Sd_{crit}$ = 10 cm | $Sd_{crit}$ = 20 cm | $Sd_{crit}$ = 10 cm | |
| **Maybar** | | | | | | | | |
| 1 | 0-2 | 28.5 | 35 | 26 | 62 | 61 | 138 | 0.1 |
| 2 | 3-5 | . | . | . | . | . | . | 1.2 |
| 3 | 6-8 | 41.3 | 105 | 72 | 108 | 160 | 237 | 2.1 |
| 4 | 9-15 | 38.8 | 350 | 63 | 99 | 141 | 218 | 12.5 |
| 5 | 16-30 | 38.9 | 508 | 64 | 99 | 141 | 218 | 19.6 |
| 6 | 31-60 | 31.3 | 172 | 36 | 72 | 83 | 160 | 38.8 |
| 7 | >60 | 30.4 | 26 | 33 | 69 | 76 | 153 | 25.7 |
| **Andit Tid, upper part of the catchment** | | | | | | | | **Total catchment** |
| 1 | 0-2 | . | . | . | . | . | . | 0.1 |
| 2 | 3-5 | . | . | . | . | . | . | 1.6 |
| 3 | 6-8 | . | . | . | . | . | 60 | 3.0 |
| 4 | 9-15 | 47.0 | 35 | 16 | 23 | 43 | 55 | 12.0 |
| 5 | 16-30 | 44.0 | 97 | 14 | 21 | 38 | 50 | 33.2 |
| 6 | 31-60 | 41.3 | 23 | 12 | 19 | 34 | . | 39.5 |
| 7 | >60 | . | . | . | . | . | | 10.6 |
| **Andit Tid, lower part of the catchment** | | | | | | | | |
| 1 | 0-2 | . | . | . | . | . | . | |
| 2 | 3-5 | . | . | . | . | . | . | |
| 3 | 6-8 | 32.6 | 27 | 7 | 13 | 19 | 36 | |
| 4 | 9-15 | 33.6 | 74 | 7 | 14 | 21 | 37 | |
| 5 | 16-30 | 32.2 | 93 | 6 | 13 | 18 | 35 | |
| 6 | 31-60 | 32.9 | 39 | 7 | 14 | 20 | 36 | |
| 7 | >60 | . | . | . | . | . | . | |
| **Anjeni** | | | | | | | | |
| 1 | 0-2 | . | . | . | . | . | . | 0.4 |
| 2 | 3-5 | 64.8 | 37 | 25 | 32 | 91 | 113 | 3.1 |
| 3 | 6-8 | 60.9 | 80 | 22 | 29 | 83 | 105 | 5.7 |
| 4 | 9-15 | 56.1 | 131 | 19 | 26 | 72 | 94 | 41.3 |
| 5 | 16-30 | 52.1 | 36 | 16 | 23 | 64 | 86 | 40.5 |
| 6 | 31-60 | . | . | . | . | . | . | 8.4 |
| 7 | >60 | . | . | . | . | . | . | 0.6 |

[1)] Observation period: Maybar: 1986-1998, Andit Tid: 1968-1997, Anjeni: 1986-1991

*Table 31: Predicted time span (cultivation years) necessary for a soil to reach a critical soil depth of 20 and 10 cm without and with soil conservation and approximate portion of the research catchments within different slope classes.*
*[Data source: SCRP Primary Database; Ethio-GIS]*

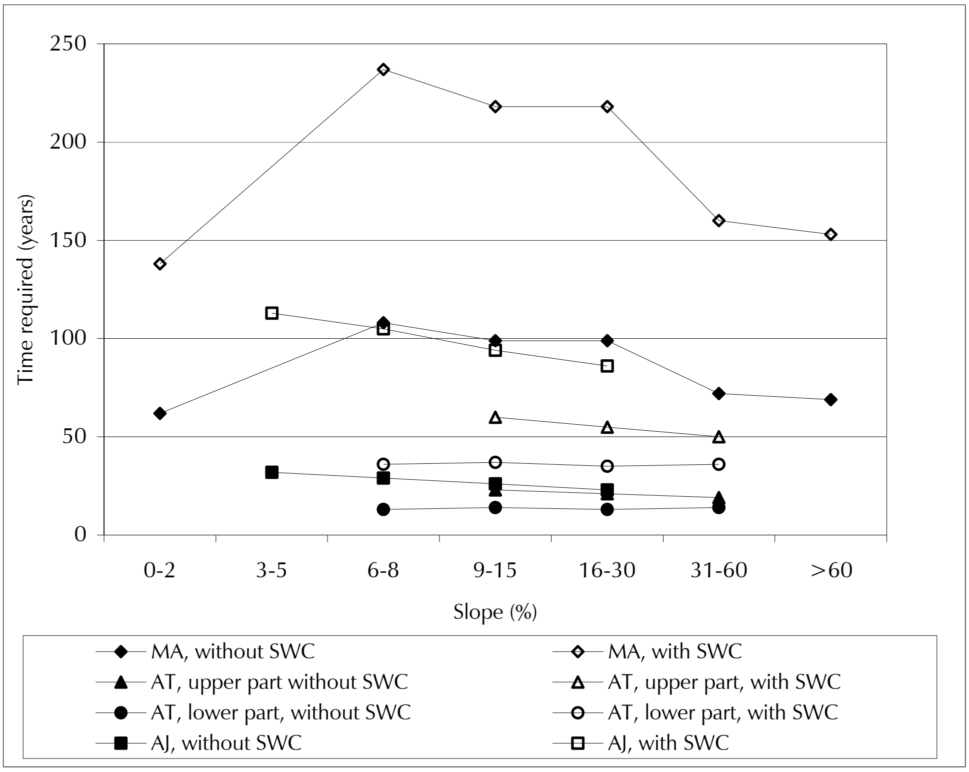


*Figure 38: Predicted time (cultivation years) required for soils in different slope classes to reach a critical soil depth of 10 cm, with and without soil conservation in Maybar (MA), Andit Tid (AT), and Anjeni (AJ). Mean soil loss was considered for all slope classes.*
*[Source: Own compilation, based on data from the SCRP Primary Database]*

Figure 38 and Table 31 above clearly show the ***effect of soil conservation on the 'life time' of soils*** in the three research locations, if a minimum soil depth of 10 cm is considered as critical. In Maybar, which is characterised by comparably low erosion rates, soils can be used for another 60 to 100 years if no soil conservation activities are carried out. With SWC, soil life at moderate slopes of 3-5% with a mean soil depth of 41 cm today would last for another 237 years if current land use practices and intensities were not changed. On steep slopes (>60%) with shallower soils, land use would be possible for another 70 years if no soil conservation were practised, and more than 150 years with soil conservation and if modest mean annual soil loss rates of 28 t/ha were assumed. In Andit Tid, a clear differentiation becomes apparent between the higher (*Dega*) and lower (*Weyna Dega*) parts of the catchment. Soil life in lower parts of the catchment would be as short as 13 or 14 years without soil conservation. With soil conservation, the soil life in this lower part of the research catchment could be prolonged to around 36 years. In the upper part of the catchment with considerably deep soils, land use would be possible for about 20 years without soil conservation, and 50 to 60 years with soil conservation. Important to consider is that until now, in this upper part of the catchment, land is cultivated only every third or fourth year. In the modelling, it has been assumed that in the fallow period soil loss is zero. If land use intensities increased, soil losses would certainly increase and the soil life would therefore decrease rapidly. Soil life in Anjeni lies in between that of Maybar and Andit Tid and would last another 23 to 32 years without soil conservation – always under the assumption that no changes in the farming system, the land use intensity, or the erosion rates occurred. With soil conservation, the soil life could be extended to 86 to 113 years.[353] Despite high erosion rates, soil life in Anjeni is comparably long as soils are much deeper than in the other two areas.

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[353] Gete Zeleke (2000, 77) calculated similar figures for Anjeni with a slightly different approach and different calculations of the annual soil loss rates. He estimates that on land with a soil depth between 25 and 50 cm, the predicted time to reach the critical soil depth is about 16 years without SWC and 110 years with SWC.

Especially in Andit Tid, where soils are heavily degraded and generally shallow and erosion rates are high, there is an acute danger of total degradation of vast areas of currently cropped land. More than 80% of the total catchment is steeper than 9%, and 50% of the catchment is even steeper than 30%. Especially for the lower part of the catchment, predicted life span of the land is only 15 years if not conserved or 35 years if conserved. For these areas, and for the people currently using them, alternatives have to be found in the short run, otherwise food production for the population will be severely constrained. An important aspect not considered in the calculation of the soil life, which is here entirely based on soil depth, is soil quality. Erosion not only decreases the soil depth but also negatively affects soil nutrient contents, organic matter content, water retention bodies, or texture and structure of the soil (cf. Figure 30). It must therefore be expected that soil life allowing crop production is even shorter than indicated in Table 31 above.

***Annual yield declines*** in the order of a bit less than 0.1% to 0.9% if the land is not conserved, and 0.07% to almost 0.4% if land is conserved, are comparably low. However, taken the ***long history of land use*** in the three sites, one must conclude that such small productivity declines are reasonable. If soil loss decreased yield more rapidly, these areas would probably have been given up for crop production long ago. Estimates based on $^{14}C$ dating of charcoal found at the basis of soil accumulations, dated back to 530 to 1,140 BC in Andit Tid and to about 2,450 BC in Maybar.[354] It can be assumed that in early times land use concentrated on favourable areas such as gentler slopes, where soil loss rates were much lower. Only with rapidly growing numbers of people depending on the land, farmers had to expand their arable land to steep and erosion-prone areas and had to cultivate the land much more intensively.

A further factor to consider is whether one is looking at ***gross soil loss*** rates as measured on erosion plots, such as those used for the above calculations, or whether one is considering ***net soil losses***. In this report, net soil loss is defined as the amount of soil lost permanently from a catchment. Thus, soil losses estimated on the basis of sediment concentrations from river gauging stations can be considered such net losses. The sediment yields calculated for Maybar, Andit Tid, and Anjeni are in the order of 12 t/ha*a, 9 t/ha*a, and 25 t/ha*a, respectively.[355] They are based on the total catchment area, thus also including land use types that do not contribute very much to total soil loss, such as grassland or forest areas. If only cultivated land was considered,[356] the values would increase to about 22 t per hectare of cultivated land per year in Maybar, 92 t per hectare of cultivated land per year in Andit Tid, and 36 t per hectare of cultivated land per year in Anjeni. Net soil losses per hectare of cultivated land are considerably lower than soil losses calculated from erosion plots, indicating that a substantial amount of soil lost on a field is re-deposited on adjacent land. Although part of the soil loss from fields is re-deposited on other fields, and can balance soil erosion taking place there, accumulations at the foot-slope of hills or in depressions can be considerable. Once soil depth has reached 1 m or more in accumulation areas, the additional soil has no substantial positive effect on crop growth anymore, as rooting depth of annual crops is in the order of 80 to 100 cm.[357] On the contrary, such soil accumulation areas, especially in high-rainfall locations, are susceptible to waterlogging. Thus, redeposition of eroded soil must be distinguished carefully and cannot be uniformly distributed over the whole catchment area.[358] It must be concluded that, taking into account redeposition within the catchment, the actual net soil loss from a field is somewhere between the soil loss estimated from erosion plots and the soil loss estimated from river gauging stations.

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354 Yohannes G/Michael, 1989, 35, quoting Hurni; Hurni, 1985, 665.

355 Herweg & Stillhardt, 1999, 16. Measurement periods: Maybar: 1982-89, 1993, Andit Tid: 1983-93, Anjeni: 1985-93.

356 In Maybar, about 60% of the total catchment is cultivated each year, in Andit Tid about 10% (in each cropping season), and in Anjeni about 70%. (SCRP, 2000)

357 Landon, 1991, 289. cf. Footnote 269, where the critical maximum soil depth for major crops, after which crop growth is constrained, is indicated.

358 e.g. Bojö & Cassells (1995) estimate that redeposition of eroded soil would lead to a net soil loss of only half of the figures usually quoted. However, they do not consider that areas suffering from soil erosion account for more than 90% of the area, whereas areas gaining from redeposition represent a small fraction of less than 10%. (cf. Table 31)

Another point not considered so far is ***soil formation***.[359] Soil formation is directly linked to the problem of soil erosion, because the latter will not be problematic as long as soil formation rates are at least the same as soil erosion rates.[360] Soil formation is determined by factors such as climate, flora and fauna, topography, water table, parent material and time.[361] In the Ethiopian case, soil formation rates must be distinguished according to altitudinal ranges, as climatic factors (e.g. rainfall, temperature) and accordingly land use systems differ considerably according to different altitudes. Geological differences play a minor role, as most of the highland is covered by tertiary volcanic deposits of similar composition.[362] Based on data from the Simen Mountains, which allow to estimate soil formation rates for very high, mountainous areas to lowland areas below 2,000 m asl, Hurni (1983, 136) estimates soil loss tolerance, which he took as equal to soil formation, of 2 t/ha*a for altitudes between 3,000 and 3,500 m asl, 4 t/ha*a for altitudes between 2,500 and 3,000 m asl, and 6 t/ha*a for areas between 2,000 and 2,500 m asl. Applied to the three research locations Maybar, Andit Tid and Anjeni, soil loss tolerance can be assumed to be in the order of 4 t/ha*a for Maybar, 2 t/ha*a for Andit Tid, and 6 t/ha*a for Anjeni.[363] Compared to the estimated mean annual soil loss rates ranging between 27 t/ha and almost 150 t/ha (cf. Table 28), these figures are very low, if not altogether negligible. Thus, soil formation does not compensate for soil loss; however, it does contribute, albeit little, to slow down the negative process of soil erosion. Nonetheless, soil formation rates have not been included in further calculations, since soil productivity was estimated on the basis of the depth of reworkable topsoil and not directly linked with soil erosion. With the consideration of topsoil as a proxy indicator for soil productivity, the relation soil erosion – soil formation, as well as soil transportation, is expected to be taken into account sufficiently.

### 5.1.6 Rill erosion as a special form of soil erosion

The above-mentioned mean annual soil loss as measured on test plots represents the general picture of sheet and partly rill erosion. As the TPs are surrounded by corrugated iron, no run-on is possible, and the amount and energy of the running water is not big enough to create larger rills. On TPs, mainly rainsplash, sheet, and prerill erosion occurs, while rill erosion is a rare phenomenon.[364] Accumulation within the plot would be diffuse accumulation of eroded material. It can be expected that similar erosion patterns occur between two conservation structures, provided that the structures are well maintained and have no overflow leading to rills or even gullies in the lower part of the field.

In all three locations, a detailed ***assessment of erosion damages*** (ACED)[365] caused by single storm events has been carried out. This method is comparably cost effective and complements the erosion measurement on test plots. As the fields are not artificially delimited and usually much longer than test plots, with this method, different erosion damages such as rills or concentrated accumulations can be assessed. The first step of the method is to measure the volumes of erosion features (e.g. rills) and the area of the field or land management unit where this damage occurs. The features observed in the field are linked to causes of erosion on the damaged field, such as inappropriate land management and damaged or inappropriately designed

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359 Soil formation can be distinguished in three separate processes: (i) accumulation on the surface (decomposition of organic material, deposition of material transported by wind and water), (ii) soil formation within the A horizon (humus formation, root development and decomposition), and (iii) weathering of parent material (development of B horizon). Soil formation rates as quoted are the sum of the three processes, as it is extremely difficult to separate them properly. (Hurni, 1983, 132)

360 Not considering for the time being that soil formed from parent material is of a different quality than soil eroded from the surface.

361 Hurni, 1983, 132.

362 Mesfin W/Mariam, 1992, 28ff.

363 Altitudinal ranges of research catchments: Maybar: 2,530-2,858 m asl; Andit Tid: 3,040-3,548 m asl; Anjeni: 2,407-2,507 m asl. (SCRP, 2000a)

364 Herweg & Stillhardt, 1999, 12f.

365 Herweg, 1996.

conservation structures (e.g. a decreasing gradient of cut-off drains leading to diminishing water velocity, accumulation of eroded particles, and diversion of runoff into the field; damaged SWC structures leading to concentrated runoff; traditional drainage ditches that are not steep enough to drain excess water and therefore lead to concentrated runoff; or overly steep drainage ditches leading to the formation of rills), changes in slope gradient, different soils, land use parameters, etc. In a second step, the up-slope area is investigated in view of its contribution to the damage. The origin of run-on (often sealed land such as roads, footpaths, village areas, or animal tracks that lead to a concentration of water, or overgrazed and degraded land with high runoff) and the places where it enters into the damaged field are identified. The third step is to document the damages downslope such as concentrated accumulations.

ACED is a rough method for assessing linear soil erosion processes. The accuracy is smaller than with measurements from plots; it depends heavily on the observer and is therefore much more subjective. By experienced RA's, the mapping of rill and gully volumes can be done with an accuracy of ±15%. Results become more inaccurate as vegetation cover increases and rills and gullies become less visible, or as the form of the rill becomes more complex.[366]

Soil loss calculated from mappings is based on the volume of the rill multiplied by the bulk density of the topsoil, which is assumed to be 1 g/cm$^3$. Results from erosion plots are usually expressed in relation to an area, i.e., for comparison reasons, usually in tons per hectare. For the calculation of soil loss from fields based on the measurement of rills and gullies, this is difficult. One possible solution is to take the cultivated field as a unit of reference, because its management certainly has an influence on the erosion damage. On the other hand, it is possible that there are only few rills on a field due to an external component such as run-on. Relating the soil loss from such isolated rills to an otherwise undamaged field is problematic. Therefore, the most feasible and meaningful option is to consider only the area of actual damage, which is the area covered by rills.

From erosion mappings done in the research sites of Maybar, Andit Tid, Hunde Lafto, and Gununo, the following conclusions can be drawn:[367]

- In half of all observations, the ***actually damaged area*** of the fields considered was below 10%. In 10% of all cases, rills and gullies damaged more than 30% of the field. In 3% of the cases, more than 70% of the field was damaged.
- The ***absolute amount of soil lost*** from rills and gullies was slightly more than 4 t in 50% of all observations. 10% of cases produced soil losses of more than 50 t, and 150 t of soil loss were calculated for 4% of all observations. Absolute maximum soil loss measured from one single event was more than 1,000 t!
- The area damaged by rills and gullies suffers from serious ***topsoil loss***. In 50% of all cases topsoil loss was 120 mm and in 5% of the cases topsoil loss amounted to 400 mm.

It is important to notice that the above-mentioned soil losses resulted from single events and do not represent annual values. They concern only the damaged area and cannot be evenly extrapolated to the whole field. It is also worth noticing that results from ***rill mappings describe the extreme***, whereas results from ***erosion plots rather describe the average***. To compare results from rill mapping to erosion plot results, it is best to use mm of topsoil lost as a unit for comparison. A comparison of soil loss per actually damaged area from mapped fields and from test plots after selected single events in Maybar and Andit Tid showed completely different results. One event in Maybar resulted in a soil loss per actually damaged area of 154 mm, whereas on the test plot, only 4.3 mm were lost. An event in Andit Tid resulted in similar figures with 144 mm of soil loss from the actually damaged field area and only 3.6 mm of soil loss from the test plot. This again demonstrates that the test plot represents the average erosion value, whereas the result from rill mapping represents extreme erosion damage.

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366 Herweg & Stillhardt, 1999, 32.

367 Herweg & Stillhardt, 1999, 34.

### 5.1.7 Conclusions

In the previous sections, different relations of crop yield to (i) soil depth and slope gradient, (ii) different sampling locations, and (iii) time have been presented. It is known that soil erosion in quantitative terms is enormous – mean annual soil loss rates on test plots are in the order of roughly 28 t/ha in Maybar and more than 140 t/ha in Andit Tid and Anjeni. Annual net soil losses based on the volume of suspended sediments at the river gauging station are still in the order of 22 t/ha in Maybar, 92 t/ha in Andit Tid, and 36 t/ha in Anjeni. However, to date it is not known, to what extent absolute ***soil erosion rates*** have an influence on ***crop production***. Crop production was chosen as the main indicator, as soil erosion negatively affects soil productivity, and therefore crop production, through various effects on physical, chemical, and biological properties of the soil. Decreasing crop production resulting from soil erosion and other degradation processes again has an influence on the well being of a large portion of small-scale subsistence farmers in the Ethiopian Highlands.

In a first step, a relation between crop yield and soil depth and slope gradient is established. This approach was chosen because not enough data was available for more sophisticated modelling approaches such as EPIC. Although 4 test plots were established in each research station, the replicability required for statistical analyses of yield declines resulting from soil loss at various slopes and under various crop types is not given. A further reason is that the plots show different soil types, slope gradients, and expositions, and because the crops grown vary from year to year according to the crop rotation cycle applied by farmers. A similar problem exists on experimental plots. They allow a comparison of soil loss, runoff, and yield under different conservation techniques but same crops and same management aspects; however, they do not provide time series data linking soil erosion to crop production. In contrast, in all three research catchments, a large number of yield samples were collected from farmers' fields, each supplemented with a set of further variables such as soil depth. This latter could be used as a proxy indicator for the effect of soil erosion – through reduced rooting depth and altered soil properties – on crop production. Soil depth was chosen as a proxy indicator for soil productivity, hence a relation linking soil depth with crop production would simulate soil productivity and soil productivity changes at least to a certain degree.

It could be shown that ***soil depth*** changed considerably between two conservation structures as a result of soil conservation measures. Soil depth differences between location A (above a conservation structure) and location C (below the next upslope structure) are in the order of 8 cm in Maybar, 6 cm in Andit Tid, and 15 cm in Anjeni. In Maybar and Anjeni, this difference of soil depth corresponds to cumulative soil erosion over the observation period based on soil loss measurements from TPs. It could also be shown that yields on the different locations in relation to conservation structures differ significantly. In Maybar, yields measured on location A are in the order of 120% to 130% of the annual mean yields, and on location C in the order of 80% to 90%. In Andit Tid, yields on location A are between 100% and 123% of the annual mean yields, and on location C between 71% and 93%. In Anjeni, yields on location A are between 112% and 127% of the annual mean yields and on location C between 72% and 94%. For most crops, the difference of mean yields between locations A and C is significant at the 1% level. It can thus be concluded that soil depth has an influence on crop production. However, it must be kept in mind that soil depth is not necessarily the only factor having a positive influence. Associated factors such as water storage, rooting conditions and accumulated soil material and nutrients just above a conservation structure also influence soil productivity. Further factors that have a positive influence on crop yields on location A could be the accumulation of seeds and fertiliser from higher parts of the same field. In all localities, farmers stressed problems related to conservation structures, such as waterlogging, weeds spreading from the vegetated structures, and pests spreading from the structures. However, despite these negative side effects of permanent physical conservation structures, yields are considerably higher above than below conservation structures. The positive effects of soil conservation thus clearly offset the negative side effects – except for the land occupied by conservation structures (cf. Table 33).

***Linear regression functions*** are calculated, linking crop yield (actual yield is converted to a percentage of the respective annual mean to exclude climatic variations or damages by pests and diseases) with soil depth and slope gradient. If taking all crop types and all sampling locations together and keeping slope gradients constant, yield changes per one centimetre of soil loss are in the order of –0.25% in Maybar, -0.62% in Andit Tid, and –0.16% in Anjeni. From the regression functions calculated per crop according to sampling location, no clear picture emerges as to which factor – soil depth or slope inclination – is more important. In addition, only few of the estimates for soil depth or slope gradient are statistically significant. In Maybar and Andit Tid, the signs of the estimated parameters – positive for soil depth and negative for slope gradient – are in most cases as expected. Anjeni does not show such a clear tendency. Here, increasing slope gradient can have a positive effect on yields, which would support the observations of increasing damage to crops caused by waterlogging in flat areas. As slope inclinations increase, the danger of stagnant water decreases. For individual crops on different sampling locations, the model as a whole only rarely proves to be significant. Weak to very weak correlations, usually explaining less than 10% of the yield variation by the two chosen parameters, indicate that other factors than the two selected are important for explaining yield variations.[368] Most probably, management aspects are also important. This hypothesis is supported by research done on the topic in different areas of the Ethiopian Highlands.[369] Other aspects to consider when looking at the very low $R^2$ are (i) the number of samples and (ii) the big variation of crop yields. This poses some problems for the calculation of linear regressions, as outliers heavily distort the outcome. However, one cannot stress enough that the enormous variability of crop yields shows what a difficult situation farmers operating in these challenging environments are facing. Yields (mean annual yields expressed as a percentage of the mean yield of that specific crop over the observation period) can vary between 20% and 200% of the long-term average yield!

***Yield changes over time*** are estimated to be in the order of -1.5% per year in Maybar and -2.4% per year in Andit Tid. In Anjeni, if fertiliser is applied, the estimated yield change is +2.9% per year, and if yields are corrected accordingly, it is +0.6% per year. Annual yield declines due to decreasing soil depth are thus only a fraction of the general yield declines, at least in Maybar and Andit Tid. As rainfall did in general not decrease but rather increase, a deterioration of climatic conditions cannot really be made responsible for yield declines. Most probably, the main reason for declining yields is soil degradation in general, also including chemical and biological degradation, as well as physical degradation not captured by the proxy indicator 'soil depth', such as changes in soil structure. Unfortunately, not enough detailed and long-term data is available to confirm this hypothesis. Although yield trends over the observation period are calculated, it must be stressed once more that the yield - time relation is rather weak. $R^2$ is generally very low, pointing at the big variation of yields. The calculated trend could easily be changed just by considering one year more or less.

Combining the yield declines per one centimetre soil loss calculated above and the observed soil erosion rates as measured on test plots and experimental plots, ***annual yield declines as a result of soil erosion*** can be postulated. On unconserved land, annual yield declines can be expected to be in the order of -0.07% in Maybar, -0.91% in Andit Tid, and -0.23% in Anjeni. Productivity losses for Ethiopia estimated by other authors range between 0.4% and 3% annually.[370] Other studies also including nutrient loss due to the use of dung and crop residues for fuel range between 0.4% and 0.8% per year.[371] The annual productivity decline in Maybar, which is very low not only with regard to the other two research sites but also with regard to productivity declines established by other authors, can be explained by rather low erosion rates of 28 t/ha*a. One centimetre of soil loss is thus reached only in about three years. Mean soil loss rates in Andit Tid and Anjeni are above 140 t/ha and year. This means that more than 1 cm of soil is lost per year, leading to the postulated considerable yield declines. Results from experimental plots, where the effect of different conservation technologies on soil loss, runoff, yield, and total biomass production is studied, shows that soil loss is reduced considerably by between 55% and 68% on conserved plots as compared to unconserved control plots within about 4 years after the construction of plots. If this reduction is taken for estimating soil loss and its effect on

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368 These results are not much different from other research findings, where $R^2$ of linear regressions linking time series data of maize yield to erosion rates are in the order of 0.03 and erosion rates have no significant influence on the time trend of yields. (Grohs, 1994, 74)

369 e.g. Schläfli, 1985; Yohannes G/Michael, 1989.

370 Bojö, 1996, 168;

371 e.g. Sutcliffe, 1991, 20.

conserved land, annual yield declines were as low as -0.04% in Maybar, -0.37% in Andit Tid, and -0.07% in Anjeni.

Annual productivity losses calculated on the basis of SCRP data range between -0.07 and -0.91% and are similar to other estimates. Soil loss as measured on erosion plots only shows the general situation. Soil loss after ***extreme single events*** leading to the formation of rills can easily reach 120 mm of topsoil loss on a damaged area of 10% of a field. Over the years, such concentrated soil loss contributes substantially to reducing the overall soil depth, as farmers try to level out rill damages through careful ploughing. Total soil loss from a field must therefore be expected to be greater than soil loss measured on erosion plots. Consequently, annual yield declines would also be bigger. Again, it has to be mentioned that for the regression functions, only topsoil depth has been considered. Other effects of soil erosion on soil properties as well as nutrient mining through continuous cultivation are not considered. Thus, physical soil conservation can partially control soil erosion, but not soil degradation. With soil conservation alone, yield declines can thus not be reduced to zero or even changed to increasing yields as long as farmers continue to use the land in an exploitative manner.

A simple ***soil life*** model is developed to demonstrate when a critical soil depth of 10 cm is reached under current erosion rates on unconserved and conserved land, taking into account current soil depth and assuming that farming practices remain the same as today. It is assumed that soils shallower than 10 cm show a drastic drop in productivity due to insufficient rooting depth and water and nutrient storage. This assumption can be supported by SCRP data, where only 0.5% of all yield samples were collected on soils with a soil depth of 10 cm or less within the research catchments. It can further be concluded that farmers stop cultivating such shallow soils because their labour and seed input would not be invested in a productive manner. Without soil conservation, under the above-mentioned assumptions, this critical minimal soil depth is reached in roughly 60 to 100 cultivation years in Maybar, in 20 cultivation years in Andit Tid, and 25 to 30 cultivation years in Anjeni. With soil conservation, the life span (i.e. the soil depth) can be maintained for another 150 to 240 cultivation years in Maybar, 35 to 60 cultivation years in Andit Tid, and 85 to 110 cultivation years in Anjeni. These calculations once more take into account only soil depth and soil erosion, and no other forms of soil degradation. If these other aspects of soil degradation were included in the calculations, it can be assumed that cultivating some of the soils that are already very shallow would prove to become uneconomical even earlier. Or, as the example from Anjeni demonstrates, farmers have to invest considerable amounts of money into fertiliser to at least keep yields at moderate levels – not to speak of increasing yields, which should be the ultimate goal of investing in soil fertility enhancement.

## 5.2 On-site Costs and Benefits of Soil Erosion and Conservation

*"The benefits of conservation are the reductions in the costs of erosion. Soil conservation cannot be assumed to completely reduce the effects of erosion [..but] may also have benefits additional to reduced erosion." (Clark, 1996, 2)*

In the previous Section 5.1 it has been shown what influence soil erosion has on crop production at the three research sites of Maybar, Andit Tid, and Anjeni. It was also shown that with physical soil conservation structures soil erosion can be reduced substantially. It could further be demonstrated that annual yield declines decrease considerably on conserved land, but cannot be reduced to zero. Neither does soil conservation increase total crop production on a field. In the following Section, different costs and benefits as used to evaluate the profitability of soil conservation in the cost-benefit analysis (CBA) will be discussed. The magnitude of these costs and benefits is essential for the valuation of conservation technologies and determines whether a technology is profitable or not.[372]

Whenever possible, market prices as prevalent in the three locations are used for the calculation of costs and benefits. Problematic in subsistence economies is that (i) even if there is a market and a price for certain goods, seasonal effects have a strong influence and prices can fluctuate considerably, (ii) many goods are bartered rather than sold and bought, and (iii) mutual exchange of labour and goods is important and has other than just economic meanings (e.g. is socially important to strengthen networks and social bonds). In the following Sections, it will therefore be mentioned which average price is used in the calculation, and whether it is an actual market price or a price calculated on the basis of opportunity costs.

As mentioned in Section 4.3, the main aim of a financial cost-benefit analysis is to examine the costs and benefits – or returns – of soil erosion and conservation as they accrue to the individual. It comprises those monetary costs and benefits associated with goods and services that can be exchanged on a market. These are valued at prevailing market prices without any adjustments made for distortions in the market (e.g. for inflation).[373] In subsistence economies, where usually only a small amount of goods and services is traded on markets, opportunity costs are used instead of market prices, if the latter are non-existing. So, for instance, crop production consumed by the household is valued at current market prices, which equal the income that could have been derived from selling the same amount of crops. Household labour is valued at market wage rates as paid in the locality,[374] which, at the same time, indicate what a person could have earned if he/she worked as casual labourer instead of working on his/her own farm.

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372 It is important to keep in mind that in the context of this CBA, the term 'profitable' is used from an outsiders' point of view ('external view') based on a certain economic understanding. It was hoped that extensive fieldwork would provide a better knowledge of how the land users concerned understand economic valuation, so that their views might be included into this study as much as possible and the results produced might approximate their situation as closely as possible. See also Section 6.2 for a discussion of some farmers' perception of SWC.

373 For any year, the nominal net benefit ($NB_t$) would have to be converted to year 0 values by $NB_t(1+p)^{-t}$, where p is the inflation rate (considered to remain constant over the whole period) and t the number of years since year 0. In the CBA, real net benefits would then also have to be discounted using the real rate of discount with a real rate of interest $i_r = [(1+i_n)/(1+p)]-1$, where $i_n$ is the nominal interest rate and p the inflation rate. (Hanley & Spash, 1993, 12) The inclusion of inflation rates has, however, been omitted, since the analysis compares different soil conservation technologies using the same input and output values and the same time frames, and therefore the analysis of the profitability of different technologies or uncontrolled soil erosion is relative.

374 Clark, 1996, 47.

### 5.2.1 On-site costs

On-site costs of soil erosion are defined as the present and future productivity lost through current erosive cultivation practices. For the case study sites of Maybar, Andit Tid, and Anjeni, production declines as a result of soil erosion have been discussed in the previous Section 5.1.3. The costs of soil conservation are mainly labour and material costs and foregone crop production.

For the different cases calculated in the CBA with and without soil conservation, two extreme situations are presented in addition to the average situation: one assuming maximum, and one assuming minimum production. This approach has been chosen because yield variances are big, both from year to year and within a given year, and mean values alone are therefore not very meaningful. In further analyses, ***maximum production*** is defined as mean yield plus one SD, and ***minimum production*** as mean yield minus one SD. ***Mean yields*** are calculated on the basis of yield measurements on farmers' fields at the three research sites (cf. Appendix 5.2). Yields as used in the CBA are further differentiated according to soil depth class and location in relation to conservation structures (cf. Appendix 5.4). Production declines are modelled using the regression functions developed in Section 5.1.3 (Table 17, 20 and 25).

For Maybar and Andit Tid, crop yields are valued at ***market prices*** of 1998/99. For Anjeni, no information was available on current market prices. They were therefore estimated on the basis of 1992 market prices[375] and market prices for the same crop in Maybar and Andit Tid. Table 32 gives an overview of average prices (EB/quintal) paid in 1998/99 for local products on the nearest market for Maybar and Andit Tid, average prices paid by traders, and the estimates used for Anjeni. On such local markets, products are usually traded in small quantities and measured in cans.[376] Bartering, i.e. the exchange of crops among farmers, is more important than selling, except when crops are sold to a trader. In the case of Maybar, the price level on the local market is roughly 23% higher than what traders pay. This could be explained by an overestimation of the value of their own products by farmers, as they usually barter but not sell. Traders, on the other hand, try to keep prices as low as possible when buying from farmers in order to make a high enough profit when selling on the nearest urban market. For the CBA, the lower price, i.e. the price paid by local traders, was used for the production valuation.

| | Maybar | | Andit Tid | Anjeni |
|---|---|---|---|---|
| Price paid per 100 kg / Crop | by trader | on local market | on local market | on local market |
| Tef | 210 EB | 240 EB | | 220 EB |
| Barley | 180 EB | 180 EB | 125 EB | 180 EB |
| Wheat | 190 EB | 220 EB | 180 EB | 190 EB |
| Maize | 110 EB | 150 EB | | |
| Bean | 160 EB | 210 EB | 190 EB | 160 EB |
| Pea | 180 EB | 210 EB | | |
| Lentil | | | 350 EB | |
| Linseed | | | 175 EB | |
| Noug | | | | 250 EB |

*Table 32: Average prices (EB/quintal) 1998/99 on local markets or paid by local traders in the three localities of Maybar, Andit Tid, and Anjeni.*
*[Source: Own investigation 1992, 1998, and 1999]*

375 Ludi, 1997, 40.

376 In order to determine the average price per product, cans from different people were filled and weighed, and people were asked for how much they would sell this quantity. (cf. Appendix 5.5)

At the three sites, no markets exist for straw, which is an important animal feed, and like grain, is influenced by soil erosion and soil conservation (cf. Appendix 5.4 for average straw values). It is assumed that 2,300 kg of dry matter is sufficient to feed one ox (i.e. one Tropical Livestock Unit, TLU) during one year.[377] Thus, straw was valued by using the price of EB 800 paid in Maybar and Andit Tid for an ox already trained for ploughing.

A critical point to consider are price fluctuations or government interventions in agricultural markets, which can have a significant impact on farm-level incentives for soil conservation. It is often argued that government regulations, which keep ***producer prices*** artificially low, create a disincentive to invest in land husbandry.[378] However, price changes can have a controversial impact: an increase in output prices can create an incentive for increased soil erosion through the use of more inputs, intensification, or the expansion of cultivation land to new areas, which are usually more fragile and erosion-prone. On the other hand, price increases – if perceived as of longer duration by land users – can create incentives to conserve more soil for future production.[379] Another aspect to consider are ***relative prices***. It can be observed that different crops lead to different soil loss rates. Results from test plots in the three research sites show that in Maybar mean annual soil erosion rates are highest in cases where emmer wheat is followed by horse bean in the second cropping season (36.9 t/ha*a). Maize, which is grown over two cropping periods, leads to less erosion (28 t/ha*a). If only crops are considered, but not fallow or grass, *Belg* barley followed by horse bean leads to the smallest mean annual soil loss (18.9 t/ha*a).[380] Similar situations can also be observed in Andit Tid, where wheat and lentil lead to considerably higher mean annual soil losses than barley.[381] In Anjeni, it could be shown that wheat and tef lead to higher mean annual soil losses than barley or horse bean.[382] It could thus be that if the price for a crop leading to comparably high erosion rates increases considerably, farmers cultivate more of this crop, thus increasing overall soil erosion rates. However, in the case of the three research areas, the problem might be less serious, as farmers sell only small quantities of their production and produce mainly for their own use. Their motivation to cultivate a specific crop is therefore targeted rather towards meeting household needs or securing a good crop rotation cycle than towards profiting from market price changes. For this reason, relative prices and crop mix are kept constant in the CBA over the whole time period considered. In order to capture price fluctuations and to evaluate whether changing price levels have an influence on the profitability of soil conservation investments, a sensitivity analysis is carried out where prices are changed by ±20% for output (farm production) prices and +67% and -33% for input (fertiliser) prices (cf. Section 6.1.5).

***Costs of production loss without soil conservation***

Two different cases are modelled for the situation without soil conservation. The first case considers only ***sheet erosion***. In this case, soil loss as measured on test plots is translated into millimetres of soil depth reduction and then used to calculate yield declines according to the equations developed in Section 5.1.3. Unfortunately, the number of untreated erosion plots available in the three research areas is not sufficient to allow the derivation of slope-specific soil erosion rates. It was assumed that soil loss rates differ according to slope inclination. In the CBA, the following assumptions are made:

- on gentle slopes (0 to 8% slope gradient), soil loss rates are in the order of mean soil loss as measured on untreated test plots minus one SD,
- on medium steep slopes (9 to 30%), soil loss rates would be in the order of mean soil loss, and
- on steep fields (>30%), soil loss rates would be mean soil loss plus one standard deviation (cf. Table 28 for mean soil loss rates and standard deviations for the three research sites).

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377 Taylor, 1984, 32.

378 Repetto, 1988, quoted in Eaton, 1996, 10.

379 Eaton, 1996, 10.

380 SCRP, 2000d, 42.

381 SCRP, 2000b, 41: wheat (n=7): 185.1 t/ha*a, lentil (n=12): 180.0 t/ ha*a, barley (n=10): 141.1 t/ ha*a.

382 SCRP, 2000c, 40: wheat (n=4): 192.6 t/ ha*a, tef (n=6): 178.3 t/ ha*a, barley (n=5): 111.9 t/ ha*a, horse bean (n=3): 115.5 t/ ha*a.

The division in these three slope classes with the corresponding annual soil loss rates is based on the following assumptions: The division in the three slope classes is based on the FAO-UNESCO Soil Map of the World.[383] The reason for such a rough division is that although slopes would be available in a much higher resolution from the measured fields, corresponding soil loss rates are not available. It would have been possible to calculate slope-specific soil loss rates based on the USLE formula adapted to the Ethiopian Highlands,[384] however a comparison of calculated values and actually measured values showed that calculated values are much lower than measured values, especially in Andit Tid and Anjeni.[385] It was thus decided to base the CBA on actually measured values, knowing that annual soil loss might be overestimated. Annual soil loss rates on TPs vary considerably from one year to another. Reasons for this big variation (e.g. in Maybar between 0.7 t/ha and 118 t/ha on the same TP) are manifold and include rainfall in relation to crop cover, date of sowing, crop type, soil type, and exceptional rainfall events. Generally speaking, the measured values are all influenced by specific circumstances, which cannot be reconstructed precisely and which cannot be modelled in the CBA. For the CBA, it was necessary to use soil loss rates that would depict the general situation in a locality as good as possible. Because the variation of annual soil loss rates on a specific TP over the years is very big, because only few plots on different slopes are available, and because gentle slopes are not represented by TPs at all, absolute values from TPs with specific slope gradients could not be used to represent the soil loss in the different slope classes. It was thus assumed that on medium steep slopes mean soil loss as calculated based on all cultivated TPs would represent the overall situation in a research area best, knowing that singularities exist, which have a great influence on the actual soil loss. A slight tendency of increasing soil loss with increasing slope gradient can be observed on TPs, especially in Maybar and Anjeni. In Andit Tid, the two steepest TPs are characterised by much lower mean soil loss than the gentler TPs. These two plots, however, are special cases because of the soil type and the crop rotation cycle taking into account the steepness of the plot.[386] For steep slopes (above 30%) it was assumed that soil loss would be in the range of mean soil loss plus one standard deviation. Such high soil losses can occur even on gentler slopes. However, it was assumed that they occur more frequently on steep slopes. On gentler slopes below 9% gradient, it was assumed that soil loss would be in the order of mean soil loss minus one standard deviation. Again, such a low soil loss can occur on steeper slopes as well, but it was assumed that on gentler slopes soil loss is lower than on medium steep slopes.

A weakness of the equations developed in Section 5.1.3, whereby production is related to soil depth using a linear regression, is that even in the case of extremely shallow soils, production levels are still considerably high. However, it must be assumed that soils shallower than 10 centimetres do no longer produce enough yield to be economically viable from a farmer's point of view, and that farmers usually stop cultivating such land. This hypothesis is supported by the fact that hardly any yield data is available from fields with a soil depth of 10 centimetres or less.[387] In the CBA, this phenomenon is modelled by including a control variable once the soil depth has reached 10 cm forcing yields to gradually drop to zero.[388]

The second case also takes into account ***rill erosion***. It is assumed that in addition to sheet erosion, rills develop in regular intervals. It is further assumed that these rills are found always in the same location of the field. Different factors are responsible for the occurrence of rills, and these factors are usually bound to a specific location (e.g. a broken bund, a footpath, or an adjacent degraded grazing area). Based on rill

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383 Landon, 1991, 37

384 Hurni, 1985, 11.

385 e.g. mean measured values on a TP in Andit Tid with a slope gradient of 39%: 212 t/ha, calculated value on a 40% slope: 68 t/ha. Similar differences also exist in Anjeni with measured mean soil loss on a 12% slope of 213 t/ha and a calculated mean annual soil loss of 20 t/ha on a 10% slope. In Maybar measured and calculated values are similar: on a TP with 16% slope gradient the measured mean annual soil loss is 22 t/ha and the calculated value is 24 t/ha. (Assumptions for the USLE: R: according to annual rainfall: MA: 666, AT: 778, AJ: 890, K: 0.2, L: 0.85, S: variable according to slope gradient, C: 0.15, P: 0.9)

386 SCRP, 2000b, 39.

387 cf. Footnote 352.

388 Control variable: 1 for soil depth >10 cm, 0.8 for soil depth 8-10 cm, 0.6 for soil depth 6-7.9 cm, 0.4 for soil depth 4-5.9 cm, 0.2 for soil depth 2-3.9 cm and 0 for soil depths <2 cm.

mappings from three research sites, mean soil depth decrease was estimated at 120 mm on a damaged area of 10% of the field considered.[389] It is not only the soil loss one has to consider in further calculations, but also the damage done to the crop itself. For the season in which the damage occurs, the yield is considered zero on 10% of the field, because soil and seed is washed away. As long as rills are not too deep, they can be ploughed in during the next ploughing season. It is assumed that the rill damage is spread to 30% of the field. For the coming seasons, the soil depth on 30% of the field will thus be reduced by 40 mm. It is further assumed that such rills occur in regular intervals depending on the crop rotation cycle: in Anjeni, in seasons 4, 8, 14, 18, etc., in Maybar, in the upper part of the catchment every 5th season, and in the lower part of the catchment every 6th season. In Andit Tid, rill damage occurs every 6th season. Because rills always damage the same part of a field, the soil depth rapidly decreases to zero in this area. After some years, 30% of the field is lost permanently for crop production.

***Costs of production loss with soil conservation***

**Introduced SWC**

One of the main negative aspects of introduced conservation technologies mentioned by farmers is that ***SWC structures occupy a large portion of the field***. If SWC structures are constructed according to the *Guidelines for Development Agents on Soil Conservation in Ethiopia,* the area occupied by SWC structures is in fact considerable, as shown in Table 33. The number of conservation structures, thus the area of occupied land, depends on (i) the slope gradient of the field and (ii) the depth of the reworkable topsoil layer. The formula generally applied in Ethiopia takes into account that (i) only as much land should be occupied by conservation structures as necessary, and (ii) terrace development is only possible if there is enough soil material to build them up. The vertical interval (VI, [cm]) between two conservation structures is 2.5 times the reworkable soil depth for slopes with a gradient of 15% or more, and 100 cm for slopes below 15% gradient. The horizontal distance [m] between two structures is defined by the vertical interval VI divided by the slope gradient [%]. Conservation structures are built continuously along the contour without taking into account field borders. In high rainfall areas, graded structures with a gradient of 2-5% are constructed to drain water laterally to the next natural or artificial waterway.

Taken the mean soil depth per slope class (only location B), the following land loss has to be expected if the field size is set to 100 by 100 m and the width of a structure is assumed to be 1 m:

*Figure 39: Introduced SWC in Anjeni. The spacing between two conservation structures is according to slope gradient and soil depth Clearly visible are the artificial waterways between fields to drain excess runoff. [Photo: E. Ludi, 1992]*

[389] These figures are median values for soil loss per actual damaged area (mm) and for area of actual damage (in %) from rill mappings done in Maybar, Andit Tid, Hunde Lafto, and Gununo (n varies between 227 and 364). (Herweg & Stillhardt, 1999, 35)

| **Slope class** | **Slope gradient [%]** | **Mean soil depth [cm], location B** | | **Vertical interval [cm]** | | **Horizontal distance [m] (approx.)** | | **No of structures per 100 m = % land loss (SWC structure = 1 m wide)** | |
|---|---|---|---|---|---|---|---|---|---|
| **Maybar** | | | | | | | | | |
| 1 | 0-2 | | 28.5 | | 100 | | 50 | | 2 |
| 2 | 3-5 | | 29.2 | | 100 | | 20 | | 5 |
| 3 | 6-8 | | 41.3 | | 100 | | 12.5 | | 8 |
| 4 | 9-15 | | 38.8 | | 100 | | 6.7 | | 15 |
| 5 | 16-30 | | 38.9 | | 100 | | 3.3 | | 30 |
| 6 | 31-60 | | 31.3 | | 75 | | (1.25)/3.3 | | (60)/30 |
| 7 | >60 | | 30.4 | | 75 | | (1.25)/3.3 | | (60)/30 |
| **Andit Tid, U= upper part of the catchment, L = lower part of the catchment** | | | | | | | | | |
| | | U | L | U | L | U | L | U | L |
| 1 | 0-2 | . | 41.0 | . | 100 | . | 50 | . | 2 |
| 2 | 3-5 | . | 43.2 | . | 100 | . | 20 | . | 5 |
| 3 | 6-8 | . | 30.8 | . | 100 | . | 12.5 | . | 8 |
| 4 | 9-15 | 47.0 | 32.8 | 100 | 80 | 6.7 | 5 | 15 | 20 |
| 5 | 16-30 | 44.0 | 31.7 | 110 | 80 | 3.7 | (2.7) / 3.3 | 27 | (37)/30 |
| 6 | 31-60 | 41.3 | 33.6 | 100 | 80 | (1.7)/3.3 | (2.7)/3.3 | (58)/30 | (37)/30 |
| 7 | >60 | . | . | . | . | . | . | . | |
| **Anjeni** | | | | | | | | | |
| 1 | 0-2 | | . | | . | | . | | |
| 2 | 3-5 | | 64.7 | | 100 | | 20 | | 5 |
| 3 | 6-8 | | 64.0 | | 100 | | 12.5 | | 8 |
| 4 | 9-15 | | 58.1 | | 100 | | 6.7 | | 15 |
| 5 | 16-30 | | 46.3 | | 115 | | 4 | | 25 |
| 6 | 31-60 | | . | | . | | . | | . |
| 7 | >60 | | . | | . | | . | | . |

*Table 33: Number of conservation structures according to slope gradient [%] and mean soil depth [cm] in the three research areas.*
*(Mean soil depth is calculated for location B only. Number of samples (n) per slope class must be >10 to be included)*
*[Data source: SCRP Primary Database]*

Figures in brackets indicate the calculated value. In cases where the horizontal distance between two conservation structures is less than 3 m, the result is censored and set to 3.3 m, i.e. to a maximum of 30 conservation structures per 100 m field length. If a conservation structure is assumed to be 1 m wide, this would translate into a land loss of 30%, which is already far above what farmers would accept.

**Adapted SWC**

From field observations made at the three research sites and from studies conducted specifically on the topic of adoption and adaptation of introduced SWC technologies and indigenous SWC technologies and land management practices,[390] it becomes apparent that today – 10 to 15 years after they were first established – the layout of conservation structures has changed considerably. For the CBA, it is assumed that the number of conservation structures in the case of adapted SWC is about one third of the number considered for introduced SWC. From the farmers' point of view, introduced SWC occupies too much precious arable land, and its construction and maintenance require too much labour. Therefore, in the case of adapted SWC, farmers have reduced the number and/or length of conservation structures to optimise the soil conservation aspect on the one hand and the amount of land occupied by conservation structures on the other hand.

[390] Yohannes G/Michael, 1999.

However, it must be expected that in the case of adapted SWC the soil conservation effect is considerably smaller than in the case of introduced SWC.

The process of adaptation of introduced SWC to adapted SWC can be distinguished in three cases:

**Case 1 – Removal of all conservation structures**

Removal of all conservation structures can be observed in all three locations, however, in the upper part of the catchment in Andit Tid it is more frequent than in other parts of the catchment or in the other research areas. As a reason for ploughing under all SWC structures in the *Dega* area of Andit Tid, farmers mentioned that the land is only cropped every third or even fourth year, and used as grazing land in the other years. During this time, animals destroy conservation structures. Therefore, maintenance would be too labour consuming, especially considering the fact that the land is not cultivated continuously. A second reason mentioned is that because the land is left fallow for two to three years, soil fertility does not diminish as fast as in other areas, and soil erosion is less a problem thanks to the closed vegetation cover during fallow periods. A third reason mentioned is that in this high rainfall area, continuous SWC structures lead to waterlogging and thus to damage to crops. In the other areas, the major reason for destroying all SWC structures is the big portion of land lost for crop cultivation, which is not justifiable in light of the low erosion rates and the resulting low yield decline.

**Case 2 – Modification of the original layout**

In Anjeni, farmers reported of having removed every second structure on steeper land and two out of three structures on flatter land. In Andit Tid, some farmers removed parts of continuous conservation structures to make ploughing easier. A system of staggered structures is clearly preferred over continuous structures. The system of staggered structures (*Dibe* in Amharic) serves the following purposes:[391]

(i) Staggered structures serve as an enforcement of fixed structures, which are usually widely spaced. They therefore control dispersed and concentrated runoff.
(ii) They present less of an obstacle to ploughing with a pair of oxen than continuous structures.
(iii) They can be applied on different soils. Being short, they do not lead to waterlogging problems.
(iv) They can be applied on different soils and being short do not lead to waterlogging problems.
(v) When combined with supplementary technologies, they can be used both to drain and to harvest water. During the spring rainy season (*Belg*), they serve to harvest water, and during the main summer rainy season (*Kremt*), in combination with traditional drainage ditches they serve to drain excess water.
(vi) The danger of damage by water or livestock is minimised, as both can pass between the structures. This reduces maintenance costs.
(vii) They are easy to move, i.e. to destroy and rebuild just below the former location.

Especially in Maybar, this last case of moving conservation structures can be observed frequently. After sediments have accumulated behind a structure, farmers destroy it and reconstruct it a little further downslope. The accumulated soil is spread over the field and used as fertiliser. The main reason given for this technology is that although yields are higher just behind the structure, total crop production on the whole field does not necessarily increase, as only part of the accumulated soil material has an influence on soil productivity. Farmers mentioned that the overall production of the plot can be improved by dismantling and rebuilding structures and spreading the accumulated soil over the whole field. Farmers decide on moving conservation structures according to several criteria that indicate when such a move is necessary or favourable:[392]

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391 Yohannes G/Michael, 1999, 91.

392 Yohannes G/Michael, 1999, 97.

(i) When the area behind the structure is filled up and overflow of water occurs.
(ii) When overall production of the plot diminishes.
(iii) When the grass harvest from the structure becomes poor.
(iv) When rodent populations in the SWC structures increase. This is an indication that the soil behind the structure has become fertile.
(v) When some of the structures develop to bench terraces, then other structures can be removed without increasing the erosion problem.
(vi) It is often easier to construct new than to maintain old ones.
(vii) When land is leased for a short period and the lessee wants to maximise profit he removes some of the structures.

*Figure 40: Moving bunds in Maybar. The stone bund has been dismantled and is reconstructed about 2 m downslope. The accumulated soil from behind the bund is distributed over the field. [Photo: E. Ludi, 1999]*

Usually, moving SWC structures are combined with fixed structures at the top and at the bottom of a field. To minimise soil erosion, structures are usually moved before the *Belg* rainy season, when rainfall is less intensive than during the *Kremt* rainy season. From the farmers' point of view, what counts most is that (i) this type of conservation structures occupies less area than if the original structures were maintained, and that (ii) they can make use of the accumulated fertile topsoil behind the structure by spreading it over the field. Farmers also argue that if topsoil is kept behind a structure and becomes deeper than about 100 cm, it no longer has any positive influence on crop yield. However, it is questionable whether this technology can control soil erosion sufficiently and whether the positive impact of distributing the accumulated soil over the field on crop yield is as big as farmers mention.

**Case 3 – Maintenance of all conservation structures without modifications**

In this third case, farmers have kept all conservation structures intact. This group, however, is rather small in all three research sites.

***Drainage ditches*** are a form of traditional conservation that can be observed in most highland areas. Especially in the Anjeni area, this is the only form of traditional conservation that can be observed. In the other areas, drainage ditches are combined with physical SWC structures. The primary purpose of these drainage ditches is not soil conservation, but drainage of excess water. A study conducted in Anjeni[393] shows that traditional ditches in combination with Fanya Juu bunds reduce problems of waterlogging by draining excess water to the next waterway bordering the field. The effect of the combination of Fanya Juu bunds and drainage ditches on yield and biomass production was slightly positive. It could also be observed that in the case where drainage ditches were lacking and maintenance of Fanya Juu bunds (e.g. emptying ditches below the bunds, rising bund height) was neglected, excess runoff overflowed bunds and caused erosion damage on cultivated land downslope. A second experiment was conducted on a plot that was treated only with traditional ditches. A control plot had no conservation structures and no drainage ditches at all. Three rainfall events were monitored. Soil loss was estimated using the procedure of rill mapping (ACED, cf. Section 5.1.6). Soil loss on the control plot ($UT_0$) was considerably higher than soil loss on the plot with drainage ditches ($UT_1$). Absolute cumulative values (in t) for the three rainfall events are 22.13 t for the $UT_0$ plot and 1.02 t for the $UT_1$ plot respectively. Rills observed and mapped on the two plots are distinctively different, as on the $UT_0$ plot runoff was not intercepted. On the $UT_1$ plot, every 5 m drainage ditches collected runoff and drained it to the field border. Flow velocity could thus not increase in the same manner as on the $UT_0$ plot, and rill development was less pronounced. Although the absolute soil loss from the two plots differs remarkably, it must be kept in mind that only three rainfall events were monitored. These results do not allow the conclusion that drainage ditches are sufficient to control soil erosion in high rainfall areas such as Anjeni. On the contrary: Long-term observations indicate that the soil loss reduction resulting from drainage ditches is not more than 10% compared to the case where no ditches are applied.[394] This is certainly in no way sufficient to control the high to very high soil losses. Farmers usually mentioned that yields from fields with traditional ditches are higher than from fields with no treatment or from fields with introduced conservation, such as Fanya Juu bunds. Results from the above-mentioned experiment show that although erosion rates are considerably higher in the case where ditches are absent, the yield difference is not significant. One of the main problems with traditional ditches is that if their layout is not properly done (e.g. if the gradient is too steep, or suddenly diminishes), the damage often outweighs the advantage. If gradients are too steep, runoff is concentrated in the ditches and flow velocity is high, which can lead to rill and later gully formation. If gradients diminish, flow velocity suddenly decreases, sediments are deposited and water overflow damages downslope areas. Unfortunately, no erosion assessment was done on the plots with combined introduced SWC and drainage ditches. It is therefore not possible to isolate the effect of drainage ditches on soil erosion rates.

Unfortunately, no long-term monitoring of soil erosion and yield comparable to the monitoring done on the experimental plots has been conducted for cases where part of the original conservation structures were removed or changed, or for cases where traditional systems, such as staggered structures, are prevalent. It can therefore only be hypothesised what the effect of these adapted systems on yield and soil loss could be. For the CBA, it is assumed that with adapted systems, which involve fewer structures, annual soil loss can be reduced to 50% of the reduction achieved with introduced SWC technologies. In the case of adapted SWC, annual soil loss in Maybar, Andit Tid and Anjeni would therefore be reduced by 28%, 30%, and 34%, respectively (cf. Table 30 for the corresponding figures for introduced SWC).

As traditional systems or adapted introduced systems – in the following, the term adapted system will be used for both – concentrate on critical locations and aim at minimising land loss, it is assumed that the land loss would be only 1/3 of the land occupied in the case of introduced SWC structures. On the other hand, compared to introduced SWC technologies, the area behind conservation structures,[395] which generally produces the highest yield, is smaller. The following Table 34 gives an overview of the estimates of how much land is occupied in total by introduced and adapted conservation structures and how much of the remaining

393 Million Alemayehu, 1992.

394 Hurni, personal communication, January 2001.

395 This area corresponds to the sampling location A (cf. Figure 32).

land can be found in which category (A: above the structure, B: in between two structures, C: below the next upslope structure), depending on slope class.

| | | Slope class | | | | |
|---|---|---|---|---|---|---|
| | **Conservation System** | 1 (0-2%) | 2 (3-5%) | 3 (6-8%) | 4 (9-15%) | 5 – 7 (>15%) |
| **Total land occupied by SWC structures** | adapted | 2% | 2% | 3% | 5% | 10% |
| | introduced | 2% | 5% | 8% | 15% | 30% |
| **Remaining land** | | | | | | |
| **A Above the bund** | adapted | 9% | 9% | 9% | 10% | 10% |
| | introduced | 25% | 24% | 23% | 21% | 18% |
| **B Between two bunds** | adapted | 80% | 80% | 79% | 75% | 70% |
| | introduced | 48% | 47% | 46% | 43% | 34% |
| **C Below the bund** | adapted | 9% | 9% | 9% | 10% | 10% |
| | introduced | 25% | 24% | 23% | 21% | 18% |

*Table 34: Total land [%] occupied by conservation structures and percentage of remaining arable land per sampling location for introduced and adapted SWC.*
*[Source: Own compilation]*

***Labour costs***

Valuation of labour for investments in soil conservation is subject to controversy. Fortunately, the argument is seldom heard anymore that ***opportunity costs of labour*** for subsistence farmers for soil conservation investments are zero. However, there are still arguments that if conservation takes up leisure time and no other activity is reduced, opportunity costs can be assumed to be zero.[396] These arguments specifically mention working parties, which they classify as social occasions. Against this position stands the argument that *"even if the farmer has nothing else to do he might prefer to sit in the shade, rather than to work in the sun"*.[397] According to this argument, leisure time is not defined merely by the absence of productive work and therefore as having no economic value. On the contrary, it must be considered an integral part of life also for a subsistence farmer. Therefore, it cannot be assumed that farmers are willing to spend their leisure time doing unpaid conservation work, be it within the framework of a project or as a member of a working party. Furthermore, it is sometimes argued that labour invested in soil conservation activities is a benefit, apparently reducing unemployment or at least seasonal underemployment.[398] If this were the case, a positive contribution to income would have to be assumed, and labour invested in soil conservation would not be a cost factor but a benefit. This could only be the case if either production increases resulting from SWC investments were very high, or if farmers were paid by a project for their labour contribution (Food-for-Work (FfW) or Cash-for-Work (CfW)). More often it is argued that opportunity costs for labour exist, but are lower than normal wage rates, because conservation activities can be carried out during the dry season, where there are little farm operations to perform and less opportunities for casual work exist.[399] Farmers, however, do not necessarily consider this period as a slack season per se. In the Ethiopian Highlands, this is the time when other non-farm or off-farm activities are carried out. In Maybar for example, this is the time when many farmers temporarily migrate to lowland areas to work as farm labourers. In Andit Tid, it is the time when farmers are engaged in trading, by buying comparably cheap highland crops and selling them on markets farther away in the lowland. Thus, their labour has a clear value, which is at least as high as the daily income they could earn by engaging in these other occupations. Moreover, the dry season is not only a time when specific off-farm income activities are carried out. It is also a peak time for social activities such as weddings, visiting family members or maintaining

396 e.g. Stocking & Abel, 1992, 209.

397 Baum et al., 1999, 7.

398 Enters, 1998b, 25.

399 Stocking & Abel, 1992, 207.

and constructing houses. And lastly, not all conservation activities can be carried out during the dry season. It is mainly major construction work that can be performed during that period. Maintenance activities, which are at least as important as the construction of structures itself, have to be carried out in times of high labour demand during the rainy season. Opportunity costs of labour thus run high.

Labour costs differ considerably according to ***wealth, age, gender, and education***.[400] Poor farmers often apply different strategies than wealthier farmers. As poor farmers generally possess less land, they are more often engaged in off-farm activities such as petty trade. Rich farmers, on the other hand, are typically older, have a bigger family that can supply the necessary labour, and are themselves more often engaged in religious or political affairs. It is also the rich farmers who can afford to hire daily labourers to do the farm work. Age plays a role because younger farmers usually have better chances of finding off-farm employment than older farmers. Their opportunity costs might be quite high, depending on the demand for casual and seasonal labour. In Maybar, for example, there are many young farmers who work as seasonal labourers on coffee plantations in Southern Ethiopia. There they earn quite substantial amounts of money. Their opportunity costs of staying at home and being involved in conservation activities would therefore be rather high. Education in rural Ethiopia plays a role in determining the opportunity costs of labour mainly because the number of formally educated people is still very low. People with formal education are often involved in the local administration, albeit still without payment. The time they have to devote to those jobs is substantial and reduces the available time for fieldwork considerably. The value of female labour is more difficult to estimate, as hardly any options exist for women in rural areas to engage in off-farm labour, except for widows brewing beer and running *talla*-houses.

Although there are only few opportunities for ***off-farm work*** in the research sites, people are quite mobile when there is a possibility for casual labour. Especially young farmers mentioned that if they hear about any activity where unskilled labour is required, such as road construction or road maintenance, they go there, even if it requires several days' travel. Usual daily wages paid for such work are EB 5. Similar daily wages are paid for farm labourers on sugarcane farms in the lowland surroundings of the study sites.

Only few farmers in the research sites are in a position to employ daily labourers. Usually, older farmers with no sons in the vicinity employ neighbours for certain farm operations. This way they can keep the land instead of having to lease it out. Few female-headed households do not lease out all the land but keep one or two parcels and employ daily labourers. Usually, farmers pay daily labourers a daily wage of EB 5. This does normally not include food and beverage. Instead of paying in cash, it is more common to pay in kind worth about EB 5.

Today, two different soil conservation approaches are applied in Amhara Region. On the one hand, there is still the ***Food-for-Work approach***, but only in areas that suffer from food deficits, be it episodical as a result of drought, or structural as a general imbalance between production level and demand. In areas where production is not negatively affected and people are considered not dependent on food aid, soil conservation is carried out by ***compulsory community work without remuneration***. Each household is required to provide one adult worker for a certain number of days per year. Each community can organise the work according to its needs. In the communities visited, farmers are required to work 1 day per week during about 3 months from the end of January to the beginning of May. In addition to this regular work, the agricultural extension agent (Development Agent, DA) can order community members to come together for special tasks. Such compulsory conservation work takes up about 12 to 15 days annually per household. The workers usually carry out larger-scale conservation activities on communal land, such as the construction of cut-off drains, maintenance of footpaths and roadsides, gully reclamation, tree planting, or the development of irrigation schemes. It is expected that farmers invest family labour additionally for the conservation of their own land. In the case of compulsory community involvement, the opportunity costs of labour are similar to what must be estimated for individual labour investments. In the case of Food-for-Work, the labour costs are equivalent to the value of the grain and edible oil distributed to the participants. Norms applied in Ethiopia for

400 Stocking & Abel, 1992, 211.

environmental rehabilitation and road-building activities are 3 kg grain and 120 g vegetable oil.[401] This has a value of slightly over EB 5.[402]

For the ***valuation of household labour***, both for labour invested in farm operations and for labour invested in soil conservation activities, opportunity costs of EB 5 per day are applied. Additionally, a second case is considered, where labour costs are valued at EB 2.5 per day for conservation activities. This applies in cases where farmers receive some form of compensation for their labour invested in SWC, such as tools, if they are partially paid, or if they receive preferential treatment or subsidies for farm implements or inputs in return for labour investments in soil conservation.[403] However, it has become apparent in past decades that subsidising or totally covering labour costs for environmental rehabilitation such as soil conservation or hillside plantations under insecure land tenure regimes and coercion is problematic. Experiences made during the 80's with large-scale conservation schemes carried out with FfW have shown that for poor subsistence farmers, the main motivation to participate in those conservation schemes was the food received rather than the conservation activities carried out.[404] Conservation structures on farmland were often maintained only as long as either reimbursements were provided in the form of FfW, or as long as the local administration exerted some pressure. Today's policy therefore suggests to use FfW only in areas with severe food shortage, where humanitarian aid is required in any case. In all other areas, farmers are to work a certain number of days per year without remuneration, since it is believed the farmers will ultimately profit from environmental rehabilitation. However, investments in soil and water conservation or other environmental rehabilitation schemes such as afforestations or hillside closures, are not only in the interest of the concerned land users, but also in the interest of the state and the private sector. These interests are two-fold: firstly, there is a direct interest of the state and the private sector to control soil erosion in order to prevent off-site damage to infrastructure, such as dams or irrigation schemes. Secondly, there is an interest to conserve the land in order to (i) reduce the vulnerability of the population with respect to the effects of draught, which is simply an interest to avoid the costs of supporting a starving population, and (ii) there must be an interest vested in the state with regard to future generations and their possibilities to use the land for agriculture. These arguments are the basis for justifying the subsidising of labour costs for SWC with EB 2.5 per day. It could also be interpreted as a form of cost-sharing arrangement between current land users, who certainly benefit from SWC and therefore pay half of the labour costs, and other parts of society, who indirectly or directly also profit from SWC investments on farm land and should therefore also carry part of the burden.

**Labour inputs for farm operations**

Labour investments for farm operations are calculated according to information given by interviewed farmers. There is a significant difference in labour investments depending on the crop type. The following Table 35 gives an overview of ***labour productivity per area*** (labour productivity = person-days, or total working days multiplied by number of persons involved, including family members, *webera*, or *wenfel,*[405] multiplied by the number of times a specific farm operation is carried out) for different crops (cf. Appendix 5.6). In Maybar, the labour input (median) for cereal crops and maize is similar. An interesting case is *sengada*, a type of sorghum, which has been grown only for a few years in the area. Compared to other crops, the labour input is low. Unfortunately, no yield data is available, which would allow a comparison of invested labour and resulting yield. Pulses in general are less labour demanding, as they require less frequent ploughing and weeding. Interesting is the comparison of labour input (human and animal labour) for tef in Maybar and Anjeni. In Maybar, less animal traction and more human labour is invested for tef, in Anjeni vice

401 Guinand, 1999a, 5.

402 100 kg wheat cost approximately 170 EB (1998/99, price as paid on local and regional market).

403 For a detailed discussion of subsidising labour for SWC investments or providing other forms of incentives for achieving sustainable soil management, see Giger, 1999 and Schrader, 2000.

404 Ståhl, 1990; Kebede Tato, 1992.

405 *Webera* is an association of several households to provide mutual aid in performing labour intensive and time consuming fieldwork such as weeding or harvesting. Tasks and meals are standardised. *Wenfel* is similar to *Webera,* but includes mostly relatives. Tasks and meals are not standardised.

versa. This can be explained mainly by smaller farm sizes and far less oxen per household in Maybar. In Andit Tid, median labour inputs are similar for all crops except linseed. Different labour intensities can be observed for barley depending on altitude. In the *Dega* zone, despite the considerable labour input for land preparation (ploughing up to four times, soil burning), labour productivity per area and per person-day is 101 m$^2$. In medium altitudes, labour productivity per area and person-day is 77 m$^2$. This is mainly because these fields are weeded in contrast to the *Dega* fields. A special situation can be found in the locality of *Ansas*, an area situated at an altitude of about 2,800 m asl in a depression not far away from the research catchment. According to farmers, soil productivity in this area is very high. Barley is grown every year during the *Belg* season. Farmers mentioned that in good years they could harvest up to 5 t/ha. Labour inputs are the highest, with only 49 m$^2$ land worked per person-day, as returns to labour are also the highest – if the mentioned yield estimates are true. The high labour input results from careful and repeated ploughing and weeding. In Anjeni, the highest labour input can be observed for tef, followed by barley. The high labour input for tef is required because tef fields are ploughed four to six times and weeded more thoroughly.

It becomes apparent from the figures presented in Table 35 (minimum, median, maximum), that the labour productivity per area varies considerably. In the CBA, median labour inputs are used as presented below in Table 35. Based on information obtained from interviewed farmers and observations made during the fieldwork, the following reasons for differing labour input could be detected:

(i) the location of the plot – the further away a plot is from the homestead, the less labour is invested and
(ii) the quality of the plot – the steeper, stonier or more heavily degraded the plot, the less labour is invested.

| | Maybar | | | | Andit Tid | | | | Anjeni | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | m$^2$ land worked per | | | | m$^2$ land worked per | | | | m$^2$ land worked per | | | |
| | person-day | | | ox-day | person-day | | | ox-day | person-day | | | ox-day |
| | min | median | max | median | min | median | max | median | min | median | max | median |
| Tef | 12 | 27 | 54 | 528 | | | | | 25 | 65 | 80 | 459 |
| Maize | 17 | 33 | 164 | 467 | | | | | 60 | 99 | 155 | 504 |
| Barley 1) | 26 | 33 | 51 | | 25 | 74 | 169 | 477 | 28 | 78 | 119 | 404 |
| Wheat | 26 | 33 | 51 | 479 | 41 | 56 | 68 | 325 | 90 | 122 | 139 | 564 |
| Emmer wheat | 20 | 56 | 88 | 465 | | | | | | | | |
| Horse bean | 28 | 76 | 180 | 525 | 47 | 64 | 91 | 485 | 82 | 144 | 187 | 701 |
| Field pea 2) | 87 | 172 | 264 | 946 | 47 | 64 | 91 | 60 | | | | |
| Lentil | | 58 | | 309 | 130 | | | 379 | | | | |
| Linseed | | | | | 73 | 109 | 209 | 598 | | 153 | | 1,375 |
| Noug | | | | | | | | | | 562 | | 2,242 |
| Sengada | | 211 | | 448 | | | | | | | | |

1) No information was obtained for barley in Maybar, same values as for wheat are used instead.
2) No information was obtained for field pea in Andit Tid, same values as for horse bean are used instead.

*Table 35: Labour productivity: Area (m$^2$) worked per person-day and per ox-day for different crops. [Source: Own investigation 1992, 1998, and 1999]*

A controversial question is whether labour input for fieldwork increases if the land is conserved, or whether it decreases in parallel with decreasing yields to maintain a constant level of labour productivity if the land is not conserved.[406] In the CBA presented here, labour inputs are kept uniform over the whole period – i.e. they are considered a fixed input and to depend only on crop type and field size –, irrespective of whether soil conservation is undertaken or not. In the case where soil conservation measures are applied, one could

406 Eaton, 1996, 17.

argue – and this is strongly supported by remarks made by farmers – that although the cropping area is reduced, farm operations are more time consuming. This can be observed particularly during ploughing time, when narrow spaces between two conservation structures pose a hindrance to turning the oxen and the plough. Farmers also mentioned that the time required for weeding increases on conserved fields. They specifically mentioned that there is more weed spreading from the vegetated structures, which is difficult to control. Lastly, they complained that an additional labour input is required for controlling rodents, which on unconserved fields can be done at the same time as ploughing. In the case of unconserved plots with diminishing yields resulting from soil erosion, one could argue that farmers try to maintain production levels by increasing their labour input. Farmers specifically mentioned that to offset declining yields, they invest more labour in activities such as more careful ploughing, and that labour input required for weeding increases on more degraded land. In both cases, irrespective of whether or not soil conservation is practised, there are arguments both for increasing and for decreasing labour input. Because no secured statements or observations exist on how much more or less labour is invested in which case, no adjustments to the median labour input for fieldwork are made.

**Labour inputs for soil conservation**

Labour inputs for soil conservation activities differ according to the type of conservation structures. In the CBA, three cases are differentiated. For the construction of ***soil bunds***, it is assumed that per working day 10 m can be accomplished.[407] This input level is assumed for Andit Tid and Anjeni for the case of introduced conservation structures. In Maybar, ***stone bunds*** are prevalent. Labour investments for this technology are considerably higher than for soil bunds. It is assumed that per day 5 m of stone bund can be constructed. This assumption is supported by statements made by farmers from Maybar, who mention labour inputs ranging from 2 to 10 m per day, with most (7 of the 12 respondents) mentioning 5 m/day. Such stone bunds are about 40 cm high and 40 cm wide. In the case of adapted conservation in Maybar, the same labour investment is assumed, as adapted and introduced stone bunds do not differ substantially. Therefore, labour requirements are only reduced according to the reduction in total length of structures. For the case of adapted conservation in Andit Tid and Anjeni, it is assumed that 15 m per day can be accomplished. Labour investments are assumed lower because much of the work is done parallel to normal ploughing. Either, farmers plough a deeper furrow and only place some stones at its lower side. Such structures are more like traditional drainage ditches and are not necessarily permanent. Alternatively, farmers do not plough certain areas but leave a grass strip, which is strengthened by stones. On steep fields, such unploughed areas can develop to considerably high terrace risers.

Adapted conservation technologies not only require less labour, but labour can also be invested according to the requirements concerning the conservation structure and the possibilities of the farmer. Grass strips, for example, are formed during ploughing. Later, during weeding, weeds and stones from the cropland are added. For stone bunds, a similar distribution of labour can be observed. At first, during ploughing, excess stones are piled up to heaps. These heaps later serve as reservoir for the maintenance of the bund. Further construction and maintenance activities are carried out parallel to other farming activities.[408] Farmers of Maybar mentioned that during ploughing time they invest up to 4 hours per day for stone bund construction and maintenance, but that they rarely work a full day for the construction or maintenance of SWC structures.

The design of introduced conservation technologies usually tends towards a watershed approach. SWC structures are constructed throughout whole catchments in a concentrated effort. The positive aspect of this approach is that supplementary structures such as cut-off drains above the cultivation land, waterways, or check-dams, which are more labour demanding and require coordination among neighbours, or which are built on communal lands, are much easier to design and construct. The problem of this approach is that site-

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407 Bekele Shiferaw & Holden, 1998, 30. Estimated labour investments are 14 m/day for soil bunds and 4 m/day for Fanya Juu bunds.

408 Yohannes G/Michael & Herweg, 2000, 29.

specific situations and considerations concerning the distribution of labour investments over time by participating farmers are not sufficiently taken into account.

Labour is not only necessary for the construction of SWC structures, but also for their ***maintenance***. Maintenance is assumed to require 10% of the construction investments, irrespective of the type of conservation.

Labour requirements for soil conservation activities should not compete with labour requirements for normal farm activities. Therefore, in the CBA it is assumed that the construction of SWC structures is not completed within one year but distributed over a period of three years (six cropping seasons) in Andit Tid and Anjeni, and five years (ten cropping seasons) in Maybar. Maintenance begins in the second season and increases gradually. Labour for maintenance is considered constant over the whole period. On the one hand, it can be expected that once the structures have consolidated and are stable, less maintenance input is necessary. On the other hand, it also has to be expected that more labour is required to control rodent populations and weed growth.

***Costs for material, fertiliser, and seed inputs***

**Material costs**

The soil conservation technologies propagated in the Ethiopian Highlands are far more labour demanding than material demanding. The construction of soil and/or stone bunds requires mainly shovels and pickaxes. Prices paid for these tools are in the order of EB 80 per shovel and EB 100 per pickaxe.[409] In the CBA, it is further assumed that per 1,000 m bund one tool has to be replaced.

**Costs for artificial fertiliser**

As has been shown in Section 5.1.3, soil productivity declines in both cases – whether soil conservation is undertaken or not. A strategy applied by some farmers and propagated strongly by the extension service, is to apply artificial fertiliser. In Maybar, 8 of the 16 respondents had applied artificial fertiliser. Of these 8, five mentioned that they had been forced to buy fertiliser by the DA, and that if it were their decision, they would not buy it. Only three farmers bought fertiliser voluntarily. One farmer mentioned that he estimates yields to double if fertiliser is applied. In Andit Tid, only two of the 15 respondents had bought artificial fertiliser. This corresponds well with information obtained from the DA. From three Kebele Associations (KA) with more than 1,200 households, only 28 households (2.3%) were applying fertiliser for the *Belg* crop in 1998, and 109 households (9%) for *Meher* crops. In Anjeni the situation is totally different. Already in 1992, only one of the 28 interviewed farmers did not apply artificial fertiliser. The widespread use of fertiliser can also be documented based on the analysis of SCRP yield data (cf. Section 5.1.3, Table 21).

In the CBA, fertiliser costs are assumed to be EB 300 per 100 kg. This is slightly above the actual price because it already includes the interest. Amounts of artificial fertiliser applied are assumed equal to recommended rates, i.e. 100 kg DAP/ha. Depending on the remaining land size in the case with SWC, fertiliser amounts are reduced accordingly. Only positive effects of fertiliser in the form of increased yield have been included in the CBA. Especially in dryer areas or areas with insecure rainfall distribution, such as Maybar, there is a pronounced danger of partial or total crop failure in seasons with poor rainfall if fertiliser is applied.

Equally ignored are the negative effects of fertiliser on water quality. Especially in cases where soil conservation is not or only partially practised and runoff is high, it must be expected that a substantial amount of fertiliser is washed into the nearest river. Since a large portion of the population still depends on rivers for their drinking water, health hazards cannot be ruled out. Costs arising from such negative effects should actually be included in a CBA, but have been omitted in this case because of lacking information relating to (i) amounts of fertiliser entering into rivers, (ii) possible health hazard, and (iii) costs for cure.

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[409] Information given by farmers from Andit Tid, 1998. The same figures are also used for the other two localities.

*Figure 41: Because most animal dung is used as fuel, it lacks as organic fertiliser. Farmers have to buy artificial fertilisers instead in order to increase production. [Photo: E. Ludi, 1997]*

**Costs for seed**

A third cost factor is seed. Although improved seed is available for various crops (mainly tef, maize, and wheat), farmers hardly buy it. The DA working in the Maybar area complained that he has to fulfil a quota: on a certain area, farmers have to use improved seed and apply artificial fertiliser. However, farmers are not willing to do this voluntarily. He estimates that yields from improved seed are about double the yield from local seed. However, a study conducted in Oromyia Region[410] shows that if improved tef seed is used and recommended quantities of artificial fertiliser applied, yields are in the order of 1.1 t/ha. If local seed and the same amount of fertiliser are used, the yield is 1.5 t/ha and thus significantly higher. Unfortunately, the authors do not offer any explanations concerning this difference. They only refer to farmers mentioning that improved seed is often damaged and that they have to increase the seeding rate to avoid a second sowing.

In the CBA, no improved seeds are used but farmer retained seed. As seeding rates differ considerably among farmers and depending on land quality, mean seeding rates are used instead of the quantities mentioned by farmers. The mean grain price of EB 180/100 kg is used to calculate the opportunity costs of seed. They are assumed to be 115 kg/ha for the upper part and 100 kg/ha for the lower part of Maybar, 100 kg/ha for the upper part and 95 kg/ha for the lower part of Andit Tid, and 90 kg/ha for Anjeni.[411]

## 5.2.2 Indirect costs

Indirect costs are linked to conservation structures, but are not part of the technology itself. In the case of the three research sites, farmers usually mentioned the following negative side effects of conservation structures: waterlogging, pests, and weeds.

***Waterlogging*** is a problem especially in the high-rainfall areas of Andit Tid and Anjeni.[412] Conservation structures in these two catchments were constructed as graded Fanya Juu or graded soil bunds with a gradient of 1 to 2% towards the next artificial waterway, thus combining introduced bunds with traditional drainage

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410 Howard et al., 1999, 25.

411 Seeding rates are assumed to be in the following order: tef: 40 kg/ha, barley, wheat: 125 kg/ha, maize: 30 kg/ha, horse bean: 150 kg/ha, field pea: 120 kg/ha, lentil: 60 kg/ha, Noug, linseed: 20 kg/ha. (Sutcliffe, 1991, Annex 7)

412 Mean annual rainfall: Andit Tid: 1,417 mm (1982-94), Anjeni: 1,690 mm (1984-94) (SCRP, 2000b, 2000c)

ditches. Graded structures fulfilled their task of draining excess water well during the first years, when after major storms farmers used to clean the ditches above or below the bund, removed accumulated material, and used it to rise bund heights. After some years, when bunds stabilised, these maintenance activities were to a certain degree neglected. Over the years, ditches silted up and could no longer drain all the water to the next waterway. This problem is further aggravated because over the years small embankments have developed parallel to waterways as a result of ploughing. The magnitude of damage to crop stands as a result of waterlogging cannot be estimated precisely. However, it has to be expected that not more than the accumulation area behind the bund (location A) will suffer. On locations B and C, waterlogging should not be a problem, since there are no barriers against overland flow and water is thus drained more easily.

The second problem mentioned by farmers of all three research sites concerns ***pests***, mainly mice nesting in the conservation structures. Mice were certainly a danger to crops before conservation structures were established, but farmers mentioned that before these permanent structures were erected, mouse burrows were destroyed during ploughing and populations were thus controlled. It can be expected that mice spread from bunds to two sides, thus affecting the yield on locations A and C.

The third problem is ***weeds*** spreading from bunds. Similar to the problem of mice, farmers reported that they can control weed infestation by ploughing carefully. Since this is no longer possible on bunds and near conservation structures, weeds are able to spread from there. In Anjeni, farmers mentioned a specific weed, which, according to their observation, was newly introduced to the area. If cut apart by ploughing, it does not die, but grows from the two halves. It was argued that this grass had not been very frequent before permanent conservation structures were established, and that it spread dramatically since the construction of bunds.

In the CBA, yields are considered according to sampling location, i.e. above a structure (A), between two structures (B), and below the next upslope structure (C). Indirect costs such as the ones mentioned above are therefore already included in the yield calculation and no further adjustment is made.

A fourth problem mentioned by farmers is that labour demand for farm operations has increased as a result of SWC. In Section 5.2.1 it is argued why no adjustment of labour inputs for farm operations is made.

### 5.2.3 On-site benefits

The main purpose of the large-scale soil conservation programmes conducted in the Ethiopian Highlands was in the first instance to control soil erosion. The technology itself was never meant to address soil productivity directly. Soil productivity was to stabilise or eventually increase, as soil erosion and excessive runoff was controlled and sediments were trapped behind conservation structures. Nevertheless, direct positive impacts on production can be observed in all three research stations. As has been shown in Section 5.1.3, in most cases yields are significantly higher just behind the conservation structure than on other parts of the field. Unfortunately, these yield increases are not big enough to compensate yield decreases due to the reduction of cropland through conservation structures.

The purpose of mechanical SWC structures – the ***reduction of soil erosion*** – could be achieved to some extent. Reductions of mean annual soil loss are in the order of 55% in Maybar, 59% in Andit Tid, and 68% in Anjeni. Unfortunately, there is little evidence that ***total yield*** on conserved land is higher than on unconserved land. A comparison of mean annual yields on experimental plots shows that in Maybar, none of the tested technologies (graded Fanya Juu, graded bund, grass strip, level Fanya Juu, level bund) led to yield increases. On the contrary, yields are 22% to 30% smaller than on the control plot. In Andit Tid, the same can be observed, with yield decreases ranging from 12% to 50% as compared to the control plot. Only in Anjeni, slight yield increases could be observed on plots with graded Fanya Juu (+4% to 14%) and grass strip (+14%). On the other plots, yield decreases range from 6% to 13% and are thus considerably lower than in the other two research locations.[413]

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413 Herweg & Ludi, 1999, 107.

Despite these rather negative findings with regard to total crop production, soil conservation could reduce soil erosion rates substantially. The predicted ***time*** span for a soil to reach a critical soil depth of 10 cm is much longer in the case where soil conservation measures are taken than in the case without soil conservation (cf. Table 31). In other words, even if the positive impact of mechanical soil conservation on crop production is not tangible in the medium term,[414] it can be expected that in the longer term, either the positive aspects of soil conservation will become more apparent, or the time gained will allow an introduction of production-enhancing technologies. Such technologies are assumed (i) to show their biggest effect on terraced land and (ii) to hopefully not only compensate for the land occupied by conservation structures but also lead to yield increases.

In the CBA, different assumptions are made relating to the influence of ***fertiliser*** on yield: It is assumed that fertiliser efficiency is maximal in cases where the land is conserved, as fertiliser is not washed away by runoff. Based on figures from Anjeni and partly also on results from experiments carried out by the NFIU,[415] a yield increase of 50% is assumed. In cases of adapted soil conservation, yields are expected to increase by 40%, as less conservation structures exist and more runoff occurs. In the case of no conservation, yield increases are still assumed to be in the order of 30%.

Although mechanical SWC structures do not directly increase crop yields, they nevertheless have a direct economic value: the production of ***fodder grass***. As the biggest part of the research catchments – with the exception of Andit Tid – is used for crop production, grazing land is in very short supply. Livestock numbers are high, and grazing land is often severely degraded. The additional grass from conservation structures is a welcome supplement to animal feed. Especially during ploughing times, grass from the conservation structures is fed to the oxen. During the crop-growing period, when grazing is restricted, farmers cut the grass and carry it back home to feed their animals. It is assumed that the annual grass production (dry matter) is about 2,000 kg/ha.[416] Currently, there are no markets for grass or hay in the research areas; therefore, no market price is available. Instead, the grass is valued in terms of livestock. The CBA uses the value of a good ox, which is about EB 800. The annual feed requirements of an ox is 2.3 t of dry matter.

An aspect that is not modelled, but shall briefly be discussed, is whether SWC increases the production of animal feed enough to allow a farm household to raise more animals. It could be hypothesised that if more animals were kept which can be fed with fodder from own production, no further negative effects on existing grazing land must be expected on the one hand, and more manure would be available on the other hand. It can be expected that if this additional manure wasn't used as fuelwood substitute, it could be applied as fertiliser and contribute to increase yields. Lastly, if more feed were available, more animals could be raised for selling. This again could serve to compensate the yield decline resulting from land loss through SWC.

In the CBA, additional straw yield thanks to SWC, and grass, which can be cultivated on the conservation structures, is included. The value of straw and grass is expressed in terms of animal feed for oxen. One could, however, also assume that more sheep and goats are raised which can then be sold to buy grain. Grass yield depends on the length of conservation structures. Assuming a medium steep slope, the mean length of terraces is 1,500 m per hectare. With an assumed grass yield of 2,000 kg/ha of dry matter, roughly 300 kg grass could be harvested on the conservation structures. However, about 180 kg of tef straw would be lost because of the terraces (approximately 1,200 kg tef straw/ha in Maybar). Nevertheless, 120 kg additional dry matter per hectare arable land could be realised if conservation structures are installed and planted with grass. 120 kg dry matter is about 60% of the annual feed requirement of a sheep.[417] As not only grain yields increase thanks to SWC (at least immediately behind conservation structures), but also straw yields (cf. Appendix 5.1), enough dry matter could be harvested to feed one additional sheep annually from own resources. For an average sales

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414 Conservation activities started in 1983 in Maybar and in Andit Tid, and 1986 in Anjeni.

415 National Fertiliser and Input Unit, Ministry of Agriculture.

416 Dry matter production for grazing land and fallow land, high potential area: 2.2 t/ha*a, low potential area: 0.75 t/ ha*a; from wood and shrub land: high potential area: 1.5 t/ ha*a, low potential area: 0.5 t/ ha*a. (Huisman, 1990, 12) Keddeman (1992, 237) estimates hay yields at 2,000 kg/ha*a at 0.15-0.2 EB/kg.

417 Annual feed requirement for one sheep: 0.2mt (Huismann, 1990, 14)

price of a sheep of EB 100, about 50 kg of tef could be purchased (at EB 200/q). The amount of tef grain lost because arable land is occupied by conservation structures (in this example, approximately 15%) would amount to 160 kg (mean tef yield in Maybar: 1,100 kg/ha), worth about EB 320. Thus, the loss of grain in this example is more than three times bigger than the amount of additional grain that could be bought thanks to additional livestock raised from grass harvested on conservation structures.

What is not considered in the above calculation is the value of manure. One sheep produces about 120 kg of dung annually.[418] 1 mt dung contains about 27 kg balanced nutrients (N and P), thus the sheep dung would amount to about 3.3 kg nutrients.[419] Per additional kg nutrients, tef yields increase by an average of 6.9 kg.[420] If the dung produced by one additional sheep is used as manure, about 23 kg additional tef yield worth about EB 46 can be produced. In a static view, even when considering both the sales price of one additional sheep (EB 100) and the additional grain produced thanks to increased dung availability (EB 46), the value of lost grain production due to the loss of arable land (EB 320) cannot be compensated in this example.

### 5.2.4 The problem of quantifying on-site costs and benefits in a subsistence economy

A widely discussed problem is how to value goods that are not marketed. Many environmentalists are deeply concerned that goods are always valued with regard to human use, thus from a utilitarian point of view. It is argued that there is an intrinsic value to nature or living species, which should not be valued in monetary terms, although it is possible to find some shadow price.[421] Despite these objections, and in the knowledge of the difficulty to find proper values for the different on-site costs and benefits of soil erosion and conservation, values are quantified and monetised for this CBA. The monetary units are not understood as the description of something desirable; they are merely used as a unit of account to compare different dimensions.

The main problem with quantification of costs and benefits of SWC is that for many goods or services ***no market*** exists. In some cases, such as crop production for home consumption or family labour, opportunity costs can be used. In other cases, when there is no market at all, the value of goods has to be expressed in other terms, such as in the case of grass and straw, which is expressed in terms of the value of livestock that can be fed with it.

The primary tasks of the SCRP were to establish research stations and to test and monitor various conservation technologies with respect to soil erosion and conservation. Therefore, many data necessary for a thorough cost-benefit analysis are not available. So, for example, there is only a very restricted number of erosion plots, and since all of them are on-farm plots, it is the farmer who decides what is planted and when farm operations are carried out. Therefore, differing crops and management practices distort the comparability of erosion results. Furthermore, for a long time the research was concentrated on introduced SWC technologies and less on traditional or adapted SWC technologies or household strategies related to soil erosion and conservation.

In the CBA, many of the input factors had to be ***estimated***, because the exact facts are not available. Through interviews with farmers and other resource persons, an attempt is made to obtain additional information. Unfortunately, interviews were only made at one point in time, and farmers were asked to estimate labour inputs, yields, or amounts of marketed produce. These estimates are distorted due to various reasons:

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418 1 TLU produces 0.92 mt dung/year, 1 sheep = 0.13 TLU (Sutcliffe, 1991, Annex 5)

419 Sutcliffe, 1991, Annex 5.

420 Tesfaye Negussie, 1995, 116.

421 Batie, 1989, 193; Bojö, 1992, 196.

(i) Farmers often estimate yields and income to be lower than they actually are. Especially when foreigners ask questions concerning income, it is an understandable strategy to underestimate own production in the hope of being eligible for support (e.g. food aid, subsidised credit, reduced taxes).
(ii) Even if estimates are not distorted due to a hidden agenda, it is difficult to remember exact amounts of yield produced and money earned or spent.
(iii) In interviews, it is difficult to obtain detailed information relating to labour invested for different tasks over one year. Farmers can give rough indications about how time they spend for which task, but details such as how many hours per ploughing day are spent for maintenance of SWC structures are rarely available.

Despite the mentioned shortcomings, the assumptions made relating to on-site costs and benefits of soil erosion and conservation in the three research sites of Maybar, Andit Tid, and Anjeni, should be exact enough to allow a meaningful CBA. Results should, however, not be used without further discussion and consideration of the social, institutional, political, and economic environment that farmers in the Ethiopian Highlands operate in. To shed light on the magnitude of the influence of certain input parameters, a sensitivity analysis is carried out, i.e. certain parameters are changed in order to detect their influence on the outcome of the CBA.

*Figure 42: Well maintained terraces near Ankober in the foreground. The forest area in the background is a state forest.*
*[Photo: E. Ludi, 1997]*

The following Table 36 summarises the input parameters used in the CBA:

| Parameter | Maybar | Andit Tid | Anjeni |
|---|---|---|---|
| Field size | Measured | | |
| Crop / straw production | Based on SCRP data, differentiated according to soil depth class and sampling location (A / B / C) (Appendix 5.4)<br>Crop: valuation according to market prices (Table 32), ± 20% in sensitivity analysis<br>Straw: valuation according to feed requirement of an ox (2,300 kg dry matter / year), value of an ox = EB 800 | | |
| Grass production | 2,000 kg dry matter / ha, valued according to feed requirement of an ox (2,300 kg dry matter / year), value of 1 ox = EB 800; +150% in sensitivity analysis | | |
| Human labour, farm activities | Median values at EB 5 / day, based on interviews, depending on crop type (Table 35) | | |
| Ox labour, farm activities | Median values at EB 5 / day, based on interviews, depending on crop type (Table 35) | | |
| Labour, introduced SWC | Depending on length of conservation structures which is a function of slope gradient and soil depth | | |
| | 5 m / day | 10 m / day | 10 m / day |
| Labour, adapted SWC | Depending on length of conservation structures = 1/3 of introduced SWC | | |
| | 5 m / day | 15 m / day | 15 m / day |
| Labour, maintenance of SWC structures | 10% of labour investment for establishing conservation structures | | |
| Labour costs | EB 5 / day, -50% and –100% in sensitivity analysis | | |
| Land loss, introduced SWC | According to conservation guidelines, depending on soil depth and slope gradient (Table 33) | | |
| Land loss, adapted SWC | 1/3 of land loss for introduced SWC | | |
| Sheet erosion | Depending on slope gradient:<br>Gentle (0-8%): mean soil loss from TP – 1 SD,<br>Medium (9-30%): mean soil loss from TP,<br>Steep (≥30%): mean soil loss from TP + 1 SD<br>(10 t/ha*a ≈ 1 mm/a) | | |
| Mean | 27.9 t/ha*a ± | 147.1 t/ha*a ± | 145.3 t/ha*a ± |
| SD | 28.8 t/ha*a | 70.3 t/ha*a | 62.7 t/ha*a |
| Rill erosion | 120 mm on 10% of the field | | |
| | Every $5^{th}$ or $6^{th}$ season | Every $6^{th}$ season | In season 4/8/14/18/etc. |
| Soil erosion reduction, introduced SWC | 55% | 59% | 68% |
| Soil erosion reduction, adapted SWC | 28% | 30% | 34% |
| Effect of sheet erosion of production level | Based on regression functions (f(slope gradient, soil depth)) (Table 17, 20, 25); differentiated according to crop type and location between two conservation structures | | |
| Material costs | EB 90 / 1,000 m conservation structures | | |
| Fertiliser costs | EB 300 / 100 kg / ha; +66% and -33% in sensitivity analysis | | |
| Yield increase with fertiliser, introduced SWC | 50% | | |
| Yield increase with fertiliser, adapted SWC | 40% | | |
| Yield increase with fertiliser, no SWC | 30% | | |
| Seed | 115 kg / ha at EB 180 (upper part of catchment)<br>100 kg / ha at EB 180 (lower part of catchment) | 100 kg / ha at EB 180 (upper part of catchment)<br>95 kg / ha at EB 180 (lower part of catchment) | 90 kg / ha at EB 180 |

*Table 36: Input variables and parameters used in the CBA.*
*[Source: Own compilation]*

## 5.3 Time Preferences of Subsistence Farmers – the Individual Discount Rate

*"Discounting of cost and benefit flows associated with a particular decision-making task (e.g. project, land use, policy) allows the decision-maker to effectively compare monetary flows that occur in different periods."*
*(Aylward & Porras, 1998, 2)*

*"The discount rate differs among farmers and is based on several factors regarding the farmers' current status, outlook, attitude towards risk and uncertainty and the length of waiting time before consumption."*
*(Enters, 1998b, 22)*

### 5.3.1 Some theoretical considerations

The question of discounting arises, because many decisions involve outcomes that are temporally remote, forcing the decision maker to compare and ***value immediate and delayed outcomes***. Individuals (just like society at large) attribute a lower value to a benefit or a cost if it arises in future than if it accrued today. The later a cost or a benefit of a certain amount arises, the lower its subjective value. Impatience, or "time preference", is one factor explaining this behaviour. Reasons given for this time preference are myopia, urgent need because of poverty, or the belief that future consumption will be greater. Another explanation for discounting can be found in opportunity costs of capital. A sum of money is worth more now than the same amount in future, since capital can be invested in a productive manner or can be lent at interest.[422] In other words, the discount rate is related to the marginal or intertemporal rate of substitution between current and future consumption; or it is the ratio of the marginal utility of one unit of consumption or investment in the future to that in the present.[423]

Standard economic theory predicts that if capital markets are "perfect", i.e. *"unlimited borrowing or saving at a single riskless rate of interest is possible, individuals optimally would discount future consumption at the market interest rate."*[424] It is further assumed that individuals have a unique and constant discount rate at any given point in time.[425] With market imperfections such as imperfect information, limited availability of credit, or government controlled interest rates,[426] individual discount rates are likely to be higher than market interest rates.

Two different discount rates can be distinguished: the ***social*** and the ***private discount rate***. The social discount rate describes how society at large values current and future consumption, i.e. reflects the social rate of time preference and the opportunity cost of capital, based on the marginal productivity of capital.[427] In

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[422] OECD, 1995, 127.

[423] Benzion et al., 1989, 271; Aylward & Porres, 1998, 2. However, Pender (1992, 31) notes, that the rate of time preference is distinct from the discount rate. He mentions that as a measure of the marginal rate of intertemporal substitution, the discount rate depends on consumption levels, whereas the rate of time preference does not. Only if consumption were constant, the time preference would be equal to the discount rate. The claim that in subsistence economies consumption is constant can clearly be rejected. Thus, the applied discount rates will most probably be different from true time preferences. Because of imperfect markets and taxes, discount rates tend to be higher than time preferences.

[424] Fisher (1930) in Pender, 1992, 7; Hanusch et al., 1994, 106; Lumley, 1997, 73.

[425] Lumley, 1997, 73.

[426] Munasinghe, 1993, 35; Holden et al., 1998, 107.

[427] Markandya & Pearce, 1991, 139.

general, interest rates in the capital market and the social rate of time preference describe the social discount rate well enough.[428] The private discount rate may be affected by the pure time preference, reflecting the individual's attitude to risk and uncertainty as well as the level of poverty, and the marginal opportunity cost of capital, which represents the scarcity value of savings and returns to alternative investments.[429] In many rural areas, capital markets are either missing altogether, or are seasonal, rationed (selectively missing), or thin (imperfect competition).[430] Thus, they affect the marginal opportunity costs of capital faced by farmers. Even in the case of perfect capital markets, individuals are presumed to have higher discount rates than society as a whole.[431] The rationale is that society can more effectively minimise risks by diversifying its investments in a wide range of enterprises, and that society 'exists' forever, whereas individuals do not.[432] This discrepancy between social and private time preference, hence discount rate, can lead to the situation where individuals discount the future excessively and consume assets that society as a whole would have conserved. Applied to the case of soil degradation, this might result in a situation where society ascribes a higher value to future crop production forgone as a consequence of soil degradation than land users would do. With regard to soil conservation investments, this would mean that society would be more willing to invest into the reduction of soil degradation than individual land users. The optimal level of soil degradation tolerated by society would thus be lower than the level of soil degradation farmers would tolerate. According to this difference in valuation of costs of soil degradation between society and individuals, the latter would perceive marginal costs and benefits of conservation as unbalanced for longer into the future. Therefore, farmers wait longer with investments in soil conservation than society would. This time gap is often used as a justification for incentives to motivate farmers to invest in SWC, incentives, which either lower costs or increase benefits for farmers (cf. Figure 28).

With regard to SWC, a special problem occurs: investment costs are borne by today's land users, yet the main benefit of the investment might accrue only to future generations. One problem of comparing 'consumption today' versus 'consumption tomorrow' is that the individuals who consume goods on different dates are often different individuals. Therefore, such choices, especially if involving longer time frames, do not only treat inter-temporal allocation of costs and benefits for a given individual, but also concern the distribution of income across generations. As long as there is a possibility of negative bequests, such as degraded soils with a lower productive capacity, there is no reason for the present generation to decrease its consumption for the benefit of future generations.[433]

In conventional neo-classical economics, the relation between present value of cash flow or consumption (denoted by P) and future value of cash flow or consumption (denoted by F) is explained by the discounted utility model and can be expressed with the following formula:

$$P = F/(1+d)^t \qquad (5.3)$$

where d is the discount rate and t the time frame. Discount rates can be obtained if P and F are known by rearranging the above formula as follows:

$$d = (F/P)^{1/t} - 1 \qquad (5.4)$$ [434]

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[428] However, Markandya & Pearce (1991, 140) also mention the point that interest rates used for accounting in development countries are considerably below discount rates usually applied by the World Bank.

[429] Barbier, 1995, 4.

[430] Holden et al., 1998, 107.

[431] Barbier, 1995, 5.

[432] OECD, 1994, 197.

[433] Stiglitz, 1994, 133.

[434] In the literature, also the following formula can be found: $d = e^{(\ln F - \ln P)/t} - 1$. Pender (1996) used the formula $d = \ln(F/P)/t$ to calculate the discount rate (based on the formula $F = Pe^{td}$). This produces an annual rate. However,

***Eliciting individual discount rates*** – in contrast to social discount rates – usually involves asking an individual to price a future reward in relation to a more immediate reward or giving a current price to a future reward.[435] Various studies have been conducted to estimate individual discount rates.[436] In these experiments, usually students of economics were asked to state their preferences for a set of choices. Only few studies have been conducted to find approximations of discount rates of subsistence farmers.[437]

A study conducted in rural India[438] shows that median discount rates are between 26% and 91%. It showed further that

(i) discount rates exceed market interest rates, with one third of the respondents showing discount rates of more than 100%,
(ii) that discount rates decrease with the magnitude of the reward,
(iii) are lower in those experiments involving a longer time frame compared to experiments involving a short time frame, and
(iv) that discount rates decline with increasing wealth – per 10% wealth increase discount rates would fall by 3-7%.

A study in the Philippines[439] found that individual time preferences are significantly lower (between 41% and 50%) than mean interest rates (between 110% and more than 400%) paid by the respondents. The author concludes from these findings that interest rates are not a suitable shadow for individual's discount rates in the sites where the study was conducted. A comparison of discount rates of soil conservation adopters and non-adopters shows no clear picture. In one of her study sites, non-adopters have much lower discount rates than adopters – which cannot be predicted by economic theory, while in another site, adopters have a much lower discount rate than non-adopters – which can be explained by economic theory. In contrast to the study in India, wealth did not correlate with lower discount rates; on the contrary, the poorest 10% of the farmers have considerably lower discount rates than the wealthiest 10% of the farmers. There is also no clear relation between age and discount rate (it is generally assumed that younger people with a longer life expectancy have lower discount rates than older people), or education level and discount rates (it is generally assumed that the better educated are likely to have a better appreciation of future advantages). The main conclusion of the study in the Philippines is that private discount rates are not the dominant determinant of soil conservation adoption, but that there is an ethical component in the decision for soil conservation in spite of high individual discount rates.

A study has been conducted in rural Ethiopia, in Ada, near Debre Zeit,[440] an area with relatively high agricultural potential, good market access, and availability of commodity-specific (fertiliser) credit at 10-12% p.a. Individual discount rates are estimated to be 71% (54% if adjusted for inflation), and decrease with wealth. Based on these findings, it is concluded that peasants are unlikely to adopt soil conservation unless the investments provide short-term economic gains. However, the model predicts that if discount rates were as low as 10%, conservation structures would be adopted in 45% of the hilly area even if yields were reduced by 20% compared to unconserved fields.

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this rate is difficult to compare with interest rates paid on official or unofficial credit markets as they are usually computed using daily compounding.

435 e.g. Benzion et. al. 1989; Pender, 1996; Coller & Williams, 1997; Holden et al., 1998.

436 e.g. Holcomb & Nelson, 1992; Benzion et al. 1989, 1996; Coller & Williams, 1997.

437 Pender, 1996; Lumley, 1997; Bekele Shiferaw & Holden, 1999.

438 Pender, 1996.

439 Lumley, 1997.

440 Bekele Shiferaw, 1999.

### 5.3.2 Methodology

In the two locations of Andit Tid and Maybar, a bidding experiment was carried out. In Maybar, the inquiry took place in January/February 1999. The experiment in Andit Tid could be repeated at three different times: April 1998, June 1998, and November/December 1998. The samples, however, are not identical. The respondents were selected randomly. For each respondent, a set of socio-economic variables was collected before the choices of the bidding experiment were presented. After completing the set of 8 binary choices (Table 37), each respondent was asked to explain his/her choice. In cases where the respondent always preferred the early reward, he/she was asked to specify how high a reward must be for him/her to be willing to wait for 7 months.

In the experiment, participants were offered a series of eight binary choices between a specified amount of barley (Andit Tid) or tef (Maybar) to be received at the time of the interview and alternative amounts received at a later date. The experiment was the same for all. The participants faced a series of choices between receiving 10 kg of grain immediately and receiving alternative amounts of grain 7 months later.[441] Such hypothetical questions have a number of methodological weaknesses, which are related to the time frame (time preferences decrease with increasing time frames), to the magnitude of gains, and to the question of whether respondents are asked to compare a variable future amount to a fixed current amount or a fixed future amount to a variable current amount.[442]

| Choice Nr | Binary choice | Discount rate |
|---|---|---|
| 1 | 10 kg barley / tef today or 9 kg barley / tef in 7 months | < -17% |
| 2 | 10 kg barley / tef today or 10 kg barley / tef in 7 months | -17% - 0% |
| 3 | 10 kg barley / tef today or 11 kg barley / tef in 7 months | 0% - 18% |
| 4 | 10 kg barley / tef today or 12 kg barley / tef in 7 months | 18% - 37% |
| 5 | 10 kg barley / tef today or 13 kg barley / tef in 7 months | 37% - 57% |
| 6 | 10 kg barley / tef today or 15 kg barley / tef in 7 months | 57% - 100% |
| 7 | 10 kg barley / tef today or 17 kg barley / tef in 7 months | 100% - 148% |
| 8 | 10 kg barley / tef today or 20 kg barley / tef in 7 months | 148% - 228% |
| (9) | Always 10 kg barley / tef today, not willing to wait irrespective of the magnitude of the future reward | $\rightarrow\infty$ |

*Table 37: Binary choices offered in the bidding experiments and related discount rates. [Source: Own compilation]*

The participants were asked to indicate which alternative they preferred within each choice pair. The choices were presented in the ordered list shown above.

If the participant "crossed over" from the preference of the early reward (keeping 10 kg today) to the preference for the later reward, a range for the discount rate can be inferred. If for example a participant preferred the early rewards for the first 6 choices and from then on preferred the future reward, his/her rate of substitution between the reward today and the reward in 7 months time is between 1.5 and 1.7, implying a discount rate between 100% and 148%.[443] If the respondent did not cross over, i.e. always preferred the early reward of 10 kg grain today (implying a discount rate of >228%), or chose the late reward from the very beginning (discount rate <-17%), only a lower or upper limit of the discount rate can be inferred.

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441 The time frame was set at 7 months in the first experiment in Andit Tid, because this would include one rainy season and one harvest only. To allow comparisons, this time frame was maintained for all other experiments both in Andit Tid and Maybar.

442 Pender & Walker, 1990 in Holden et al., 1998, 110.

443 Discount rates were calculated by the formula $d = e^{(\ln F - \ln P)/(s-t)} - 1$, where the individual is indifferent between a reward of F at date s and a reward of P at date t.

In Andit Tid, the time preference is expressed for the time period of April – November (experiment AT1), June – January (AT2), and November/December – June/July (AT3). In Maybar, the inquiry concerns the time period of January/February – August/September. Andit Tid is interesting in the sense that the different bidding experiments took place at different times in relation to the rainy season and the next harvest. This can give an indication of variable time preferences relating to food availability and scarcity.

| | **Experiment** | | **End-point of experiment** | **Rainy season** | **Harvest** | **End-point to harvest** | **Expected food shortage** |
|---|---|---|---|---|---|---|---|
| **Andit Tid** | April | AT1 | November | July – September | December / January | 1 month | very high |
| | June | AT2 | January | July – September | December / January | - | low |
| | November / December | AT3 | June / July | March – April | June / July | - | high |
| **Maybar** | January / February | MA | August / September | March – April | June / July | 3 / 4 months | high |

*Table 38: Months, during which the bidding experiments for eliciting individual discount rates were carried out in Andit Tid and in Maybar in relation to rainy season, harvest time, and expected food shortage during the time of waiting.*
*[Source: Own investigation 1998, 1999]*

Important ***variables determining the individual discount rate*** are often considered to be: age, wealth[444] (as a composition of natural, physical, financial, social, and human capital, e.g. amount and quality of land, farm implements, savings and credit, social resources, knowledge, or access to basic infrastructure), household size, sex, educational level, involvement in the formal economy (through market integration), availability of farm credits, and whether the subject is a credit-taker/borrower or not.[445] Time preferences, hence individual discount rates, are also influenced by livelihood strategies, which, especially in semi-arid areas, are geared towards coping with a high degree of uncertainty, minimising risks and meeting subsistence needs, rather than maximising production and profits.[446] It is often assumed that poor households show a higher time preference than wealthier households. However, in rural areas of Africa, it has been observed that especially poor and food insecure households rather cut back their food consumption in order to preserve grain reserves as seed stock for the next season and are extremely reluctant to sell productive assets. This behaviour would suggest that extremely poor households do not have high rates of time preferences, but are, on the contrary, willing to make significant sacrifices in the present to be able to produce in future.[447]

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444 Barbier & Bishop, 1995, 133. As Pender (1992) finds, discount rates are negatively correlated with individuals' net wealth, which he explains as a function of binding credit constraints. He further observes that wealth may be partly determined by an individual's discount rate as well as being a determinant of the discount rate. Holden et al. (1998,109) mention that wealthier farmers tend to have better access to formal credit markets and thus face lower interest rates than poor farmers.

445 Holden et al., 1998.

446 Boyd et al., 2000, 2.

447 Moseley, 2001, 320.

### 5.3.3 Results

| | Preference | Andit Tid | | | | Maybar |
|---|---|---|---|---|---|---|
| | | April – Nov. | June – Jan. | Nov. - June | Total | Jan. – Aug. |
| | | **AT1** | **AT2** | **AT3** | | **MA** |
| Choice 1 | 9 kg in 7 months | 1 | 3 | 4 | 8 | 21 |
| Choice 2 | 10 kg in 7 months | 1 | 1 | 2 | 4 | 4 |
| Choice 3 | 11 kg in 7 months | 2 | 2 | 1 | 5 | 6 |
| Choice 4 | 12 kg in 7 months | 1 | 1 | - | 2 | 2 |
| Choice 5 | 13 kg in 7 months | - | 1 | 2 | 3 | 1 |
| Choice 6 | 15 kg in 7 months | 4 | 3 | 3 | 10 | 2 |
| Choice 7 | 17 kg in 7 months | 6 | 1 | 2 | 9 | 3 |
| Choice 8 | 20 kg in 7 months | 2 | - | 3 | 5 | 4 |
| Choice 9 | always 10 kg today | 11 | 21 | 13 | 45 | 22 |
| **Total** | | **28** | **33** | **30** | **91** | **65** |
| All Choices (Set 1): | | | | | | |
| Pearson $\chi^2$ | | 24.57*** | 80.21*** | 27.6*** | 141.32*** | 74.98*** |
| Only Choice 1 to Choice 8 (Set 2): | | | | | | |
| Pearson $\chi^2$ | | 8.94 | 3.17 | 2.35 | 10.35 | 55.05*** |

*Table 39: Respondents' choices in the bidding experiments in Andit Tid and Maybar.*
*(***significant at 1%)*
*[Source: Own investigation 1998, 1999]*

If Set 1 (all possibilities) is considered, the differences in the distribution of choices are significant in all 4 experiments. If Choice 9 is excluded and only those respondents giving a valuation of future consumption (Set 2) are considered, the difference in distribution is not significant in any of the three experiments in Andit Tid. No different groups according to the amount to be received in future can be distinguished. In Maybar, however, the distribution remains significant. Here, a big portion (32.3%) of all respondents chose Choice 1, the late reward despite the smaller amount of grain to be received.

For the two sites, the following median discount rates can be inferred:

| | | Set 1 – all responses | | Set 2 – only Choice 1 to 8 | |
|---|---|---|---|---|---|
| | **Experiment** | **Median choice** | **Median discount rate** | **Median choice** | **Median discount rate** |
| Andit Tid | **AT1** | 7 | 1.00 – 1.48 | 6 | 0.57 – 1.00 |
| | **AT2** | 9 | > 2.28 | 3.5 | 0.18 – 0.37 |
| | **AT3** | 8 | 1.48 – 2.28 | 5 | 0.37 – 0.57 |
| Maybar | **MA** | 4 | 0.18 – 0.37 | 2 | -0.17 – 0.00 |

*Table 40: Median choices and median discount rates in the different experiments.*
*(Set 1: including all choices, Set 2: excluding choice 9 (preferring always the early reward, time preference $\rightarrow \infty$))*
*[Source: Own investigation 1998, 1999]*

If considering all responses (Set 1), median discount rates are high to very high, especially in Andit Tid. Compared to the official interest rate of 12% p.a. charged by the government for agricultural inputs, the median individual discount rate in Maybar is only slightly higher (especially lower bound). If excluding Choice 9 (those respondents always preferring the early reward of 10 kg), median individual discount rates drop, particularly in experiment AT2 and in Maybar, where they reach rates similar to official interest rates or even below.

***Differences in discount rates across experiments – seasonality effects***

Usually, it is assumed that individual discount rates do not vary over the year. Results from the experiment carried out in rural India, however, show that the higher discount rate in one experiment may be a result of seasonality in consumption pattern.[448] Particularly in rural subsistence economies, this can be explained by the fact that households are highly dependent on their own crop and/or livestock production, which again depends on an annual or half-yearly cycle. Farmers usually express higher discount rates at times of scarcity, e.g. shortly before harvesting time. In this case, current consumption is valued higher than future consumption (high time preference). Thus, the outcome of empirical investigations not only depends on socio-economic variables of the respondents, but includes also – albeit implicit – variables not directly linked with the respondent. This can include the above mentioned dependency of the result on the annual growing and harvesting cycle, but also the variable supply and price level at local markets, the availability of farm inputs at certain times of the year, the availability of credit, and the time when credits or interest rates are due.[449]

The three experiments in Andit Tid and particularly the very high median individual discount rate (> 2.28) in experiment AT2 allow the following conclusions concerning seasonality with regard to food shortage:

(i) The first harvest in June (*Belg* crops) mainly comprises barley, whereas the second harvest (*Meher* crops) comprises barley, wheat, linseed, lentil, field pea, and horse bean and thus helps to spread the risk. Farmers generally perceive the first harvest as less secure.
(ii) Although total production[450] is smaller for the *Meher* harvest, the variation from year to year is bigger for the *Belg* harvest (CV: 0.36 for *Belg*, 0.27 for *Meher*), implying a higher risk of failure of the *Belg* harvest.
(iii) The above-mentioned yield data only include part of the area (only the research catchment) used by farmers from Andit Tid (the respondents) and especially does not include important areas mainly cropped with *Meher* crops.
(iv) The long rainy season lasting from July to September puts a considerable stress on the health of people.
(v) Purchasing food on the market is difficult during the rainy season.

***Explanations for different choices***

Respondents were asked why they preferred the early reward of 10 kg of grain despite the additional grain they would receive if they waited for 7 months. In ***Andit Tid***, experiment AT2, usual responses were that because of the approaching rainy season the grain is needed now, at the time of the interview or in the near future, whereas the late reward in January would coincide with the harvest of *Meher* crops when food supply would no longer be a problem. This explanation was less frequent in experiments AT1 and AT3. Since at the time of the interview for AT2 (June) main crops were sown, a further explanation for the preference of the early reward was that if these 10 kg were used as seed, the additional yield would be higher than the late reward of maximal 20 kg. In AT1 more respondents mentioned that because the late reward is in November, just before the harvest starts, i.e. at a time of pronounced food shortage for many households and high prices for food crops, they would prefer to wait for 7 months to receive the grain later, because at that time they would urgently need additional food.

In ***Maybar***, almost one third of all respondents chose Choice 1, preferring the late reward of 9 kg, despite the smaller amount. The interviews took place in January/February, thus only 1 month after the harvest in December. Of the 21 respondents choosing this option, 8 mentioned that now (at the time of the interview)

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448 Pender, 1996, 276.

449 Pender, 1996, 285ff.

450 Based on SCRP data and Stuber (1998). Total production [t] = area cropped [ha] * mean yield [t/ha]. 1983-1994: mean total production *Belg*: 66,454.05 t, mean total production *Meher*: 45,573.85 t; *Belg* production in % of *Meher* production: 151,6%.

they had enough food from the last harvest, and 13 respondents mentioned that in 7 months' time it would be the middle of the rainy season. They further explained that at that time food is in short supply, and that it is difficult to go to the market because of the rain. Both explanations clearly indicate that the time of the interview as well as the time frame chosen plays an important role in determining the result of the bidding experiment. Based on these explanations, the high portion of respondents choosing Choice 1 must probably be considered to be influenced more strongly by seasonality effects than by lower time preferences of the respondents. However, the result might also point at other considerations made by the respondents. Firstly, there is a possibility that the donor agency might increase the reward if, for example, the climatic situation was bad and the harvest poor. By delaying the reward to the future, respondents maintain a chance to profit from a possible reward increase. The result mentioned above could thus be interpreted as a gambling behaviour, with respondents hoping to receive more at a later point in time. Secondly, storage possibilities and related problems might play a role. If a respondent chooses to receive the grain immediately, without using it immediately, he/she will have to store it. Thus, the respondent has to bear the risk of storage losses, which can be considerable. If, on the other hand, the late reward is chosen, the risk of loss is entirely borne by the donor.

Most respondents were asked to ***explain their choices***. In the three experiments AT1 to AT3 in Andit Tid, respondents were also asked to specify the amount necessary for them to accept the later reward.

Those respondents choosing always the early reward usually explained their choice with an insecure future, or current food or seed shortage. The majority of respondents (15 of 22 answers in MA, 8 of 14 answers in AT3) mentioned that they do not know what will happen in future. Usually, this answer is supported with the explanation that the future is in God's / Allah's hands, and that it is He who decides whether one will still be alive in 7 months' time or not. Thus, because of this insecurity or the perception of an insecure future, the choice of the early reward seems rational.

3 of the 22 respondents in Maybar that chose always the early reward mentioned that if the grain were used for trading, the additional amount in 7 months time would be more than the offered 10 kg.

Explanations given for the various other choices ranged from *"because it is an additional 1 kg of grain, I'm willing to wait"*, *"because it adds 50% I'm willing to wait"*, *"because I will receive additional 7 kg, thus 1 kg per month, I'm willing to wait"* to *"because the amount doubles I'm willing to wait"*.

In Andit Tid, the respondents choosing always the early reward were asked how much grain would be necessary for them to wait for seven months. 33 of the 47 respondents specified an additional amount, ranging from 25 kg to 280 kg (or 40 kg per month), resulting in a mean of slightly more than 100 kg. 7 respondents were not willing or not able to specify an amount or mentioned that even if the additional amount were 1,000 kg, they would not be willing to wait for 7 months. If the amount necessary for the respondents to wait for 7 months is assumed to be the mean amount of 100 kg, a hypothetical discount rate of 395% results, which is clearly an indication of high time preference. It was also asked how long the respondents would be willing to wait if the reward was 20 kg grain. Time spans mentioned ranged from 8 to 60 days, with a mean of 21 days. Such a time frame would result in a hypothetical discount rate of more than 1,000%.[451]

[451] cf. Section 'Methodology'. The disparity of discount rates depending on how the question is asked shows that there is a marked difference in responses whether the reward in future can be stated compared to a fixed reward today or whether the respondent is asked to state a variable reward today compared to a fixed reward in future or to state a time frame between two fixed rewards.

***The influence of socio-economic variables on different choices***

Socio-economic characteristics of the respondents from Andit Tid and Maybar are presented in Table 41. Amount of land (in *timmad*)[452] and number of animals (in TLU) was classified differently for Andit Tid and Maybar respectively to reflect general differences between the two locations in relation to the two variables.

| Variables | Unit | Classes | | | | Andit Tid[453] | Maybar |
|---|---|---|---|---|---|---|---|
| Number of respondents | n | | | | | 91 | 65 |
| Sex | | male | | | | 83 | 53 |
| | | female | | | | 8 | 12 |
| Age class | years | ≤ 25 | | | | 13 | 13 |
| | | 26 - 35 | | | | 11 | 7 |
| | | 36 - 45 | | | | 15 | 16 |
| | | 46 - 55 | | | | 17 | 10 |
| | | > 55 | | | | 27 | 19 |
| Household size | pers. / household | ≤ 3 | | | | 29 | 16 |
| | | 4 - 6 | | | | 36 | 24 |
| | | 7 - 9 | | | | 15 | 21 |
| | | ≥ 10 | | | | 2 | 4 |
| Educational level | | illiterate | | | | 27 | 40 |
| | | literacy campaign, Church / Koran school, grade 1-3 completed | | | | 31 | 16 |
| | | grade 4 completed or higher | | | | 10 | 9 |
| Amount of land | *timmad* | AT | ≤ 4 | MA | ≤ 2 | 11 | 18 |
| | | | 4.1 – 6 | | 2.1 – 4 | 39 | 34 |
| | | | 6.1 – 8 | | 4.1 – 6 | 5 | 12 |
| | | | 8.1 – 10 | | > 6 | 7 | 1 |
| | | | > 10 | | | 19 | |
| Land leased | | nothing | | | | 61 | 53 |
| | | lessee | | | | 12 | 9 |
| | | lessor | | | | 5 | 3 |
| Number of animals | TLU[454] | AT | 0 | MA | 0 | 18 | 6 |
| | | | 0.1 – 2.9 | | 0.1 – 2.9 | 31 | 14 |
| | | | 3 – 5 | | 3 – 5 | 18 | 12 |
| | | | 5.1 – 7 | | 5.1 - 7 | 17 | 17 |
| | | | > 7 | | 7.1 – 10 | 7 | 14 |
| | | | | | > 10 | | 2 |
| Credit | | nothing | | | | 54 | 43 |
| | | debtor | | | | 8 | 10 |
| | | creditor | | | | 21 | 12 |
| | | debtor & creditor | | | | 7 | 0 |

*Table 41: Socio-economic characteristics of the participants in the bidding experiment in Andit Tid and Maybar.*
*[Source: Own investigation 1998, 1999]*

452 Andit Tid: 1 *timmad* = 2,900 $m^2$, Maybar: 1 *timmad* = 3,420 $m^2$ (mean values).

453 Fore some respondents no information on certain socio-economic variables could be obtained. n in some analyses is thus smaller than 91.

454 TLU = Tropical Livestock Unit. Ox, cow: 1; bull, heifer: 0.75; calf: 0.5; horse: 1.1; mule: 0.85; donkey: 0.7; sheep, goat: 0.13 (Storck, 1991, 181)

For the following categorical variables, a global cross-tabulation[455] test was applied in order to detect differences in relation to 'Choice': sex, leased land, educational level, and credit.

| | Andit Tid | | Maybar | |
|---|---|---|---|---|
| **Dependent variable** | Pearson $\chi^2$ | DF | Pearson $\chi^2$ | DF |
| Sex | 4.70 | 8 | 8.97 | 8 |
| Leasing of land | 12.51 | 16 | 15.30 | 16 |
| Education | 25.84* | 16 | 19.00 | 16 |
| Credit | 40.35** | 24 | 13.60 | 16 |

*Table 42: Global tests of categorical variables.*
*(Pearson $\chi^2$, * significant at 10%, ** significant at 5%, DF = degree of freedom)*
*[Source: Own investigation 1998, 1999]*

From these results it can be concluded that in Maybar none of these variables alone explains the distribution of choices. In Andit Tid, only the variables 'Education' and 'Credit' have a significant influence on the distribution of choices. The level of significance is low.

Analysis of Variance (ANOVA)[456] was used to test the null hypothesis that several population means are equal. Comparing the variability between group means and the within-group variabilities of observations, inference can be made about the differences in the underlying population means. One-way ANOVA was applied to test whether the means of the dependent variables differ significantly over the different choices. If so, it can be hypothesised that these variables play a role in determining the choice and hence the individual discount rate. To test the null hypothesis – population means are equal – an F-test is used. Dependent variables (metric) are age, household size, number of TLU, and amount of land.

| | Andit Tid | | | | | Maybar | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Dependent variable** | Mean | (n) | F | prob. | $R^2$ | Mean | (n) | F | prob. | $R^2$ |
| Age | 45.49 | (83) | 0.96 | 0.47 | 0.09 | 40.40 | (65) | 1.53 | 0.17 | 0.18 |
| Household size | 4.51 | (82) | 0.59 | 0.78 | 0.06 | 5.24 | (65) | 0.71 | 0.68 | 0.09 |
| No. of TLU | 3.63 | (91) | 1.30 | 0.25 | 0.11 | 4.46 | (65) | 0.22 | 0.93 | 0.05 |
| Land | 6.48 | (81) | 0.49 | 0.86 | 0.05 | 2.86 | (65) | 0.37 | 0.66 | 0.10 |

*Table 43: Variable means and their explanatory power for different choices.*
*[Source: Own investigation 1998, 1999]*

The general model – a global statement whether at least one of the group means is different from the others – shows that no variable produces a significant difference in means with respect to the factor 'Choice'. All pairwise comparison probabilities were above the critical level of $p<0.05$. Another factor to consider are the low to very low squared multiple R. In the case of Andit Tid, only 9% of the variance of the variable 'Choice' is explained by the variable 'Age', 6% by the variable 'Household size', 11% by the variable 'TLU', and 5% by the variable 'Land', respectively. In Maybar, the explanatory power of the different variables with regard to the variance in the variable 'Choice' is not significantly better with 18% (Age), 9% (Household), 5% (TLU), and 10% (Land).

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455 In cases where the variables are categorical, cross-tabulation was applied and differences tested using Pearson's Chi-Square Test. (SYSTAT® 8.0, 1998, 159ff.)

456 SYSTAT® 8.0, 1998, 401ff.

### 5.3.4 Discussion of the results

Because of the hypothetical nature of the experiment, three problems have to be considered:

(i) Subjective risk must be taken into account. Because of the hypothetical character of the experiment, respondents lacked confidence that the future reward would actually be paid. This might have caused them to prefer the current reward irrespective of their actual discount rate.

(ii) The second bias can be attributed to expectations concerning the later reward. As farmers both in Andit Tid and in Maybar have experienced situations in which they received food aid, their statements concerning the minimum reward they would be willing to wait seven months for might reflect their expectation of how much food aid is necessary to sustain a person over this time. In those cases where respondents were asked to state their minimum future reward, they calculated a sum by multiplying the amount of grain a person needs per month. However, as the delivery of food aid is not necessarily secure, it is an understandable strategy of people to seize the opportunity whenever it is offered. They might have chosen to accept the early reward because it is offered immediately and delivery is therefore certain, as opposed to a later delivery, which might be insecure. Thus, respondents might have been influenced by their experiences both with failing harvest and with food aid, which is promised but not delivered on time, or not delivered at all. When offered a certain amount of grain, even in a hypothetical experiment as the one carried out, the strategy is to choose the early reward – it seems better to receive a small amount today than nothing at.

(iii) Thirdly, the problem of 'arbitrage' has to be considered. In other experiments, respondents argued that if they took the early reward and invested that amount, their gain would be bigger than the difference between the early and late reward. Respondents compared the experimental situation with real-life circumstances, despite the problem that (i) subjects usually cannot calculate the interest rate from the experimental case, but only implicitly estimate such an interest rate and compare it to the actual market interest rates, or (ii) subjects are not aware of true market interest rates.[457] Similar findings can also be observed in the experiment in Andit Tid and Maybar. Respondents mentioned that if they took the early reward and used it for trading, their gain would be higher than the 10 additional kg of grain they could earn by waiting for 7 months. Traders in Maybar were asked about possible profit margins from trading. They usually buy grain or pulses on rural markets and sell the produce on urban markets. A trader buying roughly 120 kg of barley in the highland pays of EB 120 at the most (depending on the season). On the urban market of Kombolcha, he can sell this amount for EB 180. The profit is thus EB 60 at the most. The time invested for buying and selling is two days, i.e. daily profit is EB 30. In times of oversupply just after harvest, the profit is reduced to EB 10 per day. If an average profit of EB 15 per day and an average price for the grain to be traded of EB 150 is assumed, the possible profit is roughly 10% of the invested amount. Thus, if respondents mentioned that their profit from trading would be more that 10 kg, they are right. Usually, farmers engaged in trading do it once a week. It would thus take only 10 weeks of trading to gain the additional 10 kg.

The perception of risk and uncertainty has a strong influence on the discount rates of individuals. Among the 22 respondents from Maybar that chose Choice 9 (i.e. always preferred the early reward), 3 different groups can be distinguished: Firstly, 15 respondents mentioned that they do not know what will happen in future and whether they will still be alive in 7 months' time. Secondly, 5 respondents said that they needed the grain urgently, as their reserves were exhausted and the next harvest was to come only in four months. And thirdly, 3 respondents mentioned that they could use the grain for trading and make a higher profit than 10 kg. In the literature it is argued that discount rates increase with increasing age because of the risk of dying.[458] Mean age of the three different groups mentioned above is 26 years for those who chose the early

457 Coller & Williams, 1997, 2.

458 Dinwiddy & Teal, 1996, 172.

reward for trading (25, 26 and 28 years), 43 years for the very poor, and 54 years for those mentioning an insecure future. Thus, the hypothesis that age has an influence on the individual discount rate can be supported with the findings from the interviews, although the analysis of variance (Table 43) produced insignificant results.

With regard to ***investments*** it could be concluded that the older the head of the household, who is usually the person deciding about investments, the more likely immediate consumption is preferred over investments with a delayed outcome. If this hypothesis holds true for the whole population, and if time preferences derived from the experiment based on consumption were to be transferred to similar values with regard to SWC investment decisions, this would mean that younger farmers would be more willing to undertake SWC investments. It could also be argued that younger farmers assume they will be able to use their land for longer and therefore have to invest in resource conservation in order to be able to harvest also in one or two decades' time. Another aspect is that farmers have witnessed that with soil conservation, costs accrue early but benefits only after a time lag. If the farmer is young and expects to survive the next decades, he might assume that although he has to bear the investment costs now, he might also be able to profit from the benefits of soil conservation in later times. With respect to land security, old and rich farmers with comparably large holdings might not be sure whether they can pass on the land to their descendants or whether the land will be distributed by the KA. If they believe that they can bequeath the land, they should want to pass it on in the best possible condition. If they believe, however, that the land might be distributed to other farmers by the KA, they would probably want to extract as much as possible before it is redistributed. On the other hand, age can also have the opposite effect on time preference. In the Ethiopian context, age and wealth are clearly linked. It can be observed that rich farmers are usually above about 50 years of age. Wealth does not only include assets such as land or animals, but also political power.[459] Concerning their creditworthiness, older farmers might be in a better position because of better-established reputations. They might therefore face less credit constraints and thus have a lower time preference.[460]

Factors commonly considered as having a significant influence on time preference are not so decisive in the experiments carried out in Andit Tid and Maybar. This concerns particularly ***education*** levels – the better educated are usually considered to be less impatient, ***age*** – the older, the higher the time preference, and ***wealth*** – the wealthier in economic, social and political terms, the lower the time preference. The fact that none of the variables except for credit and education in Andit Tid show as much as a slightly significant influence on the outcome of the bidding experiment can also be interpreted as follows: Reasons for choosing the early or late reward are much more strongly influenced by individual circumstances of livelihood than commonly assumed. Factors not captured by the short interviews might be decisive, such as individual experiences with political, economic or humanitarian organisations, the current household situation, needs for the education of children, or the valuation of the current living situation and expectations with regard to the future living situation. Secondly, the results point also at the high disparity with regard to many different aspects within the rural population. And thirdly, if some of the factors commonly considered as having a strong influence on the individual time preference were taken to deduce policy changes – i.e. if it were assumed that education levels had a significant influence, and education of the rural population were improved in the hope of lowering their time preference and increasing the probability of long-term investments – this would not be successful in the considered research areas. It seems that the problem of high time preferences is highly complex and depends on more than a few factors. With regard to policy options, no simple prescription of standard solutions would have a strong enough influence on time preference. Only if all factors contributing to the high time preference are considered as a set of components mutually influencing each other is there a chance of lowering the subjective perception of risk and uncertainty, which is a necessary (but not yet sufficient) precondition of motivating farmers to carry out long-term environmental investments. And secondly, the wide dispersal of answers demonstrates that the individual reasons for exhibiting a high time preference must be taken into account when proposing long-term environmental investments such as SWC. This is

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[459] Ludi, 1997.

[460] Holden et al. 1998, 116.

impossible to do with standard technical solutions. The only way these individual reasons for high time preferences can be taken into account is by proposing individually adaptable solutions.

### 5.3.5 How to choose an appropriate discount rate for long-term investments in environmental improvement – a review of the ongoing discussion

The problem of discounting future costs and benefits of investments in general is usually not challenged. However,

*"[...] many environmentalists fear that the use of discounting in formulating economic policies that will affect the control and use of the earth's natural resources may be against the natural environment."*[461]

It is argued that the higher the discount rate, the less serious long-term environmental damage will appear, the faster resources will be depleted, the more attractive immediate consumption, and the less attractive investments designed to conserve the environment for future generations will appear. Producing or consuming environmental goods does not loose its value over time, so that natural capital should have an ecological time preference of 1 because future generations have the same preference for environmental goods as current generations. It is further argued that damages occurring to the environment such as possible future loss of habitats or possible future natural catastrophes might not be registered in a CBA compared to the more immediate costs.[462] Moreover, it is argued that in the case where discount rates exceed the rate of natural regeneration, it would be rational to harvest the resource to its extinction.[463] The objections to discounting from the environmentalist point of view can be summarised under the following five headings:[464]

(i) pure time preference,
(ii) social rate of time preference,
(iii) opportunity cost of capital,
(iv) risk and uncertainty, and
(v) interests of future generations.

***Pure time preference*** or impatience (myopia) is not denied when concerning individuals. However, it is argued that pure time preference should not have an influence on the social discount rate. The ***social rate of time preference*** is composed of the rate of private time preference (z), the rate of growth of real consumption per capita (g) and the elasticity of the marginal utility of consumption (n).[465] The formula implies that if the growth rate is expected to be positive, the social rate of time preference rises above the private rate. Environmentalist now point to the fact that positive values of the growth rate g are not secure because of constraints on natural resources or on the capacity of the natural environment to act as a sink.[466]

***Opportunity costs of capital*** can be very high in developing countries. It is argued that if these costs were applied in discounting a future environmental damage resulting from an investment today, the damage would be represented by an amount much smaller than it actually is. Thus, the costs are transferred to following generations, although the investment – with its assumed benefits – concerns today's generation.

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461 Markandya & Pearce, 1991, 137.

462 Markandya & Pearce, 1991; Grohs, 1994, 19; OECD, 1994, 195.

463 Markandya & Pearce, 1991, 139; OECD, 1995, 132.

464 Markandya & Pearce,1991, 140ff.

465 $i = ng+z$, with $i$ = social rate of time preference, $z$ = private rate of time preference, $g$ = growth of real consumption per capita, $n$ = elasticity of the marginal utility of consumption. (Markandya & Pearce, 1991, 142)

466 Hampicke, 1991, 134.

The fourth argument against using high discount rates is ***risk and uncertainty***.[467] One argument is the risk-of-death argument. A good reason for being impatient and for wanting to consume today is that one may not live to enjoy the benefits of today's investment. In this case, the counter-argument in favour of applying the true social discount rate is that although individuals are mortal, society is not.[468] A second point to consider is uncertainty about future preferences of individuals. In the case of environmental goods, it is argued that instead of adjusting the discount rate, an option value should be included in the evaluation of costs and benefits. This would allow for a stock of resources to persist for future generations, whose preferences are unknown to us. In this case, neither the current generation can consume all resources that are today considered of no value to future generations, nor can it preserve all resources because they are today considered essential for future generations. A further point is that there is also an uncertainty concerning the magnitude of future costs and benefits. A difficult case is when environmental costs of an investment can be extremely high but have a low probability, e.g. the collapse of a large dam. It is argued that the precautionary principle should be applied, which would, in principle, avoid the environmental damage, provided that the costs of doing so, including the opportunity costs of inaction, are "reasonable".[469]

The fifth argument against using high discount rates is that ***interests of future generations*** might not be safeguarded. It is argued that because the state is responsible for guarding collective current welfare and the welfare of future generations, the rate of discount for state investments should not be the same as the private discount rate. It should be lower, since high discount rates discriminate against future generations. However, if discount rates were low or even zero, as some demand for environmental-friendly investments to protect the interests of future generations, this would imply a total sacrifice of current use of resources – and would also contradict the principle of eliminating discrimination between time periods or generations.[470] The issue is that if values are judged, the question remains whose preferences count. Future generations have no voice to influence resource allocation decisions taken now, yet the consequences of such decisions may have to be borne by these future generations. Similar to intra-temporal resource allocation, which might be a question of social justice (e.g. which group within a society profits from a certain investment), inter-temporal resource allocation may conflict with some notion of intergenerational justice.

| | **Efficiency** | **Equity** |
|---|---|---|
| **Intra-temporal** | Unweighed net benefits are maximised | Weighed net benefits are maximised |
| **Inter-temporal** | Present value of unweighed net benefits are maximised | Present value of unweighed net benefits are maximised subject to a sustainability constraint |

*Table 44: Alternative decision rules in temporal contexts depending on the investment objective. [Source: OECD, 1994, 205]*

There are usually two objectives linked with an investment – ***efficiency and equity***. If efficiency is given priority and time ignored, the present difference between costs and benefits should be maximised. Intra-temporal equity can be achieved by weighing the gains and losses for different groups within a society differently and then judge whether costs and benefits are evenly distributed among these groups or whether one group has to carry the biggest cost burden, while another group enjoys most of the benefits. The latter would be the case in a situation where farmers in the uplands are forced to invest in soil conservation to avoid damages to a hydroelectric power plant, while only towns further downstream profit from the electricity. Inter-temporal decisions made solely according to the criterion of efficiency are based only on discount rates of

467 Risk represents the likelihood of occurrence of an undesirable event. In the case of uncertainty, a future outcome of an action is basically unknown. (Munasinghe, 1993, 37)

468 Dinwiddy & Teal, 1995, 172.

469 OECD, 1995, 141.

470 Munasinghe, 1993, 36.

future costs and benefits. If, on the other hand, inter-temporal equity is of concern and discount rates should not be lowered (see above), an alternative is to include a sustainability constraint that has to be taken into account first before maximising the present value of benefits in the usual way. Such a ***sustainability constraint*** or 'safe minimum standard' could be a defined capital stock of a given resource that must be maintained over time,[471] e.g. a minimal forest cover per village to safeguard biological diversity, positive water regulation functions, or a minimal soil depth and quality to safeguard future production possibilities. The inclusion of sustainability constraints or 'safe minimum standards' would imply that society define a threshold of costs or irreversibility, which may not be exceeded. This would have far-reaching consequences for neo-classical economics, which assume that markets are the best resource allocators, while governments are needed only to correct market imperfections. Or, as some authors argue, the inclusion of the sustainability criterion as a valid social goal would be equally revolutionary as the Keynesian validation of the concept of government intervention to achieve macroeconomic stability.[472]

With respect to ***natural resources***, there is no unique relation between high discount rates and environmental degradation. Although high discount rates can make many environmental-friendly investments with high initial costs and late benefits less profitable compared to investments that produce high initial benefits at the cost of the environment, there is also the argument that if discount rates are lowered, this might cause even worse environmental degradation, because costs of capital are reduced and thereby costs of production are lowered. This would lead to a situation where more resources are consumed in the near term.[473] Since natural resources are required for many investments, the demand for these natural resources may be less with high discount rates than with low ones.[474]

The crucial decision with regard to the use of renewable natural resources is how much to consume now and how much to save for future generations. This decision will clearly be influenced by the valuation of present consumption – i.e. by the discount rate. The point is that the higher the discount rate, the faster the consumption. If discount rates rise above the maximum natural growth or regeneration rate of a resource, this can result in exhaustion of the resource.[475] In the case of soil use this would imply that the higher the discount rate, the more intensive the soil would be used or the higher tolerated erosion rates would be. Soil conservation would not be an option, because the high costs at the beginning would be valued high, whereas the benefits in future would hardly be relevant. Natural resources will also be excessively exploited if the private discount rate is higher than the social discount rate (cf. Figure 28). It is argued, however, that a correction of the individual discount rate is no solution for preventing over-exploitation. Rather, costs that might not be included in the calculation should be taken into account, or a resource tax added.[476]

Summarising the arguments put forward against using a 'normal' discount rate in the context of environmental cost-benefit analysis and their counter-arguments in support of the 'normal' discount rate, it can be concluded that (i) the normal range of opportunity costs of capital should be used, (ii) efforts should be made to ensure that compensating investments offset capital stock degradation, and (iii) in cases where investments lead to irreversible damage (e.g. flooding of a valley), the CBA should be adapted to include a measurement of forgone profits of preservation in the computation of costs.[477] This can be achieved by introducing a 'safe minimum standard' that must be observed in any case. Such a standard would allow the use of 'normal' discount rates for any extraction of natural resources or investment with possible negative impacts on the environment, but would prevent today's generation from exploiting a resource to its extinction.

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471 Hampicke, 1991, 140; Pearce, 1994, 471; OECD, 1995, 141; Harris, 2000, 8.

472 Harris, 2000, 10. Hopefully, the definition of sustainability criteria by social values will in future become a standard procedure even for economists – just like government intervention to achieve macroeconomic stability, once labelled revolutionary, has nowadays become a matter of course.

473 Munasinghe, 1993, 36.

474 OECD, 1994, 195.

475 OECD, 1994, 199.

476 Markandya & Pearce, 1991, 148; OECD, 1994, 200.

477 Munasinghe, 1993, 37.

If pure time preference of individuals (z) is included in the calculation of the social discount rate (i), it is likely that the discount rate will be high in poor developing economies. The argument is that this is justified because poverty itself induces high discount rates, as decisions are focussed on assuring food security over the next year rather than on long term benefits. If the argument of mortality is included in the determination of the discount rate, a high discount rate is also justified for poor countries because mortality is high. There is, however, a problem inherent in relying on pure time preference for determining the discount rate, especially in the context of environmental problems: environmental degradation and poverty are not necessarily separable. High individual discount rates can be a cause of environmental degradation, as individuals might opt for short-term profits at the expense of more sustainable practices. On the other hand, poor outlook arising from environmental degradation can play a role in generating poverty.[478]

### 5.3.6 Individual discount rates for long-term investments in environmental improvement

The discussion on whether or not to lower discount rates for environmental-friendly investments concerns only the social discount rate, and is highly dependent on normative values. The private discount rate is in any case determined by pure time preference of the individual, depending on many factors such as poverty, available economic, political and social assets, household structure, individual perception of risk and uncertainty, and opportunity costs of capital faced in reality. In other words, the discount rates as calculated on the basis of the experiment are the result of expressed time preferences and faced opportunity costs of capital.

Farmers could invest a certain sum of money in a certain productive enterprise, or they could spend the same amount of money for current consumption. The problem with SWC is that soil conservation investments are not necessarily a productive. Farmers face the following choices:

(i) They could consume a given amount of capital immediately (implying a discount rate tending towards infinite).
(ii) They could invest the same amount in a productive enterprise (e.g. fertiliser, grain for trading, or an irrigation pump) with different time frames to realise the profit (e.g. fertiliser improves yields in the next season, investing in grain for trading can yield benefits immediately, investments in an irrigation pump can produce benefits immediately as well as over a longer time span).
(iii) They could invest the same amount of capital in resource conservation, which usually yields benefits only after a certain time lag.

Which of these investment opportunities is favoured depends on the individual discount rate of the investor, but not on a social discount rate. Thus, all valid arguments against discounting environmental investments or at least against using high discount rates for such investments become irrelevant when the individual cases are considered. This, however, would only be the case if externalities were fully internalised, thus, if the costs of soil erosion are entirely borne by the individual causing them. In the Ethiopian case, however, a considerable part of the costs of soil erosion are not borne by the people causing the erosion, but either by the state or by donor agencies – through food aid which has to be distributed to farmers as soil productivity declines, or by future generations, who inherit land that is already degraded.

Based on the bidding experiment carried out in Andit Tid and Maybar, it could be shown that disparity among the respondents is high and does not allow the isolation of certain factors that could be influenced, given the political will or economic possibility. Similarly, stated time preferences are not uniform over the year but vary according to the agricultural calendar. Thus, for the evaluation of soil conservation investments it is difficult to rely on one single discount rate. In the CBA, therefore, different rates are applied:

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478 OECD, 1994, 198.

- A low discount rate of 5% is assumed. Compared to the results from interviews, such a rate is not very realistic, although the median discount rate in Maybar is even lower if considering only those answers where a future reward has been chosen (Set 2, Table 40). Such a discount rate could be advocated on the ground that otherwise, i.e. with the observed unfavourable distribution of costs and benefits over time, soil conservation investments would never be profitable. The World Bank usually evaluates projects using a discount rate between 5% and 8%.
- A second discount rate of 12% is applied. This would be equal to the annual interest rate as charged by the agricultural extension service for loans for fertiliser and other farm inputs, i.e. to the opportunity costs for capital. This rate is also used by the Government of Ethiopia for the evaluation of investment projects.[479]
- A third discount rate of 58% will be used in the CBA. Such a rate seems to be a crucial turning point, especially for Andit Tid.
- A discount rate of 149% is also considered. 149% is the lower boundary of choice 8 presented in the bidding experiment (cf. Table 37). All those respondents that chose the option of always preferring the current reward would exhibit higher time preferences, which would result in discount rates of over 149%. This extremely high discount rate has been chosen to illustrate the situation where farmers exhibit a very high time preference or an individual discount rate tending towards infinite. This would correspond to the often-heard argument that poor subsistence households do not invest in enterprises that do not yield immediate benefits. It is argued that such households have no financial leeway, because the satisfaction of basic survival needs is in the foreground. Informal credits, given either by merchants in towns or by priests, are extremely expensive. Interest rates in the order of 8% to 10% per month – 96% to 120% annually – are usual. These rates, however, cannot be considered as true opportunity costs for capital, as for farmers it is a taboo to borrow money with interest, except when they are in urgent need. Discount rates in the order of almost 150% would imply that benefits and costs in the second year are valued at only 40% of those in the first year. In other words, net benefits must more than double within one year to be worthwhile.[480] Although a considerable number of respondents show extremely high time preferences, if discount rates in the range of almost 150% were used to evaluate investments, they would never be profitable. It is hardly possible to think of any investment in the situation of smallholder agriculture as presented in the three research sites that could produce such high benefits.

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[479] Degol Hailu, 1997.

[480] An increase of 100% is sometimes considered necessary to convince farmers to adopt new technologies. Douglas (1994, 61) differentiates between totally new technologies and improvements that are more of an adaptive nature and involve only an adjustment of current farming practices. In the first case, a return rate of 100% is often required, whereas in the second case, a minimum return rate of 50% can be sufficient.

## 5.4 An Appraisal of the Planning Horizon of Subsistence Farmers

*"While there is no doubt that many upland farmers make decisions to fulfil their short-term needs, it would be wrong to assume that their decision making is generally guided by short-term thinking."*
*(Enters, 1998b, 24)*

The planning horizon is important when it comes to the optimal use of resources. In a 'steady state' situation with an infinite planning horizon, an optimal resource stock is secured infinitely, as the rate of use or extraction is in equilibrium with the rate of natural or human-induced regeneration. An often-quoted example for such a 'steady state' or sustainable situation is forest use, if the extraction of timber equals the growth rate of new trees. A second strategy is cyclical use of resources, when times of extraction alternate with times of regeneration. Slash and burn agriculture or the alternation of crop cultivation and fallow periods can be examples for this strategy. If the planning horizon is finite, however, the optimal use of resources can lead to a total depletion of the resource stock. The shorter the planning horizon, the faster the resource stock declines towards zero.[481]

***Planning horizon*** and ***discount rates*** are closely interlinked. In the context of sustainable use of renewable natural resources, it is often argued that poverty may lead to shorter planning horizons and high time preference for current consumption. This may prevent poor subsistence households from investing in conservation to protect their natural resource base from which they derive their livelihood.[482] A crucial aspect is the link between the length of the planning horizon and the ***ownership regime***, mainly concerning land. It is usually argued that without secured use or ownership rights, farmers have no interest in investing in sustainable resource use, because benefits might not necessarily accrue to the one bearing the costs.[483] This aspect is especially crucial in the Ethiopian context. The problem is not so much the land tenure regime in general, although it only grants usufruct user rights under state ownership, but rather the frequent land distributions that have taken place since the revolution of 1975.

From the interviews, no direct information on the length of the planning horizon of land users in the three research localities could be obtained. However, based on observations and information from interviews concerning ***investments*** such as tree planting or planning the marriage of a child, a planning horizon can be appraised.

In Andit Tid, it can be observed that a growing number of farmers are planting Eucalyptus trees. Reasons for this are manifold:

(i) There is a serious lack of fuel and construction wood from communal land for home consumption. As Eucalyptus grows very fast, the demand can be met within a comparably short period.
(ii) There is a market for Eucalyptus poles with fairly good prices.
(iii) Farmers of Andit Tid are in the comfortable situation of living near the main highway linking Addis Abeba with the northern parts of the country. Traders buy the poles directly from the farmer and usually buy the whole lot for a bargained price. In addition, they bring their own labourers for felling the trees. For farmers, no further costs accrue.
(iv) Land degradation is extremely serious in Andit Tid. Considerable areas of land have lost their productive capacity, both for crop cultivation and for pasture. If planted with Eucalyptus, however, such land can still be used in a productive manner, even if the survival rate of seedlings is only 50% or even less.

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481 Kappel, 1994a, 22.

482 Holden et al., 1998, 106. Counter-arguments can be found in Chisholm, 2000, 3.

483 e.g. Munasinghe, 1993, 13; Lutz et al, 1994, 13; Bojö & Cassells, 1995, 26; Wachter, 1996; Holden, 1998, 106. cf. Section 8.2 for a discussion of institutional aspects, especially property rights, in relation with soil conservation.

Of the 15 farmers interviewed in Andit Tid, only three had no trees. Two mentioned that they do not have enough land. One of them had to move his house during the last land distribution (1997) and mentioned that he will not plant trees in the near future, as he cannot be sure whether or not he will have to move his house again. The third mentioned that he had had a plantation with about 1,000 trees, but that he lost this land during the 1997 land distribution. He mentioned that if he had degraded land, he would plant trees again. 7 farmers had some trees, mostly planted at the same time the communal afforestation was established around 1967. 5 farmers have bigger plantations. Their estimates of the number of trees ranged from 200 to around 2,000. From these five, three were younger farmers who established their plantations in 1993/94. The other two farmers were older and established their plantations before 1975. One of these two elder farmers was a so-called 'bureaucrat' and therefore lost all his land except for 4 *timmad* during the 1997 land distribution. He was allowed to select the land he wanted to keep. He kept his entire plantation area, as he mentioned that the benefit from this land is much bigger than the benefit from the same area of arable land.[484] Additionally, this farmer is highly respected within the community and thus has the chance to lease land from other farmers.

Responses concerning ***land security*** (and thus the question of whether the benefits of tree plantations or investments in the land will accrue to the bearer of the costs) are not uniform. Of the 15 respondents, 7 mentioned that they believe the land to be theirs, and that they are allowed to bequeath it to their children. Two farmers mentioned explicitly that they expect a new land distribution in about 5 to 6 years (which would be around 2002/2003). They argued that they are not very interested in investments in the land, be it improving soil conservation structures or planting trees, because of that possible land distribution. 6 farmers answered that they have no idea of whether or not they could keep the land and bequeath it to their children. Interestingly, they also mentioned that they would invest in the land despite the uncertainty concerning land ownership. Also, three of these six are the ones with the largest and oldest tree plantations. They mentioned that the uncertainty of land ownership has no influence on their investment behaviour.

In Maybar, the situation is slightly different. Since the nationalisation of land in 1975 and the subsequent first distribution, no other major land distributions have taken place. There are farmers who lost land to returnees from resettlement areas, and here as well, some 'bureaucrats' were punished by being deprived of part of their land. However, the land distribution of 1997 was not carried out. The reason given for this by farmers and members of the KA committee was that since the land – people ratio in Maybar is very unfavourable, a further distribution would only aggravate the problem.[485] Farmers in Maybar feel fairly secure about being able to pass their current holding on to their children (12 of 16 respondents), although most mentioned that the amount they could give to each son (in Maybar, daughters do not inherit land when married) would not be enough to sustain a family.

Many farmers in Maybar have tree plantations (8 of the 16 farmers interviewed own more than 100 trees), either for home consumption or for selling. Most farmers having their own tree plantations mentioned that they started planting trees already during Haile Selassie's reign and continued thereafter. As farmers feel fairly secure about their land ownership rights, there is no disincentive to investing in tree plantations.

A further matter related to the planning horizon is how households organise and plan dowries. Usually, the parents both of the bride and of the groom contribute the same number of animals each. With smaller animals such as sheep and goats, this does not require a longer planning horizon. An ox however requires more careful planning. A farmer from Anjeni explicitly mentioned that he has to start thinking of this ox as dowry when his son is about 7 or 8 years old, which allows him to be prepared for any possible mishap. This would suggest a planning horizon of about 10 years.

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484 cf. Section 6.3.3 for the calculation of benefits from afforestation in Andit Tid.

485 In Dese Zuria Wereda, to which Maybar belongs, the 1997 land redistribution was carried out only in 15 of the 54 KAs. They were selected according to the criterion of average land holdings being greater than 0.5 ha per household. (Pankhurst, 2001, 9)

*Figure 43: Planning and celebrating weddings (the bride is standing in the centre) are important, but expensive social events and are part of household strategies to secure integration into the local rural society. [Photo: E. Ludi, 1992]*

Although no clear picture emerges as to whether or not uncertainties concerning land ownership play a crucial role in determining the investment behaviour – as is often claimed –, from these observations concerning bigger investments it can be concluded that investments with a cycle of 5 to 10 years are possible, and that insecure land ownership is no disincentive. It must be mentioned, however, that in most cases, these investments in tree plantations do not interfere with arable land, as tree plantations are usually established on land which is not or no longer suitable for crop cultivation. Therefore, the planning horizon that can be derived from investments in tree planting cannot necessarily be applied for investments in arable land such as soil conservation.

From these different sources, planning horizons for the CBA have been appraised. ***Different time frames*** are used in combination with different discount rates. These time frames are 10, 25, 50 and 100 seasons:

- 10 seasons or 5 years is extremely short, and benefits of soil conservation would probably not be visible. For some poor households, however, this might be the longest they can wait for investments to show positive results.
- 25 seasons, or 12.5 years, is about the planning horizon that farmers show with respect to tree plantations or dowries.
- With a planning horizon of 50 seasons, it can be assumed that the benefits of soil conservation should become visible, especially in cases where soil erosion and soil erosion reductions thanks to soil conservation are high. Also, it should be possible to amortise the high initial costs. 25 years are also about the time span after which fathers pass on part of their land to their sons. This planning horizon would

therefore give an indication of the state of the land that fathers bequeath to their children, depending on whether or not they undertake soil conservation today.[486]

- 100 seasons, or 50 years, would refer to a planning horizon of around two generations. Such a planning horizon is extremely long and especially relevant for investments with (i) a very long lifetime or (ii) possible high costs or benefits at a late point in time.

[486] In most analyses of agricultural and related projects, a project life span of 25 years is assumed as reasonable, although environmental benefits may take longer to realise. (Ninan & Lakshmikanthamma, 2001, 158)

# 6 An Assessment of the Profitability of SWC in the Ethiopian Highlands

## 6.1 The Outsider's View – Results of the CBA

*"Biophysical solutions which are not economically and socially viable must be regarded as incomplete or inadequate solutions."*
*(Anderson & Crosson, 1995)*

The basis for the evaluation of the profitability of SWC measures are ***farmers' fields*** in the three localities of Maybar, Andit Tid, and Anjeni. A total of 196 fields from 36 farmers were measured and described. The 196 fields are grouped according to (i) location within the study area, (ii) soil depth class, and (iii) slope class (cf. Table 45). In Maybar and Andit Tid, the considered area is divided into an upper and a lower part according to the different crops grown. In Maybar, maize is an important crop in the lower part, which does not grow in the upper part due to climatic limitations. In Andit Tid, the upper part is above roughly 3,200 m asl. This highland area (*Dega*) is characterised by a single barley crop during the *Belg* (small spring rains) season, followed by several years fallow. The lower part is characterised by a mixed cropping system with a dominance of *Meher* crops, depending on the summer rains (*Kremt*).

*Figure 44: Typical landscape and arable land in the lower part of the Andit Tid research area. The area in the middle of the picture (between the research station in the lower right corner, the small stream to the left, the homestead in the middle of the slope, and the small forest area in the upper right corner) is one of the measured fields used in the following calculations.*
*[Photo: E. Ludi, 1998]*

| | | | Soil depth class | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | *N* |
| | | Slope gradient | 0 – 10 cm | 11 - 20 cm | 21 - 30 cm | 31 – 40 cm | 41 - 50 cm | ≥ 51 cm | |
| | | | **Maybar, lower part of study area** | | | | | | |
| Slope class | 1 | 0 - 8% | . | . | 1 | 5 | 6 | . | *12* |
| | 2 | 9 - 15% | . | . | 1 | 8 | 1 | . | *10* |
| | 3 | 16 - 30% | . | 1 | 6 | 13 | 2 | . | *22* |
| | 4 | ≥ 31% | . | 2 | 5 | . | . | . | *7* |
| | | *N* | - | *3* | *13* | *26* | *9* | - | ***51*** |
| | | | **Maybar, upper part of study area** | | | | | | |
| Slope class | 1 | 0 - 8% | . | 1 | 3 | . | . | . | *4* |
| | 2/3 | 9 - 30% | . | 3 | 5 | 5 | 1 | . | *14* |
| | 4 | ≥ 31% | . | 3 | 6 | . | . | . | *9* |
| | | *N* | - | *7* | *14* | *5* | *1* | - | ***27*** |
| | | | **Andit Tid, lower part of study area** | | | | | | |
| Slope class | 1 | 0 - 8% | . | 3 | 6 | . | . | . | *9* |
| | 2 | 9 - 15% | . | 5 | 11 | 1 | . | . | *17* |
| | 3 | 16 - 30% | . | 1 | 18 | 1 | . | . | *20* |
| | 4 | ≥ 31% | . | . | 1 | . | . | . | *1* |
| | | *N* | - | *9* | *36* | *2* | - | - | ***47*** |
| | | | **Andit Tid, upper part of study area** | | | | | | |
| Slope class | 1 | 0 - 8% | . | . | 1 | . | . | . | *1* |
| | 2/3 | 9 - 30% | . | 3 | 5 | 3 | . | . | *11* |
| | 4 | ≥ 31% | . | . | 4 | 1 | . | . | *5* |
| | | *N* | - | *3* | *10* | *4* | - | - | ***17*** |
| | | | Soil depth class | | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6 | *N* |
| | | | 0 – 15 cm | 16 - 30 cm | 31 - 45 cm | 46 -60 cm | 61 - 75 cm | ≥ 76 cm | |
| | | | **Anjeni** | | | | | | |
| Slope class | 1 | 0 - 8% | . | . | . | 1 | . | . | 1 |
| | 2 | 9 - 15% | 2 | 7 | 3 | 7 | 2 | . | *21* |
| | 3 | 16 - 30% | . | 11 | 13 | 1 | . | . | *25* |
| | 4 | ≥ 31% | . | . | 1 | . | . | . | *1* |
| | | *N* | *2* | *18* | *17* | *9* | *2* | - | ***48*** |

*Table 45: Number of studied fields in the three research localities, differentiated according to location within the study area (upper / lower part of study area), slope class and soil depth class.*
*(Shaded cells indicate the cases considered in further analyses.)*
*[Source: Own investigation 1992, 1998, 1999]*

### 6.1.1 Soil life in the three research areas

An aspect to consider is the time (number of seasons) it takes for a soil to decrease to a depth[487] of 10 cm or less under different assumptions. Once the soil depth has decreased to below 10 cm, it is assumed that the land is taken out of crop production and is converted either into grazing land or into afforestation area. The different ***assumptions*** are that (i) soil erosion rates differ according to slope class and (ii) soil loss reductions differ according to soil conservation technologies. A special situation is given in the case of rill erosion. Besides the annual sheet erosion, rill damage occurs in regular intervals. It is assumed that rills occur always in the same location within a field. The depth of the rill from each event is assumed to be 12 cm. In following

487 The term 'soil depth' refers to currently reworkable soil depth.

seasons, the rills are levelled out by ploughing, resulting in a soil depth reduction of 40 mm on 30% of the field. Table 46 gives an overview of the different assumptions (cf. Section 5.1):

| | Soil loss – sheet erosion | | | Soil loss – rill erosion | Soil loss reduction | |
|---|---|---|---|---|---|---|
| | gentle slope (0-8%) | medium slope (9-30%) | steep slope (≥ 31%) | | introduced SWC | adapted SWC |
| **Maybar** | 5 t/ha p.a. | 28 t/ha p.a. | 57 t/ha p.a. | 40 mm per rill event on 30% of the field area | 55% | 28% |
| **Andit Tid** | 77 t/ha p.a. | 147 t/ha p.a. | 217 t/ha p.a. | | 59% | 30% |
| **Anjeni** | 83 t/ha p.a. | 145 t/ha p.a. | 208 t/ha p.a. | | 68% | 34% |

*Table 46: Different assumptions concerning annual soil loss rates and soil loss reduction thanks to different SWC measures in Maybar, Andit Tid, and Anjeni.*
*[Source: Own compilation based on data from the SCRP primary Database]*

For the calculation of the 'soil life', it is further assumed that in seasons in which the land is fallow and covered with stubble and weeds or grass, sheet erosion is zero. Thus, according to different crop rotation cycles in the two different parts of Maybar and Andit Tid study area (cf. Table 15 and Table 18), the upper and lower parts have to be analysed separately. Table 47 gives an overview of how many seasons it takes before the fields of the interviewed farmers have to be taken out of crop production because the soil depth has fallen below 10 cm, depending on whether the land is conserved with introduced or adapted SWC measures or suffers from sheet erosion, because no soil conservation is present. In the case of rill erosion the number of seasons indicated for the reduction of the soil depth to 10 cm only concerns the 30% of the field affected by rills. The other 70% are affected by sheet erosion only. The maximum time frame considered is 100 seasons or 50 years.

| | | **Maybar** | | | | | |
|---|---|---|---|---|---|---|---|
| Type of conservation / type of erosion | Soil depth / class | No of seasons for soil depth to reach <10 cm, slope class 1 (0-8%) | | No of seasons for soil depth to reach <10 cm, slope classes 2 and 3 (9-30%) | | No of seasons for soil depth to reach <10 cm, slope class 4 (≥31%) | |
| | | **lower** | **upper** | **lower** | **upper** | **lower** | **upper** |
| Introduced SWC | 20 cm | > 100 | > 100 | > 100 | > 100 | 85 | 87 |
| Adapted SWC | | > 100 | > 100 | > 100 | > 100 | 50 | 51 |
| Sheet erosion | 2 | > 100 | > 100 | 79 | 80 | 39 | 40 |
| Rill erosion | | 14 | 12 | 12 | 11 | 10 | 10 |
| Introduced SWC | 30 cm | > 100 | > 100 | > 100 | > 100 | > 100 | > 100 |
| Adapted SWC | | > 100 | > 100 | > 100 | > 100 | 99 | > 100 |
| Sheet erosion | 3 | > 100 | > 100 | > 100 | > 100 | 77 | 80 |
| Rill erosion | | 26 | 22 | 24 | 21 | 20 | 20 |
| Introduced SWC | 40 cm | > 100 | > 100 | > 100 | > 100 | > 100 | > 100 |
| Adapted SWC | | > 100 | > 100 | > 100 | > 100 | > 100 | > 100 |
| Sheet erosion | 4 | > 100 | > 100 | > 100 | > 100 | > 100 | > 100 |
| Rill erosion | | 44 | 37 | 38 | 32 | 32 | 30 |
| Introduced SWC | 50 cm | > 100 | > 100 | > 100 | > 100 | > 100 | > 100 |
| Adapted SWC | | > 100 | > 100 | > 100 | > 100 | > 100 | > 100 |
| Sheet erosion | 5 | > 100 | > 100 | > 100 | > 100 | > 100 | > 100 |
| Rill erosion | | 56 | 47 | 50 | 42 | 44 | 40 |

[Table continues on the next page]

| Andit Tid | | | | | | | |
|---|---|---|---|---|---|---|---|
| Type of conservation / type of erosion | Soil depth / class | No of seasons for soil depth to reach <10 cm, slope class 1 (0-8%) | | No of seasons for soil depth to reach <10 cm, slope classes 2 and 3 (9-30%) | | No of seasons for soil depth to reach <10 cm, slope class 4 (≥31%) | |
| | | **lower** | **upper** | **lower** | **upper** | **lower** | **upper** |
| Introduced SWC | 20 cm | 64 | > 100 | 34 | 97 | 24 | 67 |
| Adapted SWC | | 38 | > 100 | 20 | 55 | 14 | 37 |
| Sheet erosion | 2 | 28 | 79 | 14 | 37 | 10 | 25 |
| Rill erosion | | 10 | 8 | 8 | 8 | 8 | 7 |
| Introduced SWC | 30 cm | > 100 | > 100 | 68 | > 100 | 46 | > 100 |
| Adapted SWC | | 75 | > 100 | 40 | > 100 | 28 | 79 |
| Sheet erosion | 3 | 54 | > 100 | 28 | 79 | 20 | 55 |
| Rill erosion | | 20 | 20 | 18 | 14 | 14 | 13 |
| Introduced SWC | 40 cm | > 100 | > 100 | 100 | > 100 | 68 | > 100 |
| Adapted SWC | | > 100 | > 100 | 60 | > 100 | 40 | > 100 |
| Sheet erosion | 4 | 80 | > 100 | 42 | > 100 | 28 | 79 |
| Rill erosion | | 28 | 26 | 24 | 20 | 22 | 19 |
| Introduced SWC | 50 cm | > 100 | > 100 | > 100 | > 100 | 90 | > 100 |
| Adapted SWC | | > 100 | > 100 | 78 | > 100 | 54 | > 100 |
| Sheet erosion | 5 | > 100 | > 100 | 55 | > 100 | 38 | > 100 |
| Rill erosion | | 38 | 32 | 32 | 26 | 28 | 25 |

| Anjeni | | | | |
|---|---|---|---|---|
| Type of conservation / type of erosion | Soil depth / class | No of seasons for soil depth to reach <10 cm, slope class 1 (0-8%) | No of seasons for soil depth to reach <10 cm, slope classes 2 and 3 (9-30%) | No of seasons for soil depth to reach <10 cm, slope class 4 (≥31%) |
| Introduced SWC | 30 cm | > 100 | 87 | 62 |
| Adapted SWC | | 74 | 42 | 30 |
| Sheet erosion | 3 | 50 | 28 | 20 |
| Rill erosion | | 18 | 17 | 14 |
| Introduced SWC | 45 cm | > 100 | > 100 | > 100 |
| Adapted SWC | | > 100 | 74 | 52 |
| Sheet erosion | 4 | 86 | 50 | 34 |
| Rill erosion | | 34 | 28 | 24 |
| Introduced SWC | 60 cm | > 100 | > 100 | > 100 |
| Adapted SWC | | > 100 | > 100 | 74 |
| Sheet erosion | 5 | > 100 | 70 | 50 |
| Rill erosion | | 48 | 38 | 34 |
| Introduced SWC | 75 cm | > 100 | > 100 | > 100 |
| Adapted SWC | | > 100 | > 100 | 96 |
| Sheet erosion | 6 | > 100 | 90 | 64 |
| Rill erosion | | 60 | 50 | 44 |

*Table 47: Predicted time span (cultivation seasons) required for soils in different soil depth classes to reach a critical soil depth of 10 cm with different SWC measures and different forms of soil erosion in Maybar, Andit Tid, and Anjeni.*
*[Source: Own compilation]*

In ***Maybar***, low annual soil erosion rates between 5 t/ha and 57 t/ha have been considered in the CBA. Thus, it takes in most situations 100 or more seasons until the soil depth of the considered fields falls below 10 cm. Only in the case with shallow soils and medium to steep slopes the soil life is less than 100 seasons, be it with or without soil conservation. About 53% of the survey area (including the Maybar research catchment and its surroundings) were covered with shallow (25–50 cm) to very shallow (10-25 cm) soils in 1985, when a soil map was made.[488] It must be expected that since then, the soil depth has further decreased as a result of soil erosion. Almost 65% of the research catchment is steeper than 31% (cf. Table 31). If one further assumed that shallow soils are mostly concentrated on steep slopes, results presented in Table 31 would lead to the conclusion that more than 50% of the area would be covered with soils shallower than 10 cm within 85 to slightly more than 100 seasons if the soil depth is 30 cm or below and if introduced SWC measures were constructed. It would take only 50 to 77 seasons in the lower part of the study area and between 50 and a bit more than 100 seasons in the upper part for a soil to reach an expected critical depth of 10 cm or less if adapted SWC were applied on soils shallower than 30 cm. Only if soils are deeper than 30 cm the soil life can be extended to last longer than 100 seasons in the case where adapted SWC is applied. Without any conservation measures and under the assumptions as presented in Table 47, soils shallower than 20 cm on steep land can be used only for a further 39 seasons and soils shallower than 30 cm for another 77 seasons in the lower part and 40 to 80 seasons in the upper part, respectively. In the case of rill erosion, the soil depth on the affected 30% of the field decreases rapidly to 10 cm or below. In the worst case – shallow soils and steep slopes – it only takes 10 seasons until the soil depth is below the threshold of 10 cm.

Summarising, with the considered low annual soil loss rates, soils remain deeper than 10 cm in many instances during a period of 100 seasons. Two aspects have to be taken into account: Firstly, many soils in Maybar show a high stone cover with the effect of reducing the flow velocity of runoff and therefore (i) reducing the energy to detach and transport soil particles and (ii) increasing infiltration rates. This is especially the case for one of the TPs, from which annual soil loss rates are derived. Without this high stone cover it can only be speculated how much higher soil loss rates might be. Secondly, mean annual soil loss from TPs is with 28 t/ha comparably low. However, maximum annual values measured on TPs are between 96 t/ha and 119 t/ha.[489] If such values occurred on farmers' fields, soil depth reduction to critical threshold levels would be around twice as fast as indicated in Table 47 above.

In ***Andit Tid,*** the situation is markedly different from Maybar. Here, annual soil loss rates are between 77 t/ha and 217 t/ha, depending on slope class (cf. Table 46). Especially in the lower part of the study area, which is characterised by an intensive land use system, the reduction of the soil depth due to soil loss is fast. Only in few instances where soils are deeper than 50 cm, the land can be used for more than 100 seasons. Introduced SWC prolongs the soil life considerably compared to adapted SWC. Slopes steeper than 31% suffer from high annual soil erosion rates. These soils, even if deeper than 50 cm, decrease to 10 cm or below in less than 100 seasons even with introduced SWC. With adapted SWC, such soils are expected to be usable for another 54 seasons in the maximum. Without any soil conservation measures even comparably deep soils of 50 cm will last only for a further 38 seasons on steep slopes. In the upper part of the study area the situation is a bit less dramatic, as in this area longer fallow periods are still common. Soils on slopes with a gradient of less than 9% will remain deeper than 10 cm for the coming 100 seasons if conserved, either with introduced or adapted measures. Introduced SWC prevents soils from becoming shallower than 10 cm within 100 seasons even on steep slopes (>30%).

***Anjeni*** is characterised on the one hand by high annual soil erosion rates between 83 t/ha and 208 t/ha. On the other hand, soils in Anjeni are considerably deeper than in Maybar or Andit Tid. In addition, the soil loss reduction thanks to soil conservation is higher. Thus, on gentle slopes soils remain deeper than 10 cm in most cases, either with introduced or adapted SWC. On steep slopes, only introduced SWC prevents soils from decreasing to less than 10 cm within 100 seasons. Rill erosion leads to serious damage within a relatively short time. Even on soils with a depth of 75 cm, it only takes 60 seasons if the slope gradient is below 9% or only 44 seasons if the slope gradient is above 30% for the reduction of the soil depth to 10 cm or below.

488 Weigel, 1986.
489 SCRP, 2000d, 41.

***Decreases in soil depth and the need to invest in SWC***

It must be kept in mind that here only ***soil depth*** has been considered but no other ***soil quality factors*** influencing productivity such as nutrient content. It must thus be expected that with current farming practices, which are characterised by an almost total absence of measures to increase soil productivity, soil life in a sense of maintaining soil productivity and being able to produce crops is further reduced. On the other hand, with the above-presented calculations of soil life, based only on current soil depth and soil loss rates, mainly the reworkable soil depth has been considered. Sub-soils in many parts of the studied areas are not much different from the topsoil with regard to nutrient content, pH, and texture. The biggest difference between topsoil and sub-soil can be found with regard to organic matter content.[490] Thus, even if the reworkable topsoil is eroded, sub-soil coming to the surface does not necessarily make crop production impossible. With careful management, such as manuring, green manuring or crop residue management to increase the organic matter content, this sub-soil can be improved and in later years used again for crop production. This is one reason why in the Ethiopian Highlands, despite high to very high erosion rates, not more land is totally degraded or even denuded, but still used for crop production, albeit at a low production level.

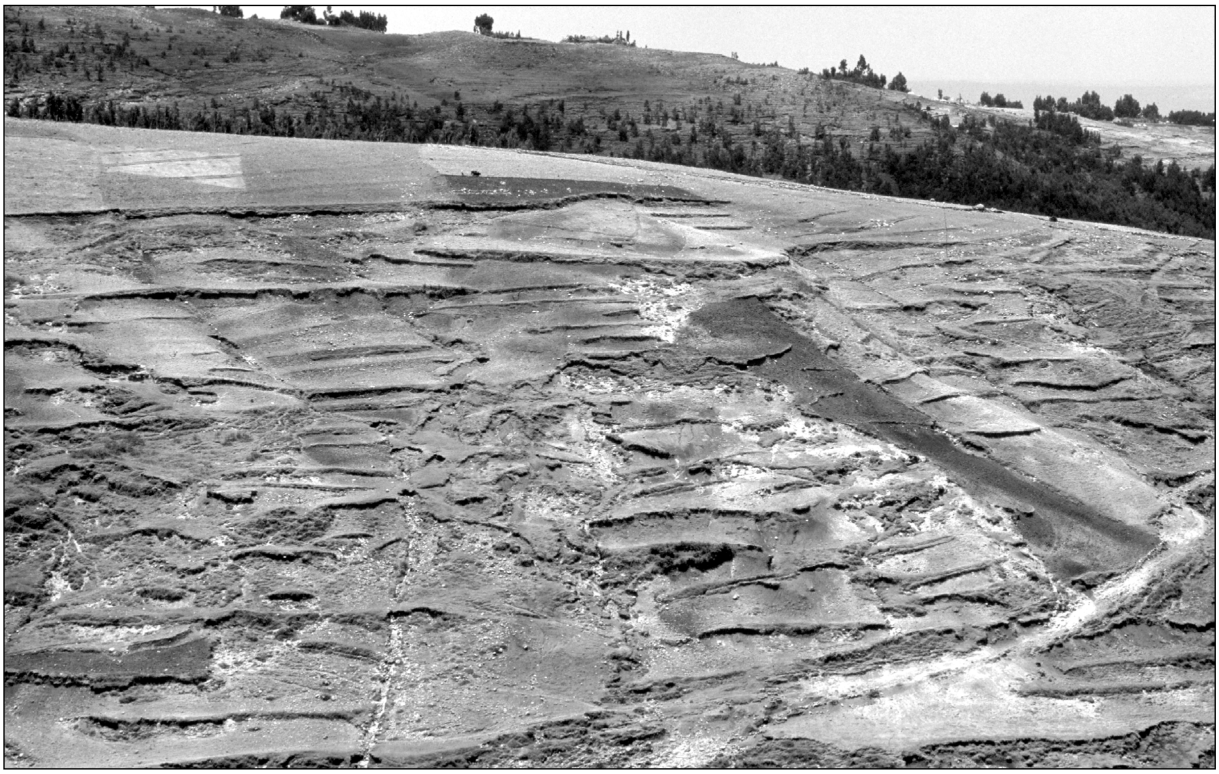

*Figure 45: Soil degradation in Andit Tid. Clearly visible are the big areas (light colour) where the soil has been washed away completely and the rock is coming to the surface.*
*[Photo: E. Ludi, 1998]*

To conclude from the above results that soil conservation is not an urgent need because even with sheet erosion many soils remain deeper than 10 cm for more than 100 seasons, would be erroneous. It is not a very realistic assumption that only sheet erosion affects a field and reduces soil depth by only a few millimetres annually. A much more frequent situation is that both ***sheet and rill erosion*** occur and that the damage from rill erosion is, although concentrated on a small percentage of a field, quantitatively often much more serious. In the CBA it has been assumed that rills occur only every 4$^{th}$ to 6$^{th}$ season and affect directly an area of only 10% of a field. After levelling out the damage in the following season by ploughing, the damage is spread to

490 Bono & Seiler, 1984, 45ff; Weigel, 1986, 69ff; Kefeni Kejela, 1995, 47ff.

30% of the field. With these assumptions, 30% of the field reach the critical threshold soil depth of 10 cm within a few years. If one assumed either more frequent damage or more serious damage, this critical level would be reached even earlier.

Soil life, at least concerning the depth of the reworkable topsoil, can already be used as an indication of the usefulness of soil conservation. With the ***assumptions regarding soil loss and soil loss reductions*** as presented in Table 47 it becomes evident that the soil depth remains for a much longer time above 10 cm with introduced soil conservation compared to the situation with no soil conservation. Even compared to adapted SWC, the lifetime of a soil thanks to introduced SWC is considerably longer. Especially on shallow soils and/or steep slopes with comparably high erosion rates, the time a soil remains deeper than 10 cm with SWC but decreases rapidly to below 10 cm without SWC is an important aspect. It might even be that soil conservation is not profitable in economic terms, but at least the soil remains deep enough for a time long enough to continue crop production and at the same time to search for alternatives. Such alternatives could either be improvements of the farming or land management system with the ultimate goal of increasing production and thus being able to pay back the investment costs or to search for alternative income generation opportunities for the affected population. The situation without SWC might be economically the more appealing solution, but once the soil is lost an array of possible options for improvement is also lost. With the focus on keeping the possibility for other options, such as changes of the farming and land management system or alternatives to crop production, open, there is a strong argument in favour of soil conservation without considering the economic performance of the technology. Only in a second step should the question of costs be raised – and especially the question of who covers the costs in the case that the technology is not profitable enough. A further discussion of this will follow in Section 6.1.6, after having analysed the economic profitability of the selected SWC technologies at field and farm level.

### 6.1.2 The economic profitability of SWC investments

One of the criteria to evaluate whether an investment is profitable or not is the ***Net Present Value*** (NPV) (cf. Section 4.2.1). An NPV > 0 indicates that discounted benefits exceed discounted costs. In the context of this study, benefits are mainly the value of the yield 'saved' thanks to SWC and additional grass production on the conservation structure. Costs are additional labour for the construction and maintenance of the SWC structures, costs for tools, and decreased yield because part of the arable area is occupied by conservation structures. Whether an investment is profitable or not, not only depends on effective costs and benefits of that investment, but also on the discount rate and the time span for which the costs and benefits are calculated.

The basis for the evaluation of the performance of SWC are two different ***SWC technologies*** and two different assumptions concerning ***soil erosion***. SWC technologies are assumed to be introduced SWC and adapted SWC. The former case corresponds to a situation where SWC structures are constructed according to guidelines developed for Ethiopian conditions, implying a considerable high portion of arable land occupied by the structures, but also the highest effect on reducing soil erosion. The latter case is an approximation to current situations on farmers' fields where originally constructed SWC structures have been modified and are combined with traditional forms of SWC. The amount of arable land occupied by SWC structures is smaller, but the technology is less effective in controlling soil erosion. These two situations with SWC are compared to the case without SWC where sheet erosion continues uncontrolled and decreases the soil depth continuously. A special case is modelled, in which rill erosion is assumed to damage a portion of a field in regular intervals leading to a reduction of the soil depth to a threshold value of 10 cm within a short period of time.

For the following analyses, ***planning horizons*** have been selected to be 100, 50, 25, and 10 seasons (cf. Section 5.4).

***Discount rates*** for the following analyses are assumed to be 5%, 12%, 58% and 149% (cf. Section 5.3).

In Section 5.2.1, the aspect of ***opportunity costs for labour*** has been discussed. For the following analyses two cases are distinguished: In the first case, opportunity costs for labour are EB 5/day, irrespective of the type of labour. In the second case, it is assumed that labour for SWC activities is partly subsidised and opportunity costs are reduced to EB 2.5/day.

In Section 5.1.3, the ***influence of artificial fertiliser*** on yields has been discussed. Two situations in the CBA are distinguished: Firstly, the situation without the application of artificial fertiliser. Here, yields as measured on farmers' fields in the three research catchments are used for modelling. The second case assumes that artificial fertiliser is applied and increases yields by 50% on land which is treated with introduced SWC, 40% on land which is treated with adapted or indigenous SWC, and 30% on land which is not conserved.

Figure 46 gives an overview of the different assumptions made for the calculation of the NPV:

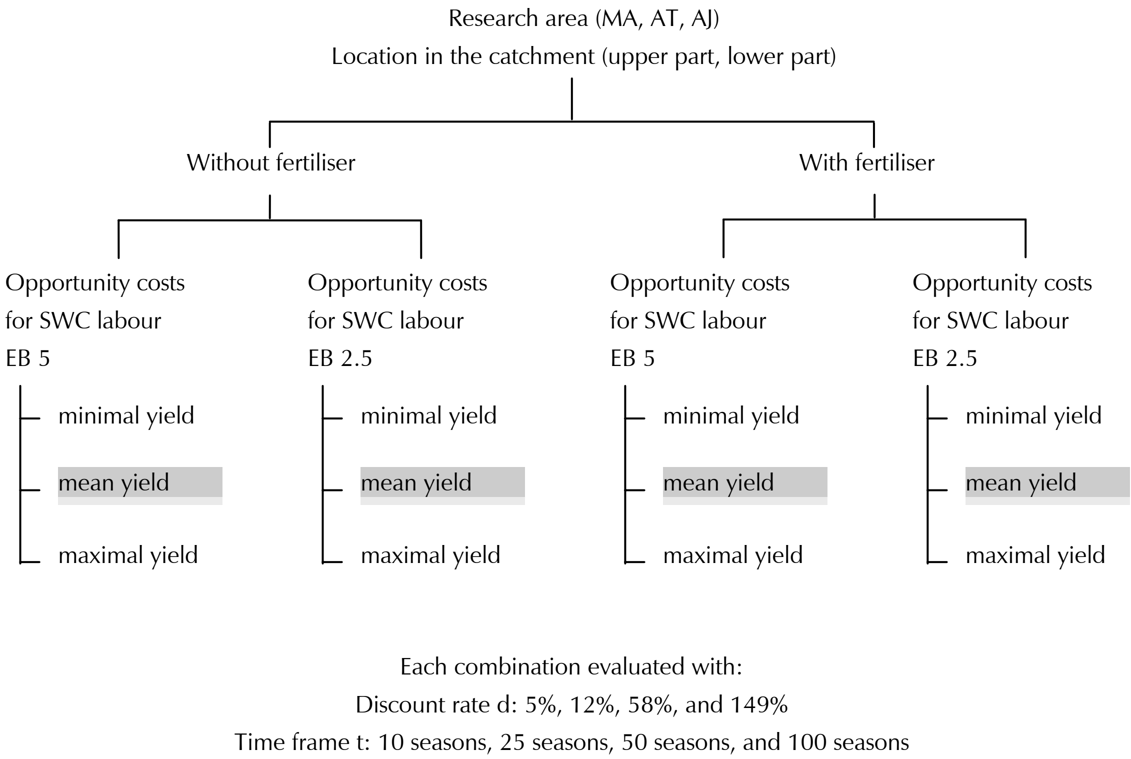


*Figure 46: Combinations of parameters for the calculation of the Net Present Value of different conservation technologies and erosion forms.*
*[Source: Own compilation]*

In the coming Sections, the following cases are differentiated:

- ***Case 1*** compares the NPV's resulting from the two different conservation technologies. The Discounted Net Gain (DNG) is calculated by subtracting the NPV resulting with adapted SWC from the NPV resulting with introduced SWC. A positive result means that introduced SWC performs better than adapted SWC.
- ***Cases 2 and 3*** compare the NPV's resulting from the two conservation technologies with the NPV that can be realised without SWC. The worst case of erosion, the combination of sheet and rill erosion, is considered. Like in case 1, the DNG is calculated. Positive results indicate that introduced or adapted SWC is more profitable than no SWC.
- ***Case 4*** calculates the difference between the NPV resulting if only sheet erosion is assumed and the NPV resulting if a combination of sheet and rill erosion is assumed. This gives an indication of the magnitude of losses resulting from rill erosion.

The discussion below only considers the DNG that results with mean yields (shaded cells). More detailed figures, including DNG's for with maximal and minimal yields are to be found in Appendix 6.1.

***Maybar – Lower part of the study area***

For the lower part of Maybar the following general conclusions can be made with regard to the profitability of soil conservation. For detailed figures, refer to Appendix 6.1.

**Case 1 – Introduced SWC – adapted SWC**

- If slope gradients are 8% or below, and the soil depth between 31 and 50 cm, introduced SWC performs better than adapted SWC if artificial fertiliser is applied. The additional yield that can be achieved with the application of fertiliser in the case of introduced SWC is comparably bigger than in the case of adapted SWC. This can compensate (i) the higher costs for the construction of and (ii) the bigger area occupied by introduced conservation structures. Subsidising labour costs alone does not make introduced SWC more profitable than adapted SWC. The magnitude of the discount rate has only an influence on the magnitude of the NPV. The utilisation of a lower discount rate would not make introduced SWC more profitable in other than the above-mentioned situations with the application of artificial fertiliser. Also the length of the time frame has no effect on these general findings. The original soil depth only plays a role in determining the magnitude of the difference of the NPV. The deeper the soil, the bigger is the difference of the two NPV's in those cases where introduced SWC performs better than adapted SWC and the smaller is the difference if adapted SWC performs better than introduced SWC.
- On slopes with gradients of 9% or above, adapted SWC always performs better than introduced SWC, which can be concluded from the negative DNG (NPV with introduced SWC < NPV with adapted SWC). The additional yield thanks to the application of artificial fertiliser cannot compensate the yield loss because of a higher percentage of area occupied by introduced SWC structures. Also the additional grass yield on the conservation structures does not contribute enough. The length of the time frame and the discount rate do not change these general findings, but have an influence only on the magnitude of the achievable NPV.

**Case 2 – Introduced SWC – sheet & rill erosion**

- On slopes with gradients of 8% and below, a subsidy of labour costs can turn the NPV of introduced SWC compared to the NPV in the case of sheet & rill erosion from slightly negative to slightly positive, if the time frame of analysis is 100 seasons and the discount rate is low. If the discount rate is increased and/or the time frame shortened, the NPV of introduced SWC becomes smaller than the NPV in the case of sheet & rill erosion. If fertiliser is applied, neither subsidising labour costs, changing the magnitude of the discount rate, nor the time frame has an influence on the general situation of a higher NPV with introduced SWC compared to the NPV in the case of sheet & rill erosion. The yield level (maximum, mean, minimum) only plays a role in the case of a time frame of 100 seasons, discount rates of 5%, not subsidised labour costs and no fertiliser application. With these assumptions, the NPV with introduced SWC is smaller than the NPV in the case of sheet & rill erosion if the yield were minimal.
- On slopes with inclinations between 9% and 15%, the application of artificial fertiliser can compensate the higher investment costs and costs caused by the land lost in the case of introduced SWC. In the short run of 10 seasons, however, besides the fertiliser application also a subsidy of the labour costs is necessary. Without fertiliser and either subsidised or standard labour, costs the NPV of introduced SWC is always lower than the NPV with sheet & rill erosion.
- If slope gradients are 16% and above, introduced SWC is no longer profitable, neither in the case where labour costs are subsidised nor in the case where fertiliser is applied. The land occupied by conservation structures is too big, reducing the arable area by 30%. This loss of arable land and crop production cannot be compensated by reduced yield declines thanks to soil conservation and by additional grass production on the conservation structures.
- An interesting case is presented on slopes steeper than 31% and rather shallow soils between 21 and 30 cm. If sheet & rill erosion continues uncontrolled, the soil depth is reduced to 10 cm or below within 14 to 26 seasons. In the special case where fertiliser is applied, labour costs subsidised, the discount rate with 5% very low, and the planning horizon 100 seasons long, introduced SWC can become again

more profitable than sheet & rill erosion. This can be mainly explained by the fact that in both cases – introduced SWC and uncontrolled sheet & rill erosion – 30% of the field are lost for crop production, although because of different reasons. It takes, however, a rather long time – more than 50 seasons – for the positive effects of SWC to show in the form of reduced declines of yields to pay back the investment costs.

**Case 3 – Adapted SWC – sheet & rill erosion**

- With the exception of the case where slope inclinations are between 16% and 30% and a soil depth between 31 and 40 cm, adapted SWC exhibits a higher NPV than sheet & rill erosion if considering a time frame of 100 seasons and a low discount rate of 5%. In the mentioned special case, the NPV of adapted SWC without the application of fertiliser is smaller than the NPV with sheet & rill erosion. This might be explained by the fact that soils are of comparably deep. It thus takes a relatively long time for soils to decrease to a depth of 10 cm or below even if rills occur. In the other cases the discount rate as well as the time horizon play a more important role. On slopes with a gradient of more than 8%, the NPV of adapted SWC in general is smaller than the NPV with sheet & rill erosion if the time frame considered is below 25 seasons. If the planning horizon is 25 seasons or longer, adapted SWC in combination with fertiliser application becomes more profitable than sheet & rill erosion. If the time frame of analysis is 50 seasons or more, also a subsidy of the labour costs alone without additional artificial fertiliser can change adapted SWC to being profitable. Increasing the discount rate from 5% to 12% would turn the NPV in the case without fertiliser application again to negative.

**Case 4 – Sheet & rill erosion – sheet erosion**

- The comparison of sheet & rill erosion with the situation of sheet erosion only reveals the high costs that are associated with rills. These high costs are composed of (i) the reduced yield in the season the rill forms, as besides soil also seeds are washed away, and (ii) the rapidly decreasing soil depth on 30% of the field to a depth of 10 cm or below. Especially if considering a long time frame of 100 seasons, the discounted costs of rill erosion alone compared to the situation with sheet erosion only amount to about EB 3,000 on gentle slopes (≤8%) with deep soils to more than EB 5,100 on steep slopes with shallow soils.

***Maybar – Upper part of the study area***

For the upper part of Maybar the following general conclusions regarding the profitability of soil conservation can be made:

**Case 1 – Introduced SWC – adapted SWC**

- On slopes with a gradient of 8% or below, introduced SWC is more profitable than adapted SWC only if fertiliser is applied. Subsidising labour costs, decreasing discount rates or increasing the time frame of analysis does not change these general findings.
- On slopes with a gradient of 9% and above, introduced SWC mostly performs worse than adapted SWC. A few exceptions can be observed if soils are extremely shallow (11-20 cm) and yields are minimal. Here, the effect of better erosion control thanks to introduced SWC as well as the increased grass production become visible together with the additional yield that can be achieved thanks to the application of artificial fertiliser. In the case of adapted SWC it only takes 51 seasons for a formerly 20 cm deep soil to be reduced to 10 cm or below, from when on crop cultivation is given up. In the case of introduced SWC, this threshold is reached only after 87 seasons. Soils that are shallower than 20 cm reach this final soil depth of 10 cm even faster.

**Case 2 – Introduced SWC – sheet & rill erosion**

- A comparison of introduced SWC and sheet & rill erosion shows that on gentle slopes of 8% and below the NPV with introduced SWC is higher than the NPV achievable with sheet & rill erosion already with a short planning horizon of 25 seasons. The magnitude of the discount rate plays a role only if yield levels are minimal. Here, the NPV turns from positive to negative if discount rates are increased from 5% to 12%, or from 12% to 58%, depending on the time frame considered.

- On slopes with an inclination between 9% and 30%, the soil depth is decisive in determining the profitability of introduced SWC. In the case of medium deep soils (31-40 cm), introduced SWC is never profitable. If the soil depth is reduced to 21 to 30 cm, introduced SWC becomes profitable if supplemented by artificial fertiliser, provided that the planning horizon is 50 seasons or longer. If the soil depth is further reduced to 11 to 20 cm, already subsidising labour costs without the application of artificial fertiliser can make introduced SWC profitable in the medium term (planning horizon 25 seasons or longer).
- The situation is similar to the above-mentioned case if the slope gradient is 31% and above. If in this case the soil depth is between 21 and 30 cm, introduced SWC is only profitable if fertiliser is applied, labour costs are subsidised and the planning horizon is at least 50 seasons. If the soil depth further decreases to 11 to 20 cm, introduced SWC is also profitable if labour costs are not subsidised but fertiliser applied in cases where the planning horizon is at least 50 seasons long.

**Case 3 – Adapted SWC – sheet & rill erosion**

- Adapted SWC on slopes with a gradient of 8% and below is profitable in most cases. Only if yield levels are minimal and discount rates above 12% in the case of a planning horizon of 50 seasons or more, or discount rates above 5% in the case of a planning horizon of 25 seasons or below respectively, adapted SWC is no longer profitable, compared to the situation with sheet & rill erosion. On these gentler slopes, it thus needs a certain time for the benefits of adapted SWC to show, i.e. for the damage of uncontrolled soil erosion to reach a level that is higher than the investment costs of adapted SWC.
- On slopes with an inclination between 9% and 30%, the profitability of adapted SWC increases with decreasing soil depth. If soils are shallower than 20 cm, adapted SWC already performs better than no conservation after 10 seasons – with the exception if yields are minimal. On soils with a depth of 21 to 30 cm it takes between 10 and 25 seasons for the benefits of adapted SWC to show, i.e. it takes a longer time for soils which are not protected with any conservation measure to reach the critical shallowness. If the soil depth is above 31 cm, it takes the application of fertiliser as well as a subsidy on labour costs for adapted SWC to be profitable in a time frame of 25 seasons. If the planning horizon is 50 seasons or longer, either subsidising labour costs or applying fertiliser makes adapted SWC profitable, at least if yield levels are average or maximal and discount rates low. Normal discount rates of 12% reduce the benefit of adapted SWC to such an extent that it is no longer a profitable option unless artificial fertiliser is applied.
- If slope gradients are above 31%, adapted SWC is profitable in most situations. If the soil depth is between 21 and 30 cm, the planning horizon must be at least 50 seasons long and the discount rate with 5% very low to achieve a positive NPV of adapted SWC compared to the situation of sheet & rill erosion. If the soil depth is between 11 and 20 cm only, it takes a time frame of only 25 seasons and a discount rate of 12% or below to achieve the same.

**Case 4 – Sheet & rill erosion – sheet erosion**

- The costs of rill erosion are not yet pronounced in the case of a planning horizon of only 10 seasons. The longer the planning horizon the higher the costs caused by rill erosion. After 100 seasons, these costs sum up to more than EB 8,000 in the case of medium steep slopes and average to shallow soils.

***Conclusions with regard to factors influencing the profitability of SWC in Maybar***

It is important to keep the following aspects in mind when interpreting the above-presented results:

***Soil erosion rates*** in Maybar are comparably low, even on slopes with a gradient of 31% and more. If higher soil loss rates were used for the modelling and the calculation of Net Present Values with different conservation technologies and erosion forms, the result might change considerably. Therefore, the absolute

NPV's as well as the comparison of the NPV's that can be achieved with different conservation technologies compared to different erosion forms are only of indicative nature. In reality, on farmers 'fields, it might well be that (i) sheet erosion is more pronounced because of higher erodibility of the soil (e.g. due to less stone cover than on TPs, which were the basis for the determination of annual soil loss rates) or (ii) more serious damage from rill erosion occurs, depending on the surrounding area causing run-on.

Compared to the other two research areas, ***labour input*** for the construction of introduced and adapted SWC structures is high. It is assumed that per day only 5 m of stone terraces can be constructed. This has two effects: Firstly, labour costs are high for the installation of the terraces. Secondly, maintenance costs are assumed to be 10% of construction costs. This assumption, especially in the case of well-designed and well-constructed stone terraces, leads to an overestimation of maintenance costs. It can be expected that in Maybar – provided that the construction is carried out in a careful manner – total maintenance costs are not higher than in the other two localities; on the contrary, it should be expected that they are lower. Based on the slope gradient – soil depth combinations found in the lower part of Maybar (cf. Table 45), a sensitivity analysis has been carried out to show the effect of decreased labour input for the construction and maintenance of SWC structures. Interestingly, the doubling of terrace construction per day (10 m/day instead of only 5 m/day) has only a marginal effect on the profitability of either introduced or adapted SWC. Only in few cases a change in relative profitability takes place (cf. Appendix 6.2 for the detailed Table). The analysis shows that decreasing labour inputs by 50% leads to a shift in the relative profitability only in those cases where fertiliser is applied. In other words, the labour savings alone do not compensate the yield decline because of the land occupied by conservation structures. In the maximum, labour savings per hectare add up to 260 days at EB 5 (EB 1,300, EB 650 if labour is subsidised with EB 2.5/day). Furthermore, within a planning horizon of 100 seasons, a change in relative profitability of different technologies and erosion forms occurs mainly in situations where only a minimal yield is harvested. 6 cases with different slope gradient - soil depth combinations are modelled.[491] With maximal yield levels and opportunity costs for labour of EB 5, only in one situation – slope gradient 30%, soil depth 25 cm –a decrease of the labour input by 50% leads to a change in the highest profitability from the case with sheet erosion to the case with adapted SWC. If labour is subsidised, this shift of the highest profitability from sheet erosion to adapted SWC can be observed only in two cases (slope gradient 30%, soil depth 25 cm and slope gradient 31%, soil depth 25 cm). In the case of minimal yield levels, more such shifts of the highest profitability take place. It can even be observed that if slope inclinations are 8% or below, a decrease in labour input can shift the highest profitability from adapted SWC to introduced SWC, which means that savings in labour can compensate the additional land occupied by conservation structures in the case of introduced SWC. It can be concluded that a change from a comparably labour-intensive conservation technology based on stone terraces to less labour-intensive soil bunds makes soil conservation more profitable only in very few and specific cases. Aspects such as land occupied by conservation structures are much more important. Higher profitability of introduced SWC as compared to adapted SWC resulting from decreased labour input can only be achieved on slopes with a gradient of 8% or below.

The regression functions calculated in Section 5.1.3 (Table 17, 20, and 25) show that in Maybar, the variable ***'slope gradient'*** explains yield variations better than the variable 'soil depth' (regression coefficient for slope gradient: -0.48, regression coefficient for soil depth +0.25, both coefficients are significant at the 1% level). In the CBA, the variable 'slope gradient' was only used for determining the number of necessary conservation structures and the erosion level. The variable 'soil depth' was used for modelling the effects of soil conservation or uncontrolled soil erosion on yields. No adjustment was made in the model for changing slope inclinations as a result of soil conservation. Soil conservation is not only designed to shorten slope lengths in order to slow down flow velocities of runoff and reduce its capacity to detach and transport soil particles; the effect of decreasing slop gradients is at least as important, as it increases infiltration and reduces runoff, both its quantity and its velocity. Reducing the slope gradient by 1 percent increases yields by +0.48%, whereas in the case of an increase in soil depth by 1 cm, the positive effect on the yield is only +0.25%. Maybar is located in an area with insecure rainfall – not so much with regard to the annual amount, which is

[491] (a) 8% slope, 35 cm soil depth, (b) 8% slope, 45 cm soil depth, (c) 15% slope, 35 cm soil depth, (d) 30% slope, 25 cm soil depth, (e) 30% slope, 35 cm soil depth, (f) 31% slope, 25 cm soil depth.

sufficient for crop production, but more with regard to the temporal distribution pattern. Water conservation aspects are therefore more important in Maybar than in the other two high-rainfall areas. It could be hypothesised that through soil conservation and gradually decreasing slope gradients infiltration of rainwater is enhanced, which leads to the observed positive effects on yields.

The calculation of the DNG was always done for the same ***yield level***, i.e. minimum, average, or maximum. It could be hypothesised, however, that SWC and, in the case of Maybar, specifically water conservation effects, increase the chance of harvesting average or even maximal yields. In comparison, on fields without any conservation, average or even minimal yields have to be expected more often. To illustrate the idea briefly, the NPV's of different conservation technologies and different erosion forms for a specific field (1 ha, 15% slope gradient, 35 cm soil depth, lower part of the study area, opportunity costs for labour EB 5, no fertiliser application) are presented in the following Table.

| NPV in the case of | Introduced SWC | Adapted SWC | Sheet erosion | Sheet & rill erosion |
|---|---|---|---|---|
| **Minimum yield** | -7,134 EB/ha | -4,452 EB/ha | -3,061 EB/ha | -4,476 EB/ha |
| **Average yield** | 14,068 EB/ha | 18,577 EB/ha | 20,654 EB/ha | 17,370 EB/ha |
| **Maximum yield** | 35,270 EB/ha | 41,606 EB/ha | 44,370 EB/ha | 39,217 EB/ha |
| **Expected NPV** | 14,068 EB/ha | 18,577 EB/ha | 20,654 EB/ha | 17,370 EB/ha |

*Table 48: Expected NPV for SWC technologies and erosion forms on a specific field in Maybar, lower part of the study area.*
*[Source: Own compilation]*

In the case presented in Table 48 above, the NPV achieved without soil conservation, but also without rill damage is always the highest, irrespective of the yield. If an expected NPV is calculated for the different cases and the probability of achieving a minimal, an average or a maximal yield is assumed the same for all, the highest expected NPV results in case of sheet erosion. If one assumed, however, that SWC positively influences yields, and that on fields with SWC an average or maximal yield can be achieved more often, the highest NPV may shift to another case. For example, it could be assumed that with SWC, in 3 out of 10 years a maximal yield can be achieved, in 4 years an average yield, and in 3 years a minimal yield, while without SWC, maximal yields could be achieved only in 2 out of the 10 years, and average and minimal yields in 4 years each. In this case, the following overall expected NPV's would result:

| NPV in the case of | Introduced SWC | Adapted SWC | Sheet erosion | Sheet & rill erosion |
|---|---|---|---|---|
| **Minimal yield** | 0.3 * -7,134 EB/ha | 0.3 * -4,452 EB/ha | 0.4 * -3,061 EB/ha | 0.4 * -4,476 EB/ha |
| **Average yield** | 0.4 * 14,068 EB/ha | 0.4 * 18,577 EB/ha | 0.4 * 20,654 EB/ha | 0.4 * 17,370 EB/ha |
| **Maximum yield** | 0.3 * 35,270 EB/ha | 0.3 * 41,606 EB/ha | 0.2 * 44,370 EB/ha | 0.2 * 39,217 EB/ha |
| **Expected NPV** | 22,509 EB/ha | 29,724 EB/ha | 15,911 EB/ha | 13,001 EB/ha |

*Table 49: Expected NPV for different conservation technologies and erosion forms based on different assumptions with regard to the distribution of years with minimal, average, and maximal yields. [Source: Own compilation]*

Based on these assumptions, adapted SWC would be the best option, followed by introduced SWC. However, this approach also has its drawback, as yields differ considerably between minimum and maximum. It remains questionable, whether, in a year with climatic limitations, SWC really can have such a strong positive effect on the yields.

The ***comparison of introduced or adapted SWC*** with the situation where erosion continues unabated showed that in many instances soil conservation is not profitable, i.e. the NPV resulting in the situation with

SWC is smaller than the NPV achieved in the case of uncontrolled erosion. According to standard economic wisdom, this implies that since the considered SWC technologies are not profitable, there is no incentive for investing. On the other hand, the comparison of sheet and rill erosion with mere sheet erosion clearly showed that losses resulting from rills are considerable. It must therefore be a primary goal at least to avoid rill erosion, if SWC remains unprofitable. Thus, targeted measures to prevent run-on from entering a field, in combination with small measures inside the field to prevent rills from developing, could already help to avoid considerable costs in the form of lost production in the year the rill develops and lost arable land after soil depth decreases to 10 cm or below. It can be expected that such measures are neither too costly nor too labour intensive. Moreover, the amount of arable land occupied by conservation structures can be kept low. Such small expenses should be justifiable in light of the high costs of rill erosion.

***Andit Tid – Lower part of the study area***

For the lower part of Andit Tid the following general conclusions regarding the profitability of soil conservation can be made:

**Case 1 – Introduced SWC – adapted SWC**

- On slopes with a gradient of 8% and less, introduced SWC performs better than adapted SWC if considering a long planning horizon of at least 50 seasons. This is especially the case if soils are very shallow (11 to 20 cm), irrespective of whether fertiliser is applied or not and of whether labour costs are subsidised of not. On deeper soils subsidising labour costs does not help to improve the performance of introduced SWC vis-à-vis adapted SWC. In this case, only the application of fertiliser makes introduced SWC more profitable than adapted SWC. If planning horizon is 25 seasons and below, the NPV with introduced SWC is higher than the NPV with adapted SWC only if fertiliser is applied. The discount rate plays a role in the situation with a long planning horizon of 100 seasons. In this case, the NPV with introduced SWC and fertiliser application is higher than the NPV with adapted SWC as long as the discount rate is below 58%. If no fertiliser is applied, this turning point is reached already with discount rates between 5% and 12%.
- On slopes with an inclination between 9% and 15% it takes at least an average yield and the application of fertiliser to make introduced SWC more profitable than adapted SWC in the long run (planning horizon of 50 seasons and longer). If the planning horizon is only 10 seasons, introduced SWC is not profitable compared to adapted SWC. In the long run, again, the magnitude of the discount rate is essential. Introduced SWC is, if at all, only profitable compared to adapted SWC if discount rates are below 12% in the case where no fertiliser is applied or if discount rates are below 58% in the case where both fertiliser is applied and labour costs are subsidised.
- On slopes with a gradient between 16% and 30%, introduced SWC is only profitable within a planning horizon of at least 50 seasons and if both fertiliser is applied and labour costs are subsidised. In all other cases, the portion of land occupied by conservation structures is too big and cannot be made up with higher production levels and lowered investment costs. Also the grass harvested on the conservation structures does not change these findings.

**Case 2 – Introduced SWC – sheet & rill erosion**

- On gentle slopes (≤ 8%), the NPV with introduced SWC is always higher than the NPV that can be achieved in the situation of sheet & rill erosion as long as the planning horizon is longer than 10 seasons and the discount rate below 58%. Within a planning horizon of only 10 seasons, only the application of fertiliser contributes to increase the NPV with introduced SWC enough compared to the situation with sheet & rill erosion.
- On medium steep slopes (9 to 15%) and shallow soils (11 to 20 cm) the NPV with introduced SWC is only higher than the NPV with no conservation if the yield is at least average. On such shallow soils the soil depth reduction even in the case with introduced SWC is considerable. Introduced SWC cannot prevent soils from becoming shallower than 10 cm. It only takes 34 seasons for the soil depth to be reduced to 10 cm or below. Thus, a seemingly paradox result can be observed: if the planning horizon is only

25 seasons, the NPV with introduced SWC is higher than the NPV with sheet & rill erosion, but if the planning horizon is 50 seasons or longer, the NPV with introduced SWC is below the one with sheet & rill erosion. This can be explained by the fact that during these 50 seasons on the one hand all the investments have been carried out, thus the full costs enter into the calculation, but that after about 34 seasons, despite all these investments, the land has to be taken out of production because the soil depth is 10 cm or less. Without soil conservation, 30% of the land has to be taken out of production after 8 seasons because rill erosion has damaged the soil and reduced its depth to 10 cm or below, and the rest after 14 seasons. Thus, the discounted costs of SWC (labour, land loss) are higher than the discounted benefits, i.e. crop production, which can be achieved from season 7 to 34 (on 70% of the land, 30% are shallower than 10% due to rill erosion) or 14 to 34 (on the rest of the land the soil depth has reached 10 cm or less resulting from uncontrolled erosion), respectively. For introduced SWC to be profitable compared to sheet & rill erosion, the discount rate must be between 12% and 58% if the planning horizon is 50 seasons or longer. If the soils are between 21 and 30 cm deep, a similar picture emerges as in the above-mentioned case. The main difference is the magnitude of the NPV, which is considerably higher, as the yield on soils with a medium depth (21 to 30 cm) is about 50% higher than the yield on shallow soils (11 and 20 cm).

- On slopes with a gradient between 16% and 30%, and a soil depth between 21 and 30 cm and within a planning horizon of at least 25 seasons, introduced SWC is more profitable than doing nothing if fertiliser is applied and opportunity costs for labour are EB 5, or if labour costs are subsidised. Discount rates should be below 12%, otherwise introduced SWC is no longer profitable with the exception of the case where labour costs are subsidised as well as fertiliser applied.

**Case 3 – Adapted SWC – sheet & rill erosion**

- On gentle slopes below 9%, adapted SWC is in the majority of analysed situations the more profitable option than sheet & rill erosion if the discount rate is below 58%. In some cases where yields are average or maximal, fertiliser is applied and/or labour costs subsidised, adapted SWC is even more profitable than sheet & rill erosion at a high discount rate of 58%. In the case of maximum yield, subsidised labour and fertiliser application, adapted SWC is even the better option than sheet & rill erosion if discount rates are 149%. The damage resulting from rill erosion – loss of 30% arable land within 10 to 20 seasons, depending on soil depth – is thus bigger than the decreased area of cropland that results with adapted SWC. In the maximum 8% of the arable land is occupied by conservation structures on such gentle land.
- Also on steeper slopes between 9% and 15% adapted SWC is the better option than sheet & rill erosion as long as discount rates are low (5 or 12%). As the threshold soil depth of 10 cm is reached within 8 to 18 seasons in the area affected by rill erosion, the length of the planning horizon is only decisive in determining the profitability of adapted SWC relative to sheet & rill erosion if it is below 25 seasons.
- Even on steep slopes between 16% and 30%, adapted SWC is more profitable than sheet & rill erosion if the planning horizon is longer than 10 seasons and the discount rate below 58%. Within a planning horizon of only 10 seasons, adapted SWC only performs better than sheet & rill erosion if fertiliser is applied. Otherwise, the installation and maintenance costs for adapted SWC and the area of arable land occupied by conservation structures exceed the costs resulting from sheet & rill erosion.

**Case 4 – Sheet & rill erosion – sheet erosion**

- The difference between sheet erosion and sheet & rill erosion is highest on slopes with a gradient below 9%, as the damage caused by sheet erosion is comparably lower here than on steeper slopes with higher annual soil loss rates. The maximum damage caused by rills over a planning horizon of 100 seasons is more than EB 2,600 on gentle slopes and around EB 1,200 on steep slopes. Again, it becomes apparent that within a planning horizon of only 10 seasons, the damage resulting from rills is not yet visible. It is thus important for the analysis of the profitability of SWC technologies compared to situations with uncontrolled erosion to have a planning horizon of at least 25 seasons to calculate meaningful results. With a planning horizon of 10 seasons only, often the wrong option – such as not investing in SWC and tolerating sheet & rill erosion – often seems more profitable.

***Andit Tid – Upper part of the study area***

For the upper part of Andit Tid the following general conclusions regarding the profitability of soil conservation can be made:

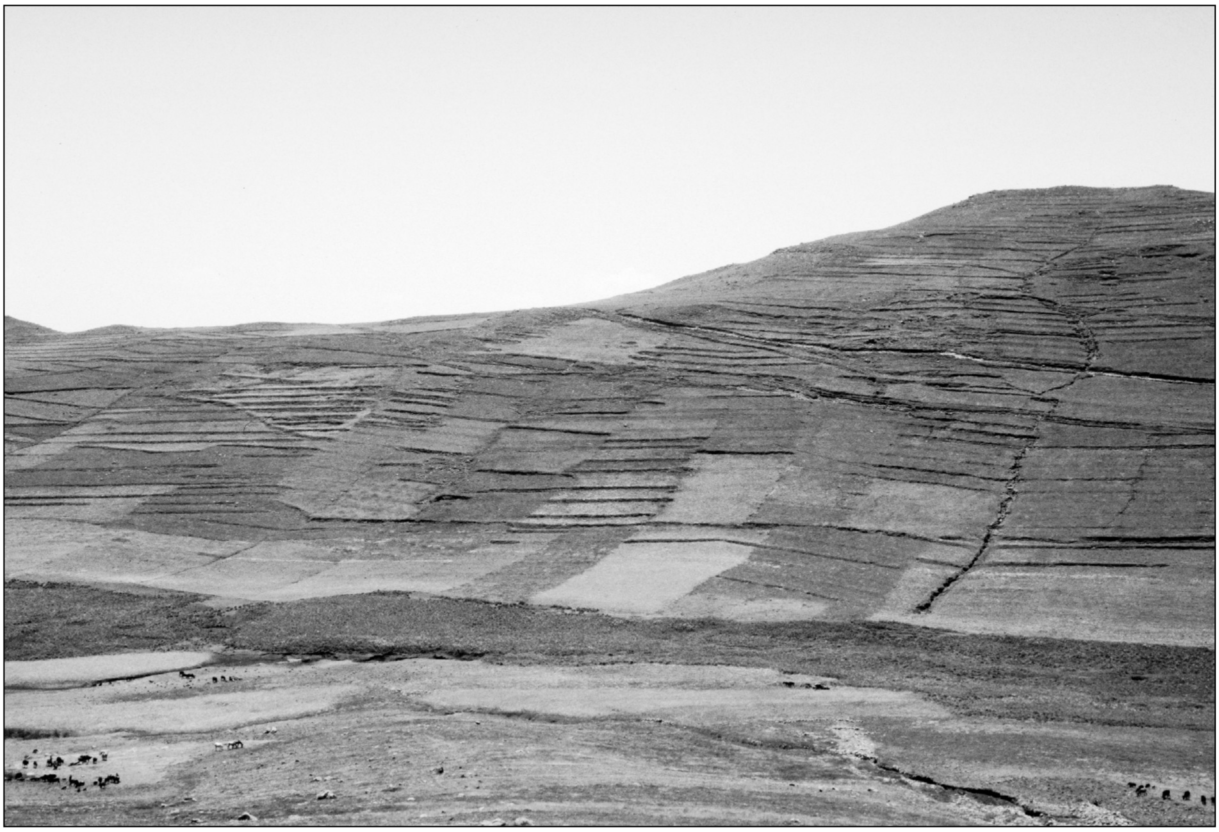

*Figure 47: The upper part (Dega) of Andit Tid research area at about 3,230 m asl. Some farmers have removed all conservation structures on their fields, while others have kept some or even all bunds. [Photo: E. Ludi, 1998]*

**Case 1 – Introduced SWC – adapted SWC**

- Contrary to the lower part of the Andit Tid study area the comparison of the performance of introduced SWC and adapted SWC shows that only in very few situations introduced SWC performs better than adapted SWC. These few cases concern those situations only where the soil depth is above 21 cm, irrespective of the slope gradient, of fertiliser application and of subsidising labour costs. That adapted SWC usually performs better than introduced SWC can be mainly explained with the land use system in this *Dega* area. Here long fallow periods are necessary in between barley cultivation. Although soil erosion rates are assumed to be high to very high in years in which barley is cultivated, it is also assumed in the CBA that in fallow years there is no soil erosion as the land is covered with a closed grass vegetation cover. Investment costs for introduced SWC and loss of arable land, which is between 15% and 30% (cf. Table 34), are thus higher than the yield loss that can be avoided with introduced SWC compared to adapted SWC.

**Case 2 – Introduced SWC – sheet & rill erosion**

- On slopes with a gradient between 9% and 30%, the NPV with introduced SWC is higher than the NPV with sheet & rill erosion if the planning horizon is longer than 50 seasons and the discount rate low. Only in the case of shallow soils (11–20 cm), the NPV of introduced SWC is smaller than the NPV with sheet & rill erosion. In this case introduced SWC cannot prevent soils from becoming shallower than 10 cm within

100 seasons, thus making it necessary to give up crop cultivation. The discount rate should not exceed 5% if only labour costs are subsidised or only fertiliser is applied. If both fertiliser is applied and labour costs for SWC activities lowered, introduced SWC remains profitable also if the discount rate is 12% on medium to shallow soils and even with an extremely high discount rate of 149% on deep soils. If the planning horizon is reduced to 10 seasons only, introduced SWC is hardly ever more profitable than sheet & rill erosion, as in this short time with the long fallow periods soil loss reductions and rill damages are not yet very big, and are certainly smaller than the avoided yield losses thanks to introduced SWC.

- On slopes with an inclination of above 30% and soil depths between 21 and 30 cm, introduced SWC is profitable within a planning horizon of 100 seasons. If the planning horizon is only 25 seasons, both the lowering of opportunity costs for SWC activities and fertiliser application is necessary to make introduced SWC more profitable than sheet & rill erosion. In the case of a very short planning horizon of 10 seasons only, introduced SWC is no longer profitable.

**Case 3 – Adapted SWC – sheet & rill erosion**

- The NPV with adapted SWC is in most cases higher than the NPV with sheet & rill erosion even if the discount rate is high or the planning horizon short. Thus, the additional labour that must be invested for the construction and maintenance of adapted SWC and the area that is lost for crop production, which does, however, not exceed 15%, can be justified in light of the reduced soil loss and the positive effect on the yield in comparison to the situation with sheet & rill erosion.

**Case 4 – Sheet & rill erosion – sheet erosion**

- Discounted losses over a period of 100 seasons resulting from rill damage are with more than EB 1,700 considerable. Depending on slope gradient and soil depth (cf. Table 47) it takes only between 7 and 19 seasons until the soil has reached the critical depth of 10 cm. It must be stressed here that these 7 to 19 seasons do not concern only seasons in which barley is grown, but also those seasons in which the land is left fallow.

***Conclusions with regard to factors influencing the profitability of SWC in Andit Tid***

In sum, it can be concluded that ***introduced SWC*** in Andit Tid only performs better than adapted SWC in the lower part of the study area if slope gradients are below 9% or if, on steeper slopes, fertiliser is applied and labour costs are subsidised. In the other situations, yield loss due to arable land being occupied by conservation structures and the higher labour costs of introduced SWC outweigh the positive effect of introduced SWC on reducing soil loss and therefore yield loss. Adapted SWC is more often the better solution than introduced SWC if compared to the situation with sheet & rill erosion.

In connection with a long planning horizon of 50 to 100 seasons, two effects have to be considered: on the one hand, introduced SWC is more labour intensive and the portion of land occupied by conservation structures is considerably higher than in the case of adapted SWC. On the other hand, the effect of introduced SWC on reducing soil loss is more pronounced, i.e. the soil depth decreases less rapidly to the critical depth of 10 cm. However, in certain situations (e.g. soil depth below 20 cm, or slope gradient above 9% on deeper soils), introduced SWC cannot prevent soils from becoming shallower than 10 cm. With adapted SWC the soil depth decreases more rapidly to 10 cm or below (cf. Table 47). Nevertheless, the extra costs of introduced SWC – in the form of additional labour and land loss as compared to adapted SWC – are higher than the benefits from production that can be realised in the additional seasons, in which crop production is still possible in the case of introduced SWC, but no longer in the case of adapted SWC.

In many cases, the calculation of the NPV for a period of only 10 seasons produces results, according to which sheet & rill erosion seems the better option than either introduced or adapted SWC. This points out how important it is to consider a ***time*** frame of at least 25 seasons when analysing of the profitability of SWC investments. The investment costs for SWC that have to be borne at the beginning are simply too high compared both to the positive effects of SWC on yields in later years or to the costs of uncontrolled SWC in early years.

The phenomenon observed in Maybar, where a negative NPV with introduced SWC on deep soils becomes positive when soil depth decreases, could not be observed in Andit Tid. Here, the high annual soil loss rates, even in the absence of rill erosion, decrease soils rapidly to a depth of 10 cm or below, after which crop cultivation has to be given up. By investing in SWC, the soil remains deeper than 10 cm for a longer period of time, although on shallow soils, SWC cannot in any case prevent soils from becoming shallower than this threshold depth within 100 seasons. Nevertheless, the high investment costs can be justified, as is shown by positive NPV's of both introduced and adapted SWC in most cases.[492] Only if time frames for analysis are short, investment costs exceed the benefits of conservation. The fact that the NPV is positive despite the high investment costs is explained mainly by the additional seasons of crop cultivation in the case of soil conservation as compared to the case of no soil conservation. The production in those additional years offsets the investment costs even if discounted at medium discount rates of 12%.

***Anjeni***

For Anjeni the following general conclusions regarding the profitability of soil conservation can be made:

**Case 1 – Introduced SWC – adapted SWC**

- Introduced SWC compared to adapted SWC on medium steep slopes between 9% and 15% performs better the shallower the soils are. On comparably deep soils between 46 and 60 cm, adapted SWC is the better option. On shallow soils (16 to 30 cm), introduced SWC is mostly the economically more profitable option. However, it takes a planning horizon of at least 50 seasons and a low discount rate of 5% or 12%, otherwise adapted SWC performs better because of lower investment costs. On soils deeper than 45 cm, the critical soil depth of 10 cm in the case of adapted SWC is reached within 74 to more than 100 seasons. Although this is still faster than it would happen with introduced SWC, the lower costs of adapted SWC make up the additional production that can be realised in the case of introduced SWC. On shallow soils, however, the time the land can be cultivated thanks to introduced SWC is more than double what would be possible with adapted SWC (87 seasons instead of only 42 seasons). In this case, the higher costs in the form of additional labour input and additional amount of land occupied by conservation structures are justifiable.
- On steeper slopes between 16% and 30%, the situation is similar to the above case. Here, the subsidising of labour and/or the application of fertiliser is additionally required to make introduced SWC more profitable than adapted SWC even on shallow soils between 16 and 30 cm.

**Case 2 – Introduced SWC – sheet & rill erosion**

- On soils with a depth of less than 30 cm and slope gradients between 9% and 15%, introduced SWC is the better option than no soil conservation even if the planning horizon is relatively short. On soils with a depth of 46 cm and above, the NPV with introduced SWC is only higher than the NPV that can be achieved in the case of sheet & rill erosion if fertiliser is applied. Again this can be mainly explained by the fact that on deep soils, despite the high annual soil loss rates in Anjeni, the soil depth without SWC does not decrease rapidly enough to critical levels to justify the high investment costs. The magnitude of the discount rate is essential in determining which option is profitable. Only in the case of low discount rates of 5% or 12%, introduced SWC performs better. Otherwise, the continuation of uncontrolled sheet & rill erosion is economically more profitable.
- On slopes with a gradient between 16% and 30% the situation is similar to the situation on flatter slopes. One difference is that if the planning horizon is only 25 seasons or shorter, the application of fertiliser is required additionally to make introduced SWC more profitable.

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492 This observation corresponds to findings by other authors that shallow topsoils increase the present value of early adoption of soil conserving technologies, since these defer the date of land abandonment. (Coxhead, 1996, 8)

**Case 3 – Adapted SWC – sheet & rill erosion**

- Adapted SWC on medium steep slopes (9 to 15%) and soils shallower than 30 cm is the more profitable option even in the short run compared to no SWC. On soils deeper than 45 cm, it already takes a longer planning horizon of at least 50 seasons for the positive effects of SWC to materialise. If the time frame of analysis is shorter, only the application of fertiliser can increase the benefits of adapted SWC enough to make it economically more profitable. Similar to the situation with introduced SWC the discount rate should not exceed 12%. Otherwise, the benefits of soil conservation accruing only after several years are weighed too low compared to the initial investment costs.
- On steeper slopes between 16% and 30%, the situation as described above for medium steep slopes is the same.

**Case 4 – Sheet & rill erosion – sheet erosion**

- The shallower the soils and the longer the time frame of analysis the more pronounced are the costs of rill erosion. Discounted losses over a period of 100 seasons sum up to almost EB 1,900. In the short run of only 10 seasons, the losses of rill erosion are negligible. Even if it takes only between 14 and 18 seasons on soils shallower than 30 cm for the soil to reach the critical depth of 10 cm or less, the effect of sheet erosion alone on yield levels is small, some crops, especially tef (cf. Table 24), even react positively to decreasing soil depth. Thus, the full costs of rill erosion only show after a comparably long time.

***Conclusions with regard to factors influencing the profitability of SWC in Anjeni***

In Anjeni, in many situations neither introduced nor adapted SWC performs better than no SWC. This is mainly due to the following factors: Firstly, soils are comparably deep. Although soil loss rates are high to very high, negative effects of decreasing ***soil depth*** show late. Secondly, the regression functions linking yields with soil depth and slope gradient indicate that some crops show the tendency of reacting positively to decreasing soil depth. Especially on gentle slopes – and, accordingly, behind conservation structures – stagnant water is a serious problem. The deeper the soil, the more water it can retain, and the more severely the crops will be damaged. In contrast, shallower soils which retain less water, dry out more quickly, and therefore do less damage to crops. As rainfall amounts are not a limiting factor in Anjeni, water conservation is less important. On the contrary, it can be observed that with better soil and water conservation the problem of waterlogging increases and thus leads to decreasing yields with increasing soil depth and/or decreasing slope inclination.

Due to the comparably deep soils in Anjeni, positive aspects of SWC generally become noticeable only after a long period of 50 to 100 seasons. The magnitude of the ***discount rate*** is therefore of great importance. With a discount rate of 12% and above, the late positive effects of SWC weigh much less than the high immediate costs, such discount rates therefore result in a negative NPV.

Like in Maybar, SWC is less profitable on deep soils than on shallow soils, especially in the short run. However, it would be erroneous to conclude that as long as soils are still comparably deep, e.g. deeper than 45 cm, soil conservation should not be undertaken. With the observed high annual soil loss rates, soils quickly degrade to critical depth.

### 6.1.3 Conclusion and comparison of the profitability of SWC in Maybar, Andit Tid, and Anjeni

A general conclusion to be drawn from the analysis is that the profitability of introduced or adapted SWC is pronouncedly ***situation-specific***. It clearly depends on slope gradient and soil depth, annual erosion rate and the reduction of soil loss rates by the considered SWC technologies. Thus, a conservation technology that is profitable in one research area with a specific combination of slope gradient and soil depth, specific annual soil erosion rates and specific factors of soil erosion reduction through the considered SWC technology is not necessarily profitable in another research area. This is an important finding when it comes to promoting SWC, as it indicates that a standard solution for a whole area – be it in terms of the research catchments and surrounding areas or in terms of Amhara Region as a whole – is thus not advisable. Because the soil conservation campaigns of the past decades were based on such standard solutions, in many localities the conservation technologies propagated proved unprofitable from the farmers' point of view. This has certainly led to the rather negative attitude of many farmers when it comes to further SWC investments.

***Conclusions with regard to introduced SWC***

The findings show that in ***Maybar***, compared to the situation without SWC, introduced SWC is, if at all, profitable in the following cases:

(i) if slope gradients are small (≤8%), or
(ii) on medium steep slopes (9-30%) in the upper part of the study area if the soil depth is below 30 cm. or
(iii) on steep slopes (≥31%) in the upper part of the study area if the soil depth is below 20 cm.

These findings point at two very crucial issues: Firstly, if soil loss rates are low and decreasing soil depth has a small negative effect on yields, as is the case in Maybar, investment costs usually outweigh benefits that can be achieved with soil conservation, i.e. prevented yield decreases. Only on gentle slopes, where not more than a few terraces are necessary, the discounted investment costs (labour, loss of arable land for crop production) are lower than the discounted benefits. As slope inclinations increase and more conservation structures become necessary, the investment costs rapidly exceed the benefits of SWC. Secondly, SWC is often not profitable as long as the soils are at least medium deep (i.e. deeper than about 30 cm) and thus produce acceptable yields. In such situations, the investment costs are higher than the benefits in the form of prevented yield decline. Only if the soil depth decreases to critical levels, investments in SWC become more profitable than the laisser-faire strategy. This only becomes visible if the situation is analysed over a long – for a subsistence farmer usually too long – planning horizon. The indication that, compared to the situation in which uncontrolled soil erosion occurs, SWC is only profitable if soil depths are shallow, gives the wrong signal. It could be interpreted as an indication that it is economically wise to first use the land without any SWC investments until the soil depth has decreased to a critical level. Those cases where the NPV with introduced SWC is higher than the NPV with sheet & rill erosion on medium steep slopes (9-30%) with a soil depth of 30 cm or below can only be explained by the fact that within a relatively short time, crop production will have to be stopped on 30% of the field because the soil depth will have decreased to 10 cm or less. If only sheet erosion was considered, introduced SWC would be profitable in even fewer cases. Nevertheless, it would be totally misleading to conclude from this that it is generally the economically better option to first let the soil depth decrease and only then invest in SWC. It is important to consider is that in the CBA, other than the depth of the reworkable soil, no other soil properties were included for modelling the effects of degradation on productivity. Uncontrolled soil erosion, however, not only decreases the soil depth, but also changes other soil properties, such as organic matter content, nutrient content or soil structure, which are at least as important as soil depth. Especially in Maybar, where annual soil erosion rates are low, the effect of decreasing soil depth on yields is rather small, and because only this one factor contributing to soil profitability has been considered, probably underestimates yield declines resulting from soil erosion. This could be one explanation for the low profitability of introduced SWC in Maybar. If other factors contributing to soil productivity were included in the calculations, the result might look quite different.

In ***Andit Tid***, introduced SWC is in most cases profitable compared to the situation of sheet & rill erosion if the planning horizon is at least 50 seasons. Within a planning horizon of only 25 seasons, a subsidy of labour costs and/or the application of artificial fertiliser are necessary. This frequent profitability of SWC is explained mainly by the high annual soil loss rates, which rapidly reduce the soil to a critical depth of 10 cm or below if no SWC is applied.

In ***Anjeni***, introduced SWC is profitable if the planning horizon considered is at least 50 seasons. Often, in addition, a subsidy of labour costs and/or the application of fertiliser are necessary. The shallower the soils on constant slopes, the bigger the difference between the NPV's of introduced SWC and sheet & rill erosion respectively. This can be explained mainly by the time necessary to reduce the soil depth to 10 cm or below in the part of the field affected by rill erosion. The shallower the soil, the earlier this definitive loss of 30% of the arable land is reached.

The fact that introduced SWC performs differently in each of the ***three study areas*** can be explained with (i) different soil loss rates,[493] (ii) different 'initial' soil depth, (iii) different reaction patterns of crops to decreasing soil depth, and (iv) different effectiveness of introduced SWC in controlling soil erosion. In Andit Tid, the postulated annual yield decline resulting from uncontrolled soil erosion is -0.91%. In Anjeni, the annual yield decline in the case of uncontrolled soil erosion is only one quarter of that observed in Andit Tid (-0.23%) and in Maybar it is even only -0.07% (cf. Table 30). Thus, in Maybar it takes much longer than in Anjeni or in Andit Tid for the negative effects of decreasing soil depth to manifest themselves in the form of decreasing yields. Because erosion rates are low in Maybar, the 'initial' soil depth must be much shallower than in the other two study areas for the negative effects of soil erosion to show.

Despite the high annual soil loss and the generally shallow soils in Andit Tid, it takes a planning horizon of at least 50 seasons for the positive effects of soil conservation to show. 50 seasons or 25 years is already an extremely long planning horizon for a small-scale subsistence household. It will hardly be possible to convince farmers in this area to invest in introduced SWC without any outside assistance, as the possibility of not being able to profit from these investments is simply too big.

The fact that introduced SWC is not more profitable in Anjeni can be explained by (i) the comparably deep soils, which hardly ever degrade to 10 cm or below within 100 seasons even with high annual soil loss rates, and (ii) the positive reaction of some crops to decreasing soil depth. In this high rainfall area, by addressing the problem of soil erosion one often creates another problem – that of stagnant water.[494]

***Conclusions with regard to the relation between introduced and adapted SWC***

The comparison of introduced and adapted SWC shows for all three research areas that in most situations adapted SWC performs better than introduced SWC. Better performance in this context is considered a higher absolute DNG. (Positive values in the figures indicate that the NPV with introduced SWC is higher than the NPV with adapted SWC). In Anjeni, introduced SWC often performs better than adapted SWC if soils are shallow (16-30 cm). This is mainly due to the fact that on such shallow soils adapted SWC cannot in any case prevent the soil depth from dropping to 10 cm or below. On soils deeper than 30 cm the investment costs for introduced SWC are higher than the gains compared to adapted SWC. For introduced SWC to perform better than adapted SWC it additionally takes a planning horizon of at least 50 seasons, and discount rates must be below 12%. In very few situations, subsidised labour costs and fertiliser application can make introduced SWC more profitable than adapted SWC already within a planning horizon of 25 seasons. The fact that discount rates must be below 12% for introduced SWC to be more profitable than adapted SWC, demonstrates the effect of discounting in cases where costs and benefits are distributed over time in an unfavourable manner. Especially in Anjeni, where the positive effects of soil conservation are visible only after several years, if not decades, high discount rates make these late benefits too small in comparison with the high initial investment costs.

In the lower part of the ***Andit Tid*** study area, introduced SWC performs better than adapted SWC if slopes are gentler than 9%. The performance of introduced SWC vis-à-vis adapted SWC can be further increased if fertiliser is applied. Subsidising labour costs alone does not sufficiently contribute to increasing the NPV of introduced SWC. The steeper the slope, the less profitable introduced SWC is compared to adapted SWC. Again, this is mainly because of the high initial investment costs and the considerable portion of land occupied by conservation structures. The fact that soil loss rates can be reduced much more efficiently with introduced than with adapted SWC is not enough to compensate the additional costs. Also the additional grass that can be harvested on the conservation structures does not contribute enough. In the upper part of the study area, introduced SWC is hardly ever the better option than adapted SWC. This is mainly due to the fact

493 Depending on annual amounts of rainfall, rainfall distribution, erosivity, soil properties, cropping systems, etc.

494 Herweg & Ludi, 1999, 107.

that despite high annual soil loss rates in those seasons in which barley is cultivated, decreasing soil depth is slowed down during the long fallow periods of several years. The much higher investment costs for introduced SWC compared to adapted SWC are thus not justifiable. The cases, in which introduced SWC performs better than adapted SWC concern those few situations where labour costs are subsidised, fertiliser is applied, and the planning horizon is at least 50 seasons long. Neither subsidising labour costs alone nor using fertiliser alone contributes to a better performance.

In ***Maybar***, introduced SWC only performs better than adapted SWC if slope gradients are 8% or below. In addition, labour cost subsidies for SWC activities as well as fertiliser application are required. The location within the study area, i.e. in the lower or in the upper part, has no influence on these general findings. Interestingly, the magnitude of the discount rate does not play a role either. Even with extremely high discount rates of 149%, in the specific cases mentioned introduced SWC performs better than adapted SWC. In these situations the additional gains achievable with introduced SWC thus justify the additional costs, both in terms of labour and land lost. If slopes are steeper than 8%, introduced SWC is always the less profitable conservation technology. The higher portion of land occupied by conservation structures and the higher labour costs are not justifiable in light of the low annual soil loss rates with the resulting small yield declines.

***Conclusions with regard to costs of rill erosion***

Costs of rill erosion are considerable in all three localities. A clear differentiation can be made according to the length of the ***time*** frame considered. Within a time frame of only 10 seasons, the costs are not yet pronounced. The shallower the soils, the higher the costs are, as the soil depth in the area affected by rill erosion rapidly decreases to 10 cm. Damages resulting from rill erosion are visible later in Maybar than in Andit Tid, where annual soil loss rates are high and soils generally shallow, and in specific situations also in Anjeni. In Anjeni, soils are considerably deeper than in Andit Tid. Thus, despite similar annual soil loss rates it takes more time for the soil depth to drop to 10 cm or below. A crucial aspect is once again the magnitude of the discount rate. If the time horizon of analysis is kept constant at 100 seasons and a discount rate of 12% instead of 5% is used, the damage resulting from rill erosion drops to roughly one third to one fifth in Maybar and in Andit Tid, and to even less than one sixth on deep soils in Anjeni. By increasing the discount rate, costs in later years, i.e. reduced yields resulting from soil erosion, are valued much less than costs in early years, i.e. labour costs and arable land occupied by conservation structures. Generally speaking, the deeper the soils and the longer it takes for the soil to decrease to 10 cm in the part of the field being affected by rill erosion, the smaller this damage is assessed with increasing discount rates.

### 6.1.4 Conclusions with regard to the relation between soil erosion and soil productivity used in the CBA

The primary goal of conducting a CBA is to show if, and under what conditions, soil conservation is profitable in comparison to the situation where soil erosion continues unabated. In addition to an integration of the direct investment costs for SWC, which are comparably easy to determine, this requires the establishment of a soil loss – soil productivity relation. As was mentioned in Section 5.1.1, this relation is extremely complex, as it involves many and very different factors, from both the ecological and the socio-economic sphere, which, in their multifaceted relations, are not always fully understood. In this report, for the modelling of the soil erosion – soil productivity relation, only two indicators – that of the reworkable soil and slope inclination – have been considered. It was assumed that soil erosion reduces the soil depth and that this indicator also represents other factors contributing to soil productivity that are affected by soil erosion. As the regression functions linking yield with soil depth show (cf. Table 17, 20, and 25), the explanatory power of the variable soil depth in determining the yield is rather small (small value of $R^2$). This means that other factors in the physical and in the land management environment also play an important role. However, for a variety of reasons, these factors were not included in the regression function.[495] It could well be that if these other factors, which contribute to soil productivity and are affected by soil erosion, such as nutrient content, organic matter content, water retention capacity or soil structure, were included in the regression functions, soil erosion would be shown to have a more pronounced negative effect on yields.

The results of the CBA presented in Section 6.1.2 in the form of incremental discounted net gains (DNG) of different soil conservation technologies compared to different situations without soil conservation depend heavily on the ***assumptions*** made relating yield declines to soil depth decrease. If, for example, one assumed that yields decline more dramatically per one centimetre soil depth reduction, *ceteris paribus*, SWC would be economically profitable in more situations. In many CBA's of soil conservation investments it is often wrongly assumed that once the investments are carried out, soil erosion can be controlled efficiently enough to stop soil depth from further decreasing.[496] The analysis of data from the SCRP, however, shows that also in the case of SWC, soil erosion cannot be totally stopped but only reduced, at least in the first five years after the terraces have been established. Linked to the assumption that SWC investments can control soil erosion in an efficient manner are assumptions relating to yield changes. It is often assumed that once soil conservation structures are established, crop yields remain constant. Again, SCRP data show that this is not the case. For the analysis of the profitability of SWC investments, yield differences are often calculated between accumulation zone, i.e. just above the conservation structure, and the loss zone, i.e. below the conservation structure.[497] It is then assumed that the yield as measured from the accumulation zone – usually a small area of a few square metres – represents the situation with soil conservation, while the yield from the loss zone represents the situation without soil conservation.[498] The analysis of SCRP data clearly shows that the yield in the accumulation zone (A) is significantly higher than the yield from the loss zone (C) or the area in between (B). Total yield between two conservation structures is composed of the yield from the accumulation zone, the loss zone and the intermediate zone inbetween. Unfortunately, the accumulation zone is only a small percentage of the total area between two conservation structures (cf. Figure 32). Thus, the high yield from the accumulation zone can be realised only on a small portion of the total field. For the CBA in this study, the yield as achievable in the case with SWC is thus calculated by taking the yield from all three locations, A, B, and C, according to the area percentage of the three zones between two conservation structures. This lowers the total yield considerably compared to the case where only yields from location A were taken into account to represent the situation with SWC. For the modelling of yield changes in the case of no conservation, the yield from location B has been used as the best approximation, as in this zone soil detachment, soil transportation, as well as soil deposition occurs.

Thus, the here presented CBA takes into account three things that are often not considered: Firstly, it acknowledges the fact that ***soil erosion cannot be entirely controlled*** even with introduced soil conservation. Secondly, its calculations are based on yields that represent a slope-specific ***combination of yields*** from the three locations A, B, and C in relation to the conservation structures. And thirdly, the ***land occupied by conservation structures*** is taken into account in its true extent, according to soil depth, slope gradient, and conservation technology (i.e. a maximum of 10% for adapted, and 30% for introduced SWC). In consequence, results show that total yields from conserved fields are often smaller than yields from unconserved fields, especially in the first years. In those situations where soil loss rates and the effect of decreasing soil depth on the yield are low, yields from unconserved fields remain higher than yields from conserved fields even after a long period. In these cases, the small annual yield loss due to uncontrolled erosion is much smaller than the yield loss due to the considerable reduction of arable area if SWC is practised.

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495 These other factors were not included in the regression functions because they are not available as time series. It was therefore not possible to establish a relationship between absolute annual soil loss, changes in the nutrient content, organic matter content, or soil structure, and their influences on yields.

496 e.g. de Graaff, 1996, 101.

497 Accumulation zone corresponds to sampling location A and loss zone to sampling location C, respectively (cf. Figure 32).

498 e.g. Berhanu Gebremedhin, et al., 1999, 571 (cf. Section 4.5.6 for a discussion of his results).

To compensate the yield loss, the conservation structures can be used in a productive manner. In this study, it has been assumed that ***fodder grass*** is grown on the structures. However, the value of the grass production cannot compensate the value of the decreased yield.

By ***discounting benefits and costs to present values***, the high initial investment costs as well as the negative yield difference in early years are valued much higher than the positive yield differences in later years that can be achieved thanks to soil conservation. Investments in SWC are a good example for the often-observed unfavourable temporal distribution of costs and benefits, which is a characteristic of many environmental investment projects. By considering input factors as measured or observed, and thereby portraying this unfavourable timely distribution of costs and benefits, the result is often a negative NPV of SWC compared to the situation without any soil conservation investments.

Through manipulations of either the effect of soil erosion on yield declines, the efficiency of SWC in controlling soil erosion,[499] or the yield in the case where soil conservation is practiced, the NPV of SWC might be increased. However, the scope of the present CBA was not to prove that SWC is profitable but to show whether and in which situations SWC is profitable with currently measured soil loss rates and yields and currently achievable efficiency of mechanical soil conservation in controlling soil erosion under the circumstances farmers are faced with. Any manipulations of input factors are thus out of the question. Instead, the following questions should be asked:

- How could the ***technology*** be improved to control soil erosion more efficiently and contribute to stabilised or even increased yields?
- How could ***total production*** of the field be improved by additional production on the conservation structures?
- How could ***costs*** for SWC (e.g. labour, arable land occupied by conservation structures) be minimised?

### 6.1.5 Conclusions with regard to input parameters used in the CBA – a partial sensitivity analysis

Input parameters such as prices used to calculate opportunity costs of subsistence production and labour, prices for fertiliser, grass production and the like (cf. Table 36) contribute to determining the magnitude of the NPV. Although these input parameters were assessed locally as far as possible, in many instances they could not be assessed directly, but were interpolated from other information sources. The ***magnitude of the parameters*** only gives an indication about the current situation. It must be assumed that within a time frame of 25 and more seasons, i.e. 12 and more years, in a highly dynamic environment like the one observed in the case study areas in ecological, economic, and political terms, major changes may occur – similar to the ones in the past 10 to 30 years, which have seen major political, administrative, economic, environmental and social transformations. Therefore, a sensitivity analysis has been carried out for a selection of parameters. The baseline situation was assumed with a planning horizon of 50 seasons or 25 years, a discount rate of 12%, unsubsidised labour and no application of artificial fertiliser. The DNG between introduced and adapted SWC, between introduced SWC and the situation with sheet & rill erosion, and between adapted SWC and sheet & rill erosion will be considered. The NPV is calculated on the basis of fields showing the most prevalent slope

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[499] A partial sensitivity analysis, in which it is assumed that introduced SWC can totally stop the soil depth from decreasing, shows that in Maybar, out of the 11 considered fields only on one field an improved efficiency of the technology changes the relative profitability. Improved SWC becomes more profitable than adapted SWC and sheet erosion if d=5% and t≥50 seasons. (Total considered cases: 528.) In Andit Tid, an improvement of the efficiency of the conservation technology seems to have a stronger influence. Out of the 8 fields considered, a shift occurs in 5: introduced SWC > adapted SWC with d=5% and t≥50 seasons (4 cases), introduced SWC > sheet erosion with d=5% and t≥50 seasons (3 cases) and introduced SWC > sheet & rill erosion with d=12% and t≥50 seasons (2 case). (Total considered cases: 384.) In Anjeni, an improvement of the efficiency leads to a shift only in one situation, where introduced SWC becomes more profitable than sheet erosion with d=5% and t=100 seasons. (Total considered cases: 240.) (cf. Appendix 6.3)

gradient – soil depth combinations in the three research areas (shaded cells, Table 45, Appendix 6.4). In order to compare the results, the field size has been standardised to 1 ha.

| Parameter | Base case | Change to alternative parameter | | |
|---|---|---|---|---|
| Time horizon | 50 seasons | - 40 seasons to 10 seasons* | - 25 seasons to 25 seasons* | + 50 seasons to 100 seasons* |
| Discount rate | 12% | - 7% to 5%* | + 46% to 58%* | + 137% to 149%* |
| Crop price | | + 20% | - 20% | |
| Fertiliser price | EB 300 / 100 kg | + 200 EB to EB 500 / 100 kg | - 100 EB to EB 200 / 100 kg | |
| Fertiliser application | no | + 100 kg / ha* | | |
| Opportunity costs for labour invested in SWC | EB 5 / day | - 2.5 EB to EB 2.5 / day* | - 5 EB to EB 0 / day | |
| Opportunity costs for labour | EB 5 / day | + 3 EB to EB 8 / day | | |
| Grass production | 2,000 kg / ha | + 3,000 kg to 5,000 kg / ha*a | | |

*Table 50: Magnitude of change of CBA input parameters and resulting alternative parameter. (* indicates parameter alternatives and their influence on the NPV already discussed in Section 6.1.2) [Source: Own compilation]*

***Maybar***

**a) Change of crop price**

Price changes for crops in the order of ±20% lead to changes of the NPV difference between introduced and adapted SWC of ±10% to ±16%. The steeper the slope inclination, the bigger is the difference. The NPV calculated with higher crop prices weighs labour costs for SWC investments comparatively less but weighs the land loss, i.e. the yield loss of introduced SWC vis-à-vis the land loss of adapted SWC higher. Adapted SWC generally performs better in Maybar than introduced SWC. A price change of ±20% does not have an influence on these general findings. In all 11 considered cases, the NPV achievable with adapted SWC is higher than the NPV that can be achieved with introduced SWC, irrespective of the price level. If fertiliser were applied, the NPV achievable with introduced SWC would be higher than the NPV achievable with adapted SWC only on slopes with a gradient below 9%. A change of crop prices in the range of ±20% does not change this situation.

Changing prices for crops has not a significant influence on the relation between the NPV as achievable with introduced SWC and the NPV as achievable in the case of sheet & rill erosion. A price change for crops in the range of ±20% does not lead to different results than presented in Section 6.1.2.

The difference in DNG between adapted SWC and sheet & rill erosion indicates that changing crop prices has no big influence on the general findings presented in Section 6.1.2. Only in one case, crop prices have an influence on the relative profitability. Decreasing crop prices reduce the NPV resulting in the case of adapted SWC so much that it becomes smaller than the NPV of sheet & rill erosion. This concerns a field on a medium steep slope (9-30%), but with a very shallow soil (11-20 cm).

**b) Change of fertiliser price**

A change of the fertiliser price by +67% and –33%, respectively, does not change the situation of introduced SWC being more profitable than adapted SWC on flat slopes below 9%, and adapted SWC being more profitable than introduced SWC in all other cases. The effect of fertiliser price changes on the NPV ranges between –12% and +6%. Also if the DNG's of either introduced or adapted SWC and sheet & rill erosion are compared, a price change of fertiliser does not have an influence on the relative profitability. SWC remains profitable in the same cases as is presented in Section 6.1.2. A subsidy of fertiliser costs would not make either introduced or adapted SWC more profitable than sheet & rill erosion.

**c) Change of opportunity costs for labour**

Three cases are differentiated. In the first case, a full subsidy of labour costs for SWC activities is paid. Opportunity costs for labour invested in SWC are considered to be zero. The second case assumes that opportunity costs of SWC labour are subsidised to half the normal opportunity costs. This case has already been discussed in Section 6.1.2. The third case assumes a general rise of labour costs by 60% to EB 8/day, for farm labour as well as for labour invested in SWC.

A full labour subsidy for SWC does never change the relative profitability of introduced SWC as compared to adapted SWC. Subsidising labour costs for SWC to EB 0 would only make introduced SWC more profitable than no SWC in 3 of the 11 cases considered. One case concerns a situation in the lower part of Maybar area on a flat slope (≤8%) with deep soils (31-40 cm). The two other cases concern situations in the upper part of the catchment; one is a field with a medium slope gradient (9-30%) and a medium soil depth (21-30 cm), the other a field on a steep slope (≥31%) with shallow soil depth (11-20 cm). In these three cases, the saved labour costs would compensate the reduced production resulting because part of the arable land is occupied by conservation structures. The comparison of adapted SWC and sheet & rill erosion shows similar results with respect to changed labour costs. Only in two cases, the NPV achievable with adapted SWC becomes bigger than the NPV that is achieved with sheet & rill erosion, which would otherwise be smaller. The two cases concern steep fields with slope gradients above 30%. Here, the subsidy of labour costs can compensate the yield loss on the 10% of the field that are occupied by conservation structures. In all other situations, a full subsidy of labour costs for SWC does not change the relative profitability of adapted SWC as compared to sheet & rill erosion.

A general rise of opportunity costs for labour leads to an increase of the DNG of introduced and adapted SWC of between 19% and 46%. In no case, however, does this lead to a change in the relative profitability. Rising labour costs would make introduced SWC less profitable compared to the case with sheet & rill erosion also on flat slopes. This is especially critical as these flat slopes were the only area, where introduced SWC was profitable at all. If labour costs are increased from EB 5 to EB 8/day, even in these few cases, in which introduced SWC formerly performed better than sheet & rill erosion, introduced SWC becomes economically unprofitable. In contrast, adapted SWC becomes slightly less profitable than sheet & rill erosion only in one single case if opportunity costs for labour raised.

**d) Change of grass production**

Often, it is assumed that by using mechanical conservation structures in a productive manner, e.g. by planting fodder grass or shrubs with an economic value, the economic performance of mechanical SWC could be improved. In the sensitivity analysis, this was tested by increasing the grass production on the conservation structures from 2,000 kg/ha to 5,000 kg/ha. It could be shown that the grass production of 2,000 kg/ha in Maybar has only a very small influence on the profitability of SWC. By increasing the grass production considerably, there is, however, no change in the relative profitability of introduced as compared to adapted SWC. Introduced SWC remains more profitable than adapted SWC in the same cases, irrespective of whether grass production is 2,000 kg/ha or 5,000 kg/ha, and it also remains less profitable than adapted SWC in the same cases as without the change of the variable. Comparing introduced SWC with sheet & rill erosion, a higher grass production would make introduced SWC more profitable only in one case. This concerns a field located in the lower part of the catchment on a flat slope. With a grass yield of 2,000 kg/ha, sheet & rill erosion would be the more profitable option on this field. With a yield of 5,000 kg/ha, the value of the additional grass harvested on the conservation structures is thus bigger than the labour invested for SWC and the foregone production due to part of the arable land being occupied by conservation structures. On all other fields, the relative profitability, whether considering introduced SWC in relation to sheet & rill erosion or adapted SWC in relation to sheet & rill erosion, remains the same.

***Andit Tid***

**a) Change of crop price**

Changing crop prices in the range of ±20% does not have an influence on the relative profitability of introduced to adapted SWC if the planning horizon is 50 seasons and the discount rate 12%. On the 8 fields selected that represent the most common slope gradient – soil depth combinations, adapted SWC always performs better than introduced SWC, irrespective of the price level. Also when introduced SWC is compared with sheet & rill erosion, no change in the relative profitability occurs. Introduced SWC shows a higher NPV than sheet & rill erosion in the same cases as discussed in Section 6.1.2. The same can be observed for the comparison of adapted SWC and sheet & rill erosion.

**b) Change of fertiliser price**

Changing fertiliser prices by +67% and –33%, respectively, does not lead to different results than presented in Section 6.1.2, except in one case. This case concerns a field with a medium slope gradient (16-30%) and a soil depth of 21-30 cm, and the comparison of introduced SWC to no conservation. If the fertiliser price is assumed to be EB 300/100 kg or below, sheet & rill erosion is the more attractive option. If, however, the fertiliser price is increased to EB 500/100 kg, this leads to a comparably better performance of introduced SWC. The higher costs for fertiliser can only be compensated because the fertiliser efficiency is greater in the case of SWC than in the case without SWC. If costs for fertiliser are low, the yield decrease and the labour savings in the situation without SWC are bigger than the increased crop production thanks to fertiliser.

**c) Change of opportunity costs for labour**

If labour for SWC is fully subsidised so that the opportunity costs are zero, introduced SWC would in most analysed cases (6 of 8) become more profitable than adapted SWC. With standard opportunity costs of EB 5/day, adapted SWC would be the more profitable option. The remaining two cases concern fields with very shallow soils between 11 and 20 cm. On such shallow soils, introduced SWC cannot prevent the soil depth from decreasing to less than 10 cm within 50 seasons. Thus, the additional land occupied by SWC structures in the case of introduced SWC weighs more than the saved labour costs and the additional years in which farming is still possible. To make introduced SWC more profitable than sheet & rill erosion does not in any case require a full subsidy of labour costs. On flat slopes between 0% and 8%, normal opportunity costs of labour of EB 5/day are already sufficient for the NPV with introduced SWC to be higher than the NPV in the case without SWC. Only on very steep slopes (≥31%) or on medium steep slopes (9-30%) with shallow soils (11-20 cm) a full subsidy is necessary. In the other cases with medium steep slopes and medium deep soils, a subsidy of half the normal wage rate is already sufficient to achieve a positive DNG if comparing introduced SWC and the situation without any soil conservation. Labour cost subsidy has no influence on the relative profitability of adapted SWC vis-à-vis sheet & rill erosion. Even with normal opportunity costs for labour of EB 5/day, adapted SWC performs better than sheet & rill erosion in the analysed cases.

A general rise of labour costs to EB 8/day would not change the relative profitability of introduced SWC as compared to adapted SWC. Introduced SWC performs worse than adapted SWC also with opportunity costs for labour of EB 5/day. Increasing opportunity costs would simply make the DNG of introduced SWC minus adapted SWC bigger. Comparing the NPV that can be achieved with introduced SWC and the NPV as achievable without SWC shows that a rise in opportunity costs of labour would lead to a change in the relative profitability only in two out of 8 cases. These two cases concern fields on flat slopes. Increasing labour costs would make introduced SWC less profitable. Increasing labour costs would have an influence on the relative profitability of adapted SWC and sheet & rill erosion only on steep slopes with shallow soils. Here, the increase of labour costs would make adapted SWC too expensive compared to the situation with no conservation. In all other cases, adapted SWC is the better option than no conservation as can be seen from the positive DNG.

**d) Change of grass production**

Increasing the grass yield to 5,000 kg/ha has no influence on the relative profitability of introduced SWC as compared to adapted SWC. Adapted SWC remains the better option in all cases analysed. The higher grass yield can thus not compensate the higher demand for labour and the bigger portion of land occupied in the case of introduced SWC. If the grass yield is increased, introduced SWC becomes the more profitable option than sheet & rill erosion in all cases analysed. With a small grass yield of 2,000 kg/ha, with the exception of the two flat fields, introduced SWC is less profitable than sheet & rill erosion. The additional yield of 3,000 kg/ha, however, can compensate the additional labour costs and the land occupied by conservation structures. Adapted SWC is the better option than sheet & rill erosion in all cases analysed even with standard assumptions, and increasing the grass yield has no other effect than increasing the DNG.

***Anjeni***

**a) Change of crop price**

Changing crop prices by ±20% never brings about a change in relative profitability, neither when introduced SWC is compared with adapted SWC, nor when SWC, either introduced or adapted, is compared with the situation where sheet & rill erosion continues uncontrolled. Adapted SWC remains the better option than introduced SWC in all cases. Unfortunately, in most cases sheet & rill erosion remains the more profitable option, irrespective of crop price changes, or of whether it is compared to introduced or to adapted SWC. Only in two of the 5 cases considered, adapted SWC is more profitable than no SWC. This situation is not altered by crop price changes.

**b) Change of fertiliser price**

Variations of fertiliser prices have a very limited influence on the relative profitability of SWC as compared to the situation without SWC. Only in two cases, a price change of fertiliser leads to changing relative profitability. The two cases concern fields on medium steep slopes with a slope gradient between 16% and 30%. Introduced and adapted SWC become more profitable than the situation without SWC in one case each, despite the higher fertiliser price; the higher fertiliser efficiency in the case of SWC can make up the additional costs.

**c) Change of opportunity costs for labour**

A full subsidy of labour costs for SWC so that opportunity costs are zero has no influence on the relative profitability of introduced SWC as compared to adapted SWC. Adapted SWC remains the better option in all cases. A comparison of introduced SWC to no SWC indicates a better economic performance of the former thanks to subsidised labour costs in 2 cases. They both concern fields with comparably shallow soil depths of 16 to 30 cm. On the steeper of the two fields, labour costs must be subsidised fully to increase the NPV of introduced SWC enough to be higher than the NPV without SWC. On the flatter of the two fields, subsidising labour costs to half of the normal wage of EB 5/day is already sufficient. Out of the analysed 5 cases, two show a higher NPV with adapted SWC than without SWC if opportunity costs for labour are EB 5/day. Subsidising labour costs would make adapted SWC the more profitable option in only one additional case.

A general rise of opportunity costs of labour to EB 8/day has no influence on the relative profitability of introduced SWC as compared to adapted SWC. It also does not have an influence on the relative profitability of introduced SWC vis-à-vis the situation without SWC. Sheet & rill erosion remains the more profitable option in all 5 cases. Rising labour costs only leads to an increased difference between the two. Increasing labour costs by 60% has a negative effect on the relative profitability of adapted SWC as compared to the situation without SWC in only one case. With normal opportunity costs of labour of EB 5, adapted SWC would be the more profitable option in two cases. By increasing the labour costs to EB 8/day, the NPV with adapted SWC becomes smaller than the NPV that can be achieved without SWC in one case. In the second case, even with high opportunity costs of labour the NPV with adapted SWC would remain higher than the NPV without SWC.

**d) Change of grass production**

Increasing the grass yield harvested on the conservation structures has only a marginal effect on the relative profitability of either the two conservation technologies or the conservation technologies compared to the situation where sheet & rill erosion occurs. Even with higher grass yield, introduced SWC would not be the more profitable option than adapted SWC. The only effect is that the difference between the two NPV's is about halved. In two cases, one concerning the comparison introduced SWC – no SWC, the other the comparison adapted SWC – no SWC, the additional grass yield of 3,000 kg/ha leads to the situation where soil conservation would become more profitable than no conservation at all. The two cases concern fields on shallow soils (11-20 cm). On the flatter of the two fields, the NPV with adapted SWC and the lower grass yield of 2,000 kg/ha is already more profitable than no conservation. If the grass yield is increased to 5,000 kg/ha, even the more expensive introduced conservation technology becomes profitable. On the steeper field, the increased grass yield only increases the profitability of adapted SWC sufficiently. The NPV achievable with introduced SWC remains smaller than the NPV that can be achieved without SWC even with the increased grass yield.

## 6.1.6 Conclusions with regard to labour costs for SWC and possible subsidies

Despite considerable changes in opportunity costs for subsistence production and labour, prices for important inputs, and additional production on the conservation structures, the general findings presented in Section 6.1.2 are seldom changed. It has to be kept in mind, however, that only a partial analysis has been carried out, i.e. only one input parameter at a time has been varied. It could well be that changes in the political or economic environment would lead to a general rise in prices. It might thus be with an increase in all prices for crops, inputs, and labour, the relative profitability of SWC would change. Secondly, only one combination of length of planning horizon (50 seasons) and discount rate (12%) has been considered. By either changing one of the two or both at the same time, the results of the sensitivity analysis might be different. Nevertheless, the sensitivity analyses carried out show that the magnitude of ***economic input parameters*** has not a very great effect on the relative profitability of SWC. ***Parameters of the ecological system***, such as soil depth and slope gradient, soil loss rate, or production potential of the land, have a more pronounced effect. Also technological parameters, such as the efficiency of the considered technology in controlling soil loss, are not decisive.

24 fields are the basis for the sensitivity analysis. For each field, three comparisons are made: introduced versus adapted SWC, introduced SWC versus sheet & rill erosion, and adapted SWC versus sheet & rill erosion. For each field and technology comparison, 4 parameters are varied: crop price, fertiliser price, opportunity costs for labour, and grass yield (cf. Appendix 6.4). Totally, 288 combinations result. Changing input parameters lead to changes in relative profitability only in 41 of the 288 cases. From these 41 cases, 21 (51%) involve subsidising labour costs for SWC activities, 9 (21%) involve increasing grass yield, 7 (16%) involve rising opportunity costs for labour, 4 (10%) involve increasing fertiliser prices, and 1 case only (2%) involves changing crop prices. Changing input parameters has the biggest influence in Andit Tid. Here, the relative profitability of the various investment options changes in 22 out of a total of 96 combinations (23%). In Anjeni, a change occurs in 8 out of the 60 combinations considered (13%), and in Maybar, in 12 out of a total of 132 combinations (9%).

Interestingly, out of the parameters considered in the sensitivity analysis, labour cost subsidy for SWC activities is the most important. ***Increasing fertiliser prices***, which would be the same as decreasing subsidies on fertiliser, has only a limited effect on the profitability of SWC. This corresponds well with observations made in other countries of sub-Saharan Africa, where a subsidy removal led to a decreased demand for mineral fertiliser in some countries or regions within a country, and to an increased demand in others. ***Price reforms*** alone will therefore not have a strong influence on the willingness of small-scale farmers to invest in soil conservation. It has also been observed that structural adjustment programmes often have a negative impact on soil fertility management and soil conservation. The abolition of subsidies for agricultural inputs often leads to less intensive agriculture, the expansion of arable land into marginal areas, and nutrient mining.[500]

Two aspects are important with respect to ***subsidising labour costs***: Firstly, it was assumed that a subsidy is paid both for the initial construction of SWC structures and for maintenance activities. In this respect, the results are pronouncedly different from the Food-for-Work (FfW) approach, in which only the initial construction costs were paid. If subsidy were paid only for construction works, the effect on relative profitability would not be as pronounced. Secondly, the amount of subsidies that would have to be paid per hectare is considerable, as the following Table 51 shows:

| | Introduced SWC | | Adapted SWC | |
|---|---|---|---|---|
| | **Initial construction** | **Maintenance** | **Initial construction** | **Maintenance** |
| **Maybar** | EB 500 – 2,600/ha | EB 2,363 – 12,285/ha | EB 167 – 867/ha | EB 804 – 4,182/ha |
| **Andit Tid** | EB 400 – 1,300/ha | EB 1,930 – 6,273/ha | EB 100 – 325/ha | EB 483 – 1,568/ha |
| **Anjeni** | EB 700 – 1,300/ha | EB 3,378 – 6,273/ha | EB 175 – 325/ha | EB 884 – 1,568/ha |

*Table 51: Total costs (in EB/ha) for subsidising labour with EB 5/day for SWC investments. (Minimum and maximum costs depend on total length of conservation structures per hectare, depending on slope gradient and soil depth. Maintenance costs are calculated for a time period of 50 seasons.) [Source: Own compilation]*

***Subsidising investments*** for environmental conservation or rehabilitation is a highly disputed matter. It is often argued that the change to a more sustainable land use system should be profitable enough to motivate farmers to change their management practices without any other incentive. When technologies such as mechanical SWC are considered as part of the necessary shift towards a more sustainable land use system, it is argued that the technology itself must be economically viable. If not, and if subsidies have to be paid to convince farmers to adopt the technology, this is simply to mask the shortcomings inherent in the technology.[501] However, the present study shows that the analysed SWC technologies are under given circumstances often not profitable from a farmer's point of view. Only if labour costs are subsidised, mechanical SWC becomes profitable in more situations.

When investments in soil conservation are considered, ***two groups of beneficiaries*** have to be distinguished: on the one hand, there are the land users, on the other hand, there is society at large. Land users generally carry the largest part of the costs for soil conservation, while other segments of society often profit at least as much from those investments. Without incentives from society, the land users are often unlikely to do enough, i.e. they tolerate higher levels of soil degradation than society does[502] (cf. Figure 28). A variety of incentives has been used to induce land users to abandon practices that lead to land degradation and to adopt conservation-effective ways of using the land.[503] In the Ethiopian Highlands, ***Food-for-Work*** was the dominant approach. Farmers received food grain and edible oil per working day or per defined length of constructed terraces. An evaluation of the success or failure of the approach concludes that the goal of supporting segments of the rural population suffering from food deficits and poverty could be met, whereas the goal of inducing land use changes and the adoption of SWC could not be achieved.[504] It could be observed that land users participated in the FfW schemes only in order to receive the food ratio. Once the

500 Drechsel & Gyiele, 1999, 17.
501 Giger, 1999, 25.
502 Sanders et al., 1999, 3; Huszar, 1999, 59.
503 Sanders & Cahill, 1999, 12.
504 Ståhl, 1990; Sanders & Cahill, 1999, 16.

support stopped, conservation structures were allowed to break down.[505] This demonstrates the following problems of paying subsidies for SWC: (i) mixing humanitarian efforts with the objective of conserving the resource base does not lead to the desired outcome,[506] and (ii) not only the initial investment costs are a burden to poor farmers, but much more also the maintenance costs (cf. Table 51). Labour costs for maintaining SWC structures over a period of 50 seasons are almost five times the initial investment costs. Additionally, the long-term negative effects of SWC in the form of reduced yields because of a smaller arable area (cf. Section 5.2.1) have to be considered. The results of the sensitivity analysis clearly demonstrate that if only initial investment costs were subsidised, mechanical SWC would not yet be profitable. Only when subsidies are paid also for maintenance activities, mechanical SWC becomes profitable in more situations.

Effects of soil degradation can be on-site and off-site effects. Measures to address soil degradation can be grouped into measures which are economic from a farmer's point of view and such which are not economic:[507]

| | On-site | Off-site |
|---|---|---|
| **Economic** | 1 | 2 |
| **Uneconomic** | 3 | 4 |

*Table 52: Categorisation of effects of soil degradation. [Source: Own compilation]*

***Category 1*** is unproblematic, as the effects of land degradation are on-site and felt by the land users, and the possible treatment is economic. It will most probably be in the farmer's own interest to address the problem because the investment is profitable. ***Category 2*** is also not problematic, as profitable technologies are available to solve the problem. An example for this category could be the safe drainage of excess water so as not to induce damages to adjacent farmland. In ***category 3***, the analysed SWC measures applied in the Ethiopian Highlands can be subsumed. The problem of soil degradation is mainly on-site in the form of reduced yields. There are technologies available to treat the effects, at least partially, but these technologies are mostly not profitable from a farmer's point of view. There are three possibilities to address the issue:

(i) the land user treats the problem for the sake of the public interest contrary to his own economic interest;
(ii) the land user is forced to carry out the required measures through regulations or even coercion;
(iii) the land user is subsidised to do what is required through one ore more incentives.[508]

***Category 4*** comprises the most difficult cases. Here, damage occurs to people who are not responsible. There are possible solutions, but they are not economic, thus it is not in the interest of either party to invest. Subsidies from public money seem the only solution.

Subsidies for SWC are not undisputed. As the experience in Ethiopia with FfW has shown, they often not lead to the desired outcome – the adoption of SWC by small-scale land users. Kerr et al. (1996)[509] formulated 5 key conditions that must be met in order to use subsidies for SWC:

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505 Holden & Shiferaw (1999, 279) report from areas in the Ethiopian Highlands where conservation structures were constructed with FfW support, that when the contribution stopped and coercion was relaxed after the government change in 1991, conservation structures were dismantled on 53% and partly removed on 31% of the studied plots.

506 Giger, 1999, 9.

507 Sanders & Cahill, 1999, 18.

508 Sanders & Cahill, 1999, 18.

509 Quoted in Giger, 1999, 45. It is further assumed that the measure is technically feasible and fits into the farming system, which is, with some modifications, given in the considered case.

| Key Condition | Assessment | Example | Consequence | Appreciation with reference to study areas |
|---|---|---|---|---|
| 1. Do major externalities exist (off-farm costs of soil degradation, global benefits, intergenerational equity)? | This condition is often fulfilled, however, on-farm costs are frequently more important than off-farm costs | ▪ Sedimentation of water reservoirs<br>▪ Intergenerational equity, conservation of resource base for future generations | Can be used as justification for public intervention | Although on-site costs are usually more important than off-site costs, the argument of intergenerational equity and conservation of the resource base for future generations can be used to justify subsidies (cf. Table 47 showing the soil life for current erosion levels) |
| 2. Does the subsidy aim at removing the root cause of the problem? | This condition is very often not fulfilled. | ▪ Soil degradation because of open access to land at no cost<br>▪ Insecure land tenure rights do not favour long-term strategies and investments<br>▪ Main problem is poverty | If the root problem has not been identified correctly, the subsidy will not help to achieve the objective. If poverty is the main problem, other types of intervention might be more efficient. | Subsidising does not necessarily address the root causes of soil degradation, which are, *inter alia*, (i) land scarcity, (ii) insecure land tenure, (iii) management aspects such as free grazing after harvest prohibiting more productive use of conservation structures, or (iv) differing perceptions between farmers and extension personnel / scientists about the severity and consequences of soil erosion. |
| 3. Are the side effects minimal? | Condition frequently not fulfilled. | ▪ May create a dis-incentive for non-beneficiaries<br>▪ May increase equity problems<br>▪ Farmers become beneficiaries instead of partners | Side effects are often important and difficult to minimise. | As long as the opinion of farmers concerning the severity and consequences of soil degradation is not changed, SWC subsidies are considered a form of income and not a support for investments in SWC. This can create a 'receiver-mentality' causing land users to expect remuneration for any activity. |
| 4. Is the proposal cost-effective, or are there cheaper ways to achieve the same result? | The costs of direct incentives can be high. Costs of the subsidy consist not only of direct financial costs but also of a delay in identification and promotion of sustainable measures. | ▪ Abandoned conservation structures often show that the effort has been wasted<br>▪ Administering direct incentives is costly in terms of managerial competence and the work load of project staff | Other, more gradual improvements are preferable. | Neglected maintenance and conservation structures ploughed under indicate that the objective was not met. Subsidies were paid only for initial construction, but not maintenance, which is expensive. Indirect incentives, such as financing the clinic in Anjeni, seem the more promising option, if direct subsidies can only be paid for the construction but not for the maintenance. |
| 5. If the subsidy will be continuously needed to sustain the result, is a permanent source of funding available? | One-time subsidies are not problematic. However, one-time subsidies are rare. | ▪ Soil conservation measures continue to demand high labour inputs and occupy arable land throughout their lifetime | If the subsidy is not continued, no permanent result will be achieved, as farmers will return to the previous system. | Using FfW for the installation of SWC schemes but not for their maintenance has in many areas led to neglect and abandonment of SWC structures after payment or coercion stopped. No source for permanent funding available. |

*Table 53: Assessing the need for and feasibility of subsidies for soil conservation. [Source: Giger, 1999, 45, adapted]*

As the above Table 53 shows, the ***conditions for using subsidies*** successfully for soil conservation are often not or only partially fulfilled. Some points seem especially noteworthy: Firstly, The main problem of using FfW or any other subsidy for labour was that after the installation of SWC structures, the subsidies were stopped and farmers were expected to maintain the structures on their own. This can partly be explained by the mixing of the two objectives of humanitarian aid and of the initiation of adoption of SWC, and partly also by the false expectation that through mechanical SWC yields can be stabilised or even increased. Secondly, it was assumed that the technology and its positive effects on production would be an incentive enough for the land users. Thirdly, using FfW often masked the negative feelings of land users towards mechanical structures, as (i) farmers were not asked about their opinion, and (ii) even if they had expressed a negative opinion they would have participated in the FfW schemes, as the remuneration was a simple necessity at that time. Fourthly, while FfW was used, positive and negative aspects of the technology as well as possible improvements were never thoroughly discussed with farmers, and their participation was interpreted as a general consent that the technology is good and does address the main problems. This wrong interpretation led to a neglect of (i) the search for more cost-efficient technologies, and (ii) trials on how best to combine the necessary mechanical structures with biological or agronomic measures to address the problem of soil productivity decline. And lastly, the root causes of soil degradation were not addressed by using FfW and are still not addressed today. The problem of land shortage and the need of many farmers to use the land in an unsustainable way remains the same, land security is still not guaranteed, and the better integration of land users in the market system is not achieved.

The CBA and the sensitivity analysis show that the following parameters have a much stronger influence on whether the considered technology is profitable or not than the magnitude of the above discussed economic input variables:

(i) physical parameters depending on ***slope gradient and soil depth***, such as annual soil erosion rates, or the percentage of land occupied by conservation structures;
(ii) ***yields*** as a combination of improved yields on location A and reduced yields on locations B and C and the percentage of yield declines resulting from soil depth decreases;
(iii) factors related to the ***conservation technology*** itself, such as the percentage of land occupied by conservation structures or technology-specific reductions of soil loss;
(iv) the considered ***planning horizon***.

This conclusion can be valued both positively and negatively.

A ***positive*** circumstance is that the result of the CBA is relatively insensitive to changing magnitudes of input parameters. Thus, the model can be considered to be robust. Changes in the political or economic environment which might, for example, have an influence on the price system, do not change the outcome of the CBA fundamentally. The outcome of the CBA depends much more on environmental and technology-specific parameters. In this respect, there are possibilities for changes and improvements of the technology, which are independent of the wider political or economic environment. This means that there is a potential for fine-tuning SWC technologies, on the initiative of both the land users themselves and the extension service or research organisations involved. Such fine-tuning may, for example, comprise experimentation with more or less conservation structures per field to optimise the erosion control and at the same time minimise the portion of arable land occupied by conservation structures, with location-specific design of mechanical structures, or with combinations of mechanical, biological and agronomic technologies. Such experimentation could, on the one hand, increase the efficiency of the SWC technology in reducing soil loss; on the other hand, there might be additional possibilities to enhance soil productivity through better nutrient and organic matter management and thus to address the ultimate goal of the land users – increasing production and income and reducing risk. A ***negative*** circumstance is that input factors which cannot be easily influenced, such as soil depth or slope gradient play a more important role in determining the outcome of the CBA than factors that could be influenced, given the political will or the economic possibilities. Thus, there is little scope for improving the performance of mechanical SWC through changes in the wider economic or political environment, except if labour costs for SWC are fully subsidised. This, however, exceeds the capacities of the

Ethiopian Government by far, given the magnitude of necessary subsidies per hectare. It must be concluded that the often demanded enabling environment, such as price stability, fair producer prices, etc. have a rather limited influence in making the considered SWC technology a viable opportunity for small-scale subsistence farmers in the Ethiopian Highlands (cf. Chapter 7 for a discussion of the economic environment).

### 6.1.7 Conclusions with regard to the analysed SWC technologies

It was mentioned in Section 5.1.2 that the primary goal of initiating large-scale conservation schemes mainly based on mechanical SWC in the Ethiopian Highlands was not to address soil productivity directly, but to address in the first instance soil erosion as one manifestation of environmental degradation. The aim was to eventually achieve positive effects on soil productivity by controlling soil loss rates. The analysis of mechanical SWC shows that the goal of controlling soil erosion could be realised to a great degree,[510] but that the positive effect on soil productivity is not pronounced.[511] With ***mechanical SWC***, such as stone or soil bunds, important factors contributing to soil productivity, such as nutrient or organic matter content, are addressed only indirectly, if at all. It can be assumed that by reducing soil loss rates, also fewer nutrients are removed from the field through soil loss and runoff. However, one also has to take into consideration the dominant land use system in the research areas. Whether soil nutrients are mined or whether there is an active management of the nutrient pool or the organic matter content is entirely independent from the mechanical conservation technology. Soil organic matter content or nutrients cannot increase if all crop residues and weeds are removed and used as animal fodder, if animal dung, which accumulates during the time of free grazing, is partly collected as a fuel substitute, or if continuous crop cultivation is practised without major investments in restoring the pool of nutrients, be it through fallowing or green manuring, manuring, or the application of artificial fertiliser. Another aspect to consider in relation to nutrient management is that especially Andit Tid and Anjeni are both located in high rainfall areas. Nutrients are not necessarily only removed horizontally by runoff and soil loss, but vertical leaching might also contribute to diminishing available nutrient pools. All these aspects can obviously not be addressed by mechanical soil conservation. Investments in mechanical SWC must rather be seen as a supplement to (i) any other investment aiming at increasing soil productivity or (ii) changes in the land use and land management system. Investments in constructing stone or soil bunds must be seen as a means to prolong the soil life, i.e. to maintain a soil depth that is capable of producing yields. This time gained must then be used to develop strategies or technologies that address the complex issue of soil productivity.

The analysed conservation technologies concern introduced mechanical structures, which are not free of problems (cf. Section 6.2.2). Often, it is then proposed to rely more on ***indigenous, local technologies*** and on ***biological*** and ***agronomic measures*** instead of mechanical technologies. In the Ethiopian Highlands, there are many more technologies known, introduced as well as local. Krüger et al. (1997) list almost 40 indigenous or local technologies found throughout the Ethiopian Highlands. About 22 are agronomic or biological technologies. Many others, like rough ploughing or strip cropping mainly concern a different management of tasks otherwise also performed. Indigenous systems are targeted towards minimising costs and risks, increasing diversification, serving multiple purposes, and sustaining or increasing production. Usually, the rationale of indigenous SWC systems and measures is not soil and water conservation per se. Resource conservation is an integral part of the prevailing farming system. Indigenous technologies have been developed locally and are therefore highly situation-specific in ecological and economic as well as in socio-cultural, institutional and organisational terms. They are fully embedded in the prevailing land use system, can be adapted to changing circumstances and are thus very flexible.[512] Biological or agronomic SWC enhance soil cover, which is considered a highly efficient means of controlling soil erosion. It is even mentioned that soil cover is at least as

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510 Herweg & Ludi, 1999, 107.

511 cf. SCRP, 2000b, 2000c, and 2000d.

512 e.g. Krüger at al., 1997, 11.

effective as the runoff barrier approach, but less costly.[513] However, one should not conclude that biological SWC could entirely replace mechanical structures. It is not possible to maintain a closed vegetation cover permanently in an agricultural production system. Even if the soil is covered by vegetation to a high percentage, soil losses can still be considerable.[514] This is not at all to deny the important role plant cover plays in reducing soil erosion. However, there are limitations to biological and agronomic measures, especially during extreme rainfall periods. Plant cover is low at times of highest erosive rainfall at the beginning of the rainy season. Climatic limitations, finally, can slow down vegetation growth rates, thus limiting the protective effect. Mechanical structures are therefore an indispensable component of SWC. The results presented in Section 6.1.2 demonstrate that unfortunately, introduced mechanical structures are expensive, certainly more expensive than indigenous biological or agronomic technologies. On the other hand, introduced, mechanical technologies are more efficient in controlling soil erosion, certainly during critical times of the year. Thus, both the indigenous and the introduced technologies have their advantages as well as their disadvantages. Mechanical technologies are considered necessary to prevent soil erosion in critical times or critical locations. Such mechanical technologies do, however, not increase crop production, which is an ultimate goal of the concerned land users. Biological or agronomic measures must therefore supplement the mechanical structures to increase total production of a field and to improve soil conditions. One could also look at the issue the other way round: Indigenous technologies were not able to prevent soil degradation under the given circumstances of, for example, population pressure or changed market conditions. The available indigenous SWC technologies and management practices should, however, be taken as a starting point, be improved, and, if necessary, supplemented with introduced, mechanical structures. The fact that in the present report only mechanical, introduced structures were analysed should not be considered as a judgement against indigenous technologies. It is believed that both, introduced and indigenous technologies, are necessary and should complement each other, but should not be seen as competing each other.

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513 Young, 1989, quoted in Herweg & Ludi, 1999, 112.

514 Soil loss recorded on TPs for single storm events was as high as 10 t/ha with 65% plant cover. (Herweg & Ludi, 1999, 112).

## 6.2 The Insider's View – How do Farmers Perceive Costs and Benefits of Soil Conservation

*"The yield on a field with Fanya Juu bunds as they were built by the Project is smaller than on a similar field with traditional bunds. If the new system is improved, the yield is higher than with our traditional conservation"*
*(Farmer from Andit Tid)*

*"I destroyed the bunds because of rats, they ate all the crop. Now my problem is where to put all the stones."*
*(Farmer from Maybar)*

### 6.2.1 Farmer's perception of land and soil degradation

Before positioning land users actions and strategies observed in the different research sites with respect to the three main theories explaining farmer's economic behaviour and the framework of strategies of action (cf. Section 6.3.1), land users own point of view of land and soil degradation and soil conservation shall be presented.

Most farmers mentioned that they face a sever shortage of arable land and are thus forced to cultivate the available farmland more intensively than what they think would be good and also more intensively than their fathers did. Most farmers recognised very clearly that the land shortage will increase dramatically in the future as long as population growth rates remain high, and as long as hardly any possibilities for off-farm employment exist. ***Decreasing farm sizes*** force farmers to shorten fallow periods, if not to give them up altogether. It was generally realised that continuous crop cultivation without any fertility enhancing investments is a strategy that is not sustainable in the long run. Farmers also mentioned that their current problems are aggravated because the land has been used intensively for many generations. Their way of describing this is by saying that 'the land has become old'. Similar to old people the land is exhausted after many years in use and has a right to rest. However, farmers mentioned that they lack the means to either leave the land fallow or to increase soil productivity by supplementing the available nutrient pool because

(i) there are no more land reserves;
(ii) fertiliser is expensive, and many farmers do not like to buy it because they fear indebtedness, and because there is a considerable risk of crop failure associated with artificial fertiliser in areas with insecure rainfall;
(iii) manure is in short supply, as in many households the number of livestock is too low;
(iv) arable land has been expanded at the cost of grazing land and shrub and forest land, leading to a severe shortage of firewood which makes it necessary to use animal dung as a fuel wood substitute;
(v) as a result of decreasing size of grazing land, crop land after harvest is grazed more intensively and remaining stubble is eaten by animals;
(vi) although the necessary knowledge concerning composting and green manuring is available, labour and raw material is lacking.

With regard to ***soil erosion***, farmers usually mentioned that their efforts to control runoff and erosion are sufficient. Soil erosion was hardly ever made directly responsible for decreasing soil productivity and declining yields, which almost all farmers mentioned as one of their major problems. Only in Mesobit & Gedeba, the majority of respondents (9 of 15) mentioned that soil productivity is good and even increasing because of investments in soil conservation, combined with the application of green manure and artificial fertiliser.

Not only is arable land becoming scarce, but there is also a pronounced ***shortage of grazing land***. Two processes can be observed: on the one hand the growing number of households makes it necessary to expand arable land at the cost of remaining land, which is usually grazing land. On the other hand, each family needs a minimal number of animals to (i) perform all the necessary fieldwork, and (ii) to accumulate reserves and wealth. Farmers specifically mentioned that the balance between people and livestock, arable land and grazing land is highly distorted. A number of conflicts have already arisen. Usually, old and rich farmers with a consolidated farm and herd size oppose young and poor farmers without their own land who would like to decrease the grazing land at the cost of arable land.[515] A potential livestock crisis is expected to have far-reaching consequences,[516] as without the ox-drawn plough a smaller arable area per household can be cultivated. Food security will thus further diminish.[517]

With the exception of the Simen Mountains, ***forestland*** is in most research areas almost totally absent. Remaining forests are either state forests, or as in the case of Simen, protected because of a National Park. Farmers usually complained about these forests because there is no direct benefit and forests occupy precious land. Usually, farmers are not allowed to collect fuelwood from state forests. This is a further reason for their rather negative attitude. Only in the vicinity of Maybar, where a major afforestation still exists today, farmers mentioned positive aspects such as less erosion from the steep forest land damaging lower lying crop land. Farmers who were asked whether there is also a positive effect on the microclimate or the base flow of the nearby river, which is used to irrigate the cropland, did not register positive changes.

In most areas farmers observe that ***springs and small streams*** dry out during the dry season, and that flooding during the rainy season happens more often. Flooding was usually brought in connection with less vegetative ground cover holding back runoff. Springs drying out were mostly brought in connection with decreasing rainfall amounts and only rarely with decreased water storage capacity of the soil. Women mentioned that the collection of drinking water has become more time consuming, as some of the springs near the villages have dried out and that they therefore have to walk further distances.

In Maybar and Andit Tid the interviewed farmers were asked to estimate ***yields 10 to 15 years ago***. In Maybar farmers estimated current yields to be only between 30% and 50% of the yields achieved 10 to 15 years ago.[518] The main reasons given for this considerable yield decline are climatic irregularities (10 respondents),[519] continuous cropping without fallow (7 respondents), Allah (2 respondents), neglected SWC because of government change (2 respondents) and neglected crop rotation (1 respondent). No one mentioned soil erosion as a reason for declining soil productivity and declining yields.

In Andit Tid, 10 of the 15 farmers interviewed mentioned that yields decreased, and 5 mentioned that there is no general tendency of decreasing or increasing yields, but that it fluctuates from year to year. Those

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515 Ludi, 1997, 42.

516 Hurni (1993) has developed a model based on total available arable land, total livestock population, total human population, growth rates of arable land, livestock, and population, annual land and soil degradation, and interventions in the field of reproductive health, environmental rehabilitation, agricultural development, and livestock development. Without substantial interventions, a livestock crisis – the demand of the growing number of animals exceeds available and potential grazing land – is reached 10 to 25 years earlier than the cropland crisis – the demand of the growing number of people exceeds the production potential of the arable land.

517 Pankhurst (1986, 57ff) brings the great famine of 1888-1892 in connection with the outbreak of a rinderpest in 1888, affecting vast areas of the Ethiopian Highlands. Lacking draught animals did not allow the farmers to cultivate their land, and harvests were further decreased because a combination of climatic irregularities, locusts, caterpillar, crop diseases, and political turmoil, including the Italian occupation of Eritrea. All these factors contributed and interacted and brought about the devastating famine, which was followed by human diseases affecting the starving population, killing about one-third of the Ethiopian population.

518 This observation stands in contrast to long-term yield measurements, which indicate that in Maybar yields slightly increased over the observation period of 1982 – 1998. (cf. Figure 34)

519 One farmer pointed out that for the last three years he has been able to grow tef in the upper part of the catchment, which was not possible before because temperatures were too low. He also mentioned that about at the same time farmers started to grow *sengada*, a type of sorghum, in the lower part of the catchment. Before, *sengada* was only cultivated in the *Kolla* area (lowland, below approximately 1,500 m asl). He stressed that temperatures have risen considerably in about the last 5 years.

farmers mentioning decreasing yields estimated yields today to be about 50% (between 30% and 75%) of those achieved 10 to 15 years ago. Main reasons given for declining yields are climatic irregularities, especially untimely *Belg* rains and more frequent frost (7 respondents), intensified crop cultivation because of population pressure and the necessity of shortening or abandoning fallow periods (3 respondents), decreasing soil productivity because of soil erosion (2 respondents), and decreasing soil productivity because of a shortage of manure (1 respondent).

It is interesting to note that the tendency of declining yields in Maybar is less dramatic as perceived by farmers, whereas the yield decline in Andit Tid seems to be much more pronounced. In both localities, the considerable fluctuation from year to year becomes evident (cf. Figure 34 to 37 and Appendix 5.2). Thus, yield estimates could be influenced by current situations. Interviews in Maybar were carried out in January and February 1999. There should be some rainfall at this time of the year that allows sowing of *Belg* crops. However, during that time no rainfall was recorded. Farmers mentioned that it is already the second year in sequence in which the small rainy season (*Belg*) failed, and that also the last main rainy season in summer (*Kremt*) was not very good. Their reserves are therefore reaching an end, and a growing number of families depend on food aid. It could thus be that because farmers feared another poor harvest, their perception was pessimistic.[520]

Other problems mentioned besides climatic irregularities affecting yields are increased occurrence of pests and plant diseases, increased weed infestation, and increased occurrence of stagnant water. Farmers related all these problems to shallower soil. The shallower the soil, it was argued, the weaker the plants to resist diseases, the less dense the plant cover and the more space for weeds, and the smaller the volume of the soil to absorb water.

### 6.2.2 Farmer's perception and valuation of SWC

***Mechanical soil conservation*** in the Ethiopian Highlands is often associated with unintentional side effects. The complaints most often heard from farmers are that

(i) SWC structures occupy precious cropping area;
(ii) because the area occupied by SWC structures is not ploughed, weeds and rodent habitats are no longer destroyed, and cultivation land is infested;
(iii) stagnant water is frequently observed above the conservation structures despite a drainage gradient of the structures of 2 to 5%;
(iv) maintenance of SWC structures requires high labour inputs, especially during the rainy season and competes with other labour;
(v) farm operations, especially if the spacing between two conservation structures is narrow, cannot be performed as usual, i.e. ploughing in diagonal lines is impeded and turning the ox-drawn plough is difficult.[521]

Despite these negative attributes of mechanical SWC in all three principal research areas, most land users have kept part of the originally constructed embankments. In the following the arguments given by farmers for (i) keeping conservation structures, for (ii) modifying the layout of the conservation structures in a field, and for (iii) destroying SWC structures will be discussed.

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520 The anticipated poor harvest became reality. *Belg* rains failed in most parts of the eastern highland and food aid had to be distributed in Dese, the capital city of South Wello Zone, which is in the vicinity of Maybar.

521 Ludi, 1997, 69ff; Herweg & Ludi, 1999, 109.

***Maybar***

Level stone and soil bunds were introduced in the Maybar research catchment in 1983. Since then considerable change has taken place. In most instances farmers have modified the original layout. The reason most often mentioned is that introduced bunds consume too much arable land. Therefore, when the spacing between two structures is considered to be too narrow, every second terrace is removed. Secondly, some farmers mentioned problems with waterlogging. They mentioned that a system of staggered structures is better in this respect, especially if combined with drainage ditches (*boyi*). In Maybar, only about 10% of the originally constructed bunds were totally removed.[522] In contrast to the other two research areas, bunds can also be observed more frequently outside the research catchment.

In Maybar, most fields show some conservation structures. Even before large-scale conservation schemes were carried out, the lower and more intensively used part of the research catchment was treated with indigenous stone embankments. The steep slopes, which were left fallow for several years before cultivating them again, and which were used as grazing land until recently, bush or forest land, and which were part of the area closure show less SWC structures. What is more typical here are unploughed strips which gradually develop into natural terraces.

From the 88 fields observed and measured in Maybar, 19 (22%) do not have any visible structures. From these 19 fields, one third (7 fields) is located in the vicinity of the lake with slope gradients between 3% and 8%. On such plots, soil erosion is not the main problem; here, more damage is caused by stagnant water during the rainy season and nutrient leaching. A system of drainage ditches and artificial waterways is constructed to minimise the damage to crops. The other 12 fields not showing any conservation structures are homesteads (3), are located in the upper part of the research area and have been cultivated only for a few years (4), or are located in the lower part of the research catchment and were until 1989 part of the closed area (3). Only on two fields conservation structures have been totally removed by the owner. The other 69 fields (78%) show a mixture of introduced and traditional conservation structures.

A traditional practice in Maybar is to move bunds.[523] Whenever the area behind a stone bund is silted up, the structure is dismantled and the stones are used to construct a new bund further downslope. The main reason given by land users for moving bunds is that by spreading the accumulated sediment over the field total production can be increased. They further mentioned that the sediment accumulated behind the terraces is of no use, even worse, it is favouring weed growth. Destroying bunds is also a means of controlling rodent populations. Problematic however is that by moving structures one aim of SWC – reducing slope gradient by gradually increasing the height of terrace risers – will not be achieved.

The high rate of adoption and adaptation of introduced SWC structures in Maybar can be explained by the following factors:

- Farmers already knew stone bunds even before the SCRP started working in this area.
- Introduced stone bunds are very similar to traditional stone bunds. The main difference is the layout of introduced structures, which depends on soil depth and slope gradient. Secondly, introduced stone bunds are much longer and not restricted to a single field but constructed continuously along a hill slope. Thus, they require more coordination effort between neighbours concerning the drainage of water and passage of draught oxen.
- Stone bunds show fewer problems related to stagnant water than soil bunds. In Maybar, soils are in general less susceptible to waterlogging than in the other two research areas, with the exception of the flat land in the vicinity of the lake.
- Stones are readily available in most areas of the Maybar catchment.
- Water conservation effects might play an important role.

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522 Yohannes G/Michael, 1999, 134.

523 Yohannes G/Michael, 1999, 96.

### *Andit Tid*

Soil conservation was introduced in Andit Tid in 1983 and 1984 through a Food-for-Work campaign. In this high rainfall area, mainly graded Fanya-Juu were constructed to drain excess water. Until then, this technology had been unknown in the Ethiopian Highlands. It consists of a bund-ditch combination, with the ditch situated below the bund (cf. Figure 6). Out of the 15 farmers interviewed in Andit Tid, most (12) mentioned that Fanya-Juu without adaptation are not suitable. The reasons given are that Fanya-Juu bunds

- occupy too much land,
- lead to waterlogging,
- provide a welcome hiding place for rodents,
- make ploughing much more difficult because the bunds were constructed over the whole width of a field,
- although artificial waterways were constructed to drain excess water safely to the next river, there is a pronounced danger of gully development, which also endangers the bordering field.

Moreover, labour inputs for the construction and especially for the maintenance are considered too big to be worthwhile, especially in the upper part of the catchment where – thanks to long fallow periods – soil erosion is less of a problem. For the farmers of Andit Tid another aspect was perceived as contradictory: If the very goal of mechanical structures is to protect the soil, why is soil used to construct the bunds, soil which is then lost and cannot be used to grow crops. There is little scope to change the technology, because stones are not abundant enough in Andit Tid to allow the construction of stone bunds, and for biological measures, the climate is not suitable. Unfortunately, the only material locally available to construct bunds is soil.

Farmers mentioned that their traditional way of conservation is much more suitable for the area. Traditional conservation generally includes a cut-off drain (*golenta*) above the field to collect run-on, small, staggered stone or grass bunds in critical locations, and drainage ditches (*boyi*) throughout the field to drain excess water towards the field border or waterway. It was also mentioned that on steep land parts of the field are not ploughed and gradually develop into natural terraces.

In contrast to the situation in Maybar, where only few fields show no physical conservation structures and where introduced SWC has been adapted to suit the needs and possibilities of the land and the farmers, adaptive processes in Andit Tid have taken less place. More often, a total removal or neglect of Fanya-Juu bunds can be observed. It is estimated that Fanya-Juu were adopted only on 10% of the fields, while on 53% they were totally rejected and removed.[524] From the 70 observed and measured fields for this study 13 (18%) show a slightly modified layout of the originally constructed Fanya-Juu bunds. On 14 fields (20%) Fanya-Juu bunds were partly removed to increase the spacing between two structures or bunds were shortened at the field border or opened in the middle of the field to allow draught animals and water to pass. On 10 fields (14%) outside the research catchment natural terraces that developed from unploughed strips or rock outcrops are prevalent. On 9 fields (13%) within the research catchment, Fanya-Juu bunds have recently been totally removed, and on 24 fields (34%) no conservation structures are visible at all. Some of these fields (6) have never been treated, as they are located in a valley depression (locality of *Ansas*). On the others, conservation structures have been removed some time ago and constant ploughing has levelled out whatever remained from the structures.

### *Anjeni*

In Anjeni, a different approach to introduce SWC was applied in 1986. Instead of Food-for-Work, the communities involved in the construction of bunds were offered a health clinic. In general, the approach was successful, as both the conservation structures and the clinic still exist to date. However, many farmers cultivating land inside the catchment complain that it is unfair that all community members who participated in the construction of bunds in the Anjeni catchment are entitled to use the clinic, while only some farmers actually have bunds on their land.

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[524] Yohannes G/Michael, 1999, 141.

The perception of problems of introduced SWC in Anjeni is similar to that of Andit Tid. The major problems mentioned by farmers is the big amount of arable land occupied by conservation structures, stagnant water, rodents and weeds, and more difficult farm operations. Negotiations with the staff of the SCRP in the early 1990s led to some changes of the layout of the structures. Usually, every second bund was removed. Only on few plots farmers have removed all conservation structures.

***Estimates of yields from conserved and unconserved land***

In Maybar and in Andit Tid, farmers were asked to estimate the yield difference between a field with and without soil conservation structures. In ***Maybar***, farmers estimated the yield from a field without mechanical structures to be only between 50% and 80% of the yield from a field with conservation structures. No one estimated yields from conserved land to be smaller than those from unconserved land. However, farmers also mentioned that there are no fields without any conservation measures. At least drainage ditches in the field and raised field borders or cut-off drains at the top of the field to prevent run-on are present. Farmers estimates regarding yields in Maybar stand in contrast to results obtained from experimental plots, where yields from the treated plots are between 20% and 30% lower than yields from the untreated control plot.[525] This yield difference is mainly due to the smaller arable area in the case of the treated experimental plot. On farmers' fields, the percentage of land occupied by conservation structures is considerably smaller than on experimental plots, and it was this adapted conservation that farmers referred to when talking about conserved land. Own observations and statements by farmers indicate that the adaptation of introduced measures in Maybar results in a smaller percentage of land occupied by conservation structures than what would be the case with unmodified introduced SWC. It can be hypothesised that because soil loss rates in Maybar are generally rather low, adapted structures are comparably efficient in reducing soil loss, especially if placed in critical locations. Usually, some introduced structures within a field are left and stretch over the total field width and they are supplemented with smaller structures in critical locations. Farmers mentioned that if the plot is moderately steep, every second or two from three introduced structures have been removed, but that the remaining terraces are maintained and increased in height. It can be assumed that therefore the effect of this combination of different structures leads to a better efficiency in terms of soil loss prevention and less negative effects on yields than what would be concluded from the results of the experimental plots, and thus to a more positive valuation of SWC in general.

Farmers from ***Andit Tid*** estimated yields from land which is conserved with introduced Fanya-Juu to be considerably lower than yields from fields that are treated with traditional measures such as a cut-off drain at the top of the field and drainage ditches within the field. If the yield from a field with traditional measures were 100%, yields from fields with Fanya-Juu range between 50% and 75% only. Results from experimental plots seem to support these estimates. Yields from plots that are conserved with graded Fanya-Juu are roughly 50% smaller than yields from the control plot, although the area occupied by conservation structures is only about 10%.[526] The remaining yield difference must be explained by other negative side effects, which seem to be more pronounced in Andit Tid than in Maybar.

For ***Anjeni*** no farmer's estimates of yields from conserved and unconserved land are available. The impact of SWC structures on yields shows that graded Fanya Juu do not have a negative influence on yields, on the contrary. Yields are between 4% and 14% higher than the yield from the control plot, which is only treated with traditional drainage ditches.[527]

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525 Herweg & Ludi, 1999, 107.

526 Herweg & Ludi, 1999, 107.

527 Herweg & Ludi, 1999, 107.

***Adaptations of introduced SWC***

Generally, farmers agreed that there is a need to prevent soil loss. They also mentioned that mechanical structures are one possibility to achieve this. None of the interviewed farmers mentioned that soil erosion is not a problem at all. Asked whether there is a link between soil erosion and yield decrease, soil erosion was rarely mentioned as a reason for declining yields but more often climatic factors, more frequent pests and diseases, and punishment by Allah or God for committed sins were made responsible. Most farmers mentioned that their ***traditional conservation measures are effective*** enough to deal with soil loss. It was also argued that although introduced SWC might be better in erosion control than adapted or traditional measures, the negative effects of introduced SWC on crop production and labour clearly outweigh these possible positive effects. Farmers thus try to find a compromise between the effectiveness of mechanical SWC with respect to erosion control and its negative effects such as decreased production. It seems that in Maybar farmers have found this compromise by removing only selected conservation structures and maintaining those that are kept. Such a compromise has not yet been found in Andit Tid. Some farmers mentioned that especially in the upper part of the catchment they are going to plough under more, if not all bunds in future, especially also in view of the growing land scarcity. They mainly mentioned that the negative aspects of introduced SWC clearly outweigh the positive aspects – if they mentioned any positive aspects at all. It must therefore be expected that in future even more introduced mechanical structures will be ploughed under. The situation in Anjeni is interesting insofar as in 1992 most farmers mentioned that if they were allowed they would dismantle conservation structures. They perceived the problems related with mechanical SWC to be far bigger than the presumed positive aspects. Although already at that time the local administration was no longer in a position to punish farmers ploughing under conservation structures – something the administration did before 1990/91 – farmers have not remove all the structures until now. An important role is certainly played by the SCRP staff. After the change of government in 1991, they did not leave the area but remained and discussed advantages and disadvantages of mechanical SWC and possible ways of adaptation with farmers. Also the clinic, which was partly financed by the SCRP, acted as an incentive for keeping SWC investments. Because the clinic was still functional, farmers did not want to endanger this benefit. Visits to Anjeni in 1997 and 2000 showed that the negative attitude of 1992 luckily remained mainly rhetoric and not as many structures were ploughed under as expected.[528] As Figure 48 shows, selected conservation structures are maintained and terrace risers have reached considerable heights.

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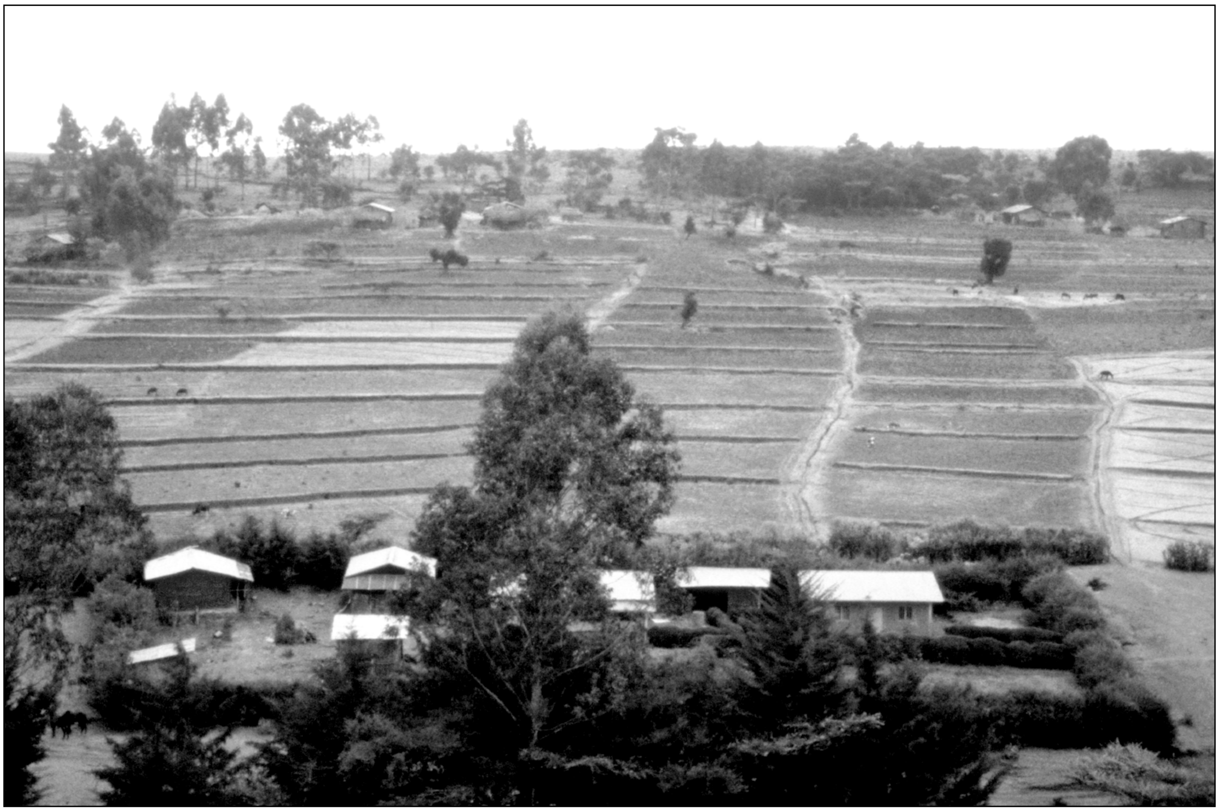
[528] cf. Ludi, 1997.

*Figure 48: Anjeni in 1992 (top) and 2000 (bottom). In the foreground the research station. After 1992 many families moved back to their former places from which they had to move during the villagisation. This explains in part the many new homesteads and the increased number of trees. Clearly visible on the fields behind the research station are the adaptations farmers made to the layout of conservation structures. Despite the negative attitude farmers showed in 1992, less terraces than expected have been destroyed.*
*[Photos: E. Ludi, 1992, 2000]*



In all three research areas, Government control relaxed considerably after 1990/91. Farmers were no longer punished if they ploughed under conservation structures. A process of adaptation took place, especially in Maybar, but also on selected fields in Anjeni and Andit Tid. The most frequently mentioned and observed modifications are:

- Every other conservation structure or two out of three conservation structures is/are removed.
- As the distance between two conservation structures becomes wider, more drainage ditches are constructed.
- Although farmers remove some of the introduced structures, they replace them with shorter stone heaps or stone bunds in selected locations if they observe runoff concentration that could eventually lead to rill formation.
- Terraces are opened to allow a better flow of water and the passage of draught animals (staggered structures). This can be observed particularly along field borders. On the one hand, this makes field operations easier, on the other hand, however, terraces formerly enhancing water drainage towards the next waterway can no longer fulfil this purpose, which leads to a pronounced danger of rill and eventually gully development within the field.
- Terraces are destroyed and rebuilt further downslope ("moving bunds"). The accumulated sediment is spread throughout the field and used as fertiliser.
- On land susceptible to waterlogging, such as the upper part of Andit Tid, all structures are removed.
- The width of conservation structures is reduced in order to minimise the land occupied. In Andit Tid and Anjeni, this often leads to a collapse of soil bunds because they are not strong enough if too narrow.

Farmer's ***perception concerning the usefulness of SWC*** in Maybar is considerably more positive than in Andit Tid and Anjeni. Especially in the lower part of the Maybar catchment, stone bunds are maintained or newly constructed. This positive attitude – or the perception that terracing helps to slow down land and soil degradation – is also visible in the amount of conservation structures outside of the research catchment which are maintained. In Anjeni, although farmers have kept at least part of the initially constructed bunds and now also admit that they have positive aspects, there are no investments on land outside the catchment – with the exception of recently constructed earth bunds through a new SWC campaign. Similar observations can be made in Andit Tid. All farmers interviewed, also those mentioning that introduced SWC is positive with respect to erosion control and preventing further yield declines, have not constructed additional Fanya-Juu or earth bunds on their land. Reasons given for not doing so are the following: Firstly, there is a lack of knowledge and tools required for the construction of Fanya-Juu bunds, which must be properly laid out in order not to cause more harm than benefit. Secondly, it was argued that other technologies than soil bunds should be developed, as soil is already in short supply. Grass strips were seen as one alternative, especially if additional production were possible. And thirdly, farmers mentioned time and again that they lacked the labour force necessary for constructing additional bunds. Traditional conservation measures such as drainage ditches can be made during normal field operations. Also small stone bunds and unploughed areas are established during ploughing or weeding time and do not require extra labour. And lastly, it was pointed out that traditional stone bunds require hardly any additional time for maintenance, while Fanya-Juu bunds must be maintained after every major storm. These arguments relating to lack of labour force can be seen as an indication of the fact that the initial investment costs, if they have to be borne by the land users themselves, outweigh the benefits. It could also be concluded that there are other opportunities available where labour can be invested in a more productive way, that there is a competition between farming activities and conservation investments (e.g. maintaining conservation structures during the rainy season versus weeding), or that there is a competition between off-farm income generation and conservation investments (e.g. construction SWC structures versus seasonal migration during the dry season). Only if some sort of support is provided, either individually (e.g. Food-for-Work) or communally (the clinic in Anjeni), and perceived or real labour shortages are relieved, the investment seems profitable enough.

### 6.2.3 Socio-economic factors influencing the attitude towards SWC

***A comparison of households maintaining and households not maintaining SWC***

The most common ***explanatory variables of technology adoption*** include farm size, subjective and objective risk, human capital, labour availability, credit, and type of tenure.[529] These variables can be grouped into personal characteristics, farm characteristics, physical characteristics of the land, and economic and institutional factors. The personal characteristics include age and education of the farm operator, household composition and labour availability. Farm characteristics concern variables such as type, size and fragmentation of the farm. The physical characteristics include slope gradient, soil type, exposition and agro-ecological location. Economic and institutional factors are related to farm and off-farm income, planning horizon, land tenure regime, technical and educational services, and other public policies. A review of conservation adoption studies shows that micro-level variables such as education, wealth, farm and off-farm income, or farm size have an inconsistent influence on the adoption behaviour of small-scale farmers.[530]

For the following analysis, the interviewed households are divided in two groups – Group A mainly maintaining formerly built conservation structures and Group B mainly destroying conservation structures. A binary LOGIT regression is run to detect factors that might have an influence on either keeping or destroying conservation structures. For the model the following factors are assumed to have an influence: age of the household head (AGE), literacy level of household head (LITERACY), family size (FAMILY), producer-consumer ratio (PCRATIO), size of own land (LAND_OWN), size of rented land (RENT_SIZE), number of plots (PLOTS), fertiliser application (FERTILISER), number of oxen (OXEN), number of other livestock (TLU_EXCEPTOX), off-farm income (INCOME), and credit (CREDIT_T). With the exception of literacy level, fertiliser application and off-farm income all variables are metric. LITERACY is coded 1 if the household head has formal education, otherwise 0, FERTILISER is coded 1 if fertiliser was ever used on the farm and 0 otherwise, and INCOME is coded 1 if the household head is engaged in off-farm income generation activities such as trading or working as a daily labourer for the SCRP and 0 otherwise.

| | | **Group A – maintaining SWC (N=15)** | **Group B – not maintaining SWC (N=14)** | **Overall** |
|---|---|---|---|---|
| Parameter | Unit | **Independent variable means** | | |
| CONSTANT | | 1 | 1 | 1 |
| AGE | years | 50.74 | 52.00 | 51.35 |
| LITERACY_0 | 0-1 | 0.93 | 0.86 | 0.90 |
| FAMILY | nr | 6.07 | 5.43 | 5.76 |
| PCRATIO | | 0.93 | 0.97 | 0.95 |
| LAND_OWN | ($m^2$) | 15,218.73 | 14,500.50 | 14,872.00 |
| RENT_SIZE | ($m^2$) | 3,550.93 | 1,075.50 | 2,355.90 |
| PLOTS | nr | 4.6 | 4.86 | 4.72 |
| FERTILISER_0 | 0-1 | 0.67 | 0.64 | 0.66 |
| OXEN ** | nr | 1.73 | 1.07 | 1.41 |
| TLU_EXCEPTOX | nr | 4.51 | 3.86 | 4.20 |
| INCOME_0 | 0-1 | 0.67 | 0.64 | 0.66 |
| CREDIT_T | EB | 18.0 | 100.00 | 57.59 |

*Table 54: Means of variables used in LOGIT regression on maintaining or not maintaining SWC in Maybar and Andit Tid.*
*(Means difference: * significant at 10%, ** significant at 5%, *** significant at 1%)*
*[Source: Own investigation 1998, 1999]*

529 Feder et al. 1985, quoted in Berhanu Gebremedhin, 1998, 25.

530 Berhanu Gebremedhin, 1998, 28.

From Table 54 the following can be concluded: Household heads of Group A – those households maintaining SWC structures – are slightly younger than household heads not maintaining SWC. The difference, however, is very small. The difference of the median age for the two groups is already slightly more pronounced, with a value of 53 years for Group A and 56.5 years for Group B. In Group A, 93% of all household heads are illiterate, whereas in Group B only 86% of the interviewed household heads are illiterate and the others have some formal education. Total family size is slightly bigger in Group A than in Group B, and also the ratio of producers to consumers is lower, indicating fewer producers per consumer. Own land and amount of rented land is bigger in Group A. The number of plots, however, is slightly smaller. In both groups around 2/3 of the considered households have never used artificial fertiliser. Households of Group A have considerably more oxen and other livestock than households of Group B. Off-farm income is similarly with around 2/3 of all household heads in each Group not engaged in off-farm income generation activities. Credit is comparably more common in Group B with a mean value of EB 100. With regard to the differences in mean values, the only variable with significantly different means is the number of oxen.

The LOGIT regression produces the following estimates:

| Parameter | Estimate | Standard error | t-ratio |
|---|---|---|---|
| CONSTANT | 6.84 | 8.27 | 0.83 |
| AGE | -0.14 | 0.08 | -1.91* |
| LITERACY_0 | 2.88 | 2.27 | 1.27 |
| FAMILY | 0.48 | 0.40 | 1.20 |
| PCRATIO | -2.10 | 5.89 | -0.36 |
| LAND_OWN | 0.00 | 0.00 | -1.46 |
| RENT_SIZE | 0.00 | 0.00 | 0.28 |
| PLOTS | -0.90 | 0.48 | -1.90* |
| FERTILISER_0 | 0.19 | 2.17 | 0.09 |
| OXEN | 3.69 | 1.28 | 2.88*** |
| TLU_EXCEPTOX | -0.49 | 0.28 | -1.74* |
| INCOME_0 | 0.87 | 1.37 | 0.63 |
| CREDIT_T | -0.01 | 0.01 | -1.99** |
| Chi-square | | | 19.02* |
| McFadden's Pseudo Rho-Square | | | 0.47 |
| N | | | 29 |

*Table 55: Parameter estimates for LOGIT regression on maintaining SWC structures in Maybar and Andit Tid. (* significant at 10%, ** significant at 5%, *** significant at 1%) [Source: Own investigation 1998, 1999]*

Out of the selected 12 variables only 5 are significant. The overall model is with a Chi-square of 19.02 rather weak and significant only at the 10% level. AGE is slightly significant and shows a negative coefficient. With increasing age the probability that SWC structures are maintained slightly decreases. The variable OXEN has the opposite effect, increasing the number of oxen per household would increase the probability that households maintain SWC structures. Increasing the number of plots (PLOTS), increasing the number of livestock except oxen (TLU_EXCEPTOX), and increasing the amount of credit (CREDIT_T) has a slightly to medium significant negative effect on the willingness to maintain SWC structures.

The interpretation of these results poses some difficulties. ***Age*** is the least difficult. That increasing age has a negative effect on maintaining SWC would coincide with observations made elsewhere in similar studies. Or otherwise formulated, younger farmers tend to invest more with regard to maintaining land productivity because they have to live from that land for a longer period in future than older farmers. It could also be that younger farmers, being more mobile than older farmers, have more frequent contact with extension agents or have even seen positive examples of SWC outside their community. Furthermore, generally it is assumed that younger farmers are more open towards new technologies or farming practices than older farmers are. There is one hypothesis that ***resource-poor farmers*** generally cultivate more marginal areas and apply more mechanical structures than rich households. One explanation is that because these marginal areas are steep and often cultivated by hoe instead of ploughed, the narrow spacing between the conservation structures is less a hindrance.[531] The above-presented results would indicate the contrary, the more oxen the household has the higher the willingness to invest in SWC. More oxen also do not make mechanical SWC more easily to construct and maintain. The only explanation why oxen play a considerably important role in determining whether a household belongs rather to Group A or to Group B could be that the number of oxen is a sign of wealth and that wealthier farmers tend to invest more in SWC. This interpretation, however, would be contrary to the sign of the variable TLU_EXCEPTOX, which states that with a bigger herd size the readiness to maintain SWC structures decreases. The two variables number of ***plots*** (PLOTS) and ***credit*** (CREDIT) and their negative influence on the willingness to invest in SWC could be interpreted as follows: more plots means higher fragmentation. It can be observed in both research areas that farmers generally tend their fields far away from the homestead less carefully than those in the vicinity. The more plots a household has the higher the chance that they are scattered throughout the community. That credit has a negative influence seems contrary to other studies. Often it is assumed that those farmers who have access to credit can relax cash constraints and have thus more capital available for SWC investments. In the case of the two research areas of Maybar and Andit Tid, the conservation technology is not capital, but labour intensive. Thus, cash constraints play a minor role. One can rather observe that those farmers taking credit are belonging to the poorer stratum of the community or face specific problems such as sick family members and mishap such as destroyed houses or loss of animals and are thus forced to take credit. Thus, the more credit a household has, the bigger are specific current problems, and the higher is the probability that the attention is focussed on other aspects than soil and water conservation.

***A comparison between research sites***

With respect to ***labour availability***, Andit Tid and Anjeni are distinctively different from Maybar. The inhabitants of Andit Tid and Anjeni belong to the ***Orthodox Christian*** Church, whereas the population of Maybar is ***Muslim***. The Orthodox Church knows a number of holidays with strict rules what type of labour is allowed or forbidden. Forbidden are all tasks related to fieldwork such as ploughing, weeding, harvesting or threshing. In the two Christian villages, a total of about 130 working days without restrictions are available per year. The others are either Saturdays (usually used for marketing), Sundays, strict holidays or less strictly observed holidays.[532] Holidays are related to Saints' days and are thus observed every month. In addition to these regular Saints' days, additional annual holidays are observed, such as Easter (two weeks of strict holidays) and several others (cf. Section 8.3 and Appendix 8.1). In Maybar, only Friday is a strict holiday. Some farmers do also not work on Wednesdays. In addition, annual holidays are also observed. However, in total more than 200 working days remain. It is not so much the total number of available working days that is important, but their distribution. Especially the two weeks around Easter and another 10-day period at the end of July and beginning of August prevent Christian farmers from performing necessary fieldwork at the right time. In Simen, where both Christians and Muslim live in near vicinity, Christian farmers confirmed that their Muslim neighbours are much more flexible in performing the necessary fieldwork and can also invest more time in laborious tasks such as weeding. These strict rules related to Saints' days in Christian areas are problematic because generally any type of work involving soil is forbidden. This makes it impossible also to either construct or maintain SWC structures. Those days on which farming is allowed have to be devoted entirely to the necessary fieldwork. Additional demands, such as those deriving from SWC, simply become too much.

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531 Yohannes G/Michael, 1999, 151. Further explanations for more mechanical SWC of poor households are that (i) because their cropland is marginal they have to use mechanical SWC, otherwise crop production would not be sufficient to sustain a family over one year, (ii) marginal land shows a higher stone content, thus constructing terraces is a means of removing the stones form the land and (iii) marginal crop land often borders grazing area, thus physical structures, which serve multiple purposes such as soil conservation and fencing, are necessary to prevent damage to crops inflicted by livestock.

532 All types of work are allowed with the exception of ploughing, planting and weeding.

Secure ***ownership*** or usufruct rights are often considered a crucial prerequisite for farmers to invest in SWC.[533] Farmers of Maybar, Andit Tid, and Anjeni did feel rather secure about their land. Although in most parts of the Amhara Region a land distribution took place in 1997 and some farmers lost land (cf. Section 8.2.1), most respondents believed that the plots they currently cultivate will also be theirs in future. Ownership security was seldom mentioned as a reason for not investing in SWC. Investments in SWC were rather used as a means to oppose a new land distribution as it happened in Mesobit & Gedeba. Farmers clearly indicated that they have invested significant amounts of labour in the conservation of their land, which they do not intend to loose in a distribution process. With respect to tree planting, the recent land distribution created more insecurity. Several farmers mentioned that unless they are sure that they can keep the land on which trees are planted and can enjoy the benefits, they are not willing to plant tress except in homestead plots.

Different perceptions exist of whether there is a ***difference in value*** of conserved and unconserved land. Farmers from Anjeni mentioned that it is more difficult to lease out land with conservation structures. One farmer also mentioned that he could not marry his daughter because the groom's parents did not like his land that is partly conserved. In Maybar and Andit Tid, no such statements could be recorded. Farmers leasing out land mentioned that it makes no difference whether the land is conserved or not. The demand is much bigger than the supply, therefore those farmers that want to rent land cannot be choosy. It was also mentioned that there is no difference in sharecropping arrangements whether land is conserved or not. That there is no difference in the value of the land whether it is conserved or not can be mainly explained by the absence of a land market. Land belongs to the state and farmers only enjoy usufruct rights. Therefore, their investments in maintaining or eventually increasing the land productivity are not rewarded through a higher value.

A distinctively different situation is presented in ***Mesobit & Gedeba***. Here, farmers have built and maintained stone terraces for generations. All farmers interviewed have treated their land with stone terraces, some of which reach heights of more than 2 m. This allows the formation of almost level bench terraces. With this measure, not only soil erosion can be controlled, but farmers also mentioned that sediment harvesting from adjacent bush or grazing land is an important side effect. Besides the soil conservation aspect, also water conservation and water harvesting should not be underestimated.

Most farmers have realised that with investments in ***soil conservation*** alone the productivity decline cannot be compensated. ***Intensification*** and ***diversification*** of the farming system gains more importance. Almost all farmers apply manure or compost, many are using the terraces in a productive manner, and the application of artificial fertiliser is also widespread. Because in Mesobit & Gedeba the land holding is not fragmented like in other parts of the highland, the application of manure is feasible, as cropland is usually in the vicinity of the homestead. The application of manure is furthermore possible because most farmers have planted trees for firewood already some years ago. Thus, not all manure is used as fuel substitute. Farmers of Mesobit & Gedeba have developed a system of green manuring. The leaves of the bisana tree (*croton macrostachytus*) are mixed with manure and household wastes and composted in a pit near the homestead, or the leaves are cut and directly distributed over the field. An important aspect mentioned by the interviewed farmers is to use the stone terraces in a productive manner. Many are planting *gesho* (local hop) on the terrace edges, and some have even started to grow *chat*. The application of artificial fertiliser can be constrained by the availability of cash. Many farmers therefore have started to produce cash crops for the nearby markets. Most important grain crop for selling is tef, which is highly valued. Whether the market orientation followed the increased need for cash to buy fertiliser to overcome soil productivity declines, or whether fertiliser could be bought because of higher cash income from selling goods on the market is not clear.

Thanks to a rather ***favourable market environment*** the strategy of diversifying and intensifying the land use system can be applied and leads to the desired outcome. A second important factor besides the market environment is that although the inhabitants of Mesobit & Gedeba are mainly Christian, they do not respect Saints' days in the same strictness as farmers in other Christian areas. They mentioned that they need the time for fieldwork and investments in land improvement. It seems that the contact with their Muslim neighbours and the opportunities offered through better market integration has loosened restrictive religious rules.

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[533] e.g. Wood, 1990; Desalegn Rahmato, 1993; Douglas, 1994; Lutz et al, 1994, Wachter, 1996.

All interviewed farmers from Mesobit & Gedeba mentioned that without investments in soil conservation this intensified land use system with the integration of cash crops would not be feasible. They specifically mentioned that without soil conservation the application of artificial fertiliser would be useless because it would be washed away with runoff. Farmers have integrated mechanical SWC fully in their land use system. Thanks to the combination of mechanical SWC, inputs such as artificial fertiliser, and the production of high-value crops also for the market a more intensive land use system becomes possible, which makes the high investment costs for SWC, which are borne entirely by the land users, profitable

In the ***Simen Mountains*** land users observed a steady decline of yields per land unit, coupled with decreasing farm sizes per household. Most respondents mentioned that decreasing land size is caused by high population growth rates. Reasons for declining yields were mostly seen in unfavourable climatic conditions. Only rarely soil degradation was mentioned, except in cases where land degradation was visible and so widespread that cultivation had to be given up. Farmers mentioned that 'the land has become old', which is a paraphrase for soil degradation, mainly nutrient depletion because the land has been used for a long time. Another reason mentioned for declining yields was the shortening of fallow periods. Farmers had to give up the intermediate fallow year in the highlands[534] in recent times. The problems that arose – diseases in the barley monoculture, weeds, depletion of specific nutrients – are clearly recognised, however, farmers see no possibility to reverse the negative trend. In the lowlands,[535] farmers shortened fallow periods from formerly 8 to 10 years to currently 2 to 4 years. They reported that during that time the soil cannot regenerate enough, because only small bushes and grass grow. If burned, which is the common practice for clearing the land, only small amounts of ash result. Another consequence of shortened fallow periods with less tree vegetation is that more animal dung has to be used as fuelwood substitute.[536] Mechanical soil conservation was hardly ever observed in the Simen Mountains. So far, long fallow periods were sufficient to replace eroded soil and nutrients. Burning vegetative ground cover in the lowland areas additionally improved soil fertility. However, with the dramatic shortening of fallow periods and the more intensive use of very steep slopes, increased nutrient mining and soil erosion declining soil productivity will be the result. Trainings for land users in carrying out SWC have been initiated by the Department of Agriculture. However, little concrete actions have been carried out so far. Farmers mentioned that they are not willing to invest labour as long as ownership or use rights are not clarified. It seems that although the negative consequences of a more intensive land use system without any investments in the land are recognised as problematic by farmers, they still judge the option for intensification of current farmland and extensification into currently not cultivated areas without major investments intact. Farmers living in villages in the vicinity of the National Park specifically mentioned that much of the land currently under forest cover would be very suitable crop land and could be converted in future, if need arises. They are fully aware of possible conflicts with the National Park authorities, but they claim that this land belonged to their ancestors before the National Park was established.

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534 Highlands in the Simen Mountains are referred to areas above roughly 2,800 m asl. The land use system is very similar to that of the upper part of Andit Tid area, with a barley-fallow rotation and in favourable places beans and potatoes.

535 The term 'lowland' used in Simen does not directly correspond to the agro-ecological altitudinal zonation used in Ethiopia. Areas referred to as 'lowland' are usually below 2,800 m asl. (Hurni & Ludi, 2000, 7)

536 Hurni & Ludi, 2000, 105.

### 6.2.4 Conclusions

The above paragraphs show that in most areas ***soil degradation*** is considered a problem, although it is not seen as the major factor responsible for declining soil productivity. Whenever soil erosion is considered posing a threat to the land and to crop production, farmers know a variety of traditional conservation technologies such as cut-off drains, drainage ditches, natural terraces and stone bunds. There are many more technologies known for maintaining or enhancing soil productivity such as fallowing, crop rotation, manuring, applying green manure and compost, and soil burning. However, under current circumstances, these measures alone cannot prevent soil productivity from further declining. Farmers are forced to use the land more intensively because in most areas there is an acute shortage of suitable arable land. With an intensified cropping system, the intermediate fallow periods have to be shortened, if not cancelled altogether. Small farm sizes force farmers to alter the crop rotation cycle in favour of more grain crops at the cost of pulses. Extension of cropland at the cost of grazing land or bush land increases the shortage of fuel wood, and the use of animal dung as fuel substitute becomes more prevalent. Extension of cropland in less favourable areas increases total soil erosion. Using manure as fuel substitute and crop residues as livestock fodder reduces the amount of organic matter which could be incorporated into the soil. This affects soil properties negatively and increases soil erodibility.

The major problem mentioned by farmers as threatening their livelihood are ***crop production declines*** per household as a result of declining farm sizes and declining soil productivity. Farmers observe a steady decline of average yields and increasing yield fluctuations. In view of the observed yield fluctuations in Maybar, Andit Tid and Anjeni (cf. Figure 34 to 37), it is absolutely understandable that the small annual yield decline of less than 1% as a result of soil depth decrease is hardly noticeable. Farmers often mentioned that if introduced soil conservation had a positive influence on yields they would invest much more in soil conservation. However, since there is no noticeable positive effect, farmers compare the total yield from a field with introduced SWC with that from a field with locally adapted and traditional conservation measures. Their impression is that yields from land which is treated with introduced measures is considerably smaller than from other fields – a fact supported by research experiments. However, it is also stressed that yields from land without any conservation measures such as cut-off drains or drainage ditches would be even smaller.

A marked difference in ***socio-economic aspects*** between farmers maintaining and farmers not maintaining SWC structures in Maybar and Andit Tid could not be detected. Whether farmers maintain or rather destroy structures depends more on where their land is located and on their general attitude towards SWC. Fields where SWC structures are more often maintained can be found in Maybar in the lower and flatter part of the catchment. These areas are traditionally treated with stone bunds. In the upper part of the catchment, bunds are generally more widespread at the footslopes of hills and less on the very steep slopes. Areas newly cultivated show less conservation structures even if slope gradients are extremely high. In Andit Tid, farmers consider soil conservation on fields in the *Dega* area as generally not necessary and as wasted investment. It is argued that because the land is left fallow for several years and covered with grass, soil degradation is not widespread and soil fertility can regenerate. A further negative aspect of Fanya Juu bunds in these highland areas mentioned is that waterlogging is a severe problem. In the lower part of the catchment, introduced SWC is considered to have serious negative aspects as well. Most often, the considerable portion of arable land occupied by the structures was mentioned as the reason for ploughing under some or all structures. It was stressed that yields from fields that are treated with introduced SWC are considerably lower than yields from land that is conserved with traditional technologies. On steep land, patches of the field are not ploughed. If these strips are enhanced with stones and weeds, they can over time develop into natural terraces. However, they seldom stretch out over the total width of the field; water drainage effects are therefore minimal if not negative when leading to concentrated run-off within the field.

In general the ***attitude*** of farmers from Maybar towards SWC is more positive than in Andit Tid and Anjeni. Several reasons play a role:

- Conservation structures in Maybar are built of stones, whereas in Andit Tid, soil bunds are more prevalent. Constructing stone bunds in Maybar is a means of decreasing the high stone content of arable land. In Andit Tid, building soil bunds is considered a waste of soil that is in short supply anyway. Conservation structures made of stones are probably also less susceptible to waterlogging than soil bunds.
- Although annual rainfall is generally sufficient in Maybar, distribution over time and recurrent drought is a problem. Soil conservation can increase water infiltration and relieve moisture stress. In Andit Tid and Anjeni, soil conservation more often leads to stagnant water because of soils with high clay content.
- In Maybar, mechanical soil conservation has been known for a long time, whereas in Andit Tid and Anjeni, physical structures were hardly known before the SCRP became active. Before, draining excess water was more prevalent in these localities.
- Total yield reductions resulting from the reduction of arable area and unintentional negative side effects on conserved land are 20% to 30% in Maybar and thus considerably smaller there than in Andit Tid, where they can be as high as 50%.

In Mesobit & Gedeba, the situation is distinctively different. In this area, mechanical SWC has a long history, and farmers have integrated SWC fully in their land use system. On flatter land, terrace heights allow the development of almost level bench terraces. The combination of active fertility management through manuring, green manuring and the application of artificial fertiliser can increase yields to such an extent that the area loss can be compensated. Secondly, the farmers currently using the land are not necessarily those who have built the terraces. In most cases, a considerable part of the conservation structures has been built by their fathers and the current generation is only maintaining and extending already existing structures. Thus, a considerable part of the investment costs does not have to be borne by the current generation, while the benefits of former investments can now be harvested. In the eyes of the farmers, the additional investments for extending and maintaining the conservation structures are therefore fully justifiable. The intensified land use system relying on artificial fertiliser and the integration of cash crops on the one hand makes mechanical SWC a necessary investment; on the other hand, thanks to the high prices for certain marketable crops, investment costs can be recovered.

Decreasing farm sizes and declining yields pose an acute threat to the livelihoods of many farm households in the visited areas. Farmers consider their possibilities to achieve a decent living severely restricted. For coming generations, the outlook is even bleaker. Farmers often mentioned that future generations have to search for other employment opportunities than farming. On the other hand, it was also stressed that being a farmer is the most appreciated occupation besides being a government employee. The strategy of decreasing the dependency of certain family members on the land is important in some, but not in all households interviewed. More often it was mentioned that the government has to find solutions for future generations by providing additional farmland and developing resettlement schemes. Only rarely did the farmers see any possibilities for them and their fellow farmers to reverse the negative trends within their community, other than the solutions that are already applied, such as traditional technologies with regard to maintaining soil productivity. On the one hand, this can be attributed to lacking knowledge about existing possibilities; on the other hand, under current economic, political and institutional circumstances or in specific marginal areas such as Andit Tid, not so many possibilities actually exist. And lastly, falling back on traditional safety nets and known values is a possibility of increasing at least the subjectively perceived security, which is an understandable strategy, since most interview partners consider the current situation as insecure. Innovations or adaptations of current practices are considered risky, either with regard to securing a family's livelihood or with regard to the integration into the rural society.

## 6.3 A Comparison of the Internal and the External View of the Profitability of SWC

*"Land users' groups, commodity associations, NGOs, government agencies, and research institutes, each of which have different roles and goals in natural resource management, have to share group responsibilities and work together towards common goals. This way, knowledge becomes multi-disciplinary and more attuned to supporting livelihoods than just conserving soil and water."*
*(Hurni et al., 1996, 72)*

In the previous Section 6.1 it was argued that whenever a conservation technology is economically less profitable than the continuation of an erosive farming practice it would be uneconomic for a small-scale subsistence farmer to change from the erosive to the conserving farming practice. This argumentation assumes that the rationale of land users' behaviour is one of profit-maximisation. In Section 6.2 it was mentioned that farmers consider the risk of innovation or of adaptation of current practices too big in comparison with the expected benefits. This argumentation assumes that farmers avoid risks as far as possible. In the discussion of strategies of small-scale subsistence farmers with respect to economic action, three broad theoretical schools exist. The debate over the economic rationale of small-scale subsistence farmers or peasants[537] began with the proposition by Schultz that peasant households are 'efficient but poor',[538] thereby implicitly criticising the prevailing opinion at that time that peasant households do not operate in an economically rational way. The argumentation that there are few inefficiencies in the allocation of production factors of small-scale land users led to the formulation of the neo-classical theory of the 'profit-maximising household'. As a counter-reaction and more influenced by anthropologists was the formulation of the theory of the 'risk-adverse household'. Not influenced by these two lines of thought was the theory formulated in the 1920s by the Russian agricultural economist A.V. Chayanov, who described farm households maximising utility through optimising production and consumption.

The most important hypotheses that can be derived from the three theories will briefly be described in the following.[539] An actor-oriented structural model of development and environmental problems explaining farmers actions will be presented which incorporates various aspects of the three major economic theories. These models will be further used in Section 6.3.2 as a framework for analysing observed actions of farmers in the various study areas.

### 6.3.1 Farmer's rationality of action – four explanations

***The theory of the profit-maximising household***

Simply speaking, the basis of this neo-classical theory is the assumption that farmers allocate production factors (i.e. land, labour, capital, knowledge) under a given technological situation in an efficient manner. Efficiency in this context would require that there are no adjustments neither in input nor in output which would give the household a higher net income, measured either in monetary or in physical terms.[540] Efficiency can be further broken down in technical efficiency, which is the maximum achievable output for a given level of production inputs, given the range of alternative technologies available to the farmer, and allocative

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537 cf. Footnote 192 and 193.

538 Schultz, 1994, quoted in Ellis, 1988, 63.

539 based on Ellis, 1988; Ludi, 1994 and 1997; and Wiesmann, 1998.

540 When considering a single production function, this would mean that marginal factor costs equal marginal product value.

efficiency, which refers to the adjustment of inputs and outputs to reflect relative prices, provided that the technology of production has already been chosen.[541] Economic efficiency is given if both technical and allocative efficiency is achieved. Empirical studies showed that often allocative efficiency is given, but not necessarily technical efficiency. This conclusion is not to deny that farmers decide in certain instances in view of maximising profits, but that there are constraints (e.g. lacking knowledge) and frame conditions that do not allow them to act totally efficient. This led to the formulation of '***constrained profit maximisation***', which aims at representing frame conditions as accurate as possible. Under this assumption, imperfect markets, exploitation and repression, and competition with other household aims could be included.

The hypothesis that small-scale farmers show signs of profit-maximisation and are efficient in the allocation of production factors but not technically efficient had decisive ***consequences for development policies***. A technological transformation approach was the logical consequence. It was assumed that with technical innovations the productivity of small-scale farmers could be increased substantially. Technical packages such as that of the 'Green Revolution' were promoted widely. However, it soon became clear that it is not necessarily the technologies alone that were lacking, but that there were other factors hindering technical efficiency. Interventions therefore partly shifted away from direct intervention and technology development to address and improve boundary conditions. These indirect measures focused on lowering prices for agricultural inputs and on transferring technical know-how in a first phase[542] and eliminating market imperfections in a second phase. Recently, government structures such as autocratic and bureaucratic rules,[543] and institutions came into the focus.[544]

***The theory of the risk-averse household***

The observation that land users often allocate their resources only sub-optimal led to the formulation of the theory of the risk-averse land user. It was postulated that although land users are not efficient in terms of profit-maximisation, they nevertheless make decisions that are rational in economic terms. Land users react to risks and uncertainties in their natural, economic, social and political environment. Such risks encompass climatic irregularities, yield uncertainties, market fluctuations, imperfect markets, lacking knowledge, social and legal regulations such as access to resources, and state actions.[545] Also development projects and interventions can be a factor of risk. Development projects on the one hand demand resources and farmer's participation, which is not foreseeable neither in quantity nor in timing, and on the other hand produce outputs which are, from a farmers point of view, erratic as they depend much more on decisions made at the project's headquarters than on local needs.[546] The theory is centred on decisions and resource allocation by small-scale subsistence farmers, which are targeted towards avoiding risks and uncertainties.[547] Such behaviour by small-scale land users can also be seen as 'safety-first' strategy,[548] which is compatible with the rationale of subsistence land users who try to achieve an output that is sufficient without increasing the financial burden. Assuming land users to follow the risk-avoiding strategy, resource allocation in comparison to the profit-maximising strategy is efficient in compliance with goals such as risk minimising or observing household needs.

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541 Ellis, 1988, 66.

542 e.g. strengthening the extension service

543 It is not necessarily only market imperfections leading to externalities and biases against small-scale land users, but rather government or policy failures, whereby no interventions are made in distorted markets, or even worse, which formulate policies in favour of specific groups within society, thus marginalising small-scale subsistence farmers even further (e.g. tax exemptions for logging companies or livestock owners, low producer prices to satisfy politically important supporters in cities, etc.). (Dasgupta, 1995, 395; OECD, 1995, 16)

544 Structural adjustment programs under the aegis of the World Bank addressing issues such as good governance, democratisation or decentralisation originate from positions of the modernisation theory and address government structures and institutions, which are considered as hindering economic efficiency of small-scale farmers.

545 Ellis, 1988, 81f.

546 Wiesmann, 1998, 51.

547 Risk is understood as the subjective evaluation of probabilities, whereas uncertainty refers to situations where it is not possible to attach probabilities to the occurrence of events. (Ellis, 1988, 82; OECD, 1995, 139ff)

548 Scott, 1976, 15.

Often, however, technical efficiency is not achieved. With respect to farming practices, the profit-maximising and the risk-minimising strategies can be clearly differentiated. The latter is characterised by practices such as mixed cropping, diversification, both in terms of a wide range of agricultural products and the use of different geographical or ecological locations and niches, combination of crop production and livestock raising, reliance on products that perform more evenly over time, even if other products performed better in good years, but worse in bad years, or involvement in the 'moral economy' and maintenance of social networks. Profit-maximising households would concentrate on those enterprises promising highest returns at the cost of security and fulfilling household needs in bad years or if negative economic or political changes occur. Risk-minimising households are often characterised as slow adopters of technical innovations, if not total rejecters. It is further assumed that increasing wealth and risk-minimising behaviour are negatively correlated. The poorer the household the less reserves are available to balance fluctuating income. The richer the household the more capital and reserves are available which allow a more risk-taking behaviour. Secondly, wealthier households often have better access to rural credit and information, allowing them to undertake new and riskier enterprises.[549]

With respect to ***development policies***, the assumption that farmers behave in a risk-averse manner led to interventions trying to reduce objective and subjective risks. Within the framework of technical innovations such as the 'Green Revolution', interventions to minimise production risks were first sought, such as irrigation projects and the development of resistant crop varieties. Later, market risks came more to the attention, especially input and output prices.[550] Through the intensified integration of small-scale land users in the national and global market, risks related to markets and prices rather increased. It was observed that this also led to the erosion of social networks and support systems, which were part of the moral economy. Promoting or strengthening self-help groups or co-operatives was the answer, as in most rural societies both characteristics of market economy and moral economy persist.[551] Also recent attempts such as empowering local communities and specific sections within society can be seen in this line of thought.

***The theory of the utility maximising or optimising household***

The previous two theories have mainly concentrated on the production side of rural households. However, small-scale land users or peasants are characterised by ***complex interactions between production and consumption***, between enterprise and family. The model of household decision making developed by the Russian agricultural economist A.V. Chayanov[552] takes into account these two sides of a household. His theory assumes a utility maximising household. The basic assumptions are (i) that optimal allocation of production factors follows the principle of marginal factor costs being equal to marginal product value, (ii) farm and household cannot be separated, and (iii) an equilibrium of production and consumption is sought, involving a trade-off between disutility of work and utility of income.[553]

Chayanov assumes individual family farms that are distinctively different from firms producing goods. He stresses that the motivation of a farming family differs from a capitalist firm insofar as the former aims at securing basic needs, whereas the latter aims at maximising profits. Therefore, a farming family accepts decreasing marginal benefits of labour until all basic needs are fulfilled.[554] Optimising utility is manifested through the relation between ***labour and leisure***.[555] According to Chayanov, the output of a family farm is defined by the amount of available labour force, which is physiologically feasible, and the amount of material goods needed to reach a minimum acceptable standard of living. Thereby, the amount of labour force defines the biggest possible output and the amount of necessary material goods to reach a minimum acceptable

549 Ellis, 1988, 80ff; Ludi, 1994, 22.
550 Ellis, 1988, 96ff.
551 Wiesmann, 1998, 53.
552 Also Čajanov or Tschajanow.
553 Brandt, 1990, 138.
554 Kerblay, 1987, 177.
555 Harrison, 1979, 329.

standard of living defines the smallest output. Families are considered not only as a biological entity, but rather as an economic entity. Nevertheless, the family cycle is important, i.e. the size and composition (demographic structure) of a family in a given moment as well as its change over time, which can best be characterised by its ratio of ***working to non-working members*** or as producers to consumers. This producer-consumer ratio is an important factor determining the amount of arable land a family needs to produce enough goods on the one hand, and can cultivate with the available labour force on the other hand. As families grow, the amount of land has to be adjusted, both to growing needs and to growing labour possibilities. When adult children move out of the parental household, the formerly big farm is split in smaller farms, and the process of growing starts anew.[556] Chayanov observes self-sacrifice of labour, which is defined by the growing demand of the family. A family always attempts to reach an equilibrium of marginal utility of goods and marginal product of labour.[557] As the model assumes a flexible access to land but no market for labour, i.e. neither hiring of labour by the family nor wage work by family members,[558] the equilibrium labour – land – capital is either reached through extension of farm land if capital is available or intensified labour input on the existing farm if capital is missing. In Chayanov's definition, ***capital*** describes those values which a family does not consume but advances for production.[559] Capital is accumulated through abstinence of consumption to achieve an optimal equipment of the labour force with production factors, according to technologies available and farm size. Capital is accumulated as long as the standard of living can be increased and the decrease of the burden of labour justifies the costs for investments. Investments depend on the family cycle insofar as young families show an unfavourable consumer-producer ratio and most expenses are of a consumptive nature.

Chayanov not only considers endogenous but also ***exogenous factors***.[560] Economic trends and relations to other households determine in part the amount of land a family can acquire, and social norms within the rural society define partly the minimum acceptable standard of living. As families grow, they have to acquire more land. In areas where the land frontier is closed, this can only be achieved through leasing or buying land. As demographic pressure increases, land prices increase correspondingly, and families have to accept a return to their labour that is below the subjective wage rate in order to fulfil their basic needs. Relations to other sectors of the economy and the society are equally important. As farming families can either consume their production or sell it on the market, there are strong interrelations through markets and trade, which link farm families to the wider economy and to the world trade.

Although Chayanov's model of family farms describes many aspects that can also be found in developing countries,[561] the usefulness of his theory for formulating ***development policies*** is debatable. Specifically the following aspects are crucial:

(i) The model assumes flexible access to land. In most developing countries this is not, or no longer, given. In the Ethiopian context the land frontier is closed with a few exceptions in the south-west and west of the country, leasing land was politically restricted during the DERG government and selling of land is still prohibited today. Therefore, even if growing families liked to acquire additional land to optimise the consumption – labour – land ratio, this is often not possible.

(ii) Substitution of male and female labour is assumed. This does generally not correspond to reality, as in most rural societies a rather strict division of labour according to sex and age can be observed. In the Ethiopian context, a family consisting of enough producers to, theoretically, cultivate a big farm, could face serious problems because no male adult family member is present who is allowed to plough. The crude producer-consumer ratio without differentiating sex is not a valid determinant for possible farm size.

556 Tschajanow, 1923, 9ff.
557 Tschajanow, 1923, 32ff.
558 Ellis, 1988, 107.
559 Tschajanow, 1923, 67ff.
560 Tschajanow, 1923, 99ff.
561 e.g. Hunt, 1979, 248.

(iii) The third aspect, that of missing labour markets is less critical. In many developing countries, especially also in Ethiopian rural societies, labour markets are absent, only seasonally available, or only available for specific segments of the rural society (e.g. young, single men). Labour is exchanged on a mutual basis among relatives or neighbours to bridge shortages, however, family members can only rarely engage in wage work to adjust the consumer – producer – land ratio.

(iv) Although minimal consumption needs are in part defined by the number of consumers, other needs such as social obligations have also to be fulfilled to not endanger integration into the rural society.

Later developments of micro-economic household models took into account the above-mentioned shortcomings. ***Utility-optimising farm household models*** are characterised by:[562]

- the existence of a market for labour,
- fixed land availability to the farm household,
- a combination of 'home' activities (i.e. Z-goods or subsistence production and reproduction) and 'leisure',
- the choice a household has between own consumption of output and sale of output in order to purchase non-farm consumption needs,
- ignoring uncertainty and behaviour towards risk.

These models thus deal both with a farm (a production unit in the conventional sense) and a household. Through the inclusion of a labour market and a market for goods, which have an influence on decisions of a household, a more realistic situation is modelled. This extended model also allows including economic or institutional frame conditions, such as governmental price policies or land ownership rules. It thus links the farm household to the larger economy. What Chayanov's model neglects – the labour market – is assumed in the farm household model as fully working. Both assumptions are not very realistic in developing countries. Usually, a market for labour exists, but it is incompletely working or imperfect.

***Complex strategies of action of smallholder households[563]***

The outline of the theoretical approaches in the previous Section 6.3.1 offering explanations for the rationale of economic behaviour of land users make it possible to explain certain important aspects of strategies of action, as Table 56 shows. However, all three theories in their pure form show clear deficits in explaining land users behaviour and adaptations to a changing environment. The theory of profit maximisation ignores land users various strategies, the theory of risk minimisation offers insufficient explanations of adoption and innovation processes in land users action.[564] Chayanov's theory of utility maximisation is based on assumptions which are not or no longer relevant for many rural societies, and considers a family or household too strictly as a biological entity, neglecting interactions of family farms with society at large, which are at least as important as demographic factors in determining the adaptation and innovation processes.

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562 Ellis, 1988, 128.

563 If not otherwise quoted the following discussion of the framework of strategies of action and the actor-oriented structural model of development and environmental problems in rural Africa is based on Wiesmann, 1998, pp. 53-84.

564 Wiesmann, 1998, 53.

| | Risk-minimising household | Utility-optimising household | Constrained profit-maximising household |
|---|---|---|---|
| **Land use** | Land use is as diversified as possible and independent of external markets. | Land use is partially market oriented, if this allows a more optimal combined use of labour, land, and capital. | Land use can be specialised and is market oriented. |
| **Type and level of production, and influencing factors** | The types of risks determine production. | The composition of the family (producers – consumers) defines the level of production. | Prices for inputs and outputs define the level of production. |
| **Allocation of production factors** | Production factors are not allocated efficiently in the sense of profit maximisation, but rather with the objective of avoiding risks and ensuring the survival of the household and its members. | Production factor allocation is partially efficient. | Production factors are allocated efficiently. |
| **Reaction to changing prices and changes of factor markets** | Reaction to changes in prices and factor markets are limited. | Reactions to changes in prices and factor markets only take place if they promise a more optimal combination of the use of labour, land, and capital. | Strong reaction to changing prices and factor markets. |
| **Reaction to technical innovations** | Technical innovations are adopted if they reduce risks. | Technical innovations are adopted if they allow a more optimal combination of labour, land, and capital | Technical innovations are adopted if they lead to higher profits. |
| **Reaction to changing income** | With increasing income, risk minimising strategies diminish. | Increasing income leads to decreasing labour input, leisure becomes more important. | Increasing income leads to increasing orientation towards profit maximisation. |

*Table 56: Characteristics of micro-economic household theories.*
*[Source: Ludi, 1994, 27, adapted.]*

Wiesmann (1998) proposes a ***conceptual framework*** that accepts basic hypotheses of all theories and combines them to obtain a process of utility optimisation. He assumes that peasants combine various actions into a specific strategy, which balances the diverse actions and tasks according to the principle of ***minimising risks***. At the same time, land users seek to ***optimise utility*** by taking up opportunities, which are offered in certain spheres of action. Land users' actions are geared towards fulfilling the following four main household aims:[565]

(i) ensuring enough production to guarantee a livelihood in material terms for all household members;
(ii) surplus production to ensure satisfaction of other material and non-material needs;
(iii) accumulation of capital as an insurance against unforeseen events and to ensure the material basis of livelihood;
(iv) fulfilment of social and cultural obligations to ensure social recognition and integration.

Land users not only employ risk minimising strategies with respect to land use, but they also have to consider risks originating from other spheres, such as economic or political changes. In other words, land users optimise utility by trying to ensure their basic livelihood, their position in society, and their basic material and social resources in a highly dynamic environment. A central aspect of the framework of strategies of action is

[565] Douglas, 1990, 45.

that (i) land users strategies are embedded in a societal context, and (ii) they strongly relate to environmental concerns. Thus, rural societies have been shaped by their specific history and have been influenced by their political, socio-economic, and ecological environment.

Land use systems do not only reflect individual attempts to reduce risk and optimise utility. They also include a subsistence-oriented guarantee of livelihood for all members, spreading and distribution of risks, and joint reactive measures. ***Land use systems*** are complex in terms of variety of products (e.g. crops and livestock), and technologies. At the same time, these complex land use systems are persistent over time. Strong social and cultural systems that regulate, control, and reproduce individual and societal strategies are necessary to preserve and refine complex land use systems and risk-coping strategies. Social and cultural systems in African smallholder societies show the following structural components: Within ethnic groups, kinship systems in terms of clans and lineages form a central social organisation. Families, either complex or nuclear, form part of this system of lineage. Through this hierarchical structure a second line of social differentiation runs, which assigns individuals to different classes according to age, gender, and wealth.[566] The social and cultural system must harmonise and optimise individual land use strategies in order to ensure social security and balance. The following four aspects are central:

(i) ensuring ***access to resources*** (e.g. land, water, plants, and animals) for all members of the society,
(ii) ensuring the highest possible ***ratio of producers to consumers*** within each household but also within the rural society (e.g. different forms of mutual labour exchange, complex household structures),
(iii) ensuring a variety of possible ***reactive measures*** in order to reduce and balance risks (e.g. social networks attributing clearly defined duties and rights to its members, reciprocal exchange of goods and services, investments in 'social capital', mechanisms to sanction deviant behaviour),
(iv) ensuring that ***complex knowledge*** about ecosystems and land use is preserved (e.g. 'lineage' production mode, seniority, gender systems).

These multi-faceted relationships between the social system and the land use system have produced a great number of rules and norms relating the linkages society – individual – land use system. These linkages today provide on the one hand a framework for cultural identity and enable counter-balancing risks posed by the market economy and policy interventions on the other hand.

A central aspect of smallholder societies and land use systems is that they are embedded in a web of ***influencing factors***, which are out of their direct control and to which they have to react with adaptations of their social and cultural system as well as their land use system. These dynamic conditions of action, which are particularly important for rural societies, can be grouped under the following headings:

(i) demographic change (i.e. population growth, changes in the age-sex pyramid, per capita decline in the availability of natural resources, etc.),
(ii) changes in market conditions (i.e. integration into agricultural markets, price structure, availability of market information, absence of factor markets, etc.),
(iii) changes in political frame conditions (i.e. changes of the legal system with special reference to land ownership, elites monopolising access to resources, state institutions providing infrastructure, technologies, and information, state system of control, security, and sanctions, etc.),
(iv) large-scale socio-cultural dynamics (i.e. migration, civil war, etc.),
(v) changes in natural resources (i.e. periodic and non-periodic variations, permanent changes such as environmental degradation, changes in the access to and availability of resources, etc.).

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[566] Wealth is understood in this context in a broad sense, not only encompassing material goods but also political influence, role and function in social and cultural institutions, or access to social networks outside the rural society (e.g. through relatives living in cities).

The following Figure 49 presents an overview of the actor-oriented structural model of development and environmental problems of land users in rural Africa. The principal features of the model, focussed on land users (also referred to as peasants or peasant households), are:[567]

- The guiding rationale of land users' action is to ***reduce risks and optimise utility*** to ensure material livelihood and social position.
- ***Strategies of action***, which are adapted to changing conditions and enhanced through innovations, form the foundation of action. In these strategies, material and social resources are allocated in a complex manner.
- ***Values and norms***, their representation and expression in the form of social relationships and social organisations, and their logic define a framework of meaning. On the one hand, this framework is an integral part of the land users' action, on the other hand, it is constantly modified as a result of the integration of smallholder societies in a broader social, political, and economic context.
- Land users are exposed to ***dynamic conditions*** of action, which may be perceived as potential, but more often are seen as a limitation. Dynamic conditions can originate from the ecological sphere as well as from the economic, social, or political sphere.
- In an ***adaptive process*** between (i) the value system, social norms, social networks and hierarchies, (ii) the perception, valuation and interpretation of dynamic conditions, and (iii) the ecological system, farmers permanently reshape their land use system. Land use systems are characterised by their high degree of complexity, persistence and flexibility, which is maintained through productive and reproductive inputs.

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567 The framework of strategies of actions is similar to the concept of livelihoods (cf. Footnote 197). Both concepts are centred around strategies of households to secure a livelihood under dynamic frame conditions. Both link rural societies with the wider social, political and economic environment, and include the state as an important actor. Wiesmann's framework, however, stresses the innovative potential of land users as a way of adaptation to a changing environment stronger.

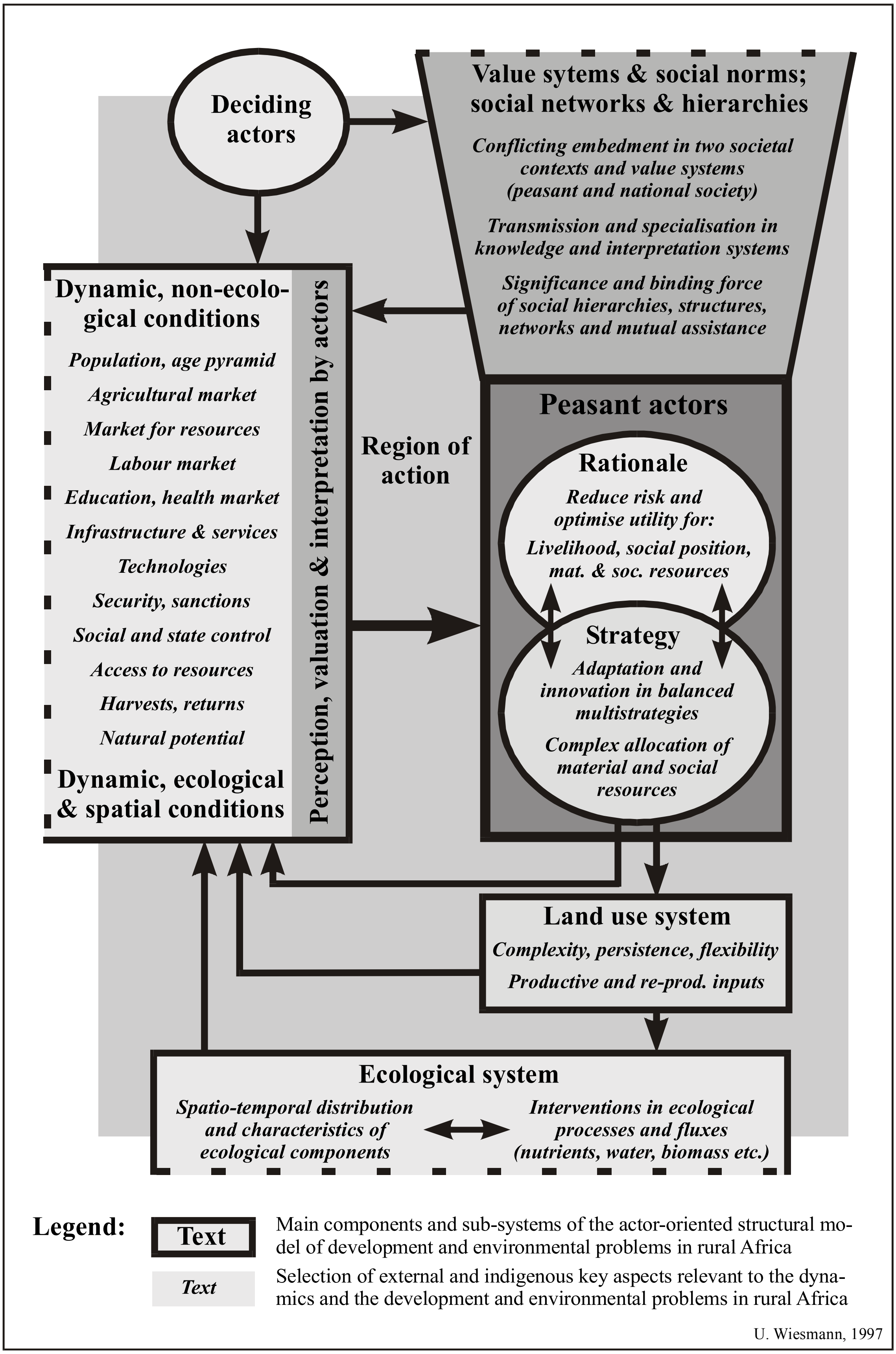


*Figure 49: An actor-oriented structural model of development and environmental problems in rural areas of Africa.*
*[Source: Wiesmann, 1998, 73]*

In the complex interactions of rural populations struggling to ensure survival on the one hand, and environmental degradation processes[568] on the other hand, which can be both a cause for and a result of the former, the above described model can be used to address the following aspects:

(i) the principles of dynamics of environmental change and degradation in smallholder areas,
(ii) the indigenous potential to deal with ecological changes, and
(iii) the consequences for environmentally oriented development approaches.

With respect to the first problem area, the model summarises that ***land use dynamics*** are dependent on the dynamics of conditions of action and on transformation processes within the social system. These two dynamic forces do not have a direct influence on the land use, but are first reflected in changes – or the lack of change – of strategies, of which farming is but one. Understanding the dynamics of peasant strategies in relation to the two forces is a key to understanding the environmental dimension of development.

With reference to the second complex – the indigenous potential to deal with ***ecological change*** – the model implies that reactions and changing strategies occur only if the environmental change appears to land users as a dynamic condition in the natural potential and is valued accordingly. It is hypothesised that environmental degradation results in either non-reaction, as it is often perceived as a persisting limitation, or in shifting weight within the whole basket of strategies of action. This leads to the further hypothesis that the capacities of land users to halt or reverse environmental degradation are rather limited and will only be activated if the necessary measures include a component of opportunity and if they are compatible with the allocation of material and social resources. Changes in the land use system are therefore more often a reaction to driving forces from the societal transformation process than an adaptation to a changing environment. In the model, the strong link between the system of social values, norms, networks and hierarchies has been stressed. Therefore, to allow changes in the land use system as a reaction to environmental degradation, changes in the system of social norms, values, networks and hierarchies have to take place accordingly. Secondly, when environmental conditions become part of the dynamic condition of action, a process of valuation and interpretation has to take place. Depending on which direction this valuation is heading, adaptive changes of strategies of action might occur. Thirdly, if transformations within the social system and the perception and valuation of environmental change favoured adaptations of the land use system, concrete implementation depends on material and social resources, i.e. the availability of labour, the availability of knowledge, and the availability of material resources.

With respect to the third aspect – ***environmentally oriented development*** – and based on the considerations above, that rural societies have limited capacities to directly react to environmental degradation processes, the following conclusions can be drawn: external support which addresses environmental problems through direct intervention in land use practices and technologies will only succeed in few cases. Success is expected to be biggest if the interventions offer further opportunities and if they are compatible with available material and social resources. More promising options address environmental problems indirectly by creating opportunities in fields of action of land users to which they tend to shift as a reaction to the additional limitation posed through environmental degradation.

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568 Which does not imply that there must always been environmental degradation processes associated with land use, but in the present study this is of special interest.

### 6.3.2 An assessment of land users actions with regard to SWC – an attempt to compare the insider's and outsider's position

***Effects of adaptation of SWC on total soil loss from the catchments***

Farmers have significantly modified the layout of conservation structures within the research catchments. The question remains what effect these changes might have on soil loss. No erosion plots are available where the effects of modified conservation on soil erosion and yield was monitored. One possibility to assess changes of the conservation technology on soil loss is to consider the whole catchment and to take the total amount of ***sediments leaving the catchment*** as an indicator of the effectiveness of soil conservation. Annual suspended sediment yield leaving the catchment was calculated based on measurements at the hydrometric station. Although not all suspended sediments measured in the river water originate from arable land, but also from grazing land, bad land, village areas and footpaths, and stream bank erosion or land slides, it must be expected that a considerable portion is actually soil loss from cropland.[569]

In ***Maybar***, no clear relation between SWC implementation and consolidation of the structures over the observation period (1982-1992) and suspended sediment yield can be detected. Amounts of sediments transported out of the catchment vary considerably over the years. River bank erosion and landslides probably play a major role. However, annual sediment yields seem to be considerably lower after 1986 than before, with two major exceptions (1988, 1992).[570] It could thus be hypothesised that after the initial years and terrace stabilisation, soil erosion was controlled partially and suspended sediment yields were reduced. Starting in 1989, parts of the steep land designated as closed area was claimed back by farmers and ploughed. This land was not treated with bunds. When it was used again for crop cultivation, farmers did not construct new SWC measures. It is thus possible that the peak in 1992 could partly be explained by an increase in soil loss originating from this newly cultivated land. In ***Andit Tid***, suspended sediment yields fluctuate considerably over the years[571] and do not indicate a major impact of mechanical SWC in early years or neglected maintenance or ploughed under structures in later years. In ***Anjeni***, suspended sediment yields gradually declined after implementation of SWC between 1985 and 1989. After 1990, when farmers started to remove SWC structures, suspended sediment yield again rose and remained at higher levels, at least until 1993.[572]

What role large-scale soil conservation activities in the research catchments play in relation to the total amount of suspended sediment yield is difficult to conclude from the above-mentioned indications. In most research areas a decline of suspended sediments could be observed after the construction of SWC structures. One could even argue that the effect of SWC on arable land is considerable, as at the same time degradation of other areas such as grazing land increased in the course of increased pressure on such areas and expanded agricultural activities into marginal areas. Relaxed government control after 1991 allowed farmers to plough under conservation structures. If they had done this on a large scale, one could assume that it would have shown in an increasing amount of suspended sediments leaving the catchment. However, from the available results, no clear conclusion can be drawn. There are signs that suspended sediment amounts increased after 1991, however as the source of the sediments is not clear one can not conclude that it is a direct result of reduced SWC. It could also be a result of increased pressure on grazing land and bush land, or expanded degraded areas no longer used for crop cultivation.

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569 Gete Zeleke (2000, 49) calculates that 97% of the total soil loss of Anjeni research area originates from cultivated land. Sediment yield, which is different from soil loss (the latter is the amount of soil particles detached and transported, but maybe deposited further downslope, the former is the amount of sediments leaving a specified area), originates not necessarily in the same percentage from cultivated land.

570 SCRP, 2000d, 54.

571 SCRP, 2000b, 51.

572 SCRP, 2000c, 58.

***Negative side effects of mechanical SWC and how they are included in the CBA***

Mechanical soil conservation in the Ethiopian Highlands is often associated with unintentional side effects. The complaints most often mentioned by farmers are that

(i) SWC structures occupy precious cropping area,
(ii) because the area occupied by SWC structures is not ploughed, weeds and rodent habitats are no longer destroyed, and cultivation land is infested,
(iii) stagnant water is frequently observed above the conservation structures despite a drainage gradient of the structures of 2 to 5%,
(iv) maintenance of SWC structures requires high labour inputs, especially during the rainy season and competes with other labour,
(v) farm operations, especially if the spacing between two conservation structures is narrow, cannot be performed as usual, i.e. ploughing in diagonal lines is impeded, and turning the ox-drawn plough is difficult.[573]

These complaints have to be taken seriously and should, through adaptation of the technology, be directly addressed. Many of the mentioned negative side effects of stone or soil bunds are also manifested in the negative NPV presented in Section 6.1.

The amount of ***cropping area occupied*** by conservation structures is considerable and, especially on steep slopes, mainly responsible for the negative NPV. The problem is, however, that by reducing the number of conservation structures, the efficiency of controlling soil loss is also diminished. Nevertheless, the comparison of adapted and introduced SWC clearly demonstrates that adapted SWC – which generally means a wider spacing of terraces and thus results in a reduced amount of occupied crop land and less labour for construction and maintenance – is in more situations economically profitable (i.e. compared to the situation without soil conservation), despite its lower efficiency with regard to erosion control. By relaxing the strict rules set forth for the design of conservation schemes and finding a compromise between the need to achieve the best possible erosion control on the one hand (i.e. the external perspective) and the need to cultivate an area as big as possible on the other hand (i.e. the internal perspective), this first complaint can be addressed. By changing the conservation technology from introduced to adapted, the amount of occupied cropland can be reduced, but not avoided. However, even a 10% loss of arable land, especially when considering the fact that yields still decrease even though the land is conserved, can already be too much for a poor household. Options to use the terrace in a productive manner have to be sought. In the CBA, this has been modelled by assuming that grass can be harvested from the conservation structures. The assumed yield of 2,000 kg/ha is far below what could be achieved with special grass species that are propagated to supplement mechanical conservation structures.[574] Yields from such species are reported to range between 6 and 15 t/ha p.a. One has to consider, however, that such yields are only achievable if the grass is cut at the optimal time, but not grazed. In the Ethiopian context this is hardly feasible. During the growing period of major crops, animals are grazed on specifically designated grazing land or even tethered. After the harvest, however, the land can be freely grazed. If conservation structures were planted with grass or any other palatable plant, the damage done by freely roaming animals would be simply too high. Thus, efforts aiming at making conservation structures more profitable through planting crops which can either be used directly on the farm, such as fodder grass, or have a commercial value, such as hop, stand in direct competition with other aspects of the farming system, such as free grazing. Therefore, the advantages of the two – higher production of the field by using conservation structures in a productive manner versus free grazing after the harvest consuming less labour and bringing manure to the land – have to be weighed against each other. It will be very difficult to find solutions where both together are possible without major changes of the farming system. Increasing production on conservation structures is also constrained by climatic limitations. In Andit Tid, both the variety of possible

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[573] Ludi, 1997, 69ff; Herweg & Ludi, 1999, 109.

[574] e.g. Bermuda grass (*Cynodon dactylon*), Nile grass (*Acroceras Macrum*), Elephant or Napier grass (*Pennisetum purpureum*), or Vetiver grass (*Vetiveria zizanioides*). [www.fao.org]

crops to be grown and the maximum possible production are limited by the high altitude. In Maybar, rainfall shortage or unfavourable rainfall distribution can hamper the growth of vegetation. Planting grass or shrubs on the conservation structures might have other negative effects such as competition between these crops and field crops over water, nutrients or even light. And finally, already now with only sparsely cultivated structures there is the problem of rodent habitats in and weed infestation from the structures.

The second complaint, increased ***rodent populations and weed infestation***, is more difficult to deal with. Either labour input must be increased for weeding and destroying of burrows, or herbicides and poison have to be used. Farmers mainly refuse the first option because they consider additional labour inputs no longer feasible. The second option would be the one preferred by farmers, but firstly it is costly and secondly negative health and environmental effects have to be taken into account. It must also be mentioned that in the analysis of yields according to sampling location (A/B/C, cf. Figure 32) the negative effects on yields of weed infestation and damage by rodents in the vicinity of conservation structures is already included in the CBA. Despite these yield-diminishing effects, the yield on location A is still significantly higher than on location B, which is certainly less affected by weeds and rodents spreading from the conservation structures. It might thus be worth finding out in more detail how big the damage by weed infestation and rodents to crops really is to develop suitable cost-efficient and environmental friendly solutions.

That ***stagnant water*** can be a serious problem in high rainfall areas could be demonstrated specifically for Anjeni. Here, crop yields often react negatively to decreasing slope gradients and increasing soil depth. Problematic is the fact that by addressing one problem – soil erosion – one creates another problem – stagnant water. In the CBA the negative effect of stagnant water is already reflected through the relations soil depth – slope gradient – yield per sampling location and crop type (cf. Table 24). Yields of those crops that suffer most from stagnant water increase slightly as soil depth decreases. Properly draining excess water must therefore be an integral part of the conservation technology, and might be even more relevant in determining yields than controlling soil depth reductions as demonstrated by the inverse relation soil depth – yield for some crops in Anjeni.

By constructing graded structures in Andit Tid and Anjeni, enhancing drainage of excess water towards the next waterway, the problem of stagnant water has been addressed. However, for graded structures to be efficient, ***maintenance efforts*** are considerable. After every major storm, drainage channels above or below the embankments have to be emptied of accumulated sediment; and this is exactly what is neglected by many farmers once terraces are consolidated. Again, the main reason given by farmers consulted is that labour is in short supply during the rainy season and that additional labour for maintaining conservation structures competes with other farm activities such as ploughing or weeding. Maintenance of conservation structures is especially in the first years of paramount importance. If conservation structures are not properly maintained, e.g. drainage channels are not emptied of accumulated sediments or small damages to the structures are not repaired, the danger of overflow and damage to adjacent cropland is considerable. It can be expected that once conservation structures have consolidated, maintenance efforts can be reduced. In the CBA, maintenance has been assumed to be 10% of initial investment costs. This is a rather high labour demand. However, it is also assumed that conservation structures are used to cultivate fodder grass. No additional labour input for the collection of this grass has been considered, but it was assumed that whenever grass is harvested from the conservation structures also minor maintenance activities would be carried out.

The last complaint – more ***difficult and time consuming farm operations*** – has been included in the CBA by not decreasing the amount of labour necessary for farming, despite the smaller arable area in the case where soil conservation is practised. It was assumed that because of the mentioned problems, such as more difficult ploughing and increased necessity of weeding, labour inputs remain the same. In the case of no soil conservation, one could assume that labour inputs diminish, especially labour for harvesting and threshing, as yields decrease. In the CBA no adjustment was made neither in this case as it was assumed that because yields decrease farmers try to increase labour inputs for tasks such as ploughing and weeding to maintain yield levels as long as possible. The complaint of more difficult and time consuming farm operations in the case of soil conservation was mainly articulated in those areas which have no or only limited traditional experience with mechanical SWC. This is especially the case in Anjeni and partly in Andit Tid. In the Anjeni area, mechanical

SWC has no tradition, but drainage ditches were and still are widely applied. Farmers complained that turning the ox-drawn plough is difficult because of the narrow spacing between two conservation structures or that oxen are afraid of the structures. Experiences from other areas, for example Mesobit & Gedeba, however, show that if mechanical SWC is a traditional technology, neither the narrow spacing nor the height of the structures is a problem. It seems that these complaints are rather raised because the technology is new and farmers are not yet used to it, but not because it is an inherent problem of the technology. It can be expected that with better adaptation of the technology to local circumstances and habituation of farmers over time, this problem will be solved automatically.

***The amount of land occupied by conservation structures – its effect on total production and self-sufficiency of households***

Farmers most often complained that mechanical SWC consumes far too much arable land and that thus the food supply is no longer secured. In the following Table 57, land size per household ($m^2$), annual food requirement per household (in kcal, according to consumption units),[575] and annual crop production (in kcal)[576] under different conservation technologies is presented. ***Annual crop production*** was calculated on the basis of crop types cultivated the season before the interviews were conducted and the season in which the interviews did take place. If part of the cropland land is rented in, the yield of that field is reduced according to the sharecropping arrangement. If a household leases land to another farmer and receives grain instead, the amount estimated by the household head is included in the calculation of production. Column 2 assumes the situation without any soil conservation and considers for the calculation of crop production the total land area. Column 3 shows the case with introduced SWC. Land occupied by conservation structures is according to slope gradient of the field, and varies between 2% and 30% (cf. Table 34). Column 4 considers the production in the case of adapted SWC. Land occupied by conservation structures ranges between 2% and 10% (cf. Table 34). In the two cases with SWC it is further assumed that all conservation activities are carried out at once and that the remaining arable area is reduced accordingly. Crop yields for the calculation of the total calorie production are according to soil depth. Average values are considered (cf. Appendix 5.4). In the case without SWC, only the yield from sampling location B is considered. For the case with either introduced or adapted SWC, yields from sampling location A, B, and C are considered according to the percentage of the respective areas between two conservation structures (cf. Table 34). In all three situations, total crop production calculated on the basis of SCRP yield data is reduced by 15% because part of the yield has to be put aside for seeds for the next season and post-harvest and storage losses can be considerable.

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575 Daily energy requirement in subsistence farming communities, based on WHO recommendations: ***Male***: age group (in years): 1-5: 1,350 kcal, 6-9: 1,875 kcal, 10-12: 2,200 kcal, 13-15: 2,500 kcal, 16-19: 2,725 kcal, 20-60: 3,000 kcal, >60: 2,350 kcal. Male household members between 20 and 60 who are not household heads: 2,800 kcal. ***Female***: age group (in years): 1-5: 1,350 kcal, 6-9: 1,875 kcal, 10-12: 1,950 kcal, 13-15: 2,125 kcal, 16-19: 2,150 kcal, 20-60: 2,200 kcal, >60: 2,000 kcal. Female household members who are not household head or spouses of household heads between 20 and 60: 2,100 kcal. (Wudnesh Hailu, 1991, 72)

576 Calories per 1 kg: barley: 2,270 kcal, wheat: 2,620 kcal, tef: 2,650 kcal, maize: 3,270 kcal, *sengada*: 3,090 kcal, bean, pea, lentil: 3,400 kcal, noug, linseed: 4,400 kcal. (Huisman, 1990, 8; Ludi, 1994, 108)

| | | | No land loss | | Introduced SWC | | Adapted SWC | |
|---|---|---|---|---|---|---|---|---|
| Household * | Land size ($m^2$) ** | Annual require-ment per household (1,000 kcal) | Annual production (1,000 kcal) | Balance (1,000 kcal) | Annual production (1,000 kcal) | Balance (1,000 kcal) | Annual production (1,000 kcal) | Balance (1,000 kcal) |
| | | (1) | (2) | (2)-(1) | (3) | (3)-(1) | (4) | (4)-(1) |
| **Maybar** | | | | | | | | |
| 1 (p) | 8,870 | 4,310 | 4,020 | -290 | 3,310 | -990 | 3,790 | -520 |
| 2 (p) | 5,350 | 2,460 | 3,250 | 790 | 2,370 | -90 | 2,980 | 520 |
| 3 (p) | 4,420 | 6,210 | 2,240 | -3,970 | 1,780 | -4,440 | 2,090 | -4,130 |
| 4 (p) | 8,690 | 5,250 | 3,970 | -1,280 | 3,290 | -1,960 | 3,750 | -1,500 |
| 5 (p) | 8,290 | 2,660 | 4,320 | 1,650 | 3,410 | 740 | 4,020 | 1,350 |
| 6 (p) | 10,800 | 6,540 | 6,450 | -90 | 4,910 | -1,640 | 5,950 | -590 |
| 7 (p) | 8,280 | 2,570 | 5,250 | 2,670 | 3,760 | 1,190 | 4,720 | 2,150 |
| 16 (p) | 15,700 | 7,410 | 7,760 | 350 | 5,500 | -1,910 | 6,990 | -420 |
| ***Mean*** | ***8,800*** | ***4,680*** | ***4,660*** | ***-20*** | ***3,540*** | ***-1,140*** | ***4,280*** | ***-390*** |
| ***SD*** | ***3,230*** | ***1,840*** | ***1,660*** | ***1,870*** | ***1,140*** | ***1,680*** | ***1,480*** | ***1,790*** |
| | | | | | | | | |
| 8 (r) | 11,590 | 4,190 | 7,820 | 3,630 | 6,620 | 2,430 | 7,430 | 3,240 |
| 9 (r) | 11,820 | 4,380 | 9,110 | 4,730 | 6,890 | 2,510 | 8,450 | 4,070 |
| 10 (r) | 11,230 | 3,290 | 8,390 | 5,100 | 6,640 | 3,350 | 7,840 | 4,550 |
| 11 (r) | 10,810 | 6,290 | 7,870 | 1,580 | 6,780 | 490 | 7,490 | 1,200 |
| 12 (r) | 16,290 | 4,400 | 11,700 | 7,310 | 9,610 | 5,210 | 11,010 | 6,610 |
| 13 (r) | 10,590 | 7,520 | 14,530 | 7,010 | 11,600 | 4,080 | 13,580 | 6,060 |
| 14 (r) | 13,480 | 2,700 | 9,890 | 7,190 | 7,570 | 4,870 | 9,140 | 6,440 |
| 15 (r) | 8,950 | 5,650 | 4,580 | -1,070 | 3,980 | -1,670 | 4,380 | -1,260 |
| ***Mean*** | ***11,850*** | ***4,800*** | ***9,230*** | ***4,430*** | ***7,460*** | ***2,660*** | ***8,660*** | ***3,860*** |
| ***SD*** | ***2,060*** | ***1,490*** | ***2,760*** | ***2,790*** | ***2,120*** | ***2,160*** | ***2,550*** | ***2,580*** |
| **Andit Tid** | | | | | | | | |
| 1 (p) | 25,600 | 5,060 | 4,990 | -60 | 3,260 | -1,440 | 4,520 | -530 |
| 4 (p) | 10,300 | 2,390 | 1,150 | -1,240 | 890 | -1,500 | 1,060 | -1,330 |
| 10 (p) | 22,870 | 5,060 | 4,170 | -900 | 3,520 | -1,540 | 3,950 | -1,110 |
| 11 (p) | 8,060 | 1,900 | 680 | -1,220 | 510 | -1,380 | 620 | -1,280 |
| 12 (p) | 13,880 | 2,880 | 2,470 | -420 | 1,950 | -930 | 2,320 | -570 |
| 13 (p) | 10,320 | 2,570 | 2,390 | -190 | 1,870 | -710 | 2,210 | -370 |
| 14 (p) | 9,810 | 2,620 | 1,960 | -660 | 1,690 | -930 | 1,870 | -750 |
| ***Mean*** | ***14,410*** | ***3,210*** | ***2,540*** | ***-670*** | ***2,010*** | ***-1,200*** | ***2,360*** | ***-850*** |
| ***SD*** | ***6,460*** | ***1,200*** | ***1,440*** | ***440*** | ***1,100*** | ***310*** | ***1,320*** | ***360*** |
| | | | | | | | | |
| 8 (a) | 44,080 | 4,380 | 6,610 | 2,230 | 4,680 | 300 | 5,980 | 1,600 |
| 15 (a) | 13,790 | 1,300 | 760 | -530 | 550 | -740 | 690 | -610 |
| | | | | | | | | |
| 2 (r) | 19,400 | 5,580 | 4,410 | -1,170 | 3,050 | -2,530 | 4,120 | -1,460 |
| 3 (r) | 13,460 | 3,530 | 2,280 | -1,250 | 1,840 | -1,700 | 2,130 | -1,400 |
| 5 (r) | 32,130 | 7,980 | 7,180 | -800 | 5,680 | -2,300 | 6,740 | -1,240 |
| 6 (r) | 11,950 | 3,910 | 4,970 | 1,050 | 4,320 | 410 | 4,750 | 830 |
| 7 (r) | 38,700 | 7,860 | 6,950 | -910 | 5,400 | -2,450 | 6,510 | -1,350 |
| 9 (r) | 15,390 | 6,410 | 3,220 | -3,200 | 2,770 | -3,650 | 3,070 | -3,350 |
| ***Mean*** | ***21,840*** | ***5,880*** | ***4,830*** | ***-1,050*** | ***3,840*** | ***-2,040*** | ***4,550*** | ***-1,330*** |
| ***SD*** | ***10,050*** | ***1,740*** | ***1,790*** | ***1,240*** | ***1,400*** | ***1,240*** | ***1,680*** | ***1,200*** |

[Table continues on the next page]

| | | | No land loss | | Introduced SWC | | Adapted SWC | |
|---|---|---|---|---|---|---|---|---|
| Household * | Land size ($m^2$) ** | Annual requirement per household (1,000 kcal) | Annual production (1,000 kcal) | Balance (1,000 kcal) | Annual production (1,000 kcal) | Balance (1,000 kcal) | Annual production (1,000 kcal) | Balance (1,000 kcal) |
| | | (1) | (2) | (2)-(1) | (3) | (3)-(1) | (4) | (4)-(1) |
| **Anjeni** | | | | | | | | |
| 1 (p) | 21,110 | 2,570 | 2,870 | 300 | 2,310 | -260 | 2,560 | -10 |
| 4 (p) | 25,790 | 5,350 | 5,210 | -140 | 3,220 | -2,120 | 3,650 | -1,700 |
| | | | | | | | | |
| 5 (a) | 40,970 | 5,180 | 8,120 | 2,940 | 5,120 | -60 | 6,300 | 1,110 |
| | | | | | | | | |
| 2 (r) | 36,340 | 5,070 | 5,640 | 560 | 3,280 | -1,790 | 4,180 | -890 |
| 3 (r) | 63,820 | 6,470 | 7,480 | 1,010 | 4,650 | -1,820 | 5,650 | -820 |

*Table 57: Annual calorie requirements (in 1,000), and annual calorie production (in 1,000) with different conservation technologies per household and resulting balance in the three research areas of Maybar, Andit Tid, and Anjeni.*
** Wealth group of household: p = poor, a = average, r = rich*
*** in Maybar and Andit Tid only own land is considered, in Anjeni also rented land*
*[Source: Own investigation 1992, 1998, 1999]*

**Static consideration**

From the above Table 57 it becomes evident that under a static comparison ***introduced SWC*** with the associated loss of arable land[577] would lead for most households to a ***food deficit***. The situation is especially bad in ***Andit Tid***, where even in the case with no land size reduction only 2 of the 15 interviewed households could produce more than what they need. Rich households do not seem better off than poor households. In ***Maybar***, a clear distinction between rich and poor households can be observed. With introduced SWC and the associated loss of arable land in the range of 20%, 6 out of the 8 poor households would face a food deficit. Only one of the 8 rich households would be negatively affected. It must be noted, however, that this household no. 15 is not even self-sufficient if considering the total land area. This household is a special case. The concept of wealth in rural Ethiopia is not only based on material goods a household possesses, but also on the household head's political influence and functions in traditional organisations. Based on the amount of land and the number of animals, household no. 15 should belong to the group of poor households. However, it is an old and influential family in Maybar. In addition, the household head is an important member in the *Kire*, the traditional local court. This historical status and influence and the household head's functions in local organisations are valued higher than the material wealth, therefore the household was considered rich. In ***Anjeni***, none of the five households was self-sufficient in the case of a land loss of around 20% resulting from introduced SWC, even the two rich households. One reason is that household no. 2 has a rather unfavourable consumer-producer ratio (high calorie requirement). That household no. 3 cannot meet its food requirements despite a total land area of more than 6 ha can be mainly explained by the fact that almost half of the land (2.8 ha) is rented in. From this land, half of the yield has to be given to the owner.

In the case of ***adapted SWC*** the above-described situation is hardly ever changed. Only one household each from Maybar and Anjeni would be better off in the case with adapted SWC instead of introduced SWC, although the amount of arable land occupied by conservation structures is only one third of that of introduced SWC, and in the average ranges between 6% and 8%.

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[577] Mean loss of arable land (all fields considered, land occupied by conservation structures based on soil depth and slope gradient, cf. Table 34) is 21% in Maybar, 20% in Andit Tid, and 23% in Anjeni. In the case of adapted SWC the land loss would amount to 7%, 6%, and 8%, respectively.

An interesting aspect can be observed in Maybar and Andit Tid in relation to the ***land distribution*** carried out recently. In ***Maybar***, no land distribution was carried out in 1997. The main reason given by officials at Wereda level was that the land holding size in Maybar and other KA's in the vicinity is already so small that a further division of available arable land would not help to reduce poverty. If considering the mean calorie balance of the poor and the rich households, a significant difference becomes evident. Poor households face in the case of introduced SWC a deficit of around 1,140,000 kcal annually. Rich households, on the other hand, produce a mean annual surplus in the order of around 2,660,000 kcal. If land were distributed among the 16 considered households more equally, based on the number of consumers per household, self-sufficiency for all households could be achieved with a positive balance of 760,000 kcal. However, it has to be mentioned that according to the KA president of Maybar almost a quarter of the population has no land. If we consider the 16 households to be a more or less representative sample of the population with own land in Maybar, together they comprise 68 consumption units (C),[578] or 4.25 C per household. If landless households showed a similar family composition with respect to age and gender, an additional 17 consumption units would have to be supported from the available land if all landless households received land on their own. In total, 21 ha (including rented land) are cultivated by the 16 households. Total production amounts to slightly more than 111,100,000 kcal annually if total land area is considered, thus no deduction for conservation structures is made, but if seeds and post-harvest and storage losses are deducted. If distributed to 85 consumption units (68 plus 17), per C slightly more than 1,300,000 kcal annually resulted, which is still more than the required 1,100,000 kcal per consumption unit and year. If we assumed a situation with introduced SWC, a total production of a bit more than 88,000,000 kcal annually could be realised from the 21 ha arable land. Per consumer (including the currently landless) annually 1,040,000 kcal would be available, which is slightly below the required minimum amount. Thus, in an average year production in Maybar would be slightly below sufficiency levels to support the total population, those with currently own land as well as the landless. Contrary to Maybar, land has been distributed among all households in ***Andit Tid*** in 1997. Young farmers have received at least 2 *timmad* of land, approximately 0.5 ha. Household no. 4 and no. 11 are such young households who have received own land in the 1997 land distribution besides a plot that they receive each from their father. It can be expected that the percentage of young farmers is similar to Maybar, thus the available arable land was distributed in 1997 among many more households. As no land reserves are available in Andit Tid, young households could only receive land from rich households, which were dispossessed of part of their holding. Today, 57 consumption units have to share a total production of about 54,180,000 kcal in the case where no SWC is undertaken and no land loss considered, or about 42,340,000 kcal with introduced SWC, thus an arable area reduced by about 20%. Annual production per consumption unit in the case of no SWC, thus no land loss, would be with 945,000 kcal already below the required minimum. In the case of introduced SWC annual production per consumption unit would only amount to about 740,000 kcal, which is considerably bellow the required 1,100,000 kcal. If one assumed that before the land distribution of 1997 about one quarter of the population of Andit Tid was without own land, and the sample households are more or less representative with respect to age and gender, the land the 15 interviewed households cultivate today (31 ha) was distributed among only 46 consumption units before 1997. Annual production without SWC would be at 1,180,000 kcal, i.e. slightly above annual requirements. Considering the land occupied by conservation structures in the case of introduced SWC, total annual production would be around 42,340,000 kcal. Annual requirements of the 46 consumption units would sum up to 50,400,000 kcal, which is still above possible production. Thus, even before the land distribution those households with land could not produce enough to satisfy the calorie requirements in the case with 20% land taken out of production because of SWC structures. In the case of adapted SWC where the amount of land occupied would be in the range of 6%, annual production would be about 50,500,000 kcal, just enough to support the population (cf. Appendix 6.5).

It has been mentioned by many farmers of ***Maybar*** that they oppose a land distribution with the argument that it does not help to improve livelihoods, but that it would simply distribute poverty among all and that all would be worse off. The above calculations for Maybar do not fully support this perception. In an

[578] cf. footnote 575 for the definition of consumption units.

average year total production would be only marginally below what would be necessary to support all households, those who currently have own land as well as the landless. It Andit Tid, land per household and land productivity is already so low that almost all households suffer a food deficit. Without the land distribution and without considering the landless, which have to be supported by someone, usually the parents, however, annual production would just be sufficient in the case without SWC or with adapted SWC, but not with introduced SWC. In ***Andit Tid***, most farmers complained about the land distribution. Old and rich farmers who lost land mentioned that before 1997 their land holding was enough to sustain the family. They also mentioned that their sons remained at home and helped in farm work. Labour could thus be invested more efficiently. With the land distribution, they had to give away land and at the same time lost their adult sons, who founded an own homestead. However, it was mentioned by both, the old as well as the young farmers, that the approximately 0.5 ha a young family received is far below what would be necessary. It was also mentioned that before the land distribution when adult sons remained on the parent's farm, the same amount of land was available as today for the father's and the son's family. Today, however, because this land holding is split into two farms, fragmentation increased and, although fathers and sons often work together, labour can no longer be allocated efficiently. Lastly, it has to be expected that traditional knowledge about the land and best management practices is no longer passed from the father to the son. Nowadays, sons receive land somewhere where they cannot rely on a pool of knowledge.

**Dynamic consideration**

The above observations relating food self-sufficiency to SWC are based only on a static analysis. If the ***annual yield decline*** resulting from uncontrolled soil loss, on the one hand, and the ***population increase***, on the other hand, were taken into account, the following conclusions could be drawn (cf. Appendix 6.6):

In ***Maybar***, annual yield declines resulting from decreasing soil depth are small with -0.07% in the case without SWC, and -0.04% in the case with introduced SWC. Mean annual production per ha, seeds, post-harvest and storage losses in the order of 15% already deducted, is around 5,300,000 kcal without SWC, and 4,200,000 with SWC based on average yields. This difference of 20% can be mainly explained by the amount of land occupied by SWC structures in the later case. Considering the annual decline in the two cases, even after 100 years unconserved land would still produce considerably more than conserved land – provided that no changes in either erosion rates or land productivity would occur. If the population currently living off the land remained constant, i.e. no further land distribution would take place to accommodate those without land, and no land would have to be taken out of production because of degradation, food self-sufficiency would still be guaranteed. If, however, the land were distributed in regular intervals according to the population growth rate, which is currently around 2.5% annually, food self-sufficiency could no longer be achieved after 10 years in the case with SWC or after 21 years in the case without SWC.

In ***Andit Tid***, the dynamic perspective reveals that because annual yield declines in the case of uncontrolled erosion are considerably higher than in the case of introduced SWC (-0.91% versus -0.37%), mean annual production (in kcal) per ha would be higher with than without SWC after 45 years. However, total annual production with SWC, thus with about 20% less arable land, is already today below the annual requirement of 57 consumption units (annual production per C: 740,000 kcal, annual requirement per C: 1,100,000 kcal). Even without SWC, if one assumed that the total land area could be used for crop cultivation, annual production is with 950,000 slightly below annual requirements.

In ***Anjeni***, annual yield declines without SWC are postulated to be in the order of -0.23%. With introduced SWC yield declines can be reduced to -0.07% annually. After 100 years of constant erosion, production per hectare would still be higher without than with SWC. The yield difference per hectare between the case with SWC and the case without SWC is higher in Anjeni than in the other two research areas because yields on conserved land are not only reduced due to land occupied by conservation structures, but also because some crops react negatively to increasing soil depth. Food self-sufficiency is not achieved in the case of introduced SWC with an annual production per consumption unit of 670,000 kcal. In the case without SWC annual production would be 1,060,000 kcal and thus only negligibly below the required 1,100,000 kcal per annum. In both cases, where soil erosion alone or soil erosion combined with population increase is considered, the annual production – provided that no major changes in either the degradation process or the land management system occur – is not sufficient to secure the livelihood of the concerned population.

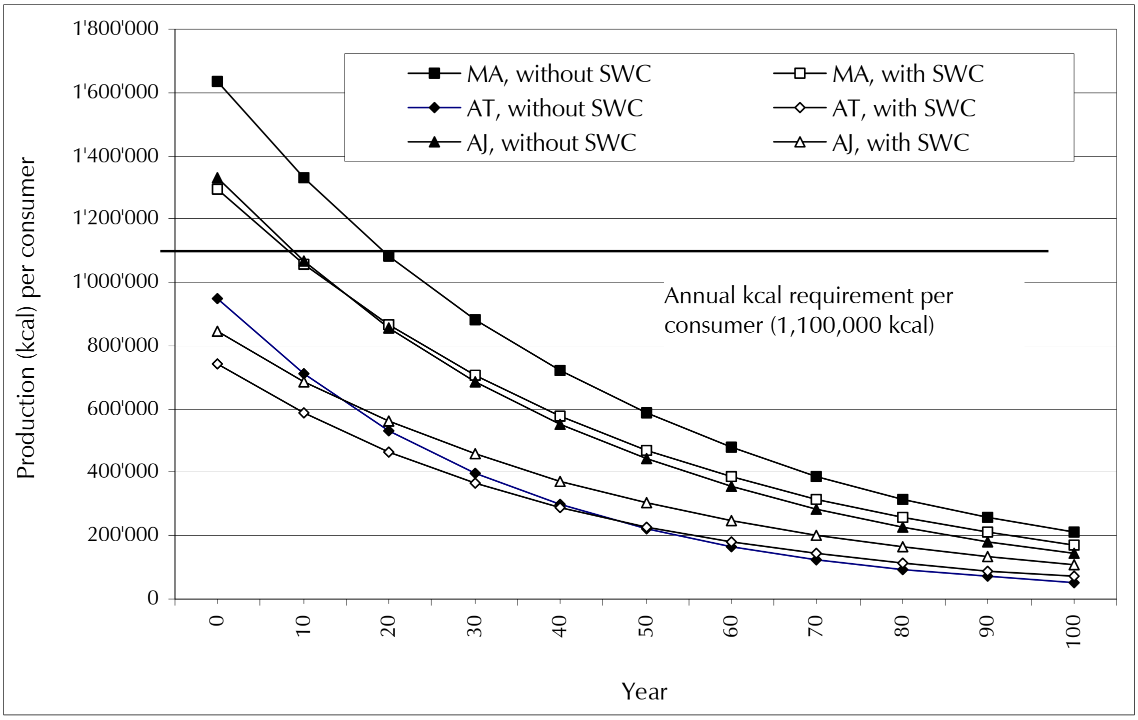


*Figure 50: Annual production (in kcal) per consumer in Maybar, Andit Tid and Anjeni on the assumption of annual population growth rates of 2% and continuing soil degradation with and without SWC. [Source: Own compilation]*

For the above calculations, it is furthermore assumed that soils are sufficiently deep, i.e. do not decrease to a threshold depth of 10 cm within the observation period, after which they have to be given up for crop production. As results from the calculation of soil life show (cf. Table 47), however, even deep soils are often reduced to below 10 cm under current erosion rates within an observation period of 100 years. Self-sufficiency would thus be reached even earlier because the soils are too shallow to produce crops. The above calculations are based on average yields. Minimum and maximum production is distinctively different from average production and ranges between 45 - 155% in Maybar, 35 - 166% in Andit Tid, and 53 - 149% in Anjeni (cf. Appendix 5.2). From Figure 34 to 37 it becomes evident how much yields fluctuate from year to year. Annual yield decreases resulting from soil depth reductions range between 0.07% and 0.9%. It must be expected that farmers are unable to recognise these small annual yield decreases, but very well recognise the considerable reduction in arable area if SWC structures are constructed as well as the high yield fluctuations. In this respect the external and the internal perspective become apparent and are distinctively different. From the ***farmers' point of view***, the production decrease in the range of 20% with SWC becomes immediately evident. As Table 57 shows, for many households such a loss of production is live-threatening, as food self-sufficiency can no longer be achieved in an average year and even less so in a year with poor rainfall or the occurrence of pests and diseases, all of which decrease yields to only 35 - 53% of the average. It is thus understandable that farmers opt for no SWC investments as this allows – at least in the short run – a production that is sufficient or at least almost sufficient to sustain a family. Negative trends such as decreasing soil productivity or increasing demand for land because of population growth are not taken into account, i.e. they are recognised, but reactions are postponed. The ***external perspective***, on the other hand, acknowledges that because of SWC investments the portion of arable land decreases and thus reduces annual production considerably at the beginning. From the external perspective it is also recognised that for many households the land reduction due to SWC that leads to smaller production is beyond their capacities. However, it is stressed that the long-term trend of uncontrolled soil erosion or increasing demand resulting from population growth is leading to a situation where food self-sufficiency as well can no longer be achieved, and will nullify the short term benefits within a few years. External actors would thus opt for immediate investments to slow down the negative trends and to gain time to search for alternative land use practices, alternative employment opportunities or alternative reproduction patterns. From an external point of view it is possible to adopt a long-term perspective, whereas from the internal perspective often sheer survival counts. Too many conditions that are out of the control of land users have an influence on the size of the arable land of an individual household. Soil conservation is just one among many. Farmers try to avoid any additional claims that might decrease the farm size, and thereby the production. In the case of SWC they feel that they can avoid the land loss – by simply not constructing bunds, whereas in other cases – such as the growing demand for arable land by a growing population, they feel that their room for manoeuvre is limited, since they continue to consider it a basic human right that all descendants of a family should receive some land. Farmers often mentioned that they recognises the threat originating from uncontrolled soil erosion and that they would know how to react to slow down this negative trend, but that their means are not sufficient to react properly. Short-term survival must first be secured to allow investments with long-term positive consequences but short-term high costs.

### *The labour demand for SWC – competition with other household goals*

Besides the amount of arable land lost, another concern raised by farmers is that SWC needs additional labour for the ***construction*** as well as for ***maintenance***. The following Table 58 presents the maximum labour demand for SWC, both for introduced and for adapted SWC. It must be noted that in most cases the initial construction work has already been carried out, at least on some fields during the SWC campaigns in the early and mid 80s. Therefore, the indicated days concern farms of similar size and with fields of similar characteristics in terms of slope gradient and soil depth, but without conservation at present.

| Household * | Land size ** | Initial investment (working days) introduced SWC | Initial investment (working days) adapted SWC | $m^2$ land per working day (introduced SWC) |
|---|---|---|---|---|
| | $m^2$ | days | days | $m^2$ |
| | (1) | (2) | (3) | (1)/(2) |
| **Maybar** | | | | |
| 1 (p) | 8,870 | 300 | 102 | 30 |
| 2 (p) | 5,350 | 300 | 102 | 18 |
| 3 (p) | 4,420 | 210 | 72 | 21 |
| 4 (p) | 8,690 | 300 | 102 | 29 |
| 5 (p) | 8,290 | 370 | 120 | 22 |
| 6 (p) | 10,800 | 510 | 168 | 21 |
| 7 (p) | 8,280 | 360 | 120 | 23 |
| 16 (p) | 15,700 | 760 | 525 | 21 |
| ***Mean*** | ***8,800*** | ***389*** | ***164*** | ***23*** |
| 8 (r) | 11,590 | 510 | 168 | 23 |
| 9 (r) | 11,820 | 600 | 198 | 20 |
| 10 (r) | 11,230 | 520 | 174 | 22 |
| 11 (r) | 10,810 | 270 | 90 | 40 |
| 12 (r) | 16,290 | 780 | 258 | 21 |
| 13 (r) | 10,590 | 550 | 186 | 19 |
| 14 (r) | 13,480 | 610 | 204 | 22 |
| 15 (r) | 8,950 | 310 | 102 | 29 |
| ***Mean*** | ***11,850*** | ***519*** | ***173*** | ***25*** |

[Table continues on the next page]

| **Household *** | **Land size **** | **Initial investment (working days) introduced SWC** | **Initial investment (working days) adapted SWC** | **m² land per working day (introduced SWC)** |
|---|---|---|---|---|
| | m² | days | days | m² |
| | (1) | (2) | (3) | (1)/(2) |
| **Andit Tid** | | | | |
| 1 (p) | 25,600 | 510 | 126 | 50 |
| 4 (p) | 10,300 | 240 | 60 | 43 |
| 10 (p) | 22,870 | 420 | 108 | 54 |
| 11 (p) | 8,060 | 186 | 48 | 43 |
| 12 (p) | 13,880 | 318 | 78 | 44 |
| 13 (p) | 10,320 | 204 | 54 | 51 |
| 14 (p) | 9,810 | 102 | 24 | 96 |
| ***Mean*** | ***14,410*** | ***283*** | ***71*** | ***54*** |
| 8 (a) | 44,080 | 1,128 | 282 | 39 |
| 15 (a) | 13,790 | 342 | 84 | 40 |
| | | | | |
| 2 (r) | 19,400 | 432 | 108 | 45 |
| 3 (r) | 13,460 | 282 | 72 | 48 |
| 5 (r) | 32,130 | 678 | 168 | 47 |
| 6 (r) | 11,950 | 156 | 42 | 77 |
| 7 (r) | 38,700 | 900 | 228 | 43 |
| 9 (r) | 15,390 | 264 | 66 | 58 |
| ***Mean*** | ***21,840*** | ***452*** | ***114*** | ***53*** |
| **Anjeni** | | | | |
| 1 (p) | 21,110 | 450 | 114 | 47 |
| 4 (p) | 25,790 | 414 | 102 | 62 |
| ***Mean*** | ***23,450*** | ***432*** | ***108*** | ***55*** |
| 5 (a) | 40,970 | 708 | 174 | 58 |
| | | | | |
| 2 (r) | 36,340 | 816 | 204 | 45 |
| 3 (r) | 63,820 | 1,356 | 336 | 47 |
| ***Mean*** | ***50,080*** | ***1,056*** | ***270*** | ***46*** |

*Table 58: Labour investment per household for SWC: Initial construction days for introduced and adapted SWC.*
** Wealth group of households: p = poor, a = average, r = rich*
*** in Maybar and Andit Tid only own land is considered, in Anjeni also leased land is included into calculations*
*[Source: Own investigation 1992, 1998, 1999]*

From Table 58 above it becomes apparent that the labour demand for the initial construction of SWC structures is considerable, especially for introduced SWC. Although the construction of terraces can be spread over several years, not only the construction costs that are a burden, but also the maintenance costs, which are assumed to be 10% of initial construction costs and arise every year. In the fifth column, the relation between ***total land size and labour days invested for SWC*** is calculated. The higher the figure, the better the land is in terms of slope inclination (flat slopes) and soil depth (deep soils), i.e. the less conservation structures are necessary. The big difference between Maybar on the one hand and Andit Tid and Anjeni on the other hand can manly be explained by the different labour demand for the construction of SWC structures assumed. In Maybar, only 5 m of stone bund can be constructed per working day, whereas in Anjeni and Andit Tid per working day 10 m of soil bund can be accomplished. Nevertheless, the total labour demand in Maybar is higher than in either Andit Tid or Anjeni. This can be mainly explained by topographic differences of the three areas and generally shallow soils in Maybar, resulting in more conservation structures. Interestingly, there is no clear difference in labour demand for SWC investments between poor and rich households. In other words, there is no clear differentiation between rich and poor households with respect to the quality of the land they cultivate. There is no tendency that poor households generally cultivate marginal land, which is either steep or has shallow soils, and rich households who could secure better land for themselves, thanks to their wealth and influence in political and administrative committees.[579]

Table 59 below presents some basic figures per household in relation to producers (P)[580] and consumers (C),[581] cultivated land per household, labour days invested for fieldwork, labour productivity, and number of fieldwork days invested per adult household member and per producer. Although male and female labour cannot be exchanged, e.g. women are not allowed to plough, men are less involved in weeding, and transporting harvested grain from the field to the house for threshing is solely the task of women, men and women between the age of 15 and 64 are taken together. This can be justified on the ground of total amount of labour days invested annually by men and women, which is similar, although for different tasks. Households headed by a woman (household 15 in Andit Tid) are forced to lease out their land. Their share of the harvest is between half (Maybar, Anjeni) and one third (Andit Tid).

| **House-hold *** | **No M&F** | **Pro-ducers** | **Con-sumers** | **Cultiva-ted land per house-hold** | **Person-days for field-work** | **Labour produc-tivity** | **Labour produc-tivity** | **Labour produc-tivity** | **Days field-work** | **Days field-work** |
|---|---|---|---|---|---|---|---|---|---|---|
| | 15-64 | (P) | (C) | $m^2$ | | $m^2$ / P | $m^2$ / M&F 15-64 | $m^2$ / person day | per P | per M&F 15-64 |
| | (1) | (2) | (3) | (4) | (5) | (4)/(2) | (4)/(1) | (4)/(5) | (5)/(2) | (5)/(1) |
| **Maybar** | | | | | | | | | | |
| 1 (p) | 2 | 3.5 | 3.8 | 8,870 | 150 | 2,534 | 4,434 | 59 | 43 | 75 |
| 2 (p) | 1 | 1.9 | 2.4 | 5,350 | 135 | 2,817 | 5,351 | 40 | 71 | 135 |
| 3 (p) | 3 | 4.7 | 5.4 | 4,420 | 130 | 939 | 1,472 | 34 | 28 | 43 |
| 4 (p) | 4 | 4.3 | 4.6 | 5,390 | 180 | 1,253 | 1,347 | 30 | 42 | 45 |
| 5 (p) | 3 | 3 | 2.4 | 5,500 | 120 | 1,834 | 1,834 | 46 | 40 | 40 |
| 6 (p) | 3 | 4.9 | 5.6 | 10,800 | 350 | 2,204 | 3,599 | 31 | 71 | 117 |
| 7 (p) | 2 | 2.9 | 2.5 | 8,280 | 160 | 2,855 | 4,139 | 52 | 55 | 80 |
| 16 (p) | 6 | 6.7 | 6.5 | 18,990 | 320 | 2,835 | 3,165 | 59 | 48 | 53 |
| ***Mean*** | ***3.0*** | ***4.0*** | ***4.2*** | ***8,450*** | ***193*** | ***2,159*** | ***3,168*** | ***44*** | ***50*** | ***74*** |
| 8 (r) | 3 | 3.5 | 3.7 | 14,880 | 220 | 4,253 | 4,961 | 68 | 63 | 73 |
| 9 (r) | 2 | 2.6 | 4 | 18,410 | 220 | 7,080 | 9,205 | 84 | 85 | 110 |
| 10 (r) | 2 | 2.6 | 3.1 | 17,820 | 210 | 6,853 | 8,909 | 85 | 81 | 105 |
| 11 (r) | 5 | 5.4 | 5.5 | 10,810 | 120 | 2,002 | 2,162 | 90 | 22 | 24 |
| 12 (r) | 3 | 3.7 | 4.1 | 29,470 | 345 | 7,964 | 9,823 | 85 | 93 | 115 |
| 13 (r) | 6 | 6.4 | 6.5 | 27,060 | 285 | 4,228 | 4,510 | 95 | 45 | 48 |
| 14 (r) | 2 | 2.4 | 2.6 | 14,410 | 150 | 6,004 | 7,204 | 96 | 63 | 75 |
| 15 (r) | 3 | 4.7 | 5 | 8,950 | 240 | 1,904 | 2,983 | 37 | 51 | 80 |
| ***Mean*** | ***3.3*** | ***3.9*** | ***4.3*** | ***17,730*** | ***224*** | ***5,036*** | ***6,219*** | ***80*** | ***63*** | ***79*** |

[Table continues on the next page]

579 This is in contrast to findings by Yohannes G/Michael who observed that poor households generally cultivate more marginal land than rich households and invest more in physical SWC. (Yohannes G/Michael, 1999, 151)

580 Producers P: age group (in years) 0-6: 0, 7-9: 0.3, 10-12: 0.5, 13-14: 0.9, 15-64: 1, 65-69: 0.4, 70-75: 0.2, >76 years: 0. No difference for male and female. The figures are adjusted for Ethiopian conditions. (Wudnesh Hailu, 1991, 69)

581 Consumers C: ***Male***: age group (in years) 1-5: 0.4, 6-9: 0.6, 10-12: 0.7, 13-15: 0.8, 16-60: 0.9, >60: 0.8, household head: 1. ***Female***: age group (in years): 1-5: 0.4, 6-12: 0.6, 13-60: 0.7, >60: 0.6. The figures are adjusted for Ethiopian conditions. (Wudnesh Hailu, 1991, 73)

| House-hold * | No M&F | Pro-ducers | Con-sumers | Cultiva-ted land per house-hold | Person-days for field-work | Labour produc-tivity | Labour produc-tivity | Labour produc-tivity | Days field-work | Days field-work |
|---|---|---|---|---|---|---|---|---|---|---|
| | 15-64 | (P) | (C) | $m^2$ | | $m^2$ / P | $m^2$ / M&F 15-64 | $m^2$ / person day | per P | per M&F 15-64 |
| | (1) | (2) | (3) | (4) | (5) | (4)/(2) | (4)/(1) | (4)/(5) | (5)/(2) | (5)/(1) |
| **Andit Tid** | | | | | | | | | | |
| 1 (p) | 2 | 3.1 | 4.4 | 22,770 | 275 | 7,345 | 11,385 | 83 | 89 | 138 |
| 4 (p) | 2 | 2 | 2.1 | 10,300 | 140 | 5,151 | 5,151 | 74 | 70 | 70 |
| 10 (p) | 4 | 4.8 | 4.5 | 22,870 | 240 | 4,765 | 5,719 | 95 | 50 | 60 |
| 11 (p) | 2 | 2 | 1.7 | 8,060 | 90 | 4,027 | 4,027 | 89 | 45 | 45 |
| 12 (p) | 2 | 2 | 2.5 | 16,710 | 220 | 8,357 | 8,357 | 76 | 110 | 110 |
| 13 (p) | 2 | 2.3 | 2.3 | 15,980 | 170 | 6,948 | 7,991 | 94 | 74 | 85 |
| 14 (p) | 2 | 2.9 | 2.6 | 9,810 | 160 | 3,383 | 4,905 | 61 | 55 | 80 |
| ***Mean*** | ***2.3*** | ***2.7*** | ***2.9*** | ***15,220*** | ***185*** | ***5,711*** | ***6,791*** | ***82*** | ***70*** | ***84*** |
| 8 (a) | 3 | 3.2 | 3.8 | 44,080 | 390 | 13,776 | 14,694 | 113 | 122 | 130 |
| 15 (a) | 1 | 1.0 | 1.5 | 13,790 | (220) | (13,792) | (13,792) | (63) | (220) | (220) |
| ***Mean*** | ***2.0*** | ***2.1*** | ***2.7*** | ***28,940*** | | | | | | |
| 2 (r) | 5 | 5.3 | 5 | 23,650 | 280 | 4,462 | 4,730 | 84 | 53 | 56 |
| 3 (r) | 2 | 3.1 | 3.4 | 13,460 | 220 | 4,341 | 6,729 | 61 | 71 | 110 |
| 5 (r) | 7 | 7.8 | 7.3 | 32,130 | 300 | 4,119 | 4,589 | 107 | 38 | 43 |
| 6 (r) | 2 | 3.2 | 3.7 | 26,120 | 260 | 8,162 | 13,059 | 100 | 81 | 130 |
| 7 (r) | 5 | 5.8 | 6.8 | 38,700 | 350 | 6,672 | 7,739 | 111 | 60 | 70 |
| 9 (r) | 6 | 6.5 | 5.7 | 15,390 | 280 | 2,368 | 2,565 | 55 | 43 | 47 |
| ***Mean*** | ***4.5*** | ***5.3*** | ***5.3*** | ***24,910*** | ***282*** | ***5,021*** | ***6,569*** | ***86*** | ***58*** | ***76*** |
| **Anjeni** | | | | | | | | | | |
| 1 (p) | 2 | 2.9 | 2.5 | 21,110 | 250 | 7,280 | 10,556 | 84 | 86 | 125 |
| 4 (p) | 3 | 3.8 | 4.7 | 25,790 | 320 | 6,788 | 8,598 | 81 | 84 | 107 |
| ***Mean*** | ***2.5*** | ***3.4*** | ***3.6*** | ***23,450*** | ***285*** | ***7,034*** | ***9,577*** | ***83*** | ***85*** | ***116*** |
| 5 (a) | 4 | 4.5 | 4.6 | 43,520 | 280 | 9,671 | 10,880 | 155 | 62 | 70 |
| | | | | | | | | | | |
| 2 (r) | 2 | 4.5 | 4.7 | 36,340 | 360 | 8,075 | 18,170 | 101 | 80 | 180 |
| 3 (r) | 5 | 5.8 | 5.7 | 63,820 | 480 | 11,004 | 12,765 | 133 | 83 | 96 |
| ***Mean*** | ***3.5*** | ***5.2*** | ***5.2*** | ***50,080*** | ***420*** | ***9,540*** | ***15,467*** | ***117*** | ***81*** | ***138*** |

*Table 59: Number of male and female adult household members (M&F 15-64), producers (P), consumers (C), amount of cultivated land per household ($m^2$), invested labour days (person-days) for fieldwork, and resulting labour productivity.*
** Wealth group of households: p = poor, a = average, r = rich*
*[Source: Own investigation 1992, 1998, 1999]*

***Labour productivity*** per producer (P) or per adult person (M&F 15-64) is quite different between poor and rich households in ***Maybar***. In the average, poor households cultivate 2,159 $m^2$ per P, whereas rich households cultivate 5,036 $m^2$, i.e. more than twice as much. The main reason for this difference is the amount of land the households of the two groups cultivate. Both, poor and rich households are composed in the average of about the same number of producers. The average of cultivated land, however, differs considerably with 8,450 $m^2$ for the poor and 17,730 $m^2$ for the rich households. Household no. 3 works the smallest area of 939 $m^2$ of land per P. This household is a special case insofar as the family returned only five years ago from a resettlement area in southern Ethiopia.[582] The land that belonged to the household before the resettlement was distributed to other households. After their return, the land was not given back to the former owner; he had to claim land from the KA. Since there is a pronounced land scarcity in Maybar, therefore the household obtained only 3 plots.[583] On the other side of the spectrum are the four rich households no. 9, 10, 12, and 14. They all cultivate more than 6,000 $m^2$ per P. If only the own land is considered, the amount of land cultivated per P of the four rich households is becoming smaller and similar to the other farmers', with the exception of household no. 14.

In ***Andit Tid***, poor and rich households invest similar amounts of labour in fieldwork. Here, poor households cultivate slightly more land (5,711 $m^2$) per P than rich households (5,021 $m^2$). The two average households no. 8 and 15 are rather special cases. Household no. 15 is headed by a woman. As she is not allowed to plough herself and her son is not yet old enough, she has to rent out the land. Household no. 8 consists of two families. The land has not been shared between the parent's and the son's family, as the father died recently. The son now cultivates the land of both households. However there are other siblings, which will claim land in future.

In ***Anjeni***, household no. 3 invests the smallest amount of labour in fieldwork. The main reason is that almost half of the land is rented in. In these rented fields less labour is invested because the yield is shared equally between the owner of the land and household no. 3.

It is difficult to determine an average labour productivity in the three research areas. However, the findings presented in Table 59 above show that especially in Maybar poor households cultivate per producer or per adult household member only half of what rich households cultivate. This can be interpreted in two ways: on the one hand, one could argue that poor households are significantly underemployed. On the other hand, one could assume that because poor households work a smaller area per producer, they have far better possibilities to invest in labour intensive activities such as weeding or SWC. It was even mentioned by some of the rich households with comparably big farm sizes but small households that they lack enough manpower to carry out the necessary tasks carefully enough. Thus, poor households could compensate part of the smaller yield because of smaller farm sizes by investing more labour instead. Following Boserup's argumentation, population pressure reduces the availability of the production factor land in relation to the production factor labour. This induces a technical change which allows land to be used more intensively, even though the productivity of labour declines.[584] This can be observed especially for the poor households in Maybar, who can be considered as having substituted land for labour to achieve a constant output. For the rich households in Maybar a similar shift might occur in future. Most household heads of this group are comparably old. Their farms will be distributed among several sons in coming years. The factor productivity will thus also change from more land-intensive to a more labour intensive system. In Andit Tid this substitution of land with labour has taken place forcefully in the process of the land distribution. Poor and rich households currently invest about the same amount of labour per land unit. From Table 57 it becomes evident that most households face a considerable food deficit. In light of the restrictions posed by the religious system with regard to working days available per year (cf. Section 8.3), only a shift towards a more capital-intensive system would help to maintain or raise total farm production.

The amount of family labour invested for fieldwork in relation to the land size shows similarities to the behavioural pattern describe in the model of the ***'optimising household'*** (cf. Section 6.3.1). The main difference is that there is almost no scope for adjusting the amount of land according to the number of producers and consumers, as land reserves are exhausted. Especially poor households in Maybar would have

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582 About one third of the population of Maybar KA left in 1984/85 for resettlement areas in southern Ethiopia. The land of these households was distributed among those households remaining. In 1991/92 most of the resettlers returned to Maybar and claimed back their land. The usual procedure was that the former owner was given back half of his former possession. Rich farmers had to give up part of their farmland in order to compensate the returnees.

583 The problem of returnees and the lack of land to be distributed is not specific to Maybar area but concerns all areas from where people have been resettled in 1984/85. (Pankhurst, 2001, 9)

584 Birner, 1999, 78.

enough producers to cultivate a bigger farm. Also the demand for production, which is defined by the number of consumers, would justify a bigger farm (cf. Table 57). However, there is no more land available that poor farmers could cultivate. Also renting in is hardly feasible, as rich farmers usually have enough producers to cultivate the land themselves and are not forced to lease it out. Again the difference between Maybar and Andit Tid becomes apparent with respect to the recently carried out land distribution. In Andit Tid the difference between rich and poor households with respect to the amount of land cultivated per producer is small, as rich households had to hand in part of their land holding which was then distributed to new families. In Maybar, this land distribution was not carried out and rich households could more or less retain their holding. Although the average number of producers of poor and rich households is about the same, rich households cultivate much more land than poor households do.

According to the 'optimising' household model, households would decide on their own when to ***adjust the farm size to the number of producers and consumers***. According to the framework of strategies of action presented in Section 6.3.1, farmers would react to constraints in their locality such as a closed land frontier by searching other opportunities offered inside or outside their village. This might include engaging in other enterprises than farming – if there were any possibility offered. In the case of Ethiopia, the adjustment of people and land has been taken over by the state. After the revolution of 1974/75, it was an attempt of the political leaders to balance the amount of arable land per household. Big farmers were expropriated of part of their holding and poor farmers or tenants without own land received land according to the number of family members. Land distributions were carried out in regular intervals to adjust the land-people ratio. For Anjeni it could be shown that the land-people ratio was fairly evenly distributed in 1992 among the different wealth groups.[585] On the one hand this practise prevented big social disparities and a class of landless people, on the other hand farm sizes became so small that food self sufficiency could no longer be achieved, as can be observed in Andit Tid today. In Maybar, where recently no land distribution was carried out, a quarter of the population has no own land and depends on food aid, whereas the rich farmers, which make up about 25% of the population,[586] have still enough land to be self-sufficient, and in average and good years, even produce surpluses. Problematic with the fact of constant re-distributions of the available arable land is that

(i) all farmers face similar shortages of own production,
(ii) there are no rich farmers who could sell their surpluses, which could be purchased on the market if need arises to support poor farmers depending on food aid, or who could, following tradition, support poor farmers in the village,
(iii) as there are no surpluses sold there is also no financial capital available in rural areas which could be invested in other, maybe more profitable, enterprises than farming,
(iv) as farmers rely on a future land distribution, they are not forced to think about other employment than farming.

Labour days per adult household member invested annually in fieldwork range between 40 and 135 days in Maybar, 43 and 138 days in Andit Tid, and 70 and 180 days in Anjeni. This also includes mutual labour exchange such as *webera* and *wenfel*. The rich household no. 2 in Anjeni additionally uses *debo*, a sort

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585 The poorest 25% of the population cultivated 20% of the land, 50% of the population controlled 40% of the land, and the richest 10% of the population controlled 15% of the land. (Ludi, 1997, 60)

586 An informal wealth ranking carried out with a group of farmers from Maybar, however, showed that according to the local perception of wealth, there are no rich households left. Rich households are defined as those who have more than 10 *timmad* of own land (approximately 2.5 ha), have more than one pair of oxen, 5 cows, a horse and a mule, 40 sheep and goats, and several bee-hives, can satisfy all needs, produce surpluses, can send children to school without facing labour shortages, and can support the poor. Average households would be those which just produce enough for one year, but cannot support the poor, have one pair of oxen and two cows, and supplement their income with trading. 25% of the population was considered to be average. Poor households have a maximum of 2 *timmad* (approx. 0.5 ha), can produce enough from their land for several months only, eat only once a day instead of twice, have in the maximum one ox or one cow and a few sheep or goats, have no clothes for changing, are dependent from outside support, and have a "merciful expression" (the definition thus also includes intangible concepts of dignity and autonomy). 75% of the population of Maybar was considered poor.

of a working party. People are invited to help without payment but are offered a meal and drinks. The organiser of such a labour party is not requested to return the amount of labour. If the total amount of ***labour days invested for fieldwork*** is compared to the annual total amount of available labour days without restrictions, it becomes evident that some households are clearly underemployed, whereas others need almost all available labour days for fieldwork. Thus, if additional demands for labour arise, such as soil conservation, some households do not face any problems. Others can afford such additional labour only by decreasing the amount of labour invested in fieldwork, by relying on mutual labour exchange or by employing daily labourers – usually under-employed young farmers. In Maybar the problem is less aggravated as more than 200 working days per year are available without restrictions. Here, additional days for SWC could be invested. It must, however, be stressed that especially poor households are underemployed because their farm size is too small. They are usually engaged in petty trade or seasonal off-farm labour to supplement the household income. If one assumed about 120 days for fieldwork or additional off-farm work, around 50 days would be available for SWC or any other activity related to resource conservation.

In Andit Tid and Anjeni per year about 130 days without restriction are available. Days for fieldwork per adult household member invested annually are usually about these 130 days. Household no. 15 from Andit Tid is not considered as the land is leased out and other people carry out the fieldwork. If we assumed, similarly to Maybar, annually about 120 days fieldwork per adult household member, only 10 additional days would be available to carry out SWC activities.

That male and ***female labour*** has been taken together in the above analysis comparing total labour days invested in fieldwork and remaining labour days which could be invested in SWC or other resource conserving activities, can be justified on the ground that in FfW schemes also women participated. Although labour division among male and female household members is strictly respected, in the case of paid labour for SWC households have relaxed these strict rules according to interviewed farmers and women. It could thus be argued that in theory all adult household members could be engaged in SWC activities. However, what has not been considered up to now is the housework duties of women, which are considerable. A working day of a woman starts around 5 am with preparing food for the household members and continues at least until 9 pm with tasks such as fetching water, collecting fire wood and dung, preparing food and beverage, preparing household items such as baskets or containers, milling grain at home or transporting the grain to the mill, washing clothes and cleaning the house and its surroundings, and looking after small children, the sick and the old.[587] Besides these laborious housework tasks, fieldwork such as weeding, harvesting, transporting the grain to the house, threshing, and storing the grain are also part of women's chores. SWC would thus be another burden on women. The above mentioned figures of additionally 50 days in Muslim areas such as Maybar and 15 days in Christian areas such as Andit Tid and Anjeni, which could be invested in SWC activities without restricting labour for fieldwork, or without entering into conflict with religious institutions, should thus be halved to relieve women.

Considering Christian villages only, the argument that SWC consumes too much labour with regard to fulfilling other household goals is thus understandable under the given condition with so many holidays. Two options, both unfortunately similarly unrealistic under current conditions, would exist: either SWC technologies are developed which are equally effective in controlling soil erosion but less labour demanding than the current technologies. The second option would be to relax the strict religious rules and to allow on certain holidays also fieldwork and carrying out of SWC activities.

Especially in Maybar and Andit Tid, the problem of land shortage has already been mentioned. According to the KA president of Maybar, about a quarter of the households did not receive land from the KA, but only from their parents, if at all. In Andit Tid, a similar number of households received only 2 *timmad* (roughly 0.5 ha) in the course of the last land distribution in 1997. The amount of land these households have at their disposal is far below what would be necessary to secure a minimal livelihood. Underemployment is thus an often-observed phenomenon and was also mentioned by the concerned young farmers. Off-farm labour is only rarely available in Maybar or Andit Tid and its surroundings. Young farmers have to migrate

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[587] e.g. Gämperli & Bokalech Damessa, 1991, 19; Wudnesh Hailu, 1991, 57.

seasonally to lowland areas or even as far as southern Ethiopia to find labour on plantations or coffee farms. These young farmers would, however, also be available as labour force to carry out SWC or other resource conservation activities – provided that it is paid.

### 6.3.3 Strategies of action of farmers - other investment opportunities

As has been mentioned in Section 6.3.1, on the one hand, farmers face a number of ***constraints*** from the ecological, economic, social, and political environment, to which they have to react and adapt their land use system. On the other hand, new ***opportunities*** are also offered, as the ecological, economic, social and political environment constantly change. Farmers are engaged in a permanent process of adaptation and innovation to make best use of these opportunities and constraints.[588] Soil conservation is but one option, and can be judged both as an opportunity and as a constraint.

Although the CBA has shown that SWC is profitable in certain circumstances, this does not necessarily mean that it is the best ***investment opportunity*** for farmers. The CBA compares merely two different land use practices – an erosive and a soil conserving practice. There are, however, other possibilities of how to use the land or how to invest labour. When land users are confronted with different investment opportunities, but face restrictions posed by financial, labour, or land constraints, in addition to the profitability of the different investment options they consider the following dimensions:[589]

1. Temporal dimension:
   a) Benefits accrue immediately or after a short time period.
   b) Benefits accrue only after a long time.
2. Spatial dimension:
   a) Benefits accrue locally.
   b) Benefits accrue in other spatial units
3. Tangibility:
   a) Benefits are tangible and visible.
   b) Benefits are difficult to identify.
4. Distribution:
   a) Benefits accrue to the same person who carries the investment costs.
   b) Benefits accrue to other persons.

Investments are the more attractive the earlier benefits accrue (1a), the more the benefits are felt locally (2a), the better benefits are tangible and visible (3a), and if benefits accrue to those who carry the costs (4a). If we compare this to investments in SWC, we have to observe that especially from mechanical SWC, benefits usually accrue only after some time (1b); most benefits accrue locally (2a), but the benefits – reduced soil loss – are not necessarily those in the highest interest of farmers – increased production; benefits are difficult to see (3b), because also costs of soil erosion such as small annual yield declines are also only difficult to see and may be often masked by other factors such as climatic fluctuations, pests or diseases; and benefits often accrue not the to person who pays for the investment (4b), but for either downstream users or for following generations. Especially compared to directly production-related investments SWC investments do not seem to be an interesting opportunity.

In the following paragraphs several options are presented showing where and how farmers are investing their land, labour and capital in their search to increase land and labour productivity, generate cash income, and lower the dependency on their own production.

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588 Thus, there is not only a re-active chain of actions where people response to pressure, following the model of Pressure – State – Response, but land users are also pro-actively searching for innovations in a Potential – Dynamics – Innovation sequence of action. (NCCR North-South, 2000, 21)

589 Uphoff, 1986, quoted in Anderson & Crosson, 1995.

***Irrigation in Maybar***

A few young farmers with only very little own land have started to utilise the water from small springs for ***small-scale irrigation***. One example shall be portrayed here:

The young farmer received about 1,100 $m^2$ of land from his parents 3 years ago. He has dug a small pond to collect the water from a nearby spring, and a channel to divert the water to his land. The land is partly used to cultivate annual crops such as pepper, potato, onion, garlic, red beet, carrot, wheat or maize and partly to grow perennials such a coffee, *gesho*, *chat*,[590] banana, orange, and papaya. The farmer estimates the profit in the second year to be about EB 500, without valuing his own labour.

| **Expenses** | | **Income** | |
|---|---|---|---|
| Fencing material | EB 50 | Green pepper | EB 335 |
| Daily labourer (6 days at EB 4) | EB 24 | 50 kg dried pepper at 8 EB/kg | EB 400 |
| Seeds | | Maize (125 kg) | EB 130 |
| Field work: | | Green maize | |
| 3 x ½ day ploughing | EB 7.5 | Potatoes, vegetables | |
| 1 x ½ day sowing | EB 2.5 | Onion, garlic | |
| 2 x 1 day weeding | EB 10 | Coffee, *Chat*, fruits | |
| Harvesting | | | |
| Manure | | | |
| | **EB 94** | | **EB 865** |

*Table 60: Expenses for and income from small-scale irrigation in Maybar. [Source: Own investigation 1999]*

The daily labourer was employed to help constructing the fence and to help digging the pond and the irrigation channel. Seedlings for perennials as well as seeds for carrots and red beet were provided by the Department of Agriculture under its programme of promoting the cultivation of marketable crops. Labour input for fieldwork is three times one half day for ploughing, and one half day for sowing, for which the farmer asks his brother. Weeding is done twice one day and in the evenings whenever the need arises. No artificial fertiliser was applied but manure, which the farmer received from his parents. The first year the land was used mainly to grow wheat and maize. In the second year, mainly pepper and maize were grown, and some potatoes, vegetables, onions and garlic. Most of the pepper was sold in Dese, either green or dried. The value of the green maize could not be estimated. Potatoes, vegetables, onions, and garlic are cultivated mainly for home consumption. Coffee, *chat*, and fruit trees are still too young to produce a yield. An annual profit of at least EB 700 is possible. It can be assumed that once the trees produce fruits, and *gesho* and *chat* can be sold, the profit will even increase. Converted to grain, the profit of EB 700 would be sufficient to buy 300 kg tef, which is almost sufficient for a year for one adult. Asked why not more farmers utilise water from springs, streams or even the lake for irrigation, considering the potentially high profit and the availability of water sources,[591] the farmer mentioned that until now, with the exception of the drought in 1984/85, it was not necessary to irrigate the land because there was enough rainfall, the land per household was sufficient, and the land productivity was fairly good. A second reason mentioned is that only few farmers own land in the vicinity of water sources for irrigation. Thirdly, he also mentioned that some farmers are jealous and that his field has already been damaged twice. Lastly he mentioned that many farmers from the vicinity of Maybar believe that an evil spirit inhabits the lake. Using this water would bring bad luck.

590 A shrub with slightly hallucinogenic leaves. Only Muslim consume *chat*. The national as well as the international demand is high and constantly growing. In some areas of south-eastern Ethiopia near to economic centres farmers have shifted away from annual crop cultivation to *chat* cultivation in light of the achievable high profits.

591 It has already been mentioned that the *Belg* rains in 1999 were late, i.e. failed almost totally. Nevertheless, in January and February 1999, springs still had considerable water.

*Figure 51: Small-scale irrigation with simple technologies with water from a small stream in Maybar. Water from Lake Maybar in the background is only used for irrigation in villages further downstream. [Photo: E. Ludi, 1999]*

Maybar, although located at the eastern Escarpment, which is on the one hand blessed with two rainy seasons allowing two cropping seasons, but on the other hand cursed with irregular and often poor rainfall, especially of the *Belg* rainy season, leading to total crop failure, is in the comfortable situation of having a ***permanent lake*** in its vicinity. Today, the water of this lake is not utilised in Maybar itself, but in KAs further downstream. This has not always been like this. In 1984 a water pump was installed to irrigate about 15 ha land at the lower end of the catchment. In the first half of 1985, this land was irrigated and potatoes, onions, and wheat were planted.[592] The land was distributed to the inhabitants of three hamlets in the vicinity of the lake. Before, this land belonged to farmers from one single hamlet. This distribution created resentments that are still felt today. The main rainy season in summer 1985 was normal again, and farmers stopped irrigating the land and returned to normal cultivation practices. Since then, the pump has never been used anymore. Most farmers who had irrigated land during the 1984/85 drought mentioned that this saved their life. Asked why the ***pump*** is no longer working, the main answers were that

- the pump needs repair which is expensive and above the capacity of the KA,
- running costs (fuel) are high,
- the road is in such a bad condition that fuel cannot be transported to Maybar by car,
- only few farmers would profit from irrigated land if no equal distribution were conducted,
- the irrigable area is too small to be distributed among all inhabitants of the hamlets in the vicinity of the lake,
- KAs further downstream currently using the water from lake Maybar would oppose,
- with the administrative reform merging two former KAs into one, the inhabitants of this new part of Maybar KA would like to build a channel to their area and utilise the water for themselves.

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592 SCRP, 1986, 18.

These various constraints have so far blocked any attempts made to maintain the pump and use it again. Currently, the KA administration would like to sell the pump, as only costs arise (salary for a guard), but no benefit. However, this attempt is strongly opposed by several young farmers without own land. They mentioned that currently the flat land in the vicinity of the lake is not used in an efficient manner and that the farmers cultivating that land should be expropriated. They specifically mentioned that by taking away about 1,000 $m^2$ (1/2 *timmad*, which is the usual size of a plot in the potentially irrigable area) from these farmers, their survival would not be threatened. Those farmers without own land, however, could profit greatly from this small plot if irrigated. Up to now, nothing has been done, neither with respect to repairing nor with respect to selling the pump, because possible conflicts seem too big. One of the problems mentioned is that because poverty is widespread, farmers are looking only for their personal benefit and have partly lost a social way of thinking. Therefore, communal activities, such as paying jointly for the repair of the pump, contributing labour to maintain the road to allow the transport of fuel, maintaining the system of irrigation channels, sharing the irrigable land among all farmers from the three hamlets in the vicinity of the lake, and sharing the water equally are no longer possible. Especially young farmers mentioned that people are jealous, are keeping to themselves and oppose any innovation.

If one assumed that about 15 ha ***irrigable land*** were available in the vicinity of the lake, and this land were distributed, about 150 households would receive each 1,000 $m^2$. Of course this is only a small fraction of the almost 1,000 households of Maybar KA. However, the lake is not the only source of water. In the surrounding villages, farmers have developed elaborate systems of irrigation, using stream water. Irrigation is mainly practised before the *Belg* rains start. The distribution of water is usually handled by the *Kire,* and, because it is a religiously based local organisation, its decisions are widely accepted. Up to now, no major conflicts arose because of the use of water for irrigation. In Maybar as well as in villages in the vicinity farmers mainly mentioned that the distribution of water itself would not be the problem, but the distribution of irrigable land. In general, farmers believe that good and bad land should be distributed equally among all farmers. They realise, however, that the amount of good land, which can be irrigated, is in short supply. No one currently cultivating land which can already be irrigated or which could be irrigated if the pump were maintained is eager to share his land with others. The only possibility would be to start a new round of land distribution. This is, however, highly discouraged because of other reasons such as to not endangering SWC investments or to keep farms which have a viable size and are able to produce enough to meet household needs and eventually even produce surpluses for the market. Thus, it must be expected that the situation in Maybar will remain blocked in future, unless charismatic people from within the community take up the initiative to maintain the pump and the channel system on the one hand, and to initiate a fair land distribution or a rotational system of using the irrigable land on the other hand.

#### ***Eucalyptus plantations in Andit Tid***

Eucalyptus plantations in Andit Tid have a long tradition. Already before the SCRP started its activities in the area, a ***communal plantation*** was established in 1967. This plantation was later expanded during the FfW campaign. Also in the vicinity of Andit Tid, bigger communal and state forests were established. Farmers in this high altitude and high rainfall area began to plant Eucalyptus (mainly *Eucalyptus globulus*) around homesteads for home consumption a long time ago. Besides being adapted to degraded land and high-altitude climate, limiting also the occurrence of termites, Eucalyptus globulus has the advantage that if cut above the roots, new stems grow from the stump. Plantations can be cut several times before old stumps have to be removed and new seedlings planted. Andit Tid is in a privileged situation insofar as the main highway linking Addis Abeba with the Northern parts of the country and with the main port in Djibouti crosses the community. Farmers can thus sell fuelwood along this road and traders can buy poles directly from plantations along the road. No costs for transporting the wood to the next market arise to farmers.

Soil erosion has in some parts of the Andit Tid area degraded soils so much that bare rock is exposed. In other parts, a few centimetres of soil remain. Such degraded areas can no longer be used to cultivate annual crops, often even a conversion to grazing land is not possible. Eucalyptus, however, can even grow on weathered basalt. Farmers have thus started to use degraded plots as ***individual plantation*** sites. Out of the interviewed farmers, two started to grow Eucalyptus around 1967 when the first communal plantation was established. Three young farmers have converted crop land to tree plantations in 1993/94.

Besides selling bundles of fire wood along the road to passers-by, farmers can sell their whole plantation lot to traders at a price bargained in advance. Traders usually come with their own labourers to harvest the trees and transport the poles and leaves by lorry to the market in Debre Birhan or even Addis Abeba. For the farmers, no additional costs arise. An example shall be presented here:

A farmer owns a plantation just beside the main road. The area is roughly 1,200 $m^2$. Trees are planted rather densely. About 12 trees grow on an area of 9 $m^2$. For the whole plot, roughly 1,600 trees can thus be expected. The owner of the plantation was asked by a trader to sell the whole plantation for EB 4,000. The farmer refused, because he estimated the value to be EB 6,000. The price for construction poles with a diameter of about 10 cm is around EB 5, for poles with a diameter of 7 to 8 cm EB 4, and for small poles with a diameter of 3 cm EB 1. In addition, the branches can also be sold per bundle (approximate diameter 80 cm, length 1.5 m) for EB 2 to 4. The trees of the above-mentioned plantation are about 6 years old and have so far never been cut. More than half of the trees are thicker than 10 cm, the rest range between 5 and 10 cm. Thus, the value of the plantation is around EB 5,500. Seedlings are usually bought from nurseries. 25 seedlings are sold for EB 1. In regular intervals, the Department of Agriculture distributes seedlings for free in its attempt to promote tree plantations. Survival rates of seedlings are reported to be low at 25% to 50% in plantations, mainly because of damage inflicted by grazing animals, and around 75% in homestead areas. Taking a conservative estimate and a seedling survival rate of 25% only, for a plantation in the order of 1,200 $m^2$, about 6,000 seedlings would be necessary. Costs for seedlings would thus amount to EB 240. Labour days necessary for planting the trees are around 5 days. Opportunity costs for labour would thus be an additional EB 25. Additional fencing material might also be necessary. Initial investment costs might thus sum up to EB 350 in the first year. Replanting might be necessary in the following 3 years with estimated costs of EB 75, including seedlings as well as labour. It is further assumed that the first harvest in the $6^{th}$ year gives the best poles and the plot can be sold for EB 5,000. After the first harvest replanting and fencing is again necessary. The following harvests (every $6^{th}$ year) produce poles with a slightly lower quality and can be sold for EB 3,000 each. A simple CBA of this investment (time frame 25 years, discount rate 12%) would produce an NPV of EB 3,700 and an IRR of 63%.[593] The plantation considered is established in an area which cannot be used for crop cultivation. Therefore, no opportunity costs for lost crop production were considered. If a plantation of the same size (1,200 $m^2$) and production were established on former crop land, and annual crop production were to be given up, an NPV (time frame 25 years, discount rate 12%) of EB 2,380 (IRR 40%) would result if annual crop production is estimated to be 120 kg barley at a value of EB 150 (cf. Appendix 6.7).

The above calculation clearly shows that as long as prices for Eucalyptus poles and demand remain high, it is a good investment opportunity for farmers in Andit Tid area. The main problems associated with this investment strategy is that the time until the plantation can be sold for the first time has to be bridged, and farmers depend heavily on traders buying the trees. Farmers of Mesobit & Gedeba, who have started to cultivate Eucalyptus some decades ago, have already experienced declining demand. They mentioned that traders have cheaper opportunities to buy wood near the main highway where transportation costs are much lower. Secondly, the plot considered is located at the roadside. Most farmers, however, own land that is located a bit farther away from the road. Such plantations are already much less attractive for traders, as the poles have to be carried to the lorry. If one assumed that traders pay only half the amount for plots a bit farther away from the road (e.g. EB 3,000 for the first harvest and EB 1,500 for the following harvests), the NPV would drop to EB 488, which, however, is still positive and thus a profitable investment. Another problem is the recently carried out land distribution. This discouraged farmers heavily from establishing tree plantations outside the homestead area. During the latest land distribution in 1997 all land was included, also plantation areas. Some farmers who lost land could chose which parcels they would like to keep. One farmer who lost most of his land and could keep only 4 *timmad*, decided to keep all his plantation sites, which together make

593 Similar high IRR (e.g. 67% for privately managed plantations on degraded community land) were fond for an *ex ante* evaluation of Eucalyptus plantations in Tigray. (Jagger & Pender, 2000, 46)

up 1 *timmad*. He remains with 3 *timmad* of cropland, which is far from being sufficient for a family of 5. As farmers cannot be sure whether land distributions will be carried out again in future , their motivation to plant trees, which they may loose before they can harvest, has decreased considerably. Some farmers of Andit Tid specifically mentioned this as their major reason for not planting more trees than the few they grow in their homestead area.

***Increasing production through the use of artificial fertiliser***

One strategy applied to overcome soil productivity declines is to apply artificial fertiliser to maintain or increase land and/or labour productivity. However, the perception of the ***usefulness of fertiliser*** varies greatly among the different research areas. In Maybar, the general feeling of the interviewed farmers is that fertiliser does not increase yields substantially and that the danger of total crop failure is much higher when fertiliser is applied. A comment often heard (5 of 16 respondents) is that they have witnessed that at the beginning of the growing period crop growth is good and much biomass develops. However, if rain fails, no grain develops, and only biomass can be harvested. With the same climatic situation but no fertiliser applied, the damage to crops is much less serious. A study conducted in three localities in Oromyia Region[594] comes to similar conclusions. Different technologies were compared showing that local maize varieties without fertiliser application produce significantly higher yields (3.6 t/ha) than local varieties with fertiliser application (2.9 t/ha). Only in the case where improved maize varieties are combined with fertiliser, yields increase compared to the traditional cultivation technology (5.9 t/ha). Reasons hypothesised for the differences are that (i) local maize varieties perform better under poor rainfall conditions and that (ii) residual fertiliser effects from the previous year might also play a role. A comparison of local and improved tef varieties and fertiliser application shows that improved seeds and recommended fertiliser application produce the absolute lowest yield (1.1 t/ha), whereas farmers' seeds and recommended fertiliser quantities result in the highest yield (1.5 t/ha). A reason for this difference could be that farmers pay much more attention in selecting the grain for next years seed than any seed producing agency, although the authors argue that farmers' seeds also include improved varieties from previous seasons. Besides the unsatisfactory ***yield performance*** if fertiliser is applied, most farmers also mentioned that the recommended amount of fertiliser and thus the costs are far too high to be economically viable. Recommended fertiliser amounts are 100 kg DAP (Di-Ammonium Phosphate) and 50 kg UREA per hectare. The costs (1998/99 retail prices in Maybar, interest not included) are EB 239 for 100 kg DAP and EB 225 for 100 kg UREA. A study conducted by the National Fertiliser and Input Unit (NFIU) of the Ethiopian Ministry of Agriculture (MoA) shows that for every kilogram of input (balanced application of N and $P_2O_5$ on experimental plots), yield increases are in the order of 3.5 kg for tef, 6.9 kg for wheat, and 9.6 kg for maize.[595] If a farmer under his/her conditions achieved only half of this yield increase, 100 kg fertiliser worth about EB 230 would result in 175 kg additional tef, 340 kg additional wheat, or 480 kg additional maize. If valued at current market prices, additional income would amount to about EB 370 for tef, EB 640 for wheat, or EB 530 for maize – quite substantially above the costs for the fertiliser. Even if farmers knew how much more they could produce if applying fertiliser, the main problem is that this yield increase is not guaranteed. If fertiliser is applied, severe damage or even total crop loss under poor climatic conditions is a fact. Usually, farmers buy fertiliser on credit. Annual interest rates are 12.5%, and are due every month. The credit has to be paid back in most cases after 8 to 10 months. In a year with poor harvest, farmers cannot produce enough additional yield to pay back the loan. In such a situation, they either have to sell grain that was foreseen for household consumption or they have to sell livestock. In Andit Tid, farmers mentioned that fertiliser does not increase yields enough to justify the high costs. An experiment conducted by the DA, however, shows that barley yields with fertiliser are more than double the yields without fertiliser application. Yield increases in Anjeni can be documented based on SCRP data and are between 15% for wheat and 86% for *Meher* barley (cf. Table 21).

A rather different situation can be observed in ***Mesobit & Gedeba*** area. In this village, farmers use quite substantial amounts of artificial fertiliser, improved seeds and herbicides. Most farmers buying inputs and using

594 Howard, et al, 1999, 14. Conditions (climate, altitude, prevalent farming system) are similar to Maybar and Anjeni.

595 Tesfaye Negussie, 1995, 116.

improved technologies mention that they use these inputs only for tef that is later sold on the market. The area is known for its good quality of tef and traders from Addis Abeba come to Aliyu Amba to buy it. Thus, there is a functioning market for this product and the price is high. Thanks to the market and the comparably good transport infrastructure agricultural inputs are available in the necessary quantities and at the right time. Investments in inputs can be recovered by selling part or all of the tef harvest. If a farmer buys fertiliser, improved seeds, and herbicides and spends up to EB 500 per hectare, which is the average amount,[596] he only has to sell 200 kg tef at current market prices to recover the costs. Farmers mentioned, and are supported by the DA who observes yields on an experimental plot, that tef yield with artificial fertiliser is around 1.5 t per hectare. In the case where the product is marketed, it is profitable to invest in inputs. The farmers interviewed in Mesobit & Gedeba mentioned that on those fields where they grow crops for home consumption they would not use artificial fertiliser. This example shows two important aspects in relation to inputs and improved farming technologies: firstly, it is important that a market exists, both for inputs and for outputs. Secondly, inputs are only profitable for those products sold on the market, but hardly for subsistence production. And a third aspect, which was not stressed by farmers of Mesobit & Gedeba, but was raised in Maybar and Andit Tid, is that farmers prefer to buy inputs in cash and not on credit. One of the main reasons farmers gave in Maybar and Andit Tid for not wanting to buy fertiliser is that they have to buy it on credit. They are afraid of not being able to pay back the loan after 10 months if the harvest is poor. Secondly, many farmers mentioned that it is a shame, even a taboo, to be indebted, especially because interest is charged, which is religiously sanctioned. Unfortunately, the extension service is not flexible enough to take these objections into consideration. The DA in Maybar mentioned that he is not allowed to sell the fertiliser in cash to those farmers who are interested. He has an order to select a predefined number of farmers each year who have to apply fertiliser – if they want or not and that he has to sell the fertiliser to these farmers on a credit basis.

*Figure 52: In Mesobit & Gedeba, farmers invest considerably in SWC and artificial fertilisers. They have intensified the farming system and are, compared to the other research areas, fairly well integrated into the market system. The shrubs grown on the terraces are gesho, local hop, which is sold. [Photo: E. Ludi, 1998]*

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[596] Based on information from interviews.

Mesobit & Gedeba is an interesting example also insofar, as the ***link between market integration, the use of production-enhancing inputs, and soil conservation*** becomes apparent. In Mesobit & Gedeba, all 20 interviewed households have most of their land conserved and mentioned that without soil conservation land productivity would be much smaller. 15 of the 20 respondents also mentioned that they use artificial fertiliser. A reason given for the investments in terracing is that if the land were not conserved, fertiliser application would not make sense, as it would be washed away together with the soil and the seeds during the rainy season with high runoff. If we assumed that the situation as it is presented in Mesobit & Gedeba, where inputs, market integration and soil conservation are closely interlinked, could also be propagated in other areas, this would not only mean that soil conservation would become much more attractive, but also that food supplies would increase and necessary revenues for further economic development generated.

The example of Mesobit & Gedeba demonstrates the importance of a functioning market system as an incentive to invest in modern inputs and farming technologies. And further, to make these investments profitable, investments in soil conservation are a prerequisite. In a system such as Maybar, Andit Tid, and partly Anjeni, which is mainly dominated by subsistence production and where the market integration is marginal, investments in fertiliser or improved seeds are not really an option because they involve monetary expenses. Before this money can be spent, something has to be sold, which makes a market necessary. It is therefore hypothesised that to make soil conservation more attractive, farmers have to be more integrated in the wider market economy. As long as subsistence production dominates, there is no incentive to invest either labour in conservation activities or money in modern farm inputs.

***Other options to supplement the farm income***

The above-presented strategies are but three in a whole range of possibilities to either diversify income or increase land and/or labour productivity. In the following, other strategies will be briefly discussed, which are of relevance to farmers in the research areas. They seem at first of not standing in direct relation to soil degradation and soil conservation. However, they demonstrate that farmers have to search for other occupations and for other income sources, as income from farming alone is insufficient in many cases to sustain a family on the one hand, and the discussed investments in SWC do not contribute enough to maintain soil productivity, on the other hand.

Farmers often engage in ***petty trade and grain trade*** to supplement their income from farming. Petty trade is mainly a women's affair, whereas trading grain in bigger quantities is done by men. Women buy small items such as soap, thread, needles, spices, salt, sugar, coffee, etc. on bigger markets with slightly lower prices. The goods are sold on local markets. The profit is partly reinvested to buy again goods to sell and partly used to buy food items for the household. Grain is traded in bigger quantities. This strategy, however, is only viable if farmers owned a donkey or mule on their own. It has been mentioned that daily income from trading grain can be as high as EB 30, in the average it is about EB 15 per donkey-load (cf. Section 5.2.1). This income does not take into account any costs related to keeping a donkey or mule. Such a high profit is thus only possible as long as free grazing of animals is possible on communal grazing land. If animals were to be fed from other sources, poor farmers with no or only little own land would have to buy approximately 1,600 kg of dry matter per year to feed a donkey.[597] Costs for straw or hay are difficult to estimate, as hardly any market exist. Farmers from Maybar and Andit Tid mentioned that they sometimes have to buy hay or crop residues or lease a plot of grassland for several months. It was, however, not possible to estimate a price for either hay or straw or for grassland. Using opportunity costs for straw as used in the CBA, the costs for feed would amount to roughly EB 560 annually. Thus, the profit from almost 40 days trading would have to be invested just to buy the feed for the donkey. Under this assumption it becomes evident that trading is only an attractive enterprise as long as certain resources are communally owned and thus free and open to all community members. Once

597 Dry matter requirement per ox (1 TLU): 2,300 kg / per year. Donkey: 0.7 TLU.

this system changes,[598] options that are attractive today because no direct costs accrue will become less attractive if costs were internalised.

*Figure 53: Especially for women, petty trade with small household items, spices and coffee is an important income source.*
*[Photo: E. Ludi, 1992]*

Young farmers with no own land or only a small farm mentioned that they are underemployed. The production from the small farm is not sufficient to support a family. Some of these young farmers have to lease out their land. They ***migrate seasonally*** to work as daily labourers on plantations. However, they mentioned that they would not move to other areas on a permanent basis. They mentioned that because their family lives in the village they can fall back on local support systems if the need arises. In areas far away from home, local and family support mechanisms would no longer work.

In all research areas an important strategy is to rely on ***livestock as a reserve***. Especially small ruminants are raised for selling to buy grain. In Maybar poor farmers complained that the former communal grazing land has been distributed to individuals. Problematic is that rich farmers could rely on their social and political influence to secure a productive parcel, or if this was not sufficient to bribe members of the community administration. Poor farmers could not exert any influence on the distribution of grazing land, and thus received only marginal plots. For them it has become even more difficult to keep animals for selling.

In the framework of strategies of action, the influence of the ***social and cultural system*** on the decisions of farmers has been mentioned. Farmers cannot decide totally on their own what to do or how to perform certain activities. With respect to ***occupation***, in all areas, with the exception of Mesobit & Gedeba, farmers clearly mentioned that they would not engage in another job than farming, trading, tailoring, and weaving. In Anjeni, farmers specifically mentioned that it is not possible for farmers to become craftsmen with the exception of part-time carpenter. This would constitute a decline in social status.[599] It is also considered to sign of weakness if people change from farming to other occupations. In Christian areas, craftsmen are also brought in connection with the "evil eye".[600] Although Muslim areas are more liberal in this respect, here as well

598 The system of free grazing for all community members on communal grazing land has already partly changed in Maybar, where (i) the major part of the former communal grazing land in the vicinity of the lake has been distributed to individual farmers and where (ii) strict rules relating to grazing in the communal forest areas exist.

599 In the wealth ranking conducted in Anjeni the tailor was with the exception of one respondent always ranked lowest. The poor farmer considered him as rich because he has a constant income although his farm is small.

600 The 'evil eye' is understood to be associated with negative magical power. (Ludi, 1997, 47)

farmers mentioned that they would not engage in craftsmanship. It was stressed that although the goods the craftsmen produce, especially pottery and iron works, are of paramount importance for daily survival and necessary to perform fieldwork, such people are regarded inferior in the social hierarchy. In Mesobit & Gedeba, some farmers are part-time craftsmen. Although fellow villagers treat them suspiciously, the craftsmen mentioned that they do not experience clear rejection and discrimination. They can still live in the village and are not excluded from the village society. These craftsmen have taken up the opportunities offered in the wider economy – i.e. high demand for ironworks – and have partly changed their occupation.

In all areas, farming is considered the most highly regarded occupation. Farmers clearly recognise that land is scarce and that the arable land is in part severely degraded. Many households experience food shortages, if not hunger, as arable land per capita is small and decreasing and land productivity steadily declining. Time and again it was mentioned that for coming generations survival on the existing farmland would be even more difficult than it already is today, as there is simply not enough arable land. In this respect, soil conservation was considered insufficient to reverse this negative trend. The solutions mentioned by farmers were that the government should develop resettlement schemes in sparsely populated areas, and that children should be ***educated*** and should try to get a job outside the farming sector, preferably in the government administration. However, in the research areas less than half of the children aged 8 and above attend school. Simen is the most extreme case with only about 500 pupils from a population of 10,000 people in school age.[601] In those areas where schools exist, reasons given by farmers for not sending children to school were the following:

- They have themselves experienced or seen from others that attending school did not change their situation fundamentally, that they remain farmers and can hardly survive.
- The costs for sending children to school are too high, especially costs for clothing and material.
- Children are needed on the farm for certain tasks – boys are needed to look after animals, and girls have to help their mothers with household chores.
- In government school, children are spoilt with regard to religion and social obedience.

One alternative is to send children to local schools, which are affiliated with the church or mosque. However, topics taught in these local religious schools are only related to religious matters. Such schools are not valued highly if young people search for jobs outside the farming sector.

Although farmers in the Ethiopian highland are often described as being individualistic,[602] ***integration in the rural society*** is of primordial importance. Most strategies at the household level are based on individual action and not on co-operative problem solving. Their main aim is to increase the room of action for an individual household without curtailing too much the room of action for other households. This is supported by deep-rooted ***social norms and values***, which, in the Amhara society, tend to share available resources as equally as possible. This behaviour is supported by religious institutions in Christian as well as in Muslim communities. The tendency to share, even if the individual share becomes ridiculously small, corresponds well with peasant societies and their socio-economic and socio-cultural system, which seeks to ensure access to resources for all members and is aimed at preserving the status quo. Therefore, the development of a class of farmers possessing resources and a class of totally impoverished farmers without any resources at their disposal is prevented. Scarcity and poverty form sort of a ***'society of fate'*** in rural villages. Individuals are bound to each other through mutual self-help groups, the obligation to share, and the dependency on resources of others in times of need. As these bonds are important, if not necessary, for survival, individuals do not question them even if they reduce their individual room for action. Strategies applied by households are sanctioned by society and geared to not endanger the integration in the local rural society. Innovative farmers try to break out of this 'society of fate'. They therefore pose a threat to the society as a whole. To avoid such innovative behaviour and thus the questioning of the local institutions and norms and values, such behaviour is often

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601 Hurni & Ludi, 2000, 86.

602 e.g. Levine, 1965.

labelled as deceitful or innovative farmers are affiliated to belonging to another religious group. Secondly, sharing of surpluses is a social obligation. This has two main consequences with respect to investments: it is not an ultimate goal of a household to invest from own resources to produce too much surplus, as this surplus is in part claimed by either social institutions or poor community members.[603] If surpluses have to be distributed to other community members, this surplus cannot be sold and invested in other enterprises, which for the investor might be an interesting opportunity and could even be benefiting the local community as a whole. Farmers complained, for example, that there is no one willing or able to invest money in a privately owned grain mill in the village, which would generate on the one hand a considerable income for the owner, and on the other hand a release of women's work load.

### 6.3.4 Conclusions

The results of the CBA presented in Section 6.1.2 show that ***introduced SWC is profitable only in few situations***, mainly if slopes are gentle, on steeper slopes if additional fertiliser is applied, and in some cases even only if in addition to fertiliser application also labour costs for the construction and the maintenance of terraces are subsidised. A special case is given in those situations where soils are already shallow. On such fields, soil erosion can lead to a total loss of arable area within a short time, because the soil depth is reduced to critical levels, i.e. to 10 cm or below, which is assumed as the threshold depth after which crop cultivation has to be given up. Therefore, the construction of bunds to prevent sheet and rill erosion can be profitable already in the medium term. Adapted SWC, which is a better approximation to the actual situation on farmers' fields, shows a positive NPV more often than introduced SWC, as the amount of land occupied by conservation structures is only one third of what it is in the case of introduced SWC, and less labour is necessary for construction and maintenance. Observations in Maybar, Andit Tid, and Anjeni showed that the original layout of conservation structures has only rarely been maintained. Farmers thus try to find an optimal solution from their point of view, which minimises costs, i.e. labour investments and land lost for crop production, and maximises benefits, such as perceived positive effects on yield through SWC. A similar conclusion can also be drawn based on the CBA. ***Adapted SWC*** is more often profitable. However, one has to keep in mind the specific assumptions which underlie the model, such as the percentage of erosion reduction in the case of introduced and adapted SWC or the portion of arable land occupied by SWC structures. Nevertheless, the results from the CBA and the evaluation of SWC by farmers indicate that from both the internal and the external point of view, introduced SWC under given circumstances is only rarely a profitable investment. Would other evaluation criteria than the NPV be included in the analysis, such as intergenerational equity, the results must be interpreted differently. For example, society may agree to maintain a minimal soil depth, so that crop cultivation remains possible also for future generations. In this case, SWC must be carried out in order to prevent soils from becoming shallower than the agreed threshold depth even if it proved to be unprofitable.

Mesobit & Gedeba and Maybar on the one hand and Andit Tid and Anjeni on the other hand can be differentiated with regard to the ***perception of SWC*** by the inhabitants. In the former two dryer areas, physical soil conservation in the form of stone bunds has a long history, whereas in the latter two high rainfall areas, physical structures were hardly known, and the focus was on draining excess water. Stone bunds in the dryer Mesobit & Gedeba and Maybar not only serve the purpose of soil conservation, but also that of water conservation and water harvesting. In contrast, in the high rainfall areas of Andit Tid and Anjeni, if the physical conservation structures are not constantly maintained, they can lead to waterlogging and thus to crop damage. This is also reflected in the more positive attitude towards physical SWC in Maybar and Mesobit & Gedeba as compared to Andit Tid and Anjeni. Farmers' perceptions with regard to yields on conserved and unconserved

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603 Farmers have made similar experiences during the imperial times, which might still have an influence on today's behaviour. During these "feudal" times, a certain percentage of the production had to be delivered as taxes and tributes to landlords. Increases in land productivity benefited the elites rather than the farmers. Thus, there was no incentive to invest in the land, neither in production enhancing technologies nor in resource conservation. (Fekadu Bekele, 1989, Ludi, 1997, 13)

land differ considerably. In Maybar and Mesobit & Gedeba, farmers consider yields to be smaller on unconserved land, whereas farmers in Andit Tid consider yields on conserved land to be noticeably smaller than on land that is treated with traditional measures such as drainage ditches. Yield measurements on experimental plots show that total yield on conserved experimental plots in Maybar is 20% to 30% smaller than on the unconserved control plot, whereas in Andit Tid the difference can be as high as 50%.

The strong ***resistance against introduced SWC*** is due to the fact that with this technology, a considerable amount of arable land is occupied by conservation structures, which reduces total crop production. A modelling of production (in kcal) that can be achieved on the land of the interviewed households with and without SWC demonstrates that in Andit Tid only two out of the 15 households interviewed can produce enough for one year even if no land loss occurred. In Maybar, the situation is less dramatic: 6 of 16 households cannot meet their calorie requirements. In a situation where farmers are unable to achieve ***food self-sufficiency***, it is understandable that they reject any measures that lead to a decreasing farm size in the short run. The modelling shows that if SWC were adopted and the available arable area were reduced accordingly, in Maybar, three additional households would no longer be able to meet their nutritional requirements. In Anjeni, without SWC, only one household cannot meet its food requirement, while introduced soil conservation and an assumed land loss of 23% would endanger food self-sufficiency for all considered households. In the modelling, it was assumed that all SWC investments are carried out in the first year, which, under the consideration of the huge amount of necessary ***labour*** (200 days per ha in Andit Tid and Anjeni and 440 days per ha in Maybar), is hardly feasible. However, even if the initial conservation investments were spread over several years, the situation would not change, since the annual yield declines without SWC are small in comparison with the yield losses due to land occupied by conservation structures. This is shown in a dynamic modelling, where soil erosion in the case both of SWC and of uncontrolled erosion is modelled together with an assumed population increase of 2%. It shows that if both processes are considered, food self-sufficiency is not achieved in Andit Tid, irrespective of whether SWC investments are carried out or not. In Maybar, self-sufficiency for the growing population can be guaranteed for another 20 years if no SWC is undertaken. With SWC leading to a reduction of the arable area by about 21%, self-sufficiency is threatened after roughly 10 years. In Anjeni, self-sufficiency can be maintained for about 10 years without SWC. With SWC, the yield losses due to the reduction of arable land are so big that self-sufficiency can no longer be achieved. However, it must be considered that in Andit Tid the available arable land has been distributed among more households in 1997, whereas in Maybar such a distribution was postponed. In Andit Tid, therefore, food self-sufficiency is no longer guaranteed for most households because farm sizes are too small. In Maybar, however (and also in Anjeni, where it is not known to how many households the land has been distributed), food-self-sufficiency is still guaranteed for households with own land. In Maybar, the problem of population growth has thus been externalised, i.e. the Government or donor agencies are responsible for supporting the landless, whereas in Andit Tid, the community has to carry the burden in the form of reduced arable land and reduced production for all households. Any further reduction of cropland would only aggravate the situation and is therefore rejected by farmers. Farmers consider land loss resulting from SWC avoidable, whereas land loss resulting from a growing population is beyond their control.

Observations in the research areas show that ***SWC investments in critical locations*** are undertaken by land users themselves. Farmers perceive that the damage caused by rills, which eventually develop into gullies, costs them more than the land loss due to the conservation structure plus the labour invested for the establishment of a terrace. This points at the problems of visibility of damage caused by soil erosion and of the time frame within which such damage becomes apparent. Rill erosion is localised and clearly visible in the field, and the resulting damage to crops is apparent. It is also clear where to invest to prevent further damage, and the investment is comparably small. Sheet erosion, however, is not or hardly visible. Also the effect of constantly declining soil depth leading to small annual yield declines is not visible, especially considering the big annual yield fluctuations. Furthermore, it is not apparent where to construct SWC structures, as sheet erosion takes place throughout the whole field. As both the erosion process in the field itself and its effect on yields are hardly visible, omitted investment can be explained.

The comparison of the ***internal and external view*** with regard to the acknowledged problem of decreased arable area shows that from the farmers' position, SWC is no solution, since it reduces the arable land immediately. Although farmers recognise that uncontrolled soil erosion damages the soil and reduces crop production in the longer term, they are concerned with the near future and hope for the government to intervene in case food self-sufficiency continues to diminish. From the outsider's position with a long-term perspective, SWC is an option, because with its help, damage to the land can be postponed. This would allow searching for other technologies with less negative side effects and for technologies that would also address the problem of decreasing soil productivity. Furthermore, from the outsider's position it can be argued that not investing in SWC now in order not to lose arable area is a strategy that will be nullified in a few years. The two perspectives could be brought together if a conservation technology was found which would compensate the production decrease resulting from SWC structures occupying arable area. This would not yet solve the problem of a growing demand for arable land because of population increases, but it would at least address the legitimate objection against introduced SWC because of land loss.

In other instances, farmers perceive the benefits of SWC to be lower than those from other investments, such as the establishment of ***tree plantations***. In cases where the land is already so degraded that crop cultivation is no longer profitable enough, there is nothing wrong with this strategy. However, it becomes very problematic in the case where farmers decide against resource-conserving investments today with the option of converting the land to a plantation site in future, when the land will have lost its productivity and crop cultivation will no longer be economically viable. From a farmer's point of view, especially in consideration of a possible future land distribution, this strategy, although rather destructive, is understandable. Farmers try to optimise the input in the land and the achievable output not only in the short term, but also in the medium term. As they cannot be sure for how long they will be able to use a given parcel it makes no sense to invest too much labour in projects such as SWC today. The optimisation strategy is thus to extract as much as possible now by making only targeted investments in SWC in critical locations where an immediate threat to current income in the short to medium term exists, e.g. where rills might develop. This leaves the option of converting cropland to plantation areas in the longer term. However, this strategy, which decreases the potential for future crop production for the current owner as well as for future owners, is only viable if the demand for Eucalyptus poles remains the same as today, i.e. if prices remain high and traders buy the poles directly from the farmers. With more farmers embarking on that enterprise, it might well be that areas nearer to big centres such as Debre Birhan or Addis Abeba will be more attractive for traders and that thus the demand for poles will decrease in more remote areas such as Andit Tid.

In Maybar, strategies such as ***irrigation*** serve both goals, that of generating a higher income from a small area of land as well as that of resource conservation. Irrigation is only possible on land that is not too steep, thus terracing is an integral part of this strategy. If it is done properly, problems such as salt concentrations, leaching of nutrients, or erosion, can be minimised.

Similar experiences have been made in Mesobit & Gedeba, where farmers have started to ***intensify crop production*** by mainly relying on artificial fertiliser. Without terracing the land, applying fertiliser would not be economical, as nutrients would be carried away by runoff.

The CBA was carried out from an individual perspective, i.e. costs and benefits as observed in the different research areas are considered. This financial CBA shows that SWC is not necessarily profitable from the farmer's point of view. Secondly, some farmers have other investment opportunities besides SWC, where either land or labour, or both, can yield a higher benefit. Thirdly, farmers are embedded in a ***local social system***, which also demands goods or labour from households. Support of others and mutual labour exchange are just two examples, others would be claims by religious institutions or government agencies. On the other hand, farmers try to act as independently as possible from others. Mutual labour exchange, for example, is only practised for certain tasks. For additional tasks such as soil conservation activities, such forms of mutual support are not very common. For an individual household it is often difficult to provide all the necessary labour force for establishing SWC structures on its own farm. Nevertheless, it is possible to realise bigger development schemes based on communal labour, as an example from Mesobit & Gedeba demonstrates. Here, farmers invest substantial amounts of labour for the development of an irrigation system. The irrigable area should become big enough for each farmer of the surrounding villages to receive a small plot. Farmers mentioned that because the profit from irrigated land is substantial they are willing to participate in the development of the irrigation scheme without remuneration. This clearly shows that if farmers perceive an investment to be profitable they can mobilise labour and pool it to achieve a goal. However, as long as SWC is not more profitable, there is no motivation to invest labour that can be invested otherwise or used for leisure.

***Individual strategies*** of farmers try first of all to secure at least a minimal livelihood with respect to nutrition, to spread risks by engaging in different activities, and to maintain integration into the rural society. Such strategies include general strategies at the household level:[604]

- Combining crop cultivation and livestock production. Surplus crop production can be invested in livestock, crop residues are used as animal fodder, animals are used for productive purposes, animals serve as reserves, and animal dung is used for maintaining soil fertility unless used up completely as fuel.
- Diversifying the crop cultivation system to make best use of ecological niches, satisfying different household needs, providing products for markets, and meeting social obligations. The varieties grown do not give maximum yields, but they do produce a crop also in climatically bad years. Households thus forego maximum material or financial benefit in good years for the sake of ensuring survival in bad years.
- Producing as independently from the markets as possible, which is however not a goal in itself but rather a reaction to the political and economic situation faced by farmers, including high transaction costs. The capital-extensive farming system and inter- and intrafamily bonds of solidarity allow farmers this strategy unless they have monetary obligations. Even if farmers are engaged in trading grain or livestock, the profit is rarely used to invest in productive enterprises, but spent mainly for consumption purposes.
- Strategies with regard to production factors, such as pooling human labour for specific labour-demanding tasks, rearing oxen for others, borrowing or sharing oxen,[605] leasing land, and trying to increase farm sizes with the ultimate goal of achieving an optimal allocation of land, labour and capital.
- Strategies aiming at generating complementary household income through trading, engaging in casual work, producing cash crops and material goods.
- Changing food habits.

The above-mentioned general strategies that are each composed of a ***bundle of activities*** are not independent of each other and are not applied by all households in the same combination or with the same priorities. To act as independently as possible from markets makes a successful combination of crop cultivation and livestock production necessary, as well as an optimal crop mix to satisfy the different household needs. Different households mix the strategies differently according to their wealth, assets or household composition. Resource poor households have to rely more on markets or additional income, whereas for wealthy households with enough arable land and livestock, marketing activities are less important and serve more to complement own production.[606] Buying bulls on the market, training them and selling them the next year at a higher price is a strategy solely applied by resource poor households. The difference between the selling and buying price is used to buy crops for the household. There are strategies that households choose on their own and strategies that households are forced to adopt. Mutual labour exchange that helps a household make better use of production factors is an example of a chosen strategy, whereas sharing oxen or participating in working parties are strategies poor households are forced to adopt because they lack the necessary means of production. Furthermore, there are strategies that are applied to maintain the status quo of the farming system or the social order such as religiously sanctioned mutual support systems or the law of inheritance, whereas there are other strategies that aim at changing certain restricting rules, such as educating children.

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604 Ludi, 1994, 100ff.

605 Two different forms exist: *Meqenajo*: Joint venture between two farmers who own one ox each, the pair of oxen is used by turns. *Yearso*: A farmer without oxen borrows a pair of oxen from a wealthy farmer for one day and works for one or two days in return on the land of the lessor. (Yohannes G/Michael, 1999, 81)

606 In all three areas, rich farmers tend to sell less crops and livestock compared to poor households. Also in the wealth ranking in Anjeni and Maybar it was stressed that rich households produce enough to sustain a family without being forced to participate in the market. Depending on markets was seen as a clear sign of poverty.

These strategies have usually not been developed in view of resource scarcity, but they gain more and more importance as resource availability decreases. If the concept of ***optimising utility*** is taken as a guiding principle of farmers' action, it can be stated that the observed strategies correspond well with this concept. It is not pure profit maximisation or risk minimisation that stands in the foreground, but an optimal and complex allocation of material and social resources which enables a household to achieve its goals. Important goals in the Amhara society are not only those related to the household itself and centred on fulfilling its material needs. It is at least as important for a household to fulfil the various social obligations which ensure integration in the rural society. Without the many social institutions that exist, individual households could hardly survive. Thus, a combination of strategies is applied which enables a household to act as independently as possible from others and at the same time ensures integration in the rural society, thereby minimising risks. This integration is mainly secured through religiously based institutions (e.g. *mahiber*, *kire*), which also favour mutual support. This allows a household to rely on resources of others in times of shortage and guarantees a certain redistribution of wealth, thus preventing a class of totally impoverished people from developing.

It could be demonstrated that Eucalyptus plantations in Andit Tid are a highly profitable enterprise. Observations made and farmers' statements recorded clearly show that if farmers plant Eucalyptus, it is only on a small area of their farm. A full concentration on plantations and forestry – or any other profitable activity – as the only source of household income cannot be observed. On the one hand, this can be explained by the goal of ***fulfilling household needs*** as independently from others as possible, i.e. a rather strong subsistence orientation of households. On the other hand, it can be explained by ***policies*** and the ***market*** situation. Policies have an influence insofar as there is no clear forestry policy and forests are generally considered to be state ownership. A private forest might thus be expropriated. Also KA administrations are ambivalent in this respect. Forest areas, even if established as private plantations, are considered as community forests in cases where the KA needs cash. On the other hand, KA administrators promote private plantations. Secondly, in the past, policies with regard to ownership changed with every change of government. Farmers are rightly reluctant to invest in an enterprise with a long maturity under the current political system. Thirdly, as markets are weak and dominated by a few traders, planting trees which can not be transported by own means from the farm to the market means a high dependency on traders. This puts farmers in an inferior position. Since they are dependent on the cash they earn by selling a certain amount of trees each year, they can be pressurised by traders into selling at very unfavourable conditions.

Individual strategies are not static at all. They are constantly ***adapted to changes*** in the ecological, social, economic, technical, and political environment and also have an inherent tendency of innovation. If, for example, the availability of natural resources diminishes – either due to increased demand (e.g. population growth) or a decreased supply (e.g. resource degradation) – new strategies are developed, or existing strategies are adapted, so that they continue to ensure the achievement of household aims. For example, in the case of soil degradation, changes of strategies could be

- ***modifications*** of the farming system, such as a shift away from crop cultivation towards a higher dependency on livestock production,
- ***changes*** in farming practices, such as the cultivation of more tolerant crops or the change from the ox-plough to more manual labour to achieve an optimal allocation of production factors,
- ***innovations*** such as soil conservation activities to halt degradation, the increased use of artificial fertiliser to compensate nutrient loss, or small-scale irrigation to increase the output per unit area, or
- ***adaptations*** in the economic behaviour of farm households through a better market integration and reduced dependency on the own production, or adaptations in the social sphere such as a change of values in relation to occupation, which leads to a higher willingness to engage in off-farm employment or to send children to school and give them the chance to find alternative employment possibilities, with the ultimate goal of lowering the pressure on remaining resources.

For an individual household, SWC is but one option in a whole set of strategies. The CBA has shown that from an individual point of view, SWC is only rarely profitable. From ***society's point of view***, the situation presents itself quite differently. On the one hand, there are on-site costs which are not only borne by the concerned land users themselves, but mainly transferred to society at large; on the other hand, there are off-site costs which are not borne by the perpetrators at all. On-site costs imposed on society are decreasing yields which are no longer sufficient to secure a minimal livelihood for a household. More and more farmers depend on humanitarian aid, not only in bad years with adverse climatic situations, but permanently. Society or international donors have to support a growing number of people. Moreover, in light of unchanged reproductive patterns and a growing population depending on agriculture, on the one hand, and continuing resource degradation, on the other hand, it must be expected that the number of people depending on outside help will continue to grow. Although farmers have developed a wide range of strategies to cope with this worsening situation, usually these strategies are not sufficient, especially not if the current situation is exacerbated by climatic or socio-political shocks. The magnitude of resource degradation today in combination with a dense population and no alternatives to farming for survival can be regarded as such a shock. Local strategies such as traditional forms of SWC are no longer sufficient. Much higher investments in resource conservation are necessary in order to at least slow down the negative trend and to gain time to develop other strategies. Pressure on farmers to invest in resource conservation is therefore growing. For the Ethiopian society it is impossible to support the number of people depending on food aid already today. Moreover, as a society continues to exist in future, interests of future generations have to be considered. Not only will the number of people in future be bigger than today, but without major changes in the land management system, which includes SWC, the productivity of the land will be even lower. From society's point of view it is thus an ultimate goal that resource degradation be at least slowed down. The optimum would be to develop land use systems that allow a much higher production per unit area and conserve the resources at the same time. It should therefore be in the interest of society that farmers invest in SWC today so as to not further increase the problem of declining yields and the resulting costs for society. Secondly, today's generation should invest in resource conservation so as not to endanger the survival of coming generations.

Off-site costs of soil erosion that are borne by society but not by farmers causing the damage, are mainly damages occurring to infrastructure. High sediment loads in rivers lead to siltation of water reservoirs, be it reservoirs used to collect drinking water for the growing cities or reservoirs that store water to generate electricity. Silted up dams can be found throughout the Ethiopian Highlands. Furthermore, high runoff during the rainy season leads to flooding of land adjacent to rivers and to damages of infrastructure such as roads.

Finally, as the expansion of cultivated land leads to high runoff instead of enhanced water infiltration, ground water reservoirs are not recharged, and rivers carry maximum amounts of water during and shortly after the rainy season and minimum amounts of water during the dry season. Irrigation was mentioned as one option to increase production. However, if rivers carry minimum water amounts during the months when the land should be irrigated, this option quickly reaches its limits.

The Ethiopian Highlands are one of the main water sources of the Nile River. About 53% of the total water inflow into lake Nasser originates from two main tributaries in the Ethiopian Highlands. In addition to the substantial amount of water from these two tributaries, about 90% of the sediment load also originate from the Ethiopian Highlands.[607] The economies in both Sudan and Egypt depend heavily on water from the Nile River, not only in total annual quantity, but also in year-round distribution of the water. There is a growing tension between the lowland countries depending on the water and the highland countries mainly delivering the water. Especially Ethiopia and Eritrea would like to use more water for own irrigation projects. However, it is feared that if more water were used in the upper course of the river, less water would be available for lowland riparians. Also any land use change in the headwaters of the Nile Basin has consequences for downstream economies. Land degradation in the Ethiopian Highlands has led to an increase of the sediment load by 60% within 20 years, threatening irrigation systems in the lowland as well as infrastructure such as the Lake Nasser dam.[608] Such dependencies between highland and lowland countries might even lead to international conflicts ultimately linked to unsustainable resource use and underlying root causes in the highland economies.

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607 El-Swaify & Hurni, 1996, quoted in Mountain Agenda, 1998, 8.

608 El-Swaify & Hurni, 1996, quoted in Mountain Agenda, 1998, 9.

# 7 The Influence of the Economic Environment on the Profitability of Soil Conservation

## 7.1 Macroeconomic Policy Reforms in Ethiopia

> *"[T]he potential for future farm-level income and productivity growth in Ethiopia will be intimately tied to productivity growth at the various stages in the marketing system."*
> *(Gebremeskel Dessalegn, et al., 1998, 1)*

To address the widespread poverty in Ethiopia,[609] the Government embarked on a number of macroeconomic policy reforms after 1991/92.[610] The period ***1980/81 – 1990/91*** was characterised by a very low growth rate of the GDP of around 1% p.a., a drop from an average of 4% p.a. registered during the 1965 – 75 period. The agricultural sector grew on average during the 1980/81 – 1990/91 period by a meagre 1.1% p.a., while industry declined by 1.6% and the service sector by 1.9% p.a. respectively. On the other hand, population increased by an average of about 3% per year during the same period. Per capita GDP therefore declined by 16% during the 1980/81 – 1990/91 period. The balance of payment fell to a minus of EB 1,206 million at the end of 1990/91, which is largely attributed to a decline of exports. Total external dept stock (EDT) stood at US$ 1,842 million in 1981 and rose to US$ 9,119 million in 1991,[611] thereby raising the dept service ratio from 6.2% in 1980/81 to about 45% in 1990/91. The rising dept during the considered period is mainly attributed to the demand for financing the war. Following the fall of the DERG regime, the Transitional Government of Ethiopia initiated an ***Economic Reform Programme*** (ERP) to address the internal and external imbalances of the economy. The major thrust of the ERP was to transform the economy from a Marxist command economy to a market based economy. The main objectives were to ***stabilise the economy*** and to ***deregulate economic activity***. The ERP focussed on a number of key areas such as (i) exchange rate and trade system, (ii) public sector divestiture and privatisation of para-statals, and civil service reform, (iii) monetary reforms, (iv) fiscal reforms, (v) investment promotion, and (vi) reforms of various sectors such as finances, agriculture, transport and social aspects. These reforms and the ending of the civil war reversed the negative growth trends of the 1980s. Average annual GDP growth during the period 1992/93 – 1995/96 was 7.6%. The agricultural sector grew on average by 3.4% p.a. for this period. It is assumed that this positive trend can be traced back in part to policy changes in the agricultural sector, namely in areas of pricing and marketing of both inputs and outputs, combined with productivity gains resulting from increased research and extension efforts. The industrial sector grew on average by 15% p.a. for the period 1991/92 – 1995/96. Most of this growth originates from manufacturing, handicrafts, and small-scale industries. Inflation declined from 21% in

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609 Poverty measured in terms of food consumption (2,200 kcal per adult and day) estimated absolute poverty for 1989 at 61.3%. Various reforms in the economic and the social sector, coupled with favourable climatic conditions in the mid 90s, led to a decline of absolute poverty to 45.5% in 1995/96, with 47% of the rural population and 33% of the urban population below the poverty line. (FDRE, 2000, 5)

610 UNDP, 1997.

611 Berhanu Abegaz, 2001, 184. EDT increased to US$ 10,070 million in 1997, of which 62% is owed to bilateral donors, mainly to Russia for military purchases during the Soviet era. Today, Ethiopia belongs to the group of Heavily Indebted Poor Countries (HIPC). Press release by the World Bank: *"November 12, 2001—The World Bank's and the IMF announced today that Ethiopia has taken the steps necessary to reach its decision point under the Heavily Indebted Poor Countries (HIPC) Initiative, becoming the 24th country to qualify for debt relief [...]. HIPC debt relief from all of Ethiopia's creditors will amount to approximately US$ 1.3 billion in net present value (NPV) terms or 47 percent of Ethiopia's total official external debt [...]. Debt service as a percentage of exports will thus be cut by more than half, declining from 16 percent to 7 percent by 2003 [...]."* [www.worldbank.org/developmentnews/stories/html/111201a.htm]

1991/92 to 0.9% in 1995/96, despite the devaluation of the Birr and relaxing price controls. The government deficit could be reduced significantly due to improvements in revenue collection arising from tax reforms and strict expenditure measures, especially in the area of defence spending which fell from 35% of total government expenditures in 1990/91 to 8.6% in 1995/96.[612] Thanks to curtailed defence spending,[613] combined with increased flows of Official Development Assistance (ODA), public expenditure (as share of government recurrent expenditures) was raised in the education and health sector between 1989/90 and 1996/97 from 11.9% to 17.9%, and from 3.5% to 5.8% respectively.[614] An important contribution to the positive development of the Ethiopian economy was the massive devaluation of the Birr in 1992 and trade liberalisations. In 1996, all price controls with the exception of petroleum and petroleum products, fertiliser, and long-distance transport were abandoned.[615]

The ***evaluation*** of the above mentioned policy reforms produces mixed results. While overall poverty fell from 61% to 46% during the period 1989 to 1995,[616] the macroeconomic policy reforms affected different segments within the population quite differently. It seems that households with more assets (labour, land, draught animals), better education level, and better access (shorter distance to all-weather road and towns) can take advantage of reforms, while the others seem to be left out and trapped in the downwards poverty spiral.[617] Therefore, the proposed reform of the agricultural sector will also have to be evaluated against the background of poverty disparities.

### 7.1.1 Agricultural-Development-Led Industrialisation (ADLI)

Agriculture is still the backbone of the Ethiopian Economy: 83% of the population are employed in the agricultural sector, and agriculture contributes 53% of the GDP and 90% of export revenues.[618] In an attempt to shift government priority from urban to rural areas, the Agricultural-Development-Led Industrialisation (ADLI) policy was formulated.[619] The smallholder farming sector was made the ***focus of economic development,*** with a particular focus on agricultural extension and credit schemes, the expansion of primary education and primary health care, and investments in the rural water supply and rural roads. However, ADLI does not only concern agriculture, though agriculture is meant to be the first stage of economic development. ADLI defines industrialisation as a final goal of the country. The ADLI strategy is based on using agriculture as the primary stimulus to generate increased output, employment, and income. Agriculture should also serve as an input for the development of the other sectors. The agricultural sector should contribute to (i) raise the country's export earnings, (ii) meet domestic demands for food and raw materials, and (iii) expand markets for industrial commodities. The industrial sector should absorb the surplus rural labour, should expand domestic markets for agricultural commodities, and should use agricultural products as an input. In a first phase starting in 1994/95 a country-wide ***extension programme*** for areas with reliable rainfall was started. The main emphasis of the programme was based on the diffusion of ***technology packages*** including artificial fertiliser

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612 UNDP, 1997.

613 Defence expenditures for the period 1993/94 to 1997/98 were below 3% of GDP but rose sharply to an average of 10.7% for the 1998/99 – 1999/2000 period. (FDRE, 2000, 7)

614 FDRE, 2000, 6.

615 UNDP, 1997, 9.

616 Based on a survey of six below-average PA's in Central and Southern Ethiopia at two different periods in 1989 and 1994/95. (Dercon & Krishnan, 1998, 4)

617 Dercon, 2000, 12.

618 CIA World Factbook 2001 [www.cia.gov/cia/publications/factbook/]. The percentage share of agriculture of the total labour force has even increased form 80% in 1980 (including Eritrea) to 83% (without Eritrea) in 1998. (UNCTAD, 2000, 217)

619 A vision also shared by IMF stating in FDRE's Framework Paper (1998) that *"[...] Ethiopia's growth prospects rely heavily on providing the proper incentives to smallholder farmers, domestic entrepreneurs, and direct foreign investors. First, agriculture-led growth is to be driven by productivity improvements in smallholder agriculture. Progress will depend critically upon the diffusion of technology, export promotion policies, and the availability of affordable credit as a result of the active promotion of rural banks."*

and improved seeds and the provision of agricultural credits.[620] It is estimated that about 37% of the farming population were served by the extension programme in 1998/99. The first phase of ADLI focuses on agriculture with regard to improving the food security situation within the country as well as boosting the export sector. Accompanying measures include the development of irrigation schemes, addressing food insecurities with Food-for-Work projects, increasing commercialisation with more intensive farming, increasing the proportion of marketable products and decreasing the proportion of subsistence production, greater market integration, development of agricultural credit, enhanced research and extension services, establishing of service co-operatives, production of farm tools and equipment, and development of rural infrastructure.[621]

### 7.1.2 Rural markets in Ethiopia

Sustained productivity growth involves an evolution from subsistence oriented, household level production geared towards meeting mainly household needs towards a more integrated economy based on specialisation, labour division and exchange. Moving away from subsistence towards ***higher market integration*** makes available new production possibilities relying on purchased inputs. This is especially also necessary for Ethiopia, where more than 80% of the population is engaged in the farming sector, with different degrees of subsistence orientation, and where food deficits for many households are a fact.[622] Productivity growth in historical times has usually occurred parallel to the emergence of efficient and reliable markets.[623]

Mean daily calorie intake of Ethiopians is below what the World Health Organisation considers sufficient.[624] National food production must therefore grow substantially if the country wants to be successful in achieving the goal of food self-sufficiency in light of an increasing population. It is unrealistic, however, to expect a necessary annual food production growth in the order of 3% to 5% from ***low-input agriculture*** alone, especially considering the fact that land reserves are available practically only in marginal areas such as steep slopes susceptible to soil erosion or lowlands with high climatic risk, high health risks for humans and livestock, and high investment demand for land reclamation and irrigation.[625] It can furthermore be expected that farmers have exploited all available possibilities to increase production on their land. Productivity growth must thus mainly be realised on existing cropland, through yield growth relying on a ***high-input strategy***.[626] This again requires a market system where part of the production is sold to purchase inputs that allow such an increased production. Thus, a co-ordinated system of input supply and delivery, farm finance, reliable access to output markets, and an effective agricultural research and extension system is necessary.[627]

However, relying on unstable markets is an extremely ***risky business*** for poor households living on the margin of survival. Farmers react to uncertainty by relying on highly personalised social or kinship

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620 A major characteristic of the extension package programme is to rely on external inputs, mainly artificial fertiliser. The programme has shown less success, even failure and rejection in dryer areas. (Mitiku Haile, 2000, 23)

621 FDRE, 2000.

622 The National Disaster Prevention and Preparedness Commission (DPPC) estimates for the crop year 2000/2001 that some 6.2 Mio people (about 10% of the total population of 62.8 Mio in 1999 (World Development Indicators Database, July 2000, The World Bank)) need food assistance. (FAO Press Release, 9. April 2001)

623 Dejene Aredo, 1995, 5.

624 The index of per capita agricultural production decreased from 103 (1986-88) to 97 (1996-98) (1989-91: 100). Average daily calorie supply increased from 1,677 to 1,858 kcal/day between 1987 and 1997. The WHO estimate of sufficient calorie intake is 2,200 kcal/day. Food aid amounts to 50% of total import. (Figures from before 1993 including Eritrea, WRI, 2000) It could be postulated that in light of decreasing per capita agricultural production the increase of mean daily calorie intake is mainly due to increased imports, especially for the growing urban population, but that for the rural population self-sufficiency is declining.

625 An observation not only valid for Ethiopia, but for the whole of Sub-Saharan Africa.

626 This is not to deny in any way the important role of traditional low-input approaches to enhance land productivity. Purchased inputs such as improved seeds and artificial fertiliser should also not be seen as a replacement for local technologies aiming at increasing land productivity (i.e. crop rotation, manuring, green manuring, managed fallow, ect.) but as a supplement.

627 Jayne & Daniel Molla, 1995, 5; Gordon, 2000, 4.

arrangements (e.g. patron-client relations, 'moral economy', social networks) and, as much as possible, on self-sufficiency or subsistence production patterns (e.g. 'agricultural involution').[628] An important aspect in achieving sustained productivity growth is thus to improve the reliability and predictability of markets for agricultural inputs, credit, labour, land, commodities, and agricultural outputs. Besides improvements of the markets themselves, access to markets, access to information with regard to marketing, and access to information and knowledge with regard to sustainable agriculture is of paramount importance.

So far, only ***increased production*** has been mentioned, and it is intuitively clear that there is an interdependency between production increases relying on inputs (e.g. artificial fertiliser) and the market system. It is, however, not yet clear, how ***SWC investments*** fit into the market system, how an improvement of the market system could enhance investments in resource conservation, or how a weak market influences land users' investment behaviour. The following hypotheses can be formulated:

- Substantial yield increases can only be achieved by applying more artificial fertiliser, both per unit area, and in area coverage. Artificial fertiliser, however, is only of use if it remains on the field. On sloping land, runoff is high and there is a pronounced danger of fertiliser being washed away. This can largely be avoided through SWC, with conservation structures acting as barriers to control runoff.[629] SWC investments would thus at the same time contribute both towards controlling soil erosion and, in combination with artificial fertiliser, towards increasing production.
- As has been shown in the CBA (cf. Section 6.2), initial investment costs for SWC are very high. These costs can only be recouped by individual households if crop production increases substantially.
- Household income can be increased if high-value market goods are produced. There are possibilities to use conservation structures directly in a productive manner by planting such high-value goods on or directly behind the SWC structures and profiting from improved land qualities and higher soil water availability.
- In areas with insecure rainfall, land terracing can contribute considerably to water conservation. SWC could thus enable farmers in such areas to grow more high-value instead of drought resistant crops.

An important aspect of market performance is the relationship between the structural characteristic of a market (e.g. degree of concentration, the number of market participants and their size distribution, and the difficulty or ease for market participants to secure an entry into the market) and the competitive behaviour of market participants. This in turn has an influence on the performance of the market.[630] It is assumed that markets perform well if (i) the marketing margins charged by various actors in the marketing system are consistent with costs, and that (ii) the degree of market concentration is low, i.e. the number of market participants operating in a market is large enough to ensure competition,[631] which in turn is assumed to be responsible for low costs.

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628 Pausewang, 1992, 194; Jayne & Daniel Molla, 1995, 5.

629 Reardon & Vosti (1997b, 138) differentiate four types of technologies:
(i) technologies that increase production but damage the resource base (e.g. a modern variety that exhausts soil nutrients, irrigation leading to salinisation),
(ii) technologies that increase production but with ambiguous effects on the natural resource base (e.g. fertiliser use),
(iii) technologies that improve the natural resource base but with ambiguous effects on productivity (e.g. certain agroforestry systems),
(iv) technologies that improve the natural resource base and increase productivity (e.g. tied-ridging that prevents fertiliser runoff and conserves top-soil or nitrogen-fixing high-yielding varieties).

630 Gebremeskel Dessalegn et al., 1998, 4.

631 A market is competitive if (i) there are many buyers and sellers, (ii) there are no dominant market participants powerful enough to pressurise competitors or engage in unethical marketing practices, (iii) there is no open or concealed complicity among market participants regarding pricing and other marketing decisions, (iv) there are no artificial restrictions that obstruct mobility of resources, (v) there is free entrance of buyers and sellers with no special treatment of specific groups or individuals, and (vi) there is a homogenous product so that customers are indifferent between supplies offered by alternative channels. (Gebremeskel Dessalegn et al., 1998, 4)

***Rural markets*** do not perform in an optimal way because they are characterised by several risks, such as

- ***high fluctuation*** of goods offered and demanded, which depends heavily on the production (climatic risk) of farmers in the vicinity of the rural market as well as further away,
- ***co-ordination problems*** (e.g. in buying goods from other areas if the supply on the local market is restricted, and vice versa), and
- ***high transaction costs*** (i.e. transportation of goods to markets without road access, obtaining information regarding supply and demand on markets in other areas, obtaining information regarding prices, etc.).

In the Ethiopian context it can be observed that because transportation costs between major production regions and major regional markets are very high, producer prices in remote areas tend to be very low. This in turn decreases the willingness of farmers to sell surpluses. As farmers offer only small quantities of crops on local markets, costs for traders become even higher.[632] Therefore, the number of traders who can operate economically in an area is limited. A concentration of traders takes place, which can lead to situations that are detrimental to competitive markets in theory, but reasonable in light of the small volumes traded.

### 7.1.3 Grain markets in Ethiopia

A study conducted by the Grain Market Research Project under the Ministry of Economic Development and Co-operation[633] on rural markets, based on data collected from rural households and from traders, estimates for the crop year 1995/96 (which was generally a good crop year) the proportion of production marketed by farmers to be around 27%. This figure can be broken down according to ***crop type***. From cultivated oilseeds, pulses, and cereals, about 71%, 37%, and 27%, respectively, were sold. From the total of marketed grain, about 95% come from small farmers, and only 5% from state farms.[634] Small farmers have four ***different channels*** where they sell their produce: (i) direct sales to rural and urban consumers (account for about 31% of total grain sold), (ii) direct sale to rural assemblers / farmer-traders (12%), (iii) sales to retailers (20%), and (iv) direct sales to inter-regional or government traders and warehouses (36%), and direct sales to Government owned mills. A further feature observed is the concentration in the wholesale grain market. The authors of the study conclude, however, that despite this concentration of the grain trade in the hands of only few traders, their influence is not market dominating, and their power is not sufficient to influence grain prices to their advantage.

The above-mentioned study found that farmers sell on the average 79% of their grain immediately ***after harvest*** between January and March, and 21% between June and December. Although farmers know very well that prices immediately after harvest time are much lower than during the summer months, they mentioned different reasons for selling at that time: fear of theft and storage losses, meeting cash needs for the purchase of food, for covering wedding expenses, and for repaying loans and taxes. The study further concludes that farmers' bargaining power is generally weak due to the large number of farmers selling and the limited number of wholesalers buying, the lack of direct access to other than the nearest local market or to alternative channels, and the absence of all market extension services such as information about prices.[635] It

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632 Economies of scale in marketing activities play an important role in Ethiopia, as rural markets are dispersed and thin. The more traders can buy on one market (up to the maximum load of their lorry), the cheaper become the transport cost per quintal of grain.

633 If not otherwise indicated, the information is based on Gebremeskel Dessalegn et al., 1998.

634 The portion of domestically produced grain is 98.4% from farmers, and 1.6% from state farms. (Gebremeskel Dessalegn et al., 1998, 10)

635 An example from Nicaragua demonstrates the importance of market information: an NGO distributes every second week a list in every village with currently valid prices for major crops on different markets within a radius of about 150 km. Farmers in remote villages mentioned that thanks to this information they could increase mean revenues from selling their produce compared to the time before this information was provided. Farmers now travel by bus to the market with the highest price offered for their produce. Despite the considerably high travel

was further found that traders rarely provide advance payment, credit, or any other incentive other than the price paid to the farmer to encourage him/her to sell grain to him. Further, farmers selling to a specific trader were not bound through factors such as kinship, ethnic, or religious relationships.

***Traders*** calculate the price at which they buy grain by deducting miscellaneous costs and a net profit margin from the wholesale price in Addis Abeba. Prices on local markets are thus largely determined by grain prices prevailing in Addis Abeba.[636] Depending on the fluctuation of prices in Addis Abeba, the net benefit to the trader depends heavily on securing transport of purchased grain to Addis Abeba. Without own means of transport, net profits to traders can drop to minimal levels if grain prices are low in Addis Abeba, which are not sufficient to make grain trade from remote rural markets to centres worthwhile. Traders sell the grain either to terminal markets such as Addis Abeba or to grain deficit areas, but rarely to other local or regional markets.

Before 1990, grain trade was almost totally in the hands of government and para-statal enterprises. Farmers were obliged to sell a certain quota of grain at fixed prices to the then Agricultural Marketing Corporation (AMC). Producer prices were deliberately kept low[637] in order to enable the state to buy cheap grain for urban centres (34% of all grain purchases were destined for Addis Abeba alone), to support the military (12%), and to realise revenues (e.g. 27% of AMC purchased grain was sold to state owned mills and resold to consumers). Selling grain to private traders was allowed if quotas were met. The number of traders per market was restricted, and traders were obliged to sell a specified amount (usually 50% of their purchase, in surplus areas such as Gonder, Gojam, Arsi and parts of Shewa 100%) to the AMC.[638] Although these ***restrictions*** were abolished in 1990, other barriers still remain which restrict private participation in the grain trade. The authors of the Grain Marketing study mention lacking capital to be the most important. They calculate that capital investment is more than US$ 10,000 for purchasing, storing and transporting grain for one year. Despite these barriers to participate in the grain market, 95% of the grain sold by farmers was handled by the private grain-trading sector in 1996.[639]

The authors of the market study point out that exchange between different ***regional markets*** is very limited despite considerable price differences. They argue that under competitive market conditions the price difference between two markets is largely determined by transfer costs consisting of transportation, handling, and fixed costs, and transaction costs which are composed of (i) costs of time spent in identifying and negotiation transactions, (ii) risks associated with opportunistic behaviour of trading partners, (iii) contract monitoring, and (iv) contract enforcement. Transport costs are in the order of EB 5 per quintal grain per 100 km, and handling costs are another EB 2.5 per quintal. The traders' margin ranges between EB 4 to 12 per quintal grain only.[640]

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costs, revenues are still bigger than if the goods are sold in the vicinity to traders who depress prices to cover their own transport costs.

636 A study conducted in 1994 calculates the farm gate price for red tef at 78% of the retail price in Addis Abeba (farm gate price: EB 144/q, retail price in Addis Abeba: EB 185/q.) Margins at different trading stages are: assemblers margin: EB 3/q, wholesalers margin: EB 29/q, retailers margin in Addis Abeba: EB 10/q. From these margins variable and fixed costs have to be deducted. For example average wholesaler's margin of EB 29/q is broken down to EB 19/q variable costs (e.g. transport costs, grain movement checkpoint charges, labour costs, municipal charges, and broker's fee), and EB 2/q fixed costs (e.g. storage rent, depreciation of sacks). This leaves an average profit of EB 8/q (28% of total margin) to the wholesaler before tax. (Kuma Tirfe & Mekonnen Abraham, 1995, 217)

637 Compared to the pre-liberalisation period average producer prices (in 1995 constant prices) increased for white tef, white wheat, and maize by EB 63, 60 and 19 per quintal, respectively. Producer's price share of retail prices for white tef, white wheat, and maize increased by 32%, 33%, and 42%, respectively. The share of producer's price as of retail price averaged 93% for white tef, 91% for white wheat, and 86% for maize for the period 8/1996 to 7/1997. (Asfaw Negassa, 1998, 11). Dercon (2001, 8) reports an average increase in real producer prices for crops by 26%, resulting from the abolition of the quota system and market reforms. The increases are higher for those crops that used to be covered by the quota system.

638 Daniel Molla et al., 1995, 5.

639 Asfaw Negassa, 1998, 2.

640 Gebremeskel Dessalegn et al., 1998, 28.

An aspect which is of specific importance in rural Ethiopia with regard to marketing are ***transaction costs*** accruing to traders, which are not yet reflected in the above mentioned profit. As farmers are not able to produce sufficient surpluses to sell bigger quantities of crops at a time, they usually sell small quantities of a few kilograms per transaction if they need cash. If for example a trader wants to buy 100 kg of grain, he might have to negotiate with 20 farmers selling each 5 kg. Negotiation and buying includes weighing the grain, quality control, and price negotiations. Only if he bought 50 kg from 2 farmers each, transaction costs could be kept low. For traders it is thus not attractive to buy grain from rural markets located in poor areas. The amount of grain a household can sell is very small, while costs for traders in relation to the selling price are high, which brings down the possible profit.

### 7.1.4 Fertiliser markets in rural Ethiopia

In the course of increasing population depending on agriculture and the necessary transition from fallow-based to permanent cultivation, soil fertility becomes a major constraint in light of declining per-capita availability of cropland.[641] In order to increase crop yields, ***purchased inputs*** such as artificial fertiliser, improved seeds, and to a certain extent herbicides and pesticides are necessary as a supplement to and in combination with improved crop and land management practices, greater amount and more efficient use of organic fertiliser, expansion of irrigation, more efficient pest management techniques, and minimising post-harvest losses. Increased input of artificial fertiliser becomes especially important as fuelwood scarcity forces households to divert animal dung from its traditional role as agent to enhance the soil nutrient content to fuelwood substitute.[642] Increased dependency on agricultural inputs needs a functioning market that delivers the right input at the right time to the right place on the one hand, and a functioning market where farmers can sell their surplus, on the other hand.[643] Although artificial fertilisers have been widely promoted, only about a third of the rural households used them in 1995.[644] Fertiliser per hectare arable land increased from 5 kg (1985-87) to 16 kg (1995-97) (compared to about 27 kg in Kenya and 59 kg in Zimbabwe in 1995-97).[645] Results of the SG 2000 project showed that yields can be increased by 200 to 300% over the national average.[646] Incremental yields by using 100 kg DAP per one hectare tef, wheat, maize, barley, and sorghum are 3.5 q, 6.1 q, 7.4 q, 6.8 q, and 3.4 q, respectively. Current recommendations are 100 kg DAP and 100 kg

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641 Per-capita cropland availability declined from 0.29 ha (1987, including Eritrea) to 0.17 ha (1997, without Eritrea). (WRI, 2000)

642 The main reason mentioned by farmers for increasing the quantity of artificial fertiliser is declining soil productivity. Successful application of fertiliser on farm in the previous year, improved availability of fertiliser, and increased credit availability to buy fertiliser was only mentioned second. (Mulat Demeke et al., 1998, 45)

643 Pender, 1999, 24.

644 Mulat Demeke et al., 1997, 1.

645 WRI, 2000.

646 The SG 2000 (Sasakawa Global 2000) project is based on half-hectare trial plots managed by the participating farmers, utilising improved seeds, improved management practices, and fertiliser types and rates as recommended by the National Fertiliser Input Unit of the Ministry of Agriculture. (Mulat Demeke et al., 1997, 2) The objectives of the SG 2000 project are the following: (i) Accelerate the adoption by small-scale farmers of modern crop production technology (fertilizer, seed, crop protection chemicals, agronomic practices) in food crops, mainly maize, wheat, sorghum, rice, cassava, grain legumes, and potatoes. (ii) Restore and maintain soil fertility, with increased use of chemical fertilizer as the core strategy but supplemented by various organic and indigenous mineral sources. (iii) Introduce additional energy into smallholder food production systems through improved draft power (animals, implements, small-scale machinery) and conservation tillage systems using herbicides. (iv)) Expand on-farm grain storage capacity of small-scale farmers, both to fetch higher prices and to ensure greater food safety and security. (v) Introduce efficient agro-processing technology suitable for micro-enterprise development, with priority on identifying new income-earning opportunities for women's groups. (vi) Promote development of farmers' associations for saving and loan services, input supply, and output marketing. (vii) Promote establishment of private enterprises that can serve the smallholder farming sector, especially for improved seed, fertilizers, and crop protection chemicals. [http://www.cartercenter.org/agriculture.html]

urea per hectare for tef, wheat and maize. For barley and sorghum the recommended rates are somewhat lower.[647]

Until 1992, the import, distribution and marketing of fertiliser were fully under ***state control***. The handling and selling to farmers was organised by staff of the MoA. This system was characterised by shortages and delays, and in high-potential areas, fertiliser was rationed due to insufficient quantities available. After 1992, the private sector was permitted to engage in the import and distribution of fertiliser.[648] Liberalisation of the fertiliser trade was achieved in 1997, the same year as subsidies on fertiliser were abolished.[649] ***Subsidised fertiliser*** was sold at EB 200 per 100 kg. When subsidies were abolished, fertiliser prices increased to about EB 260 per 100 kg. In selected areas, farmers were asked about the fertiliser price at which they will stop buying. Mean maximum price (willingness-to-pay, WTP) was in the order of EB 245/q DAP.[650]

Within the country about 70% of all artificial fertiliser was sold to three Regions, namely Oromiya (Shewa, Arsi), Amhara (Shewa, Gojam), and Southern Region, mainly because these areas have a relatively developed transport infrastructure and a high agricultural potential, allowing profits from selling fertiliser to be highest. Remote areas are left out because profits are much smaller because of high transport costs and government-controlled price ceilings (until 1996/97). If transport costs are added to the fertiliser price according to the distance from the main import port (Assab until 1998, Djibouti afterwards), but no cost savings in importing fertiliser are considered, average fertiliser retail prices would increase to about EB 261/q. This price is considerably above the maximum ***WTP stated by farmers***, but corresponds more or less to what is currently charged in remote rural areas. The effect of market liberalisation and the devaluation of the Ethiopian currency would thus probably result in a reduced demand for fertiliser. If costs for importing and distributing fertiliser were reduced through true competition on all levels (import, distribution, wholesale, and retail market), through co-ordination, and through taking advantage of economies of scale, net savings in the order of EB 15 per 100 kg artificial fertiliser are feasible, reducing the retail price to about EB 240/q, a price similar to the stated WTP. Cost savings would, *ceteris paribus*, lead to decreasing retail prices and therefore to an increased demand of artificial fertiliser with the associated postulated positive effects on yields.

A result of partly liberalised markets after 1990 was an ***increase in farm gate prices*** for major grain crops in major surplus-producing areas. However, the authors of the above-mentioned study point out that grain markets are not yet performing in an optimal way and that there is still scope for reducing marketing costs. They specifically mention that infrastructure in many areas is still in a very bad condition, and that therefore only few surplus-producing areas can profit from the market liberalisation and the correction of overvalued currencies, as more remote areas are simply left out by traders because transport costs reduce net margins. The authors conclude that there is a strong linkage between the performance of the grain marketing system and the profitability of fertiliser use by farmers. More efficient marketing systems can help to pull out grain quickly from surplus-producing areas, therefore relieving price depressions resulting from such surpluses and delivering grain more quickly to deficit areas. Better road infrastructure and storage facilities could reduce the difference between the buying and the selling price and thus also increase the margin for farmers. The authors hypothesise that if revenues from grain production and selling increase, demand for fertiliser also increases, which again has a positive influence on total grain production.[651]

It seems that the benefits of the liberalisation of the grain and fertiliser market and the devaluation of the currency have not yet been fully realised because of various constraints in the marketing system and institutional issues.[652] Fertiliser retailing is largely controlled by a few companies with a limited network of sales outlets. The distribution system is thus not responsive to the needs of farmers. Fertiliser marketing is constrained by the inefficient ***credit system***, because credit was linked to particular fertiliser distributors.

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647 Mulat Demeke et al., 1997, 4.

648 Mulat Demeke et al., 1997, 4.

649 IMF, 1999, 22.

650 Mulat Demeke et al., 1997, 6ff.

651 Mulat Demeke et al., 1997, 23ff.

652 Mulat Demeke et al., 1997, 1998.

Fertiliser is sold to farmers on a loan base. Farmers are forced to repay the loan immediately after harvest, which can result in an oversupply of grain and low prices, forcing farmers to sell bigger quantities to recover the costs. Penalties for farmers failing to pay back the loan because of genuine problems (e.g. crop failure because of pests or climatic irregularities) induce negative attitudes towards the technology and reinforce risk-averse behaviour. There is no insurance against crop failures and no mechanisms to extend credits in case of crop failure and inability to pay back the credit. Farmers are forced to sell important assets such as livestock. Often, credit delivery to farmers is inefficient and credits are delivered on political grounds and not on real demand. Agricultural extension agents have to spend too much time to collect loans, time which should be used for other tasks.

Returns to fertiliser declined sharply between 1992 and 1997, mainly because fertiliser subsidies were withdrawn, which increased the fertiliser price relative to the output price. The ***value-cost ratio*** (VCR) fell below a critical value of 2[653] for most areas and crops. In 1992, the VCR was above 2 for all considered cases. Although it is assumed that a VCR of 2 must be reached to convince farmers to use fertiliser, it could be observed that despite the sharp decline in profitability fertiliser consumption did not proportionally decline. The authors conclude that in the absence of alternatives to maintain or enhance soil fertility, farmers have no other choice but to continue investing in artificial fertilisers. A comparison of user and non-user households and Weredas showed clearly that user households and Weredas allocated more land to tef and wheat, which fetch relatively higher prices. Less land is allocated to barley and sorghum because of the relatively lower prices and because the areas where barley and sorghum are grown are more risky production environments with regard to high altitude, high rainfall, waterlogging and risk of frost in the case of barley, and moisture stress and drought in the case of sorghum. Other important factors explaining the use of fertiliser was the higher proportion of households using improved seeds, pesticides, and irrigation compared to households not using such inputs. Those households using fertiliser are generally richer in terms of TLU and amount of land. Households with adequate productive resources can generate more cash to purchase fertiliser or may be less risk-averse compared to resource-poor households. Those Weredas where more fertiliser is consumed are characterised by a smaller dependency on food aid, have better access to banks, have more households that are members of service co-operatives, have more distribution centres for fertiliser and better access to market places and the road network.[654]

It could be demonstrated that ***fertiliser efficiency*** is only sub-optimal, as other important aspects are not sufficiently considered such as timely application of fertiliser, crop and soil specific fertiliser rates, balanced application of different types of fertiliser, to enhance soil organic matter content, which prevents nutrient leaching and improves physical soil characteristics, and soil and water conservation contributing to moisture conservation and to reducing soil loss and run-off. Moisture stress or drought, negative effects on local varieties (e.g. excessive growth, toppling over because stems are not strong enough to carry the ear, mere biomass production), and increased weed growth can lead to situations in which fertiliser application can even affect total production negatively. Fertiliser is therefore too expensive with regard to possible revenues. Generally, high risk of crop damage, be it due to climatic factors or to pests or diseases, makes investments in fertiliser unattractive.

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653 A value-cost ratio of 2 would imply that the value of the incremental crop output thanks to fertiliser application is double the costs for fertiliser. It is assumed that because the risks of applying fertiliser are considerable, market failures leading to high transaction costs are common, additional costs accrue because of fertiliser application (i.e. additional labour input necessary for weeding, harvesting and threshing), and non-monetary transaction costs associated with credit accrue, a critical threshold value of 2 must be reached to make fertiliser profitable and convince farmers to use it. (Mulat Demeke et al., 1997, 8)

654 Mulat Demeke et al., 1998.

## 7.2 The Market Environment in the Research Areas[655]

*"Last year I sold an ox. I invested part of the money to buy a bull. The rest of the money we used to buy crops, mainly tef. When the tef was expensive in Aliyu Amba we exchanged it against barley and beans from Ankober. Every year I do the same, sell the ox, buy a bull, train it for ploughing and sell it again for a higher price. The difference is used to buy grain"*
*(Farmer from Mesobit & Gedeba, 1998)*

### 7.2.1 A characterisation of local markets in the study areas

***Local markets*** in the different research areas differ considerably, mainly depending on whether the market is connected with a road or not, or on its distance to the next bigger market or consumer areas. The most developed local market is the one in Aliyu Amba serving the community of ***Mesobit & Gedeba***. Traders from Addis Abeba come with their own lorries to buy the high quality tef from the vicinity. This allows, at least partly, to avoid intermediate trade and traders do not have to share profits. Some of these cost savings are pass on to farmers through higher prices than what is paid in other localities. A second important feature of the market in Aliyu Amba is that farmers in the vicinity have started to grow tef not only for home consumption, but also for the market. Thus, they are able to sell much bigger quantities at a time, lowering transaction costs (e.g. negotiation, quality control, etc.) for traders. Also much better developed than on the other local markets is the integration of input and output supply and commodity marketing. Traders have often set up small shops around the market place where they buy grain and sell agricultural inputs such as fertiliser, herbicides, and tools, as well as food items and household commodities. Traders in Aliyu Amba are quite heavily involved in the unofficial credit business. Farmers from the vicinity not only buy the assigned quantity of fertiliser, which is linked with official government credits; they even buy larger quantities and, in addition, also herbicides and pesticides. Credits are obtained from relatives, who are still the most important source, but farmers also ask traders. Such credit is usually expensive (8 to 10% per month) and of short duration. Farmers are forced to repay the credit immediately after harvest when prices are lowest. Some farmers, however, mentioned that because they always sell to the same trader they get cheaper credit with better conditions. In addition to being rather well equipped, the market in Aliyu Amba is located on the border of two Regions, namely Amhara Region and Afar Region, different ethnic groups, namely Amhara, Argoba, and Afar, two religious groups, namely Christians and Muslim, and two production systems, namely sedentary crop cultivation and pastoralism. This market also links the highland and the lowland. This makes it an important place of exchange of goods from lowland areas, such as sorghum and millet, and livestock, mainly cattle and goats, which is the main income source of the Afar nomadic herders, and highland goods such as barley, beans, and tef, and to a limited amount sheep. Another important feature of this market linking different zones is that farmers have relaxed certain restricting regulations. It could be observed that Christian farmers do not observe religious holidays as strictly as in other areas and are more engaged in handicraft and other opportunities offered in the market.[656]

The local market for ***Andit Tid*** is Gudo Beret. This market is located on the main highway linking Addis Abeba and the northern parts of the country. This makes it attractive for grain traders, who come from either Addis Abeba directly or from lowland areas such as Shewa Robit to buy highland crops such as barley, beans, lentil and linseed. Farmers usually sell small quantities of a few kilograms only. Profit is estimated by traders to be in the order of EB 10 to 15 per 100 kg grain because they buy the grain directly from farmers and sell

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655 The information in the following Sections 7.2 to 7.4 is based on interviews, discussions held with key informants (e.g. traders) and own observations made during the field visits in 1992, 1994, 198, and 1999.

656 Ludi, 1999, 14ff.

directly to brokers on terminal markets such as Addis Abeba. However, traders complained that farmers sell in such small quantities that trading becomes very time consuming. They specifically mentioned that they have to negotiate with each farmer individually concerning the price for a given quality offered. One trader mentioned that he has employed a middleman in Gudo Beret who charges for his services according to the amount of grain he is able to acquire from farmers. The trader mentioned that because of this middleman, his profit is reduced by one third, but that this way he can come to Gudo Beret late in the afternoon, load the sacks and return to Addis Abeba. In his opinion, the time saved is worth employing a middleman.

Distinctively different is the situation in ***Maybar***. The nearest local market where farmers sell or exchange small quantities of goods is Tossa Fellana. This village is not connected by road and about 2 hours walking distance from Maybar or 6 hours walking distance from the main highway and Dese, the Zonal capital town. Traders from urban markets such as Dese or Kombolcha do not come to this place. However, intermediate farmer-traders frequently buy grain from Tossa Fellana and sell it to traders on the urban markets. If farmers can sell bigger amounts of grain they travel to Kombolcha or Dese themselves to avoid income losses from intermediate trade. Several farmers from Maybar are engaged in intermediary trade themselves. They buy the grain preferably from neighbours where they have to pay the least or from the local market in Tossa Fellana. If they can buy enough for a donkey or mule load, they travel to the urban markets to sell the grain. Most of these assemblers always sell to the same wholesaler. Some farmers also mentioned that they have an agreement with either restaurants or women preparing *talla*, the local beer.

*Figure 54: The difficult terrain in the Simen Mountains is partly responsible for the low market integration of the land users. Another reason is widespread poverty – people simply lack goods to sell and cash to buy commodity items.*
*[Photo: E. Ludi, 1994]*

In the ***Simen Mountains***, two types of markets exist. On the one hand, these are small daily and bigger weekly markets in small towns along the road, and on the other hand, there are rural markets that are extremely remote. One such market is in Arkwasiye, a day's walk from the nearest centre on the main highway. This village is located on a pass between two valleys and allows the exchange of products from two different agro-ecological zones. It also marks the crossing of old trading routes between centres such as Gonder, Mekelle, Lalibela, and Axum. An interesting aspect is that in 1976 Arkwasiye was a market place under the open sky on a meadow far away from any settlement.[657] By 1994, a village of about 50 houses had been built around the old market place.[658]

In ***Anjeni***, traders have opened up business immediately after the market liberalisation of 1990 when the obligation to sell a quota of grain to the AMC was abolished. Traders have installed themselves in the village of Anjeni, where the weekly market takes place. They buy grain from farmers from the vicinity and sell it to intermediate traders from the next town with own means of transport. It could be observed in 1992 that the quantity of marketed grain was extremely limited. According to one trader interviewed, he bought about 400 q crops from a total of 2,000 sellers within a period of 6 months. The biggest share of produce bought from farmers was rape-seed (200 q) followed by tef (100 q), noug (15 q), and wheat (10 q).[659] Reasons for this limited market integration, despite an almost three-fold increase of prices within 3 years (e.g. farm gate price for white tef was EB 53/q in 1988/89, but EB 140/q in 1991/92) were that firstly people were still uncertain about the development of the political and market situation, and secondly distrust of the market runs deep. Thirdly, the abolition of quotas has led to a similar situation as after the Revolution of 1974/75. At that time, tributes and leasehold obligations were abolished, and farmers suddenly had control over their entire harvest. They sold less than what they previously had to deliver in the form of tributes and fees. They therefore could enhance their food supply. Fourthly, the amount of crops a farmer has to sell was to a great extent determined by the price for fertiliser and the amount of taxes. As both did not increase, farmers had to sell smaller quantities to buy the same amount of fertiliser and pay the taxes. And lastly, the 'subsistence mentality'[660] of many Ethiopian farmers aimed at maximising its own independence and minimising dependence on other farmers, markets, or the government, is not expected to disappear within a short period of time.[661]

A typical feature of the markets in all research areas is its ***seasonality***. Immediately after harvest, prices are very low and gradually increase until they reach their maximum during the summer months, i.e. during the rainy season and before the next harvest. Depending on the expected harvest, prices during the summer months are between 10% and 50% higher than immediately after harvest (cf. Appendix 5.5). Indications from Maybar show that most farmers sell grain one to two months after harvest, i.e. in July and August for the *Belg* harvest, and from January to March for the *Meher* harvest. Farmers have to buy crops in April/May and from August to October. Some farmers mentioned that they have to buy crops continuously between March and end of September when the first green maize can be harvested. In Andit Tid the situation is similar. Selling crops usually takes place in May/June (*Belg* harvest) and January/February (*Meher* harvest). Farmers have to buy crops between September and December; some have such small holdings that they have to buy food from the market from June to October. Only few farmers mentioned that they have enough cash to buy grain, and to store their own grain and sell it later at the height of the rainy season when prices are highest.

A further similarity of all rural markets is the ***big number of farmers*** offering more or less the same goods in similar qualities, and the ***small number of traders*** buying the goods. Therefore, the bargaining power of farmers must be expected to be rather low, as competition among farmers is high. How dominant the position of some traders might be is difficult to estimate. They certainly try to keep prices as low as possible. However, many farmers mentioned that if the price on the local market is below a threshold value, they rather prefer to carry back home the grain and try to sell it in the coming week or even to travel to another market where they expect better prices.

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657 Stähli, 1978, 43.

658 Hurni & Ludi, 2000, 88.

659 Ludi, 1997, 40.

660 Mesfin W/Mariam, 1991.

661 Ludi, 1997, 40.

### 7.2.2 Market integration and marketing strategies

A characteristic of all areas with the exception of Mesobit & Gedeba is that the ***market integration*** of land users is generally very low. Both crop cultivation and livestock rearing is primarily targeted towards fulfilling ***household needs***. The major part of the crops produced is consumed directly by the household. Livestock, especially small ruminants, is more often sold than crops to raise cash. They serve as a form of reserve and can be sold easily when the household needs additional cash to buy grain in times of shortage or to pay for other household expenses. What could also be observed in Maybar and Andit Tid is that several farmers had to sell cattle or donkeys, i.e. productive animals, to buy grain. This can be interpreted as a strong signal of increasing impoverishment, as farm households have to sell their productive assets as all other non-productive goods had already been sold to secure survival in previous years. Goods are usually traded in small quantities on local markets to buy small household items that are not produced by the household such as spices, oil, coffee, sugar, salt, soap, cloths, pottery, tools, or medicine. When cereals or pulses are needed, barter trade, where a given quantity of a crop is exchanged for another crop, is more common than selling.

Farmers from Maybar were asked to estimate the amounts of ***crops sold and bought*** during the crop year 1998. Of the 16 interviewed farmers, only one mentioned that he is self-sufficient throughout the year and does not have to sell crops to meet cash needs. From the remaining 15 farmers, 10 are net buyers, i.e. are purchasing a greater amount of crops than selling, and only 5 are net sellers. Quantities of grain sold range between 50 and 350 kg (median: 60 kg). Amounts of grain bought range between 50 and 500 kg (median: 100 kg). The high percentage of net buyers can be explained by the generally very small farm sizes and unfavourable climatic situations in recent times, i.e. mainly failing *Belg* rains, and corresponds well with the estimate of the KA administration that about a quarter of the population of Maybar, including the landless, depends partially or fully on food aid.[662] In Andit Tid, the situation is slightly better. For the crop year 1997/98 one farmer mentioned that he had enough crops and did not have to sell grain or pulses, but that he could sell sheep if he needed cash.[663] Of the other 14 households 8 are net buyers and 6 net sellers with respect to grain, pulses, and oilseeds. One important reservation has to be made: The question concerning selling and buying of crops was usually asked men. What they mentioned concerns the selling and buying of bigger quantities. Once the grain is in the store inside the house, it is the women's task to optimise its use for home consumption, selling small quantities to buy other foodstuff, or exchanging certain crops against others. The interviewed men had no idea how much of the grain is traded in this manner by their wives. Women mentioned that when they take grain from the store, they usually barter it and rarely sell it. Since quantities exchanged are similar, the outcome can be regarded as neutral.

***Livestock*** is the most important source of income for rural households, with the exception of some farmers from Andit Tid who rely heavily on eucalyptus plantations. In Anjeni, for example, 47% of the income was obtained from the sale of livestock.[664] Also in Maybar and in Andit Tid, the biggest share of income originates from selling livestock. In Maybar, only three of the 16 interviewed households did not sell or buy any animals during 1998. 13 households had to sell animals, while only 8 households bought livestock. From the 8 households buying animals, 6 households sold and replaced oxen, horses, or mules. Usually, older and trained animals are sold at a higher price and younger, but untrained animals are bought at a cheaper price in exchange. In all cases, the difference was used to buy either grain or cloths for special occasions such as weddings. Those households not replacing the sold animals usually sold sheep, goats, and calves. However, one household had to sell a donkey and one household an ox in order to buy crops. The others mentioned

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662 A survey carried out throughout Ethiopia interviewing almost 4,400 households indicates that during the 9-month period between 10/95 and 6/96 48% of the rural households were net grain buyers. The authors mentioned that it must be expected that the percentage of net grain buyers increases if considering a whole year, as the 'hungry season' form July to September was not included in the study. (Mulat Demeke et al., 1997, 8)

663 Being able to sustain a household without having to sell crops, but being able to support poor households without compromising own demand, was identified in wealth rankings carried out in Anjeni and Maybar as a goal to achieve and a characteristic of the richest households. (e.g. Ludi, 1997, 50)

664 Ludi, 1997, 67.

that they still have enough small livestock to sell and are not yet forced to sell productive animals such as oxen, mules or donkeys. Looking at whether the interviewed households are net buyers or net sellers with regard to livestock, it becomes evident that from the 13 households selling and/or buying animals 10 are net sellers and only 3 net buyers. Thus, a tendency of farmers to sell livestock in order to buy grain can be postulated. Households lack the means of investing in herds, and shortage of grazing land forces household to de-stock.

In ***Andit Tid***, 3 of the 14 households interviewed (one female headed household has no animals at all) did neither sell nor buy livestock during the crop year of 1997/98. 3 farmers sold good animals at a high price in order to replace them with cheaper animals. Here as well, the difference was used to buy food. More frequently than in Maybar, larger animals such as bulls, cows, oxen or horses are sold without replacement, in order to buy grain. 7 of the 14 households had to sell productive animals. The others sold sheep to buy food. The balance is, similar to Maybar, clearly positive. 9 households sold more animals than they bought. Only 2 households bought more animals than they sold. Both are households with large Eucalyptus plantations. Buying animals is one form of investing the money in a productive manner. They both mentioned that these animals will later be sold to raise money to buy food when the Eucalyptus plantations are not yet ready for harvesting. Similar to the reservation made above with regard to selling crops, livestock and livestock products sold by women are not represented here. Their task is on the one hand to sell small animals such as chicken. On the other hand, women are also responsible for selling animal products such as milk, butter and eggs. However, when asked how much animal products they sell over the year, all women interviewed mentioned that they couldn't estimate the amount as they take every week a few eggs or a small portion of butter to the market.

In ***Maybar***, for most households (8 of the 11 households selling animals) the income from selling animals is bigger than the amount of money needed to buy grain. Three farmers mentioned that they had to pay back a loan they had taken up to buy fertiliser and were thus forced to sell additional livestock. Three farmers mentioned that they had bigger expenses because of marrying a child. Several others mentioned that they had to buy clothes for household members and were forced to sell more animals to cover these high costs. Only one household sold grain to buy livestock.

In ***Andit Tid***, the relation between selling livestock and buying crops is less pronounced. 5 farmers mentioned having bough crops from cash reserves from previous years and were therefore not forced to sell animals in the same amount as they bought grain. Three others mentioned that they could sell Eucalyptus wood to buy grain. Three young farmers mentioned that they work as daily labourers. This income is used mainly to buy grain. Two of these young farmers further mentioned that they wish to increase the size of their herd and thus bought additional livestock with income earned in off-farm labour. In Andit Tid it is much more common than in Maybar to borrow money from relatives or friends to bridge cash shortages. Most farmers taking such a credit mentioned that they only need it for a short period of time and pay it back after harvest. This may also explain the difference between the income generated by selling animals and the expenses for grain. On the other hand, more farmers were forced to sell productive animals in Andit Tid than in Maybar. Since no farmer would sell his productive animals if he had small animals to sell instead, this selling of productive animals in Andit Tid could be explained by the fact that farmers in Andit Tid had been facing food shortages for a longer time and had thus already converted all available small animals. This could also be brought in connection with the mentioned land distribution of 1997 and the situation that in Andit Tid almost all farmers, irrespective of whether they are considered poor or rich, face food shortages. Their holdings are too small to support the household members, and they are forced to sell animals to raise cash to buy food.

With regard to income from selling livestock or crops and the amount of money used to buy crops or livestock, two important aspects have to be remembered. Firstly, these figures are only of an indicative nature. To remember in detail how much grain was bought or sold over a period of one year is very difficult. And secondly, there is a tendency of correcting the figures of selling downwards, as farmers fear that they might be taxed upon their sales. There are rumours that the Government attempts to impose a sales tax on goods sold directly by farmers. It is unclear, however, on what goods such a sales tax will be imposed and if there might be a lower amount exempted from such a sales tax. Farmers were therefore reluctant to state precisely how much crops or animals they sold or how much income they generated.

It has been mentioned that ***Mesobit & Gedeba*** is somewhat an exception with regard to market integration. Most farmers have realised that with investments in soil conservation alone the soil productivity decline cannot be compensated. Almost all are applying manure or compost and 15 of the 20 farmers interviewed are applying artificial fertiliser. With these measures, a more ***intensive production*** can be achieved. The ultimate goal is to increase the output per unit area. The application of artificial fertiliser, however, can be constrained by the availability of cash. Many farmers therefore have started to produce cash crops for the nearby market. Most important grain crop for selling is tef, which is highly valued and has good market prices. It could not be determined which process began first, whether the market orientation followed the increased need for cash to buy fertiliser to overcome soil productivity declines, or whether fertiliser could be bought because of higher cash income from selling goods on the market.

A further strategy, which has a growing importance in Mesobit & Gedeba area, is the ***diversification*** of the production mainly oriented towards the market. Most commonly, farmers grow *gesho*, *chat*, sugarcane, coffee, pepper, and to a lesser amount oranges and lemons. Especially *gesho* is highly valued in highland areas and the demand is constant, as throughout the year local beer is brewed. Furthermore, *gesho* – once dried – can be stored for a relatively long time and thanks to its low weight is easily transportable. Similarly, pepper and coffee are also rather good cash crops, as the demand is more or less constant and transportation easy. Fresh products such as fresh fruits or sugarcane are more difficult, as they easily spoil and transport is more difficult because of its high weight and bulky nature.

### 7.2.3 Prices for inputs and outputs

With the partial exception of Mesobit & Gedeba, farmers do not react strongly to ***price signals*** with respect to decisions which crop type to grow. What seem more decisive in determining the annual crop mix are household needs to secure a sufficient and balanced food supply. In Mesobit & Gedeba farmers grow tef for the market in addition to production for their own need. It can only be hypothesised that farmers might change their behaviour in the medium term if relative crop prices changed. They might switch to other, more lucrative crops, if for example tef prices decreased, because they have to pay back loans taken up to buy fertiliser.

A shortcoming mentioned by the Grain Market Research Project[665] is ***lacking price information*** and lacking possibilities to forecast relative prices based on yield assessments. It can be expected that in the total absence of market information, farmers will not change their cropping behaviour. In order to have an effect on the crop selection, indicative price information must be available at the beginning of the agricultural year. It is hypothesised that farmers observe the market clearly, and that if they observe that the price for a specific crop is significantly higher than it was before over an extended period of time, they will use a bigger area to grow this crop.

***Output and input prices*** in all research areas did rise considerably between 1989 and 1999. Prices were administered by the Government before 1989. Farm gate prices were kept deliberately low. Agricultural inputs were comparably expensive and channelled to a vast extent to the then existing state farms.[666] Following the economic reform in 1991 crop prices rose considerably, for example for white tef from EB 53/q in 1989 to EB 220/q in 1999. This means an increase of more than 400%. For other crops, price increases for this 11-year period are in the same range.[667] For the same period fertiliser prices increased from EB 140 per 100 kg DAP in 1989 to EB 255 per 100 kg DAP in 1998, or only by 45%.

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665 e.g. Daniel Molla et al., 1995; Mulat Demeke et al., 1997; Gebremeskel Dessalegn et al., 1998.

666 More than 2/3 of all government investments in the agricultural sector were targeted at state farms and producers co-operatives, although they cultivated only about 15% of the arable land, and produced only 5% of the total production. (Desalegn Rahmato, 1993, 41)

667 Farm gate price for the year 1989 based on information from the AMC obtained in Dembecha, Gojam. AMC prices were similar in the whole country. (Ludi, 1997, 40) Farm gate prices for 1999 as obtained from local markets and information from farmers in the research sites.

With regard to investments, the value-cost-ratio (VCR)[668] is one measure showing whether the investment costs can be recovered by the additional benefit. In the case of fertiliser investments, price changes between 1989 and 1999 would imply the following:

If we assumed that the yield increase for tef is 370 kg/ha if fertiliser is applied (cf. Table 21), tef prices were EB 53/q in 1989 and EB 220/q in 1999, and fertiliser prices were EB 140/100 kg DAP in 1989 and EB 255/100 kg DAP in 1999, and we further assume that 100 kg DAP are necessary to lead to the mentioned yield increase, then the VCR for 1989 and 1999 are 1.4 and 3.2, respectively. It is usually assumed that because of the high risks involved in fertiliser investments (e.g. climatic risks, marketing risks, higher transaction costs, etc.) a VCR of 2 is necessary to make fertiliser investments attractive for small-scale subsistence farmers. Thus, in 1989 it would have not been a wise decision to invest in fertiliser and to sell the additional yield on the market. In 1999, however, investments in fertiliser were worthwhile, as the revenues are more than three-fold the fertiliser costs. This example clearly illustrates the relevance of relative prices for inputs and outputs. However, it must be stressed that such relative prices are only of relevance if farmers are integrated into the market system, at least to a certain degree. As could be observed for Maybar, Andit Tid, the Simen area, and also partly for Anjeni, market integration is very low. It must thus be expected that price changes do not have a significant influence on farmers' behaviour. In Mesobit & Gedeba, however, where tef is cultivated as a cash crop, such relative prices are of much greater importance and might have an influence on farmers' decisions.

As could be shown with the CBA (cf. Section 6.1.5) and the sensitivity analysis, price changes for crops in the order of ±20% influenced the profitability of the considered SWC technology only in one case. If we consider the profitability of SWC under the assumption that fertiliser is applied, the considered technologies are profitable in many more situations. Thus, the positive effect of fertiliser application,[669] i.e. the increase in yield achieved, can cover the high initial investment costs and can also offset the high percentage of land occupied by conservation structures. However, fertiliser application implies that part of the production is sold to pay back the fertiliser loan. If either crop prices decreased or fertiliser prices increased, farmers might opt for not investing in fertiliser anymore. If so, the profitability of SWC would no longer be given. The ***link between relative prices for inputs and outputs and SWC investments*** was also clearly mentioned in Mesobit & Gedeba. Here many farmers sell part of their tef harvest to pay for fertiliser and other agricultural inputs. They also clearly mentioned that fertiliser is only a profitable investment for tef if part of the harvest is sold. On fields that are planted with crops for home consumption, including tef, they would not use fertiliser. And lastly, it was also stressed that fertiliser is only of use if it remains on the field. This can be achieved if the land is terraced and runoff is controlled. All interviewed farmers applying fertiliser mentioned the necessity of terracing the land to make use of the benefits of fertiliser, on the one hand, and improving soil characteristics such as water retention and organic matter content, which play an important role in determining the fertiliser efficiency, on the other hand. Interviewed farmers mentioned that rising fertiliser prices and rising prices for other agricultural inputs were becoming a problem, since crop prices remained constant. They mentioned that every year they have to sell more tef to be able to pay back the loans they took from the MoA to buy the inputs – which means that their margin is diminishing. If this gap between the level of input and output prices decreases, it could well be that cultivating tef for the market relying on fertiliser is becoming uneconomical. Farmers might then stop this practice. Whether this has an influence on their willingness to invest in SWC remains an open question.

In Section 5.2, the value of grass and additional straw is discussed. An example is presented there showing that the additional grass that can be produced on the conservation structures plus the additional straw yield resulting from SWC is roughly enough feed for one additional sheep per year. However, the value of the crop production loss (the example considers tef) is about three times the selling price of a sheep. Accordingly, raising sheep thanks to increased fodder production on SWC structures does not compensate the reduced grain yield in the situation considered. If relative prices changed, however, the picture might look more

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668 cf. footnote 653.

669 In the CBA only positive effects of fertiliser application are modelled. However, under insecure climatic conditions fertiliser application can lead to total crop failure.

positive. If, for example ***livestock prices*** increased relative to ***grain prices***, the additional grass yield from conservation structures might become much more valuable. This might be an incentive for farmers to switch to the soil conserving practice. If, however, livestock prices fell relative to crop prices, the value of straw and grass included in the CBA would not contribute enough to compensate for the high initial investment costs and the land loss in the case of SWC investments. This reflection is based on the assumption that farmers feed their animals from own sources. The reality in the Ethiopian Highlands is, however, that animals are usually grazed on communal land. Increasing market prices for animals might thus lead to even higher resource degradation, as more animals are kept on the limited area of grazing land. Only if the system of free grazing is abandoned, higher prices for animals might lead to a higher attractiveness of SWC.

In Section 6.3.3, an example has been presented for situations such as Andit Tid, where a farmer has planted ***Eucalyptus*** on a degraded plot. Even in the case where opportunity costs of lost crop production are included, planting Eucalyptus is highly profitable. Again important are the prices considered. If more farmers started growing Eucalyptus and the supply of wood increased at a given demand, then, *ceteris paribus*, prices will decrease. If we assumed that prices for Eucalyptus poles were reduced to half and all other assumptions remained unchanged, then the NPV decreases from approximately EB 2,500 to EB 330.

The above-mentioned example shows how much the profitability of an investment can depend on the relative prices of considered inputs. Nevertheless, even if prices are reduced to half, the investment in a Eucalyptus plantation is still profitable, although at a lower level. The sensitivity analysis (Section 6.1.5) has shown that with a partial analysis, in which only one input parameter at a time is changed, the influence is rather limited in determining whether the investment in SWC is profitable or not. Changing several prices, which might be a result of economic reforms, might have a bigger influence. If we consider the plantation example above and assume that in addition to the price decline for eucalyptus poles, the value of foregone crop production increases by 25%, then the investment in a Eucalyptus plantation is no longer profitable (NPV at 12% discount rate, time horizon 25 years: EB -110, IRR: 10.4%).

From the results of the partial sensitivity analysis one could conclude that the influence of relative prices on the profitability of investments is not overwhelming. The above example has shown, however, that if several prices changed the profitability of a given investment might also change. In all calculations it was further assumed that relative prices remain constant over the whole time period under consideration. In a dynamic environment such as the one in Ethiopia one must, however, expect ***major economic and political changes***. Such major changes have already occurred several times during the past three decades. As could be shown, the market liberalisation of 1990 and the devaluation of the currency starting in 1994, which led to crop price increases in the order of +400%, but had a limited influence on fertiliser price increases of only +45%, investments in fertiliser became much more attractive. Other such changes might occur also in future. The farmers' main problem with regard to long-term investments such as soil conservation, tree plantations, or investments in small-scale irrigation systems is that they have to base their decisions on the current situation, while they have no possibility to foresee (i) whether changes might occur, (ii) what the magnitude of possible changes might be, (iii) what the direction of such possible changes (e.g. increasing or decreasing crop prices) could be, and (iv) whether or not the change is lasting for a longer period of time. This problem is not unique for farmers in the Highlands of Ethiopia, but concerns every investor. What is unique in the situation of highland subsistence farmers, however, is that they already live on the margin of survival. If they devote land, labour, and capital to an investment under current volatile economic conditions, they face very high risks, since they have no security whatsoever, except for family networks. Farmers have experienced major changes of the economic system in past times. Every time, government officials promised that this would be the last major change for a long time, while history then proved the opposite. Against this background, the reluctance of small-scale farmers with regard to costly investments is absolutely understandable. It is also understandable that changes of the land use system, which would mean better market integration, are even less attractive, as they might endanger the survival of the household. Under such conditions, the 'subsistence mentality' is justifiable. If farmers are to be better integrated into the market system, a more stable economic environment is of paramount importance. This would allow farmers to better foresee future outcome of land use changes and their valuation also in economic terms.

## 7.3 Markets for Inputs, Labour, Capital and Land – or their Absence

*"Market failures imply inefficiencies related to market institutions. All market imperfections do not represent market failures as some market imperfections may be optimal from an efficiency point of view. In rural economies with high transaction costs and imperfect information [...] nonmarket institutions may represent more efficient substitutes as compared to their market alternatives."*
*(Holden, 1997, 17)*

### 7.3.1 Markets for inputs

Evidence has shown that the incentives and abilities for farmers to make investments in productivity-enhancing inputs and production modes depend on the functioning of markets for inputs, credit, and crop distribution.[670] ***Markets for inputs*** such as fertiliser only function to a limited degree in the study areas. Only in Mesobit & Gedeba agricultural inputs can be bought on the free market. In the other areas, inputs are not available from traders, but only from the agricultural Development Agent. Often, fertiliser is not available in the necessary quantities, and reaches remote areas too late. What effect the full liberalisation of the fertiliser market in the research areas will have on the availability on the one hand and on the demand on the other hand remains open. Especially in areas where market integration is low, such as in Maybar, Andit Tid, the Simen Mountains, and partly also Anjeni, liberalised fertiliser markets alone will probably not have a very big effect. It is, however, to be expected that other effects are much more important.

**The agricultural extension system as input supplier**

In the course of the economic strategy of the Ethiopian Government, which is geared towards addressing underlying causes of widespread poverty, agricultural development stands highest on the agenda. The ***Agricultural-Development-Led Industrialisation*** (ADLI) contains various components needed for agricultural growth, including technology, finance, rural infrastructure, internal and external markets and the better integration of the private sector. It is foreseen that 70% of the incremental production would come from more intensive crop production and 30% from expansion of land under cultivation.[671] The ultimate goal of the ADLI strategy is to increase yields to boost economic growth. To achieve agricultural growth a package approach has been designed. Starting from 1994/95, the ***'Participatory Demonstration and Training Extension System'*** (PADETES) was launched. The package intends to help smallholders to improve their productivity through demonstrating and disseminating research generated information and technology on major food crops, namely tef, wheat, maize and sorghum, as well as on high value vegetable and fruit crops to diversify income. The package comprises improved land management practices, fertiliser, improved seeds, and credit provision.[672]

In principle, there is nothing wrong with ADLI and PADETES, neither with the goal, nor the policy or the instruments. The only problematic point is how the goal of increasing yields is achieved. Annually, ***target figures*** are envisaged, which determine by how much the agricultural sector is expected to grow under favourable conditions. These target figures are then broken down to the Region, the Zone, the Wereda, and finally the KA. Based on these figures, the number of farmers is estimated who should participate in the package programme, i.e. use improved seeds and apply fertiliser to achieve the yield increase. DA's working at the KA level complained that they are not asked for comments when the assessment is made how many

670 Gebremeskel Dessalegn et al., 1998, 1.
671 IMF & IDA, 2001, 3.
672 Mekonnen Manyazewa, 2000, 6.

farmers should participate in the new extension programme in their working area. They mentioned that the figure is simply passed down from the next higher administrative level. Also at this next higher level, the Wereda and even the Zone, the complaint is the same. DA's are obliged to at least fulfil the target in order to not be punished, i.e. transferred to an even more remote rural area. In some KA's and at higher administrative levels there is even an effort to exceed the quote in the hope of being rewarded with a promotion. This additional quota is lastly passed down to the farmer. Figures published by the MoA indicate that the targeted number of participants in the PADETES program is 10% higher than envisaged.[673] Based on statements recorded in the research areas it must be hypothesised that this high participation can not only be attributed to the farmers' eagerness to join the programme, but is due also to the DA and the KA administration putting pressure on farmers to participate in order to be able to over-fulfil the quota. Together with the KA administration, DA's select the farmers who are to participate in the programme, based on a land suitability evaluation and an evaluation of the economic possibilities of the farmers. Selected farmers can hardly reject participation. They are then obliged to purchase the necessary inputs on credit. An immediate down payment in the order of 25% is the rule. Credit periods are limited to 10 months and credits have to be paid back immediately after harvest. Even in the worst situation of total crop failure there is no possibility to postpone the credit. Farmers are then forced to sell assets such as livestock in order to repay the loan.

In all research areas and surroundings, farmers as well as DA's mentioned that the system of more or less ***forced participation*** in the extension programme is very problematic. In areas suffering under moisture stress it was mentioned that fertiliser can be more counter-productive than not. Farmers who are forced to apply fertiliser and buy it on credit have to sell assets to be able to repay the loan if the harvest fails. On the other hand, there are several farmers who would like to buy more fertiliser but are not allowed to do so, because the DA does not only have to deliver a certain amount of fertiliser, but also has to cover a certain percentage of the population within his area of work. Some farmers explained that although they were forced to buy fertiliser, they did not use it, but stored it at home and sold small livestock to pay back the loan. In all research areas, the general feeling by both farmers and the DA was that the quota system should be abandoned. The DA mentioned that if he could demonstrate on farmers' fields what the effect of improved land management, improved seeds, and fertiliser application on yields is, farmers would be willing to experiment on their own land. In the beginning they might not apply the recommended rates or continue to use their own seeds, but through this process of learning-by-doing, farmers would gain confidence in using new technologies. In contrast, if they are forced, and yields do not perform as promised, the damage is often more than just the yield loss, as farmers are forced to sell assets to pay back the loan, and after such an experience they will never be willing use inputs again. In addition, rumours will spread that have an influence on other farmers as well. The DA's recommend a much slower approach to convincing farmers, and certainly a relaxation of the rules concerning pay-back periods for fertiliser loans. It was also proposed to establish a local insurance scheme, according to which, in addition to a reserve from the MoA, all farmers would pay a small amount annually, which could be used to compensate farmers who lost their harvest. This might stimulate farmers to take more risks and thereby bring about a higher participation in the PADETES programme.

### 7.3.2 Labour market

In the research areas, hardly any labour market exists. Job opportunities are available only on-farm if rich farmers need daily labourers or off-farm if larger infrastructure projects are realised in the vicinity where unskilled labourers can be employed. Wages are similar on-farm and for unskilled labour and range between EB 5 and 8 per day, depending on the season.

***Daily labour*** is attractive especially during slack seasons with little farm work. It is also attractive for families with more than one adult male household member. In this case, farm work has not to be

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[673] A report of the MoA published by the Government spokesperson proudly presents that for the agricultural year 1998/99 the set target of farmers participating in the PADETES programme was 2,978,548 instead of the planned number of 2,702,432. [www.ethiospokes.net/Economy]

compromised if one adult male family member works off-farm. If households are forced to send male family members to work off-farm and must therefore reduce the amount of labour invested on-farm, they have to face lower yields because critical tasks such as ploughing or weeding cannot be performed to the necessary extent or at the right time. It must be expected that they do not earn more if they are engaged in off-farm work than if they invested the labour on-farm.

With regard to ***SWC investments***, the considered technologies are not capital intensive, but highly labour intensive in their construction and maintenance. Households without sufficient own labour force do usually not have the financial means to employ daily labourers for the construction of SWC structures, although the labour force is, in general, available. Communal labour is not popular in the research areas and is restricted to specific groups with specific tasks (e.g. *webera* and *wenfel* for ploughing, weeding and harvesting). The new system for carrying out resource conservation activities does no longer rely on FfW. Instead, farmers are obliged to work a certain number of days per year. The DA, who has to fulfil an ***annual quota*** of conservation work (i.e. defined lengths of cut-off drains, of earth or stone bunds on arable land, of check-dams, etc.), selects the land to be conserved. Teams of farmers are then assigned to carry out the work. All farmers interviewed mentioned that in principle, they do not oppose the compulsory nature of SWC work. However, they would prefer to work on their own land. They mentioned that if they could form teams among neighbours and then work in turn on the land of the team members, both aspects – that of pooling labour and that of working on the own land – could be respected. This view is also supported by the DA's interviewed in the research locations who mentioned that the quality of conservation structures of the compulsory teamwork on land of other farmers is extremely poor and that often, after one rainy season the structures are already dissolved. DA's therefore strongly support the idea of teams of farmers working on their own land.

### 7.3.3 Capital market

Capital from ***official sources*** is in general only available for the purchase of agricultural inputs. If a household needs additional money, there are only ***unofficial* sources** such are traders, the church or relatives. Traders and the church charge similar amounts of interest between 5% and 10% per month. Credit from relatives is without interest, because in the Christian as well as in the Muslim faith it is a taboo to charge interest. Farmers usually take credits from relatives only on a short-term basis to bridge food shortages, in emergency situations such as when a family member needs medical treatment, or in cases where high expenses accrue, such as when children are married[674] or when a house is renovated or newly built. The rule is that after harvest such credits are paid back. Credits from the church or traders are also paid back as soon as possible because of the high monthly interest.

Comparing the ***interest rates*** on the unofficial market, which amount to such high percentages as 60% to 120% annually, and the ***individual discount rates*** elicited (cf. Section 5.3.3), it becomes evident that the two are quite similar. Discount rates reflect time preference, the individual's attitude towards risk and uncertainty, and the marginal opportunity costs of capital. Opportunity costs of capital are extremely high as the amount of savings are next to nothing. Households have no other possibilities than to rely on informal credits if they need capital.

A constraint hindering the emergence of a capital market is that land cannot be used as a ***collateral***, as it is not individually owned. There is thus no incentive to develop a credit system and to lend money. This could also be a reason why traders charge such high interest rates. They have no security from the credit taker. The only way to lower the risk is to add a high risk premium on the actual interest rate.

With regard to ***SWC investments***, lacking availability of credit directly is not expected to have a major influence. However, as credits are lacking productivity-enhancing investments are hardly feasible. If from existing farm land higher income was possible, investments in SWC might become profitable or might even

674 An example of a marriage of a son costs a household approximately 1,400 EB, including new clothes for the son and the daughter-in-law, food items, and household items. (Ludi, 1997, 146)

become a necessity to realise this higher income. The example of Mesobit & Gedeba has shown this in relation to fertiliser investments. Investments in small-scale irrigation could be a similar case. However, there is no credit available to either individuals or groups of farmers for investments in irrigation systems such as small pumps or water diversion systems.

***Traditional savings groups*** (*iqub*) are gaining importance also in relation to investments. Each member contributes a monthly amount of money that is given in turn to the members. Interviewed farmers mentioned that until recently the money was usually used to buy animals for slaughtering for important holidays such as Easter and Christmas. Nowadays, many savings groups have broadened their scope and try to convince their members to invest the money in productive enterprises and not only in immediate consumption. Often farmers mentioned that because the amount to be distributed each month is rather small, investments in improved poultry or improved bee keeping is the most feasible option.

### 7.3.4 Land market

The existence and proper functioning of land markets is often mentioned in connection with land degradation and conservation. It is argued that ***poorly functioning land markets*** tend to lower land values because the effective demand is limited. This can have an influence on farmers' management decisions in several ways: Incentives to invest in the land are reduced because the owner cannot realise the benefits of these investments if (s)he sells the land. And secondly, low land values reduce the value of the land as a collateral.[675]

In the ***constitution*** of the Federal Democratic Republic of Ethiopia (FDRE) of 1994, it is stated the land shall not be subject to sale or any other means of exchange and that every Ethiopian peasant has a right to obtain land and is protected against eviction (cf. Chapter 8). It becomes evident that no land market can exist.[676] Farmers are allowed to lease land on a medium-term basis and bequeath it to descendants, but it cannot be sold or mortgaged. Therefore, investments in the land are not reflected through an increased value of the land, or, rather, they are reflected but cannot be materialised. This has two important implications: As land cannot be sold it is difficult to properly attribute a value to the land. Secondly, as land cannot be mortgaged and used as a collateral credit is very difficult, if not impossible, to obtain.

Although it is stated in the constitution that farmers are protected against eviction, the recent land redistribution carried out in several areas of the Amhara Region have violated this principle. This is especially problematic, as although the land proclamation foresees a system of compensation for investments no compensations have been paid in reality. A very problematic aspect is the right to land, on the one hand, and the right to be protected against eviction, on the other hand. In most areas of the Ethiopian Highlands land reserves are exhausted. Coming generations can only obtain land if the existing arable land is newly distributed. How the Government intends to solve this conflict in future is unclear.

Although no official land market exists where land is sold and bought, different ***sharecropping agreements*** exist in the study areas. Usually, land is leased on a short-term basis and the contract is renewed after every cropping year. Sharecropping arrangements are 50% in Maybar and Andit Tid for both parties, and 1/3 for the lessor and 2/3 for the lessee in Andit Tid. It is often argued that under sharecropping arrangements labour efforts are reduced as the sharecropper receives only part of the yield.[677] In Anjeni, it could be shown that this is true in part. A farmer renting considerable amounts of land invests less labour in the rented land to achieve a return to labour similar to the one on his own fields.[678] In Maybar and Andit Tid, such observations were made less often. One hypothesis is that the farmer in Anjeni is an elder, rich, and very influential person

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675 Wachter & North, 1996, 3.

676 This situation is not unique to Ethiopia but characterises many smallholder areas in Africa. (Delgado, 1998, 2)

677 Fafchamps, 2000, 3. He concludes from empirical analyses that labour per hectare is about 25% lower on sharecropped than on own land.

678 Ludi, 1997, 80.

and that for the lessor it would be difficult to terminate the agreement on the ground of insufficient labour input. On the other hand, in Maybar and Andit Tid often poor and young farmers are renting land. They mentioned that they do not make a difference in labour input whether it is own or rented land. They specifically mentioned that when the owner of the land is not satisfied with the yield share he/she would immediately terminate the agreement because the demand for renting land is much higher than the supply. Therefore, the lessees mentioned that they rather invest more labour in rented land to achieve a yield as high as possible to satisfy the lessor in order to keep the land also for coming seasons. With regard to investments in the land, farmers leasing land mentioned that they would not invest additional labour in constructing SWC structures, but that if the land was already terraced, they would maintain the structures. No difference is made in the sharecropping arrangement whether the land is terraced or not.

Whether a land market, which implies some sort of ownership of land for individuals or clearly defined individual use rights, would have a positive ***influence on the willingness to invest in SWC*** is difficult to estimate. It should be noted that this Chapter refers only to the land market, but not the discussion of land tenure in general and the property rights discussion. Those will follow in the next Chapter. It is generally believed that secure property rights, including land titles, are an essential prerequisite for the working of a land market. Poorly functioning land markets are believed to lower the value of the land because the effective demand is limited. This can affect land management in several ways: It is argued that incentives for conservation are reduced because owners cannot realise the benefits of the investments if they sell the land. Secondly, low land values reduce the value of the land as collateral, as the borrower cannot sell the land to recover the lost credit. It is thus argued that credits are more expensive when land markets function poorly or do not exist at all.[679] It is often argued – and the Ethiopian Government argues the same way when defending and justifying state ownership of land[680] – that if land could be sold on the market, poor farmers would eventually be forced to sell their land to unscrupulous moneylenders. Whether this is a problem of the existence of a land market or whether it is rather because of insufficient control of unfair money lending practices and lacking credits from government sources, remains debatable. It is even argued that existing land markets could be seen as a means of giving the people the flexibility in responding to new opportunities[681] and allow mobility of farmers – selling land in one locality and reinvesting the income somewhere else.

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679 Wachter, 1996, 3.

680 Desalegn Rahmato, 1999.

681 Tiffen, 1996, 176.

## 7.4 Transaction Costs and their Influence on the Profitability of Soil Conservation

*"Very few empirical studies have actually measured transaction costs to-date, probably due to the difficulties associated with their measurement. Transaction costs may be so high relative to the benefits of the transaction that the exchange does not occur, in which case the transaction costs are unobservable."*
*(Kherallah & Kirsten, 2001, 24)*

Transaction costs,[682] in principle, include all ***direct and indirect costs associated with selling or buying*** a good on the market. Transaction costs are thus a result of an economy based on labour division and specialisation, and concern the transfer of resources from one actor to another or from one production process to the next.[683] Transaction costs may include costs of transporting goods between the farm and the market, but also any other costs associated with finding sellers/buyers, with negotiating an agreement, and with the supervision and enforcement of the agreement. Transaction costs can vary by product, type of agent in the marketing chain, and individual agent within a category of agents. Transaction costs in marketing in Africa typically arise because market prices do not fully reflect the true costs and returns to participation for all market actors because of unequal initial endowments. This can especially be observed in situations where many sellers are involved who are dependent on a few buyers in a thin market. Transaction costs do not only accrue in marketing; the concept can also be applied to the production process. Most high value-added products in agriculture are characterised by a high ratio of transaction costs to final value, because of the high degree of processing embodied in such products. Typical examples are animal products and horticulture. Although such products could increase returns to family resources, the costs of diversifying into such profitable activities are often too high for poor households.[684] Small-scale households might thus continue in the subsistence mode of production, because they cannot benefit from trade or specialisation if transaction costs incurred in the process of exchange outweigh the benefits of that exchange.

Transaction costs (t) have to be added in the case of buying or deducted in the case of selling to/from the market price ($p_m$) to find the respective endogenous household shadow price ($p_h$). It is further assumed that the households is a ***net buyer*** if the shadow price ($p_h$) is below the autarky shadow price (ASP), which is defined as the shadow price at which the household is self-sufficient. The household will be a ***net seller*** if $p_h$ > ASP. There is one special case where it is unprofitable for a household to either sell or buy goods on the market: $p_m + t > ASP > p_m - t$.[685] Thus, if transaction costs are high, households do not buy or sell on the market and are forced to be ***self-sufficient***.

The following Figure 55 presents the demand and supply by the household in the presence of transaction costs:

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682 Transactions are the transfer of goods or services over a technical, in the case of property rights, over an organisational barrier. (Scheele, 1997, 85) Only the special case of transaction costs in relation with marketing shall be discussed here. Transaction cots related to maintaining 'social action', i.e. initiation, maintenance or change of relationships between different actors or maintenance of the basic social system, are not discussed. (Richter & Furubotn, 1999, 48)

683 Richter & Furubotn, 1999, 47.

684 Delgado, 1998, 3.

685 Minot, 1999, 5.

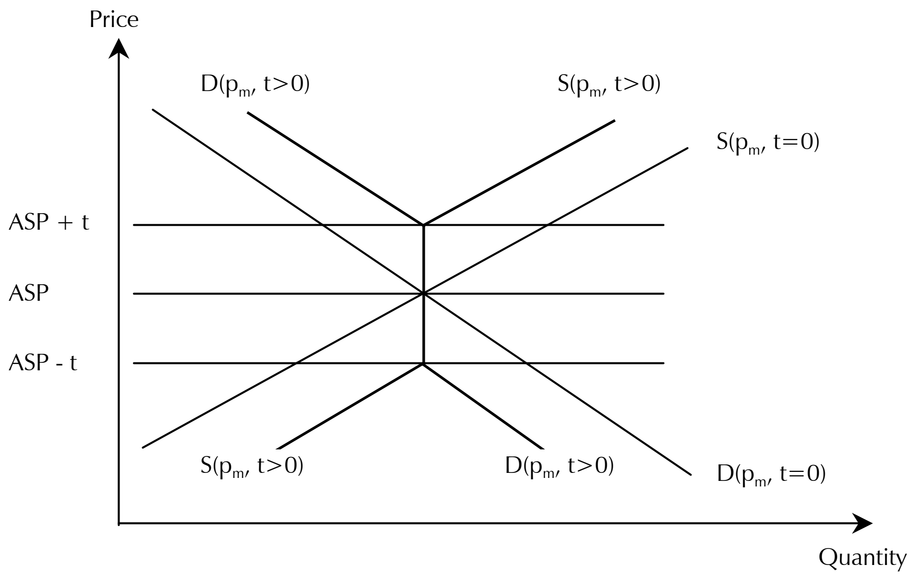


*Figure 55: Household supply and demand with transaction costs as a function of the market price. [Source: Minot, 1999, 33]*

Without transaction costs the household demand and supply is represented by $D(p_m, t=0)$ and $S(p_m, t=0)$. When transaction costs occur, the household sells its goods only if the market price ($p_m$) is above ASP + t. The demand and supply curves with the consideration of transaction costs are shifted parallel to the demand and supply curves without transaction costs. The amount the curves are shifted upwards and downwards is represented by +/- 1t. If market prices are high, i.e. above ASP + t, it is profitable for the household to be a net seller, if they are low, i.e. below ASP - t, it is profitable for the household to be a net buyer, and in between the household is self-sufficient. The higher the transaction costs, the wider the range of market prices, over which the household is self-sufficient.

A simple ***example*** is constructed to illustrate the case: let us assume a household has 1 ha land which is cultivated with tef. If we assume average yields from Maybar about 1,133 kg can be harvested. The value of the total tef harvest is EB 2,379 (at EB 210/q). We further assume that production costs comprise only labour, which is approximately 370 person days per 1 ha tef, and 19 animal traction days (with 2 oxen/day) (cf. Table 35), and costs for seed. If we further assume that the opportunity costs of labour are EB 5/day and seed costs about EB 190/ha, total production costs would amount to EB 2,231. Profits in this case would only amount to EB 148/ha. If we further assume that the household wants to sell the whole production to buy cheaper grain instead, the following costs accrue: to bring 1,133 kg tef to the market needs 22 trips at 50 kg (equals one donkey load). Each trip to the market takes one day at EB 5. In this case, production costs plus transport costs are below the market value of the good, and it would be worthwhile for the household to sell the tef harvest on the market and to buy a cheaper crop instead. If we assume that the same amount of grain as sold is necessary to support the households, the grain to be bough may not be more expensive than EB 207/q in order to cover production costs plus transport costs. If the market price of tef dropped to EB 160 per quintal, the value would be reduced to EB 1,813. Assuming the same production and marketing costs, revenues would be smaller than production costs plus transport costs, and selling on the market would be uneconomical. The price span at which the household neither sells nor buys would be between EB 207/q – production costs plus transport costs – and EB 187/q – production costs minus transport costs.

| | Average yield | Revenue | Production costs | Market price | Production costs | Autarky Shadow Price | |
|---|---|---|---|---|---|---|---|
| | | | | | | lower bound | upper bound |
| | [kg / ha] | [EB / ha] | [EB / ha] | [EB / q] | [EB / q] | [EB / q] | [EB / q] |
| **Maybar** | | | | | | | |
| Barley | 1,543 | 2,777 | 1,914 | 180 | 124 | 114 | 134 |
| Emmer wheat | 1,361 | 2,586 | 1,298 | 190 | 95 | 85 | 105 |
| Wheat | 1,345 | 2,556 | 1,914 | 190 | 142 | 132 | 152 |
| Field pea | 1,053 | 1,895 | 586 | 180 | 56 | 46 | 66 |
| Horse bean | 1,692 | 2,707 | 1,038 | 160 | 61 | 51 | 71 |
| Maize | 2,265 | 2,492 | 1,919 | 110 | 85 | 75 | 95 |
| Tef | 1,133 | 2,379 | 2,231 | 210 | 197 | 187 | 207 |
| **Andit Tid** | | | | | | | |
| Barley (*Belg*) | 1,201 | 1,501 | 1,065 | 125 | 89 | 79 | 99 |
| Barley (*Meher*) | 1,184 | 1,480 | 1,065 | 125 | 90 | 80 | 100 |
| Lentil | 528 | 1,848 | 828 | 350 | 157 | 147 | 167 |
| Horse bean | 1,691 | 3,213 | 1,167 | 190 | 69 | 59 | 79 |
| Linseed | 410 | 718 | 806 | 175 | 197 | 187 | 207 |
| Wheat | 754 | 1,357 | 1,381 | 180 | 183 | 173 | 193 |
| **Anjeni** | | | | | | | |
| Barley (*Belg*) | 469 | 844 | 1,049 | 180 | 224 | 214 | 234 |
| Barley (*Meher*) | 614 | 1,105 | 1,049 | 180 | 171 | 161 | 181 |
| Horse bean | 754 | 1,206 | 650 | 160 | 86 | 76 | 96 |
| Noug | 202 | 505 | 289 | 250 | 143 | 133 | 153 |
| Wheat | 872 | 1,657 | 747 | 190 | 86 | 76 | 96 |
| Tef | 908 | 1,998 | 1,147 | 220 | 126 | 116 | 136 |
| Linseed | 336 | 840 | 560 | 250 | 167 | 157 | 177 |

*Table 61: Average yield, revenue, and production costs per hectare and per quintal, and Autarky Shadow Price (ASP) plus/minus transaction costs for staple food crops in the three research areas. [Source: Own investigation 1992, 1998, 1999]*

From Table 61 above it can be concluded that in most situations production costs (e.g. opportunity costs for family labour, costs for seeds) plus transport costs (EB 10/q) are with few exceptions below the current market price (cf. Appendix 7.1 for the detailed figures). Only for linseed and wheat in Andit Tid and for barley in Anjeni, current market prices are below production plus transaction costs. Thus, it would be worthwhile for households to sell part of their production on the market and buy a cheaper product instead, provided that opportunity costs for labour or transaction costs do not change significantly. From these figures, theoretically, one must conclude that farmers should be much better integrated in the market system, since their ***production costs are considerably lower than the market price***. The other conclusion would be that transaction costs are much higher than the assumed EB 10/q, which include only opportunity costs for transporting the grain to the market. Other costs such as raising and feeding transport animals must also be included, as well as costs associated with maintaining a certain quality of crops to sell on the market and contract negotiation costs. In the above example it was assumed that whenever grain is brought to the market, everything can be sold. However, observations show that farmers often return from the market without having sold their goods. When asked why, farmers replied either that the price offered was below their expectation or that there were not enough traders to buy the crop. Such 'lost' days should also be reflected in transaction costs. If transaction costs are increased to include these various additional costs, the price span at which households remain self-sufficient increases as well.

In rural Ethiopia, it can be assumed that ***transport costs*** make up the biggest share of transaction costs due to limited availability of means of transport and long distances to the nearest market. In the above example it was assumed that the household owns its own means of transport. However, 17 of the 36 farmers interviewed, or almost 50%, do not own any transport animals. They have to borrow transport animals from relatives or neighbours or carry the crops to the market on their back. If relatives or neighbours are asked, the availability of transport animals at the best time of the year (i.e. when prices and demand are highest) is restricted, because the owner needs the animals himself. If no animals can be borrowed and the goods have to be carried to the market, the amount to be transported is very small and in a bad relation to the opportunity costs of labour.

The advantage of marketing grain crops or pulses is that they show a comparably good volume-weight relation and do not perish easily. The disadvantage is that they fetch rather low prices compared to production costs (i.e. labour input). ***High-value market goods*** are usually fresh products such as fruits or vegetables, and animal products such as milk, butter, or eggs. They often exhibit an unfavourable volume-weight ratio, i.e. are bulky and perish or break easily. The current density and accessibility of rural markets both for farmers to sell and for traders to buy makes such high-value crops unattractive. The only exception is *gesho* and pepper, as they can be partly processed on farm and are sold dry. Thus, unavailability of markets for high-value products or difficult access to such markets limits the possibilities of farmers to participate in the market system. They can only sell surpluses from staple food production, which are comparably cheap. Opportunities to produce for urban centres, where there is an increasing demand for fresh products, or opportunities to produce agricultural goods for processing in the industrial sector can hardly be taken up by small-scale farmers in the research areas.

Other transaction costs are costs in relation to obtaining ***information***. Although a DA is stationed in every research area, the number of farmers a DA has to attend to is very high. In Andit Tid and Maybar the administrative reform leading to a merger of three former KA's into one increased the number of households in the area of work for the DA's to about 1,200. In both areas the DA mentioned that he/she cannot visit all farmers because the area is too big. They both mentioned that they have good and intensive contact to a few innovative farmers. The others can only be addressed during meetings. General information, e.g. on fertiliser, including e.g. availability, price and broadcasting technologies, are nowadays available for all farmers in the research areas, as KA meetings, where information can be shared, are rather frequent. There is, however, still a lack of specific short-time information. Information with regard to resource conservation is available in all SCRP research areas thanks to the presence of RA's. However, only few farmers have access to information concerning new cash crops. In order to obtain such information, farmers have to visit the DA. Other sources of agricultural information are neighbours or people on the market. Only few households own a radio – in Maybar, for example, only 9 radios can be found in three villages comprising a total of 210 households. Farmers mentioned that there are only very few broadcasts with agricultural content. They complained that the radio programme is mainly about politics, but does hardly include contents that are of any use to farmers. Also with regard to market information, e.g. on the situation of prices and demand on the different markets in the vicinity, farmers in the research areas are not well served. The only way of obtaining market information is through either visiting the market or relying on personal networks based on mutual trust.

Several problems need to be solved before being able to conclude what effect transaction costs have on the ***marketing activities*** of farmers and if such transaction costs have an influence on their ***investment behaviour***. Firstly, the exact household shadow price of producing a certain good needs to be known to be able to assess whether the price paid on the market is above or below the household shadow price. This would give better information with regard to whether farmers are forced to remain in the subsistence mode of production or could profit from participating in the market. Secondly, different transaction costs have to be assessed such as costs for information, negotiation or enforcement of contracts. A third factor that needs to be included in the discussion of marketing and transaction costs is risk. Households are willing to sell part of their production on the market only if they have reliable supplies of food and other consumer goods at costs below the cost of self-production plus any transaction costs related to buying and selling.

## 7.5 Conclusions

Although ***policy reforms*** addressing macroeconomic problems are not explicitly directed towards influencing the quality of the natural environment, they may have major impacts.[686] In Ethiopia, market liberalisations began in the early 1990's and were followed by a devaluation of the Ethiopian Birr, which removed discriminating exchange rates. At the same time, government price controls and selling obligations were abandoned. The fertiliser market was liberalised in 1997, when subsidies were abolished and the import market was opened for private companies. The grain market liberalisation and abolishment of state controlled crop prices, in combination with the devaluation of the currency, led to a considerable increase in farm gate prices for agricultural products in the order of 400% for some crops. At the same time, prices for agricultural inputs increased only by about 45%. Thanks to much higher crop prices, agricultural inputs have become an option for many more farmers, as statistics concerning farmers using fertiliser and total amounts of fertiliser distributed clearly demonstrate.

Higher crop prices make land use more profitable. It is argued that a more profitable land use will enable farmers to invest in better land management and erosion control practices. It is further assumed that higher productivity and returns will mean that farmers can afford SWC investments and can either continue or adopt labour intensive erosion control measures.[687] It is doubtful, however, whether in the Ethiopian context price increases for crops are already sufficient to lead to such positive changes. One must rather conclude that price increases, if not outweighed by decreasing farm sizes, have enabled rural households to improve their economic well-being, but are not yet sufficient to free resources that could be used for SWC investments. Furthermore, empirical studies carried out elsewhere ***linking price changes with farmers' land use practices***, soil conservation decisions, and resulting soil degradation levels, present results that are sometimes diametrically opposed. In some cases, lower agricultural prices lead to more land degradation, as farmers respond to declining resource productivity by increasing the scale of production and by expanding arable land to marginal areas or formerly forested areas. Also, nutrient mining is more prevalent. Other studies conclude that increasing prices lead to more land degradation, especially in situations where property rights are not well defined, as farmers adopt extractive strategies maximising current production. A further effect of market liberalisation and currency devaluation, which is usually associated with incentives to increase international competitiveness of tradable goods and a shift towards the production of export products, is a change in the product mix of agricultural goods and market-orientation of small-scale farmers. In some countries it could be observed that after structural adjustment programmes farmers began to grow more cash crops. If these cash crops were tree crops such as coffee or cocoa, less erosion was recorded. If, however, cash crops were potatoes, grain crops, cotton, or groundnut, usually such a shift was accompanied by higher soil losses.[688] A further aspect to consider is ***risks*** associated with prices and yields. Price uncertainties and fluctuating yields may induce overproduction as a hedge against crop failures and price changes, thereby leading to soil degradation.[689] Whether or not higher prices lead to more investments in soil conservation in the research areas is difficult to conclude at this moment. It is less likely that farmers start growing more soil protecting crops. One must rather assume that there will be a tendency of increasing the cropped area, and that this area will be used for erosive grain crops. Whether that is an incentive for farmers to protect their resource base under current insecure tenure regimes, remains open. Furthermore, it can be assumed that livestock will gain more importance, firstly as a result of growing demand in urban centres resulting from income increase, and secondly, as an export product. If livestock densities increase, both in lowland and in highland areas, degradation of resources such as woody biomass, soils, and water is expected to increase.

Although in Section 6.1.5 it was concluded that changing prices have a limited effect on the profitability of SWC investments, the market environment nevertheless plays an important role. On the one hand, the

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686 e.g. Munasinghe, Cruz & Warford, 1996, 17.

687 Barbier, 1998b, 88.

688 e.g. Reed, 1996, 304.

689 Coxhead, 1996, 10.

***absence of markets*** and the weak structure of the existing markets is clearly an important aspect. In situations where markets are poorly developed or missing, farmers' production decisions cannot be separated from their consumption preferences and constraints (e.g. subsistence needs necessitating a certain mix of products). In cases where credit markets are not developed, poor farmers without own savings or assets (e.g. livestock which can be converted to cash) have no possibility to obtain production-enhancing inputs, even if they would be profitable and if farmers know that. On the other hand, missing labour markets could lead households to invest more family labour on-farm, which would enable them to invest in labour intensive land use or conservation technologies.

The comparison of Mesobit & Gedeba with the other areas emphasises the ***important role of a functioning market environment also with regard to SWC***. SWC is only a viable investment if agricultural inputs are used to increase production. Purchase of inputs, however, is only an option if part of the additional production can be sold to recover the costs, i.e. to pay back loans for agricultural inputs. Even if farmers opt for investing in agricultural inputs, only few high-valued crops that react well to fertiliser under favourable climatic conditions (e.g. tef) are an option, since subsidies on fertiliser have been removed, and fertiliser prices increased. If farmers remain in a subsistence mode of production (because of missing markets, prohibitively high transaction costs, or the lack of a possibility to increase production), the high investment costs of SWC cannot be covered, and SWC remains unprofitable. Another possibility is to produce high-value cash crops and to subsidise investments in resource conservation with the revenues. Only in Mesobit & Gedeba and in Anjeni, the cultivation of cash crops is practised somewhat more commonly (e.g. cultivation of tef, *gesho*, *chat* and fruits in Mesobit & Gedeba, rape-seed and noug in Anjeni). In the other areas, farmers usually cultivate only staple crops and sell surpluses on local markets.

Time and effort spent to reach the markets can be considerable. In order to enable farmers to purchase agricultural inputs and to sell goods, a ***transport network*** must be established, including road infrastructure, on the one hand, but also distributors with their own vehicles to bring agricultural inputs and consumer goods to rural areas, on the other hand. If the road network is underdeveloped, transport costs for distributors are too high to make it a profitable enterprise. Remote rural areas are no longer supplied with agricultural inputs and other goods, especially since para-statals or government agencies, which were responsible for serving remote areas before the market liberalisation, have been privatised. Similarly, transport costs for traders to reach rural markets are high. Traders also face high transaction costs of buying agricultural products, due to the market structure with a large number of farmers selling the same products but in small quantities. This means negotiating with a big number of farmers and leads to high transport and information costs.[690] High transport and transaction costs decrease the profit margin for traders buying goods in rural areas and selling them on terminal markets. Profit margins are often too small to make grain trading economically worthwhile. Remote rural areas are therefore not integrated into the wider market system.

***High transaction costs***, which are to a major part composed of high transport costs because market places are often far away, and high information costs, do not encourage farmers to participate in the market. Means of transport are limited, and often farmers have to carry small amounts of crops to the market on their back. Because of these high transaction costs, price spans in which it is uneconomical to either sell or buy goods on the market are considerable. In such cases, farmers prefer to consume their own production. This does not mean that farmers do not participate in the market at all. However, goods are more often exchanged among farmers than sold to traders or assemblers. This again limits the cash availability to farmers and their ability to purchase agricultural inputs to increase production. Without increased production, unfortunately, investments in mechanical SWC technologies remain unprofitable.

Lacking ***labour markets*** can largely be explained by lacking labour opportunities. If off-farm labour was available, farmers could supplement their income with off-farm activities. Usually, farms are so small that off-

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690 That transaction costs for traders are high cannot only be explained by limited transport infrastructure and a high number of trading partners, but also by quality control. New Institutional Economics differs from neo-classical economics insofar, as it includes quality as a third dimension of goods and services in addition to the usual two dimensions (price, quantity). (Ensminger, 1992, 18)

farm activities would not negatively affect farm activities; this is particularly true for the frequent case in which adult sons without own land remain at home and provide extra labour force. Additional income would on the one hand allow households to improve their livelihood (i.e. their nutritional status, housing, education, health, etc.); on the other hand, it would provide capital that could be invested either in directly productive enterprises or in SWC.

The missing ***credit market*** is a major obstacle to intensification and diversification of the farming system. Because land cannot be sold or mortgaged, credits are only offered through government channels or by traders and the church, who add a high risk premium to interest rates. As the government has limited financial resources available for rural credit, credits are linked to agricultural inputs. In principle, this should, not pose a problem. However, farmers are (i) forced to pay back the loan immediately after harvest when crop prices are lowest, and (ii) there is no insurance whatsoever in case farmers lose their harvest after having purchased inputs on a loan basis. This is one explanation of the limited participation of farmers in agricultural intensification efforts.

The current market situation, i.e. the absence of markets for labour, land, and credit, weak local markets for agricultural products, and high transaction costs both for farmers and for traders, result in a situation where most farmers remain in a ***subsistence mode of production*** as much as possible. When exchanging goods and services, they rely on social networks and on aspects of moral economy rather than on the market. Their abstinence from existing markets in turn reinforces the weakness of these markets. A weak integration in the market economy guarantees households the highest possible security in light of the extremely risky environment. However, improvements of the land use system, which often partly rely on purchased agricultural inputs or on new technologies that require contacts to agricultural services, are not feasible under such a strategy. This, in turn, has negative consequences also for the possibilities of households to invest in SWC.

# 8 The Influence of the Institutional Environment on the Profitability of Soil Conservation

## 8.1 Institutions

*"But even informal institutions and values such as notions of social justice [...] have a significant impact on economic performance."*
*(Ensminger, 1992, 4)*

The previous Chapter 7 has concluded that the market environment, in which the households in the research areas operate, reinforces the subsistence orientation of the agricultural production. This is, among other things, due to the fact that transaction costs are too high for the exchange of goods on the market to be profitable. Lacking markets for the main production factors forces farmers to rely on own assets or on social networks. In Section 5.3.3 it was shown that individual discount rates are generally high and planning horizons rather short, making long-term investments unattractive. Both facts are related to high ***uncertainties*** in the political and economic environment. Uncertainties in political, social or economic interactions are nothing unique to the research areas; they are an inherent characteristic of every human interaction. Institutions provide the setting in which individuals interact in order to reduce uncertainties and risk and to define rules of interaction.[691]

Neo-classical equilibrium economics assume that transactions are possible in any case and prices clear the market. Institutions are either ignored or taken for granted, like other variables that are considered exogenous, such as preferences, technology and initial endowments.[692] ***New Institutional Economics*** (NIE) is an answer to mainstream neo-classical economics with its rather unrealistic assumptions by integrating institutions, that is to analyse their characteristics, and explain their origin, development, and change,[693] as well as to evaluate their impact on economic performance, efficiency, and distribution.[694] Contrary to neo-classical theory where costs for transacting, which are determined by institutions and institutional arrangements, are not considered, NIE considers transaction costs as central and the key to economic performance. It is argued that the institutions of a country such as the legal, political, and social system determine its economic performance. Institutions such as social norms and rules are thus a fundamental precondition for any economic interaction.

Often, the terms "institution" and "organisation" are synonymously used. In NIE theory, however, the two have to be distinguished clearly:

*"**Institutions** are the rule of the game of a society, or more formally, are the humanly-devised constraints that structure human interaction. They are composed of formal rules (statute law, common law, regulations), informal constraints (conventions, norms of behaviour, and self imposed codes of conduct), and the enforcement characteristics of the two. **Organisations** are the players: groups of individuals bound by a common purpose to achieve objectives. They include political bodies (political parties, the senate, a city council, a regulatory agency), economic bodies (firms, trade unions, family farms, co-operatives), social bodies (churches, clubs, athletic associations), and educational bodies (schools, colleges, vocational training centres)."*[695]

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691 North, 1992, 4.
692 Heltberg, 1998, 1.
693 Heltberg, 1998, 1.
694 Kherallah & Kirsten, 2001, 3.
695 North, 1993, 5-6 (emphasis added).

Organisations and institutions are highly interdependent. Organisations such as government bodies define policies, i.e. the rules, while relationships between members of an organisation and relationships to members of other social groups are governed by conventions, norms and rules.

Institutions can, according to the above definition, be distinguished into ***formal rules*** and ***informal constraints***. This distinction is of great importance. Formal rules can (in theory) be changed rather quickly. Informal norms, however, change only gradually. Since the legitimacy of formal rules is provided by informal norms, even a 'revolutionary' change of the formal rules will not lead to a change as revolutionary as anticipated. This also implies that transferring formal rules (e.g. constitutions, rules of western market economies) to other societies is not a sufficient condition for good political, economic, or social performance,[696] as the underlying informal rules and constraints are not changed with this move. This incompatibility of institutions has been identified as a major contribution to the institutional crisis in Africa.[697]

It further implies that informal constraints can be regarded as modifications of formal rules to widen the room for manoeuvre for actors. The sum of informal rules or constraints can be regarded as the 'culture' of a society and as an important part of the human capital of members of this society.[698]

NIE operates at ***different levels***: The macro-level deals with the *institutional environment*, which affects the behaviour and performance of economic actors, and in which organisational forms and transactions are embedded. At this macro-level, institutions can be seen as a set of fundamental political, social, and legal rules that establish the basis for production, exchange, and distribution. At the micro-level, institutions describe the *institutional arrangements*. These refer more to the modes of transaction, organisation, or hierarchical modes of contracting. The focus here is on individual transactions and organisational forms and arrangements of economic units are analysed.[699] Others distinguish three levels of institutional arrangements:[700] (i) constitutional level, (ii) political level, and (iii) micro level. At the constitutional level general rules are formulated. This would include constitutional regulations such as human rights, right of ownership or mechanisms of social compensation. Institutions at this level are rather stable and should not be changed by day-to-day politics in order to guarantee the necessary secure political, economic and social environment. The second level includes institutions such as laws regulating ownership, mechanisms of allocation and transfer of ownership, or allocation of public goods. These institutions can be changed rather easily within the framework given by the superior constitutional institutions. The micro-level concerns institutions with regard to organisation of firms and contractual regulations and are embedded in the political institutions. Another aspect of institutions at this micro-level concerns activities of co-ordinating individual interests in order to have an influence on the political agenda. Usually, organisations are formed witch are defined by the common interest and goals of its members (e.g. trade unions, farmers associations).

NIE can be distinguished into eight broad categories:[701]

(i) ***New Economic History***, which looks at how economies evolve and develop over time. The focus is on analysing the role of institutional change promoting overall economic growth and explaining the differences in development among the countries. It is considered that the main driving forces for institutional change are changes in relative prices and technological innovations. Changes in relative prices can be exogenous as a result of population growth or natural disasters, or endogenous as a result of technological progress, changing resource stocks, or new knowledge.[702] In recent times,

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696 North, 1993, 7.

697 *"The origin of the institutional crisis is the structural and functional disconnect between informal, indigenous institutions rooted in the region's history and culture, and formal institutions mostly transplanted from outside."* (Griffith et al., 1999, 12)

698 Erlei, 1999, 519.

699 Kherallah & Kirsten, 2001, 4.

700 Scheele, 1997, 91ff.

701 Kherallah & Kirsten, 2001, 7ff.

702 North, 1992, 99.

technological change and especially information (i.e. access to and costs of information) have been the driving force of institutional change.

(ii) ***Public Choice and Political Economy*** concentrates on the economic analysis of political systems and political decision-making. The role of different actors in the political arena and their power to influence political decision is analysed. With this approach, the bias against the agricultural sector in many developing countries can be explained by the fact that urban segments of the population are usually politically more active and demand cheap food prices. On the other hand, this approach also allows to explain why farmers' groups in many countries cannot influence policies, as they are too large, too dispersed, and too heterogeneous compared to better organised, smaller and more homogenous urban consumer groups.

(iii) ***New Social Economics*** analyse social networks,[703] i.e. social connections, norms and trust, and social capital.[704] This later aspects also falls within the strand of transaction cost economics as an important factor in cutting down the costs and uncertainties of market exchange.

(iv) ***Theory of Collective Action*** mainly concentrates on the function, role, and action of interest groups. This category is often used to analyse management issues with regard to common resources and to overcome the free-rider problem. The theory of collective action is an alternative to solutions proposed to address the "tragedy of the commons" through the establishment of enforceable (private) property rights over resources. It has been shown that local institutional arrangements designed to induce co-operative solutions can help to achieve efficiency in the use of such resources.[705]

(v) ***Law and Economics*** concerns the application of economic analysis to the study of laws and regulations.

(vi) ***Transaction Cost Economics*** argues that institutions have emerged to minimise transaction costs. Market exchange is not costless: transaction costs in the form of costs for information, negotiation, making formal or informal contracts, monitoring, co-ordination, and enforcement of contracts arise. The emergence of firms as well as their size and organisational form can be explained by transaction costs. Patron-client relationships can be explained as a special case of principal-agent arrangement, in which transaction costs for monitoring the contract are minimised by relying on kinship ties, ritualising exchange, and giving it a moral notion.[706]

(vii) ***Economics of Information*** is related to transaction costs. It is hypothesised that searching for market information is not costless, that information is missing or that the different agents possess different amounts of information (information asymmetry). Sharecropping agreements can be analysed in such a way as this is a means to minimise transaction costs and costs for obtaining relevant market information.[707]

(viii) ***Property Rights*** are also linked to transaction costs. It is argued that if property rights were well established and if there were no transaction costs, externalities can be internalised. This argument is often heard when strategies with regard to the prevention of resource degradation (e.g. soil erosion from a farmer's field leading to externalities) are discussed. The absence of clear property rights is one important aspect made responsible for environmental degradation.[708] One solution commonly proposed was to create a system of private property. The reason, however, why private property did not develop can be twofold: (i) private property rights are not developing because it is uneconomical,

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[703] Social networks consist of actors, attributes of actors and relations between pairs of actors. The relations between actors can be understood as transactions which are controlled by institutions – a set of formal or informal rules or norms, which structure social relations in a specific way. Transactions are understood in a broad sense, not only including the exchange of material resources or information but any kind of linkage between actors. (Richter, 2001, 26)

[704] "*Social capital refers to the norms and networks that enable people to act collectively*." (Woolcock & Narayan, 2000, 3)

[705] Ostrom, 1990, 18ff.

[706] Ensminger, 1992, 112.

[707] Heltberg, 1998, 7.

[708] Which does not mean only private property, but it can also include property rights of a group with clearly assigned rights and duties and sanction mechanisms.

and (ii) private property rights are not developing because of some prohibition or government regulation.[709] A further reason can be seen in incompatibilities between formal institutions – land policies, which foresee a privatisation and land titling to anyone wishing to obtain land – and informal institutions – social norms, which foster access to land for all members of a certain society or exclude members of certain segments from access to land.

An aspect also by NIE not explicitly addressed is the question of ***power***.[710] It is obvious that especially the distribution of property rights or any attempt to change this distribution is highly interrelated with power that individuals or groups hold in society. As will be shown later, the link of property rights, social status, economic power (i.e. bargaining power), and political power is a feature known for centuries in the Ethiopian context.

In Section 7.4 the role of ***transaction costs***, a central topic in NIE, has already been discussed. It could be shown that if only transport costs are considered, transaction costs are rather small. If other transaction costs such as obtaining information, negotiating with traders, keeping quality standards, etc. are to be estimated and added, it can be expected that transaction costs would be much higher and selling on the market would be uneconomical. This can be underpinned by observations made in some of the case study areas where households mainly produce for self-consumption, i.e. refrain from being integrated in the market economy because of high transaction costs and other risks. Reasons given by farmers are that it is too expensive and time consuming to sell crops or livestock products on the local market or that farmers often have to return home without having sold their goods. It could be also shown that because quantities sold by farmers on local markets are very small, transaction costs for traders are very high. They therefore serve these local markets only to a limited extent. It has been further argued that if farmers mainly produce for self-consumption, production-enhancing inputs such as artificial fertilisers are economically not viable as no cash is generated to pay back the fertiliser costs. In the case study area of Mesobit & Gedeba it could be shown that a link exists between using artificial fertiliser and SWC in the very special situation of comparably good markets for inputs and outputs, as well as credit, i.e. in a situation with comparably low transaction costs. It can be hypothesised that in the other case study areas similar links would emerge as well.

The above paragraphs give a short overview of where NIE concentrates. In the following two aspects shall be discussed which are of great relevance with regard to whether land users in the case study areas are motivated to carry out investments in SWC or not: ***Property rights*** and institutional regulations based on ***social norms*** which are related to religion. However, the concentration on these two aspects is not to suggest that no other institutions have an important influence on incentives to carry out resource conserving investments. Such incentives are influenced by ***agricultural policies*** such as the ADLI strategy and the PADETES extension programme (cf. Section 7.1.1 and 7.3.1) at the national level, by legal rules and social norms with regard to resource use at the communal level, or by social norms with regard to labour division and inheritance at the household level, to mention only a few.

[709] Stettler, 1999, 107.

[710] Birner, 1999, 51.

## 8.2 Property Rights

*"It is important to understand that locally evolved property institutions contain complex rules, whose purpose is to meet specific social and environmental objectives. Even taboos and superstitions, regarded by some outsiders as quaint and primitive, will often [...] serve a logical purpose."*
*(Sjaastad & Bromley, 2000, 387)*

In rural areas, land is not only the primary means for ensuring a livelihood, but often also a means for accumulating wealth and social status and transferring them between generations. Because of this ***key role land plays in rural societies***, the way access to it is regulated, land rights are assigned, and ownership conflicts are resolved, has broad implications not only in the agricultural sphere, but also for the overall social and economic development of rural societies. Aspects strongly influenced by land property rights include (i) the ability of households to produce for their subsistence and generate marketable surpluses, (ii) the social and economic status of households and their collective identity, which can often be translated to their political power, (iii) the households' ability to make investments and use scarce resources in a sustainable manner, and (iv) their ability to handle risks.[711] It is thus not surprising that the institutional, policy, and regulatory framework that governs property rights to land and the way they are distributed is of great importance to societies.

Property, in economic terms, is a stream of benefits or income, and a ***property right*** is a claim to this stream.[712] Property rights or ownership can thus be described in the following terms:[713]

- the right to use the resource;
- the right to determine the use, to decide how and by whom the resource may be used;
- the right to the income from the resource;
- the right of exclusion of others from using the resource, unless the owner agrees to the use by others;
- the right of transfer (temporarily or permanently) of the above listed rights to others;
- the right to compensation if others inflict damage on the resource.

Additionally, two rules are considered relevant to the concept of property:

- Punishment rule: If some other person interferes with the use of a resource without the owner's consent, then this other person may be punished in an appropriate manner.
- Liability rule: If the resource use by the owner results in damage to persons or property of other users, the owner of the resource may be held responsible and damages can be claimed.

This ***bundle of rights*** can also be used to define property rights over land. The complexity of this system allows situations where for a specific land area different users may have different rights.[714] For example, in most of the Ethiopian Highlands the crop harvested from a specific field belongs to an individual, whereas the community has the right to graze livestock in the post-harvest time. These rights can be formal or informal. While formal rights are regulated by a legislative body, informal rights depend on the recognition within a community based on customs and conventions and are supported by social norms and values.

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[711] Deininger & Binswanger, 1999, 247.

[712] Davies & Gartside, 2001, 228.

[713] Birner, 1999, 44-45.

[714] Cousins (2000, 155) differentiates "bundles of rights and duties" with respect to (i) resource type (e.g. grass, trees, water, ect.), (ii) resource use (e.g. grazing, cutting wood, irrigating, etc.), (iii) resource users (e.g. individuals, groups, women, ect.), (iv) season of use (e.g. dry season, wet season, after harvest, drought year, ect.), and (v) nature and strength of rights and duties (e.g. exclusive use, permanent rights, seasonal rights, ect.).

For analytical purposes ***property regimes*** with respect to land are usually categorised in four basic types:[715]

(i) Open access / non-property: No defined group of users or owners exist and so the benefit stream is available to anyone. Individuals have both privilege and no right with respect to use rates and maintenance of the asset.
(ii) Common / communal property: The management group (or owners) has the right to exclude non-members, and non-members have the duty to abide by exclusion. Individual members of the management group have both rights and duties with respect to use rights and maintenance of the asset owned.
(iii) Private property: Individuals have the right to undertake socially acceptable uses, and have the duty to refrain from socially unacceptable uses.
(iv) State property: Individuals have the duty to observe use and/or access rules determined by a controlling/managing agency. Agencies have the right to determine use/access rules.

In ***open access regimes***, property rights are not specifically assigned to individual users or groups, thus also the term non-property is common. Therefore, the exclusion principle cannot be applied. In this situation, there is no incentive for individuals to invest in the land, and the free-rider problem (e.g. members trying to profit from the resource without complying with the rules) exists. However, only very few non-property regimes exist with respect to land. Open access resources and the related management problems rather concern resources such as the atmospheric air or the deep sea, where the distribution of property rights is technically not feasible. Common or ***communal property*** rights are assigned to a specific community. Members of this community have the right to exclude non-members from the use of the resource and can design management rules. Although there may still be free-rider problems, the community can design sanction mechanisms to reduce deviant behaviour.[716] Under ***private property*** rights, land is assigned to individuals or corporate entities (e.g. firms). Nevertheless, there may be formal or informal limitations on the rights imposed by the state or the community (e.g. for specific land areas certain use is not allowed). ***State ownership*** regimes imply that the state (or any part of the state such as local authorities) holds the property rights. The state may transfer temporarily some of the rights to individuals, firms or communities. If control mechanisms do not work, state property can become either an open access resource where everybody claims a right to use the land, or a de facto private property if individuals establish their rights by physical occupation.[717]

It is often argued that ***secured private property rights*** over land are a necessary condition for its efficient and sustainable use. It is specifically mentioned that the lack of permanent property rights decreases the incentives to make long-term investments in the land. This argument is supported with examples from mainly European history where an evolution from communal to private property has taken place at the same time as population densities increased and agricultural development led to increased land and labour productivity and increased agricultural output.[718] Similar cases are also cited from sub-Saharan Africa where tenure systems are moving towards private security of tenure in an attempt to capture the benefits of individualised holdings. It is argued that this move towards privatisation of resources is a necessary condition for greater economic efficiency.[719] Another point made is that well defined and secured individual property rights would ensure transferability of land, which in turn would enable available production factors to be used more efficiently. Productivity would be raised, as land would be transferred from less efficient cultivators to more efficient ones.[720] If transferability of property rights were possible, this would also improve spatial and social mobility.

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[715] e.g. Brandão & Feder, 1995, 192; Wachter & North, 1996, 10; Davis & Gartside, 2001, 228.
[716] For a detailed presentation of self-organisation and self-governance of communal resources see Ostrom, 1990.
[717] Brandão & Feder, 1995, 192.
[718] Pender, 1999, 45; Platteau, 2000, 52.
[719] Feder & Noronha, 1987, quoted in Joireman, 2001, 4.
[720] WB, 2002, 35.

Finally, it is argued that the ability to use land as a collateral, which is only possible with secured private property rights, increases the access to formal credit markets.[721]

On the other hand there are those who advocate that not private property is the precondition to motivate farmers to make long-term investments in the land, but rather ***land tenure security***, which is independent of the prevalent property regime (except for open access). It is argued that investments, be it conservation measures or investments in enhancing productivity, are only made if the investor can be sure to receive the benefits of the efforts. Secondly, it is mentioned that in order to obtain credit, land tenure rights must be secured. And thirdly, tradable tenure rights are crucial for the emergence and functioning of land markets.[722]

A common problem with both arguments mentioned above is that as long as private property rights or secured tenure rights are not enforceable, they do not provide the necessary security. This means that the mere possession of property rights does not encourage farmers to carry out long-term investments.

Lastly, there are those who support the idea that ***communal property*** does not necessarily lead to inefficient use and resource degradation. However, eight principles are mentioned, which must be fulfilled for common resources to be used in a sustainable manner:[723]

(i) clearly defined boundaries with respect to the members who have rights to use the resource and the resource itself;
(ii) congruence between appropriation rules (e.g. rules restricting time, place, technology and/or quantity of resource use), provision rules (with regard to labour, material and/or money), and local conditions;
(iii) collective choice management, by which most individuals affected by the operational rules have a right to participate in modifying the operational rules;
(iv) monitoring, usually by monitors who audit resource conditions and the behaviour of the appropriators and are accountable to the appropriators, or by the appropriators themselves;
(v) graduated sanctions, i.e. appropriators who violate operational rules are sanctioned in a gradual manner, depending on the seriousness and the context of the offence, by other appropriators or by officials accountable to these appropriators;
(vi) conflict resolution mechanisms that are available both to appropriators and their officials rapidly and at low costs to resolve conflicts between appropriators or between appropriators and officials;
(vii) minimal recognition of rights to organise by external government authorities who do not challenge the rights of the appropriators to devise their own institutions;
(viii) nested enterprises of appropriation, provision, monitoring, enforcement, conflict resolution and governance activities, depending on the number of appropriators and/or the size of the resource to be used.

In the following Section, the different stages of the property regime in the Ethiopian Highlands shall be briefly presented. A discussion will then follow on how these property regimes influence farmers' land management decisions.

[721] Deininger & Feder, 1998.
[722] Wachter & North, 1996, 2.
[723] Ostrom, 1990, 90.

### 8.2.1 A characteristic of land tenure regimes in the central Ethiopian Highlands

The following considerations are in general valid only for the central parts of the Ethiopian Highlands dominated by the Amhara, which also comprise the case study areas. Entirely different land tenure regimes are known in other parts of the country.

***The land tenure before the revolution of 1974***[724]

Until 1974, land was theoretically ***owned by the emperor***, who granted tenure of land subject to feudal[725] obligations. Such a grant of tenure was known as *gult*. However, the land was owned neither by the emperor nor by a privileged class of *gultegnas* (person who held *gult* rights), but by a kin group. Two forms of land tenure existed simultaneously: *gult* and *rist*. These terms did not imply ownership, but referred to the rights and the duties of the different "owners" who used the same piece of land.[726] Farmers considered the land communal property, which could be used by anyone. Access to land was considered a basic human right, only the yield from the land was privately owned.[727]

The ***relationship between land users and elites*** can nevertheless be characterised as feudal, even if land users enjoyed a relative degree of autonomy. Taxes or a tribute had to be paid in the form of agricultural products to the *gultegnas*. Increases in productivity thus benefited the elites rather than the land users, and land users had no real incentives to invest in the land. Agricultural products collected by the *gultegnas* were mostly used for consumption rather than investments in either the agricultural or the industrial sector, thereby helping to ensure that agricultural yields stagnated in the long term.[728]

**Rist**

***Communal ownership*** of land is generally denoted by the term *rist*. An individual was entitled to *rist* rights in a community if he or she could prove some blood relation to the founding patriarch of the commune. *Rist*, which entailed ***rights*** of use, could not be transferred to another person by sale or assignation, although *rist* rights might be leased and bequeathed. The rights conferred by *rist* were valid for a lifetime and extended over many generations. Following the death of a *ristegna* (person who held *rist* rights), his or her rights were distributed equally among sons and daughters.[729] One important feature of this system of access to land was the fact that a person held far more *rist* rights than needed for the *rist* land he or she used. Someone who had no *rist* land to cultivate in a certain community could bring suit for *rist* rights, which could lead to conflicts and disputes over rights with individuals cultivating land in the same community. This meant that individual rights to a plot of land were always limited by the rights of other descendants of a founding patriarch.

The ***kin group***[730] was of central importance in the exercise of *rist* rights. Membership in a descent group was conferred by birth. The significance of membership in the descent group clearly lay in the possibilities of access it afforded to scarce resources, i.e. to land; however, it also involved important rights and duties in relation to other members of the group. Although an individual was a member of many descent groups, and

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724 The following Section is based on Ludi, 1994, 42-52 and Ludi, 1997, 14-17.

725 The use of the term "feudal" is criticised in the Ethiopian context, as it implies an independent mode of production. The Ethiopian system, however, can best be characterised as a tributary system of production, which differed from feudalism in that land and land use were controlled by the farmers or the community and not by a feudal lord. Only towards the end of the 19$^{th}$ century, when private estates were granted to the aristocracy, did a quasi-feudal system develop. (Fekadu Bekele, 1989, 79)

726 Heinrich, 1984, 41.

727 Pausewang, 1983, 15.

728 Brüne, 1986, 19; McCann, 1995, 240.

729 Hoben, 1973; Desalegn Rahmato, 1984 17.

730 In the Ethiopian context, the term "cognatic descent" is frequently used to indicate kinship by either patrilineal or matrilineal descent

there were no criteria of exclusion or rules limiting active membership, he or she still had to meet three conditions in order to exercise *rist* rights on *rist* land:[731]

- close genealogical relationship,
- geographical proximity, and
- political influence.

In addition to economic significance, *rist* rights involved many other functions:[732]

- *Rist* rights guaranteed both ***social integration***, which could not be contested, and identification with a region or a group (family, descent group).
- The rule that people of other faiths (especially Muslims and Jews) or other professions (potters, weavers, smiths, tanners) had no access to *rist* rights meant that there was a ***limit on the number of people who could compete with farmers*** who did have access to these rights. This was a manifestation of social integration and also demonstrated a clear relation with the Coptic Church.
- *Ristegnas* were entitled to assume low-level administrative duties or seek legal redress in local courts.
- ***Social status*** and ***political power*** were always closely connected with land tenure.

In addition to entitling its holder to land use rights, *rist* was also linked with duties. Anyone who enjoyed *rist* rights within a community was obligated to pay a tithe to the *gultegna* (see below), to pay taxes, or to perform labour or military service.

**Gult**

A *gult* was not a spatial unit distinctly separate from *rist*; it applied to the same area of land. The difference between *gult* and *rist* was a difference in the nature of feudal tenure, and was linked with the ***legal and political status*** of the person who received the grant of tenure. A *gultegna* could collect payment from *ristegnas* in the form of tributes, taxes or labour. He was in turn accountable to the emperor, to whom he had to pay a portion of the taxes he collected from the farmers.[733]

In most Christian areas such as Gojam or North Shewa, the *gult* (a secular unit) and the church parish (an ecclesiastical unit) covered virtually the same areas of land. Each unit, or parish, was composed of the lands of one or more descent groups. Each parish was still an autonomous unit, even if it was subject to the control of a *gultegna.*[734]

At the lowest level, *gult* was granted to key political functionaries in local communities as a reward for services performed. *Gult* was also an instrument the emperor used to ensure the loyalty of his subjects. *Gult* was categorised according to the status of the grant holder who received it. *Gult* existed in both ecclesiastical and secular form. One special form of ecclesiastical *gult* frequently found was known as *rist-gult*. *Rist-gult* could be passed on by inheritance and, in effect, became a gift of land. All other forms of *gult* were of a temporary nature.

*Gultegnas* were the only intermediaries between the rural population and provincial governments prior to the Second World War. A *gultegna* was responsible for ***political administration*** and ***justice*** at the local level, for maintaining ***law*** and ***order***, for ensuring that obligatory labour (development of infrastructure, cultivation of land under the direct control of the provincial administrator or prince) was performed, and for collecting ***taxes*** and other fees. A *gultegna* earned the greatest part of his income from taxes levied on land. As

731 Heinrich, 1984, 43.

732 Hoben, 1973, 6; Pausewang, 1983, 25; Girma Kebede, 1988, 128.

733 Fekadu Bekele, 1989.

734 Hoben, 1973, 75.

a rule, these taxes were one-fifth of the total crop production in an area under *gult*. If the *gult* applied to an ecclesiastical unit, services were performed for the Church in lieu of paying taxes.[735]

In 1947, local communities were founded specifically to perform political functions, thereby substantially reducing both the duties and the rights of *gultegnas*. Ecclesiastical *gult* was partially excluded from this reform. Judges at the community level who handled minor cases emerged as new functionaries with important duties. In many cases *gultegnas*, who had been partially deprived of power, became judges in an attempt to preserve their social influence.[736]

**An appraisal of the influence of pre-revolutionary property regimes on the land use system and management practices of subsistence farmers**

The organisation of the Amhara into cognatic descent groups and the system of land tenure relationships had different positive and negative impacts on land use and on the options available to smallholder households.[737]

- An individual who was unable to obtain enough land in a community because of demographic pressure, land degradation, or excessive taxes could seek to become a member of another group. On the whole, there was a comparatively high degree of ***spatial mobility***.
- Cultivating land in different communities was a way of pursuing the smallholder strategy of ***spreading risk***, and made it possible to take maximum advantage of differences in land quality due to ecological conditions.
- ***Political influence*** was determined on the basis of the amount of *rist* land an individual cultivated. At the same time, a person with political influence was able to claim additional *rist* rights. This allowed for considerable social mobility.
- Access to land was determined in ways that made it possible for almost everyone to cultivate a plot. There were comparatively few landless farmers. Leasehold relationships were important, but there was no distinct ***leaseholding class*** of tenant farmers. Leaseholders were often young farmers who inherited additional land upon the death of their fathers. Lessors included large landholders, the army, and elderly people no longer able to cultivate land themselves. The relationship of farmers to their land, and the importance they accorded to their economic, social and political options became obvious during uprisings staged against land and tax reforms in the middle of the 20th century. These reforms would have had the effect of abolishing the system of *rist*. Land users resisted this move to privatise land, which not only would have made spatial and social mobility more difficult, but could also have led to concentration of land ownership in the hands of a few large landowners. The nobility equally opposed a change of the land tenure system, as they too were involved in land litigation cases and tried to expand their holding. By changing the tenure system towards a more privatised one, they would have lost the possibility to acquire more land and more political influence.[738]
- One of the greatest weaknesses of the system of *rist*, especially in areas where land reserves were minimal, were ***fragmented patterns of ownership***. The laws of inheritance provided for division of property among all heirs, so that plots became increasingly smaller. Some scholars[739] even doubt that the *rist* system guaranteed farmers access to land. In theory, a *rist* plot was guaranteed for a lifetime. However, rights of use could be called to question by anyone who could prove a closer relation to the descent group than the farmer currently exercising *rist* rights. This led to endless conflicts and disputes over rights with considerable costs in terms of both time and money.[740]

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735 Hoben, 1973, 77.

736 Hoben, 1973, 207.

737 Hoben, 1973; Pausewang, 1983; Desalegn Rahmato, 1984; Heinrich, 1984.

738 Joireman, 2001, 18.

739 e.g. Desalegn Rahmato, 1984, 18.

740 Levine, 1974, 126. Joireman (2001, 15) found for Tegulet & Bulga area (to which Andit Tid belongs), based on court records, that in 1947 almost 81% and in 1967 almost 82% of all court cases were land cases.

- ***Uncertainty about rights of use*** led to cultivation oriented towards short-term needs rather than long-term yield. Accordingly, no costly investments were made in inputs that would maintain or boost yields. This resulted in ecological damage that was almost impossible to reverse.
- ***Direct taxation*** of crop yields did little to make investments in productivity-increasing technologies more attractive. Because the *gultegna* was not the actual landowner, he had no interest in investing in agricultural inputs. The fact that land could not be mortgaged prevented individual farmers from becoming overburdened with debt, but it also made it impossible to obtain investment credits.

***Political and institutional changes following the revolution of 1974***[741]

The revolutionary government, which took power after overthrowing the monarchy in 1974, inherited a difficult economic situation. The agricultural sector, which contributed by far the most to the Gross Domestic Product, and which also accounted for the overwhelming share of Ethiopia's earnings from exports,[742] was split into a "modern" export sector controlled by foreign capital, and a smallholder subsistence agricultural sector which was closely bound to elites. Under reforms carried out in 1975, all land was immediately nationalised. ***Nationalisation*** was designed to ensure that export revenues would flow directly into the state treasury as well as to increase smallholder production and dissolve the dependency relationship, which existed between farmers and the elites. The revolutionary government expropriated large farms and established state farms, while also trying to transform the independent smallholder subsistence sector into ***agricultural co-operatives*** as rapidly as possible.[743] No redistribution of land was originally planned in the predominantly Amharic provinces where the *rist* system was prevalent. The new government believed that smallholder family farms could simply be integrated directly into a collective socialist economy, given the communal form of land ownership and the overlapping systems of jurisdiction (*rist*, *gult*, ecclesiastical land) previously in effect. There was, however, virtually no existing basis for collective land ownership or collective labour in areas where *rist* applied.[744]

**Social changes**

Initially there was ***little change*** in the social structure in provinces where the *rist* system was in effect. The law provided that every Ethiopian had the right to a maximum of 10 hectares of arable land. But widespread social and economic inequities still persisted, since even prior to the revolution only a few farms had more than 10 hectares of cropland, and the law said nothing about the distribution of important agricultural inputs like ploughs and oxen.[745]

The land reform had the overall effect of ***destroying the old social structure*** (mutual dependency of *ristegnas* and *gultegnas*) without creating anything new in its place. The dissolution of locally rooted institutions did weaken the influence of certain wealthy and powerful farmers, and it partially expanded the power of groups that had previously had no social influence. However, it also created such a great gap between farmers and decision-makers, that the farmers no longer felt any moral obligation to accept and implement decisions which affected them. As a result, decisions were sometimes implemented only under heavy threat of sanctions. Even the land use system remained largely unchanged: smallholder families continued to practice subsistence agriculture on insufficient plots, using simple technology.[746]

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741 The following Section is based on Ludi, 1994, 53-65 and Ludi, 1997, 19-22.

742 In 1965 agriculture and animal husbandry contributed 65% of the GDP, while in 1974 78% of Ethiopia's exports came from the agricultural sector (coffee, oilseed, pulses, animal pelts and skins, and live animals, to mention only the most important). (Brüne, 1986, 57)

743 Kirsch et al., 1986, 20.

744 e.g. Hoben, 1973, 229.

745 Kirsch et al. 1986, 29.

746 Kirsch et al., 1989, 29.

**The impacts of political and institutional changes on the options of land users**

Starting in 1975, all farmers within a community were forced to join a ***Peasant Association*** (PA). The basic purpose of the PA was to incorporate the rural population into an egalitarian, democratic, participatory organisation, to involve them more closely in decision-making processes and allow them to help shape local political and administrative institutions. The main task of the PA's was to carry out the land reform, specifically by assuming responsibility for the distribution of nationalised land, but also by performing political duties and providing judicial authority at the local level. ***Service Cooperatives*** (SC) were also founded starting at the end of 1975. The SC's were designed to promote co-operation between several PA's in order to organise agricultural activities both prior to and after production (provision of agricultural inputs such as fertiliser and credits, marketing of agricultural commodities, provision of consumer goods, processing of raw materials). PA's and SC's were organised in a way that reflected the formalised and politically legitimised style of pre-Revolutionary organs of administration and adjudication.[747]

After a short period of autonomy, however, PA's and SC's were gradually forced to become ***organs of transmission***. This entailed a fundamental change of their character: rather than taking initiatives and communicating the ideas and needs of the local population *from the bottom up*, they were increasingly made to transmit decisions and orders decreed by central authorities *from the top down*. PA's were continually enlisted to carry out governmental directives, to enforce collection of taxes and other contributions, including grain quotas, and to recruit young men for the war in the north. The PA's consequently lost their popular appeal and were forced to surrender much of their autonomy and their function as pressure groups or trade unions that represented the local population.[748] The state continued to expand its central control, installing PA presidents by undemocratic means. It is not surprising that local populations increasingly saw the PA's as governmental organs run along centralised lines of authority. This perception also had an impact on how farmers accepted soil conservation measures, which were often shaped at the local level by the PA or SC.[749]

In addition to paying regular ***taxes***, which gradually rose from EB 10 to EB 20, farmers were also requested to make innumerable "***voluntary contributions***". These included contributions to associations at higher levels, contributions to support infrastructure in local centres – from which rural populations rarely received any benefit – and additional war taxes.[750]

Starting in 1979, each household was required to sell a certain ***quota*** of grain at a price fixed by the state, regardless of the size of the harvest. This measure had a direct and drastic effect on farmers, as they might subsequently be forced to buy grain in order to have enough for their own household. In this case, they were obliged to purchase grain at much higher prices on the open market.[751]

It is difficult to judge the extent to which governmental ***pricing policy*** (fixing of maximum prices for agricultural products to benefit the urban population) can be considered a possible hindrance to conservation efforts. It is certain that low prices kept farmers from selling any more than they had to, with the result that they were unable to expand their capital stock or improve their yields. However, it is questionable whether higher prices for agricultural products would have provided a direct incentive to conserve more land (cf. Section 6.1.5). On another level, the combination of low prices and obligatory quotas had negative ecological effects. Farmers were forced to cultivate more land and to use the land more intensely. They could not afford to leave their fields fallow, as this would have entailed the risk of failing to meet their quotas or being unable to provide enough food for their own households.

The prohibition on cultivating land in more than one PA, ***strict controls on migration***, and the constitutionally guaranteed right to land – combined with the low social status of many handicrafts – kept

747 Goericke, 1977, 111ff, 129ff.

748 Desalegn Rahmato, 1993, 39.

749 Pausewang, 1991, 71.

750 Pausewang, 1991, 72.

751 Kirsch et al., 1989, 137.

farmers closely bound to the land. Because they only had a right to land if they earned the major portion of their income from agriculture, they had no interest in diversifying their sources of income.

Periodic ***redistributions of land*** gave farmers no increased assurance of their right to land, even though this was one of the declared aims of land reform. This uncertainty did much to discourage them from making efforts to conserve the land.

The revolutionary government, like so many others of its type, relied heavily on the ***production sector*** without giving due regard to the ***reproductive sector***. State Farms and Producers Cooperatives were encouraged, while smallholders were supported only to the extent that they produced surpluses, which could be taxed. All other sectors concerned with reproductive functions, i.e. household production and subsistence agriculture, were of no interest to the revolutionary government, and therefore not worthy of support. Surplus production was thus of no benefit to the farmers' population, and the state made no investments in smallholder plots.

The revenue collected by local, self-administering organisations, and the increasing burden on smallholder households caused by taxes, fees and grain quotas forced farmers into a mode of passive resistance; increasingly, they reverted to subsistence agriculture.[752] Their experience with government (agricultural) policy also made them mistrustful of development projects, which were frequently linked with expenditures – of land, labour or money. In the view of the farmers, development projects were merely likely to provide an additional basis for collection of state revenue in the event that they increased productivity. In the final analysis, this led to a situation of ***agricultural involution***, in which farmers increasingly concentrated on production for household consumption rather than participating in a market economy.[753]

**Soil and water conservation**

Remembering the great famine of 1973/74, the revolutionary government launched with the support from donor organisations (e.g. WFP, EEC) ***large-scale resource conservation projects***. Activities concentrated on soil conservation activities on arable land, afforestations and closures of highly degraded areas. However, an evaluation of the success of these large-scale conservation schemes comes to rather gloomy results.[754] The following reasons for the unsatisfactory adoption of SWC and the limited success of the conservation schemes are mentioned:[755]

- the 'top-down' character of the decision-making process, which leaves no space for local and individual adaptation of the technologies;
- the implementation of many conservation activities with Food-for-Work, which led farmers to regard themselves as paid workers who consequently did not take ownership in the conservation structures;
- the lack of integration of the newly proposed technologies with traditional conservation technologies and the limited combination of SWC and land use technologies;
- uniform SWC technologies and approaches despite the natural and socio-economic diversity of the country;
- the concentration on mechanical SWC technologies without due consideration of its costs and benefits;
- the linkage of SWC with villagisation and resettlement;
- the system of grain quotas and low producer prices which prevented farmers from saving;
- the insecurity with regard to land use rights and ownership of trees;
- the concentration of agricultural extension agents and financial means in Producers Co-operatives and state farms;

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752 Pausewang, 1992, 194.

753 Brüne, 1990, 27.

754 *"Despite more than a decade of government initiatives in conservation there has been limited success. An attractive approach to conservation has not been developed, and the policy environment has discouraged farmers from adopting conservation measures [...]."* (Wood, 1990, 195)

755 e.g. Alemneh Dejene, 1990, 144; Ståhl, 1990, 6; Wood, 1990, 194; Humphrey, 1998.

- the lack of consideration of the livestock sector which is often a major source of farmers' resistance to implement mechanical SWC measures and a reason why biological SWC measures often fail;
- the lack of coherent national forest policy;
- the lack of population and social policy.

Between 1976 and 1990, approximately 71,000 ha of crop land were treated with soil and stone bunds, 233,000 ha were terraced for afforestations, 12,000 km of check dams were built on gullied land, 390,000 ha of land was closed for natural land regeneration, 448,000 ha of land were planted with different tree species, and 526,425 ha (!) of land were treated with bench terraces. By 1990, however, only 30% of the soil bunds, 25% of the stone bunds, 60% of the hillside terraces, 22% of the original area of tree plantations, and 7% of the closed areas survived.[756]

***The transfer of power in 1991***[757]

In March 1990, the pressures of the civil war forced the DERG regime under Mengistu Haile Mariam to announce a policy of economic liberalisation. Farmers were given the right to sell their products free of restriction, mandatory quotas were abolished, and the co-operatives were allowed to dissolve. The result was total insecurity for farmers, which was unrelieved even after the overthrow of Mengistu in May 1991.[758] The transitional government, which was established in June 1991, published an official report on economic policy in November of the same year. This paper emphasised the need for a democratic system with broad participation by all segments of the population in decision-making processes. The state would no longer be the all-powerful determinant force in society; private initiative was to be fostered instead. Agriculture would be the cornerstone of the economy and would play a decisive role in economic recovery as well as in the future development of Ethiopia.[759]

No attempt was made to change the policy of ***official state ownership of the land***. The issue was postponed until the transitional government would be replaced by an elected government, since the transitional government was divided between two fundamentally irreconcilable ideas about how to approach the question. Some wanted the land to remain property of the state, which would grant long-term rights of use. Others wanted a free land market with no restrictions, arguing that this was the only way to guarantee freedom of access to land, and thus the only chance to achieve the rise in productivity so urgently needed.[760]

Eventually, the following measures were adopted with regard to land use:

- Farmers would be supported in their efforts to correct unjust land distribution arrangements, and landless farmers would receive land. Further fragmentation in the pattern of land ownership would be avoided.
- Land could not be sold or mortgaged, but leasing and inheritance would be allowed.
- Agricultural products could be sold without restriction.
- Wage labour would be permitted in the agricultural sector.

These changes were complemented by further measures:

- Additional resources and personnel would be made available to support the smallholder sector. Areas with particular problems (land scarcity, susceptibility to drought and erosion) would receive special attention.
- Villagisation programmes instituted by the revolutionary government would be halted.

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756 USAID, 2000, 8.

757 The following Section is based on Ludi, 1994, 66-68 and Ludi, 1997, 22-23.

758 Pausewang, 1992, 190.

759 TGE, 1991.

760 Desalegn Rahmato, 1994, 274.

- Voluntary resettlement would be supported if it did not lead to conflicts with people in the resettlement area.
- Modern agricultural operations based on private enterprise would be promoted.
- Top priority would be given to conservation and development of natural resources, using appropriate legal means, in collaboration with local populations.

***Recent developments with regard to land tenure – the 1997 land redistribution in Amhara Region***

The 1991 economic policy of the Transitional Government did not change the structure of land tenure – ***land ownership remained under the state, and farmers enjoyed only usufruct rights***. Also the constitution of the Federal Democratic Republic of Ethiopia (FDRE)[761] of 1994 did not make fundamental changes. As is stated in Chapter 3 on 'Democratic Rights' under Article 40, the 'Right to Property', Section 3,

*"The right to ownership of rural and urban land, as well as of all natural resources, is exclusively vested in the State and in the peoples of Ethiopia. Land is a common property of the Nations, Nationalities and Peoples of Ethiopia and shall not be subject to sale or to other means of exchange."*

Section 4 continues as follows:

*"Ethiopian peasants have right to obtain land without payment and the protection against eviction from their possession. The implementation of this provision shall be specified by law."*

Based on the constitution, the Regional States set up their own ***land proclamations***. The main justification in Amhara Region for the formulation of the 1997 land proclamation[762] was that a difficult situation existed in the Region, because in areas that were liberated before the overthrow of the DERG regime in 1991, land redistributions had already been carried out to provide the landless with land. A land proclamation became necessary in order to carry out a ***land distribution*** also in the other areas and to ensure a uniform and equitable land tenure system. A second justification is that although land under the former government was the common property of the people, large disparities in land holdings existed because so called "bureaucrats" – people who held a position in the PA administration during the DERG regime and "feudals" – people who held positions during the imperial time, used their position to acquire more and better land than they were entitled to.

The land proclamation foresees the following ***procedure***: two study committees are to be established per KA, one to make an inventory of different land units (e.g. arable land, grazing land, forest land, village area, degraded areas, etc.), the other to register all households within a KA, regardless of whether they already have land or are landless. These two inventories are to be approved by the inhabitants of the KA and handed over to the land distribution committee. This committee is then to determine the land size to be allocated to each household and to present the results to the residents of the KA for approval. The committee is to specifically list those households, from whom land has to be taken away, and those households who are to receive this land. The land has to be re-distributed in a lottery process in the presence of the members of the land distribution committee, elders, members of the KA administration and the farmers directly affected by the redistribution. The committee is to ensure fair distribution results with respect to the fertility of the land and irrigable areas between the previous holders and the new landholders. It should also ensure that female-headed households are not discriminated. The proclamation also addresses the question of compensation for investments in the land. It is mentioned that the "bureaucrats" who had acquired land illegally are excluded from the right to compensation. Those who have acquired the land by legal means and made investments in the form of perennial crops are entitled to compensation from the new land use right holder in the form of cash, material or labour. The KA administration has the duty to ensure that the compensation is paid. No reference is made with regard to investments in the form of SWC structures.

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761 FDRE, 1994. [www.ethiopar.net/English/cnstiotn/consttn.htm]

762 "Proclamation No .... 1989 EC – A proclamation to provide for the redistribution of rural lands in Amhara Region." Unofficial translation, no direct quotes are made.

A ***land redistribution*** was carried out in Andit Tid in 1997. In Mesobit & Gedeba, the land distribution had not yet been started in 1998 because of serious resistance by land users. In the Simen Mountains, the land redistribution has in most areas already been carried out prior to 1991. In Maybar, the process of land assessment and listing of entitled households has been made. As Maybar belongs to a Wereda that is classified as having an unfavourable people-land ratio, no land distribution was carried out.[763] For Anjeni no information is available, however, it must be expected that the distribution did also take place there.[764]

The official reason for the land redistribution in Andit Tid[765] was to give land to the increasing number of ***landless*** and to ensure a ***fair distribution*** of arable land among the community members. Problematic, however, in Andit Tid and elsewhere, was that the number of landless young farmers was far bigger than the amount of land that could be distributed, i.e. land from the deceased and reserve areas. Farmers with big holdings had to hand in part of their holding. Former landless farmers received only 2 *timmad* (approximately 0.5 ha), which is far below what a person would need to be self-sufficient.

Different ***categories of wealth*** and ***political groups*** were made. Accordingly, rich farmers are those with two or more oxen, average farmers those with a single ox, and poor farmers those without any oxen at all. Those farmers who held a position in the administration during the DERG regime were labelled "bureaucrats", while those who held a civilian or military position during the imperial regime were referred to as "feudal".

The ***maximum land holding*** per household – irrespective of wealth group or household size – was set to 12 *timmad*, approximately 3 ha. For households with less than 12 *timmad* land no change in holding occurred. For "bureaucrats" and "feudals", the maximum land holding was set to 4 *timmad* (approximately 1 ha), regardless of their family size. It seems that different rules were applied. While some of the "bureaucrats" mentioned that they could select the plots they wanted to keep, others mentioned that they had not been allowed to decide anything. The land was divided into equal plots and then distributed by drawing lots.

From the ecological point of view, the biggest problem of the land distribution was the ***lack of land use planning***. In Andit Tid, for example, the land to be distributed included areas that were either heavily degraded or totally unsuitable for cropping. A second problem was the inclusion of all land, not excluding private afforestation areas that farmers had established on degraded land. This means that a farmer could receive a sufficient amount of land, yet that land may not produce enough or may be highly susceptible to soil degradation if cropped. In general, it must be feared that erosion rates will rise, as land use intensity is increasing due to reduced fallow periods and the cultivation of erosion-prone plots. Lastly, young farmers obtained land far away from their fathers'. The traditional transfer of knowledge from fathers to sons is thus interrupted. Young farmers have to experience on their own how to best use the new land or where ecological limits are set.

### 8.2.2 An appraisal of the effect of different tenure regimes on the willingness of farmers to invest in their land

***Land tenure insecurity*** seems to be nothing new or unknown to the farmers in the Central Ethiopian Highlands. During imperial times, the land tenure regime granted security insofar as *rist* rights could not be lost and could be transferred to the next generation. Tenure security concerned only the right to land, but not the specific plots a farmer cultivated. If another farmer could prove closer relationship to the founder of the

763 Pankhurst (2001, 9) mentions that from Dese Zuria Wereda the land distribution was carried out only in 15 of 54 KAs. The criteria whether a land redistribution was carried out or not was landholding per household, which must be above 0.5 ha

764 There were large demonstrations by farmers from Gojam in 1998. Farmers were even marching to Addis Abeba. They resisted strongly a new land redistribution as they considered the land distribution highly politicised and instrumentalised by the political leaders of the country and against the interests of the Amhara people.

765 According to Yohannes G/Michael (1999,45) the situation is similar in other areas of Northern Shewa.

community, the right to cultivate a specific plot could be transferred to this new claimant. There is ample evidence that disputes over *rist* rights led to endless court cases with considerable costs in terms of money and time. As population densities increased and land reserves diminished, the *rist* system in combination with an inheritance system based on equal shares for all descendants led to decreasing farm sizes, increasing costly land disputes, and high fragmentation of land holdings. Fragmentation, however, was not in any case considered negative, as it allowed farmers to make best use of ecological niches and to spread risks.

Not only the insecurity with regard to specific plots a farmer could cultivate, but also the dominant ***societal structure*** can be made responsible for lacking long-term investments in the land prior to 1974. As a fixed percentage of the harvest had to be delivered to the feudal lord, farmers had no interest to invest in resource conserving or productivity enhancing technologies, because any additional production was siphoned off by the elites. The feudal lords themselves, because they were not the landowners, did not invest the tributes they collected from the agrarian sector in either the agricultural or the industrial sector, but used it mainly for consumption.

The land tenure regime and agricultural policies after the ***revolution*** in 1974 brought about changes that affected the motivation to invest in the land greatly. Although it was a declared goal of the 1975 land reform to eradicate inequalities and to increase security for small-scale farmers, neither of the two objectives could actually be achieved. The frequent land distributions[766] can be interpreted as a disincentive to invest in the land, since they made land tenure insecure. Price policies and the compulsory quotas of grain to be sold to the government also discouraged farmers from investing in production enhancing technologies. The constitutionally guaranteed right to land, the ban on farming land in more than one PA and strict controls of migration, coupled with the very low status of handicraft, strengthened the bond of farmers with the land. The provision that the entitlement to land is guaranteed only to those who generate their major income from farming prevented farmers from diversifying their income by carrying out another profession.

In Andit Tid, feelings towards the ***1997 land distribution*** were mixed. Young farmers obviously evaluated the land distribution positive as they received own land. It enabled them to leave their parents' household and to set up an own homestead. They mentioned, however, that the amount of land they received is far too small to survive. Many of those farmers who received two *timmad* have to rent out the land because they cannot get access to oxen for ploughing. Older farmers generally evaluated the land distribution as negative, irrespective of whether they lost land or not. It was pointed out more than once that with the land distribution, poverty is simply spread among all, and that viable farms that could produce surplus in the past will face food shortages in future. Particularly older farmers mentioned that a one-time land distribution does not change the situation at all, as the next generation of young landless framers is already waiting for the next redistribution. They feared that despite all rhetoric, also in future, land distributions will be carried out in regular intervals. They therefore considered their current land holding not secured.[767]

Those who mentioned that, in general, the land distribution was necessary, pointed out that the ***process*** was wrong. They specifically mentioned that the classification of specific households in "bureaucrats" and "feudals" was unwise. Many farmers who held minor positions during the DERG regime, positions that could not be used to acquire land illegally, were also classified as bureaucrats. It was also mentioned that because the land distribution was used also to punish former government employees, the willingness to accept positions in the KA administration is very limited. A second point criticised with regard to the distribution process was the lottery draw. It was complained that those farmers who had to hand in land gave only infertile and remote plots, and that the land distribution committee did not ensure a fair distribution with respect to the fertility of the land between the previous holders and the new land holders.

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766 Yohannes G/Michael (1999, 44) mentions for Maybar for example 7 land distributions between 1979 and 1992.

767 A modelling on the effect of land tenure insecurity and soil conservation investments produced similar results: older farmers with above village average land holdings felt less secure to keep the land in future, i.e. were convinced that part of their holding would be taken away in a future round of redistribution and were thus less willing to invest in SWC. Households with below average holdings were more secure to keep their holding also in future and carried out comparably more SWC investments. (Tekie Alemu, 1999, 26)

A very negative effect of the land distribution was that in the land proclamation, no mention is made with respect to ***compensation payments for SWC*** investments. Although it is mentioned that when land with perennial crops such as trees is distributed, the previous holder is entitled to compensation payments, such compensations were in no instance actually paid in Andit Tid. Two of the 15 farmers interviewed in Andit Tid mentioned that they lost tree plantations. One of the two mentioned that for him this is no disincentive and that he will continue to plant trees in future. The other mentioned that he will stop investing labour and capital in planting trees, because he cannot be sure whether a land distribution will be carried out again in future. Thus, the signals with regard to whether land tenure insecurity is in effect an important disincentive for investing are not clear. Extension staffs, on the other hand, mention that the land distribution has led to a declining motivation of farmers to plant trees.

In Andit Tid, most farmers were sure that in future – some mentioned a short time span of 5 years – a land distribution will again be carried out. When asked whether the land they currently cultivate could be bequeathed without restrictions, most farmers mentioned that they believe the land is theirs. This indicates that most farmers ***felt quite secure*** about their tenure, although some, especially older farmers with quite substantial holdings, mentioned that they might hand part of it in in the next round of distribution. The individual perception of quite secure land tenure should, in theory, lead to a higher incidence of SWC investments. However, the contrary could be observed; farmers had dismantled conservation structures rather than constructed new ones. It seems therefore that in Andit Tid, land tenure insecurity is not the major reason for not investing in SWC. Other factors, such as the available technology with its negative side effects, or overall land scarcity that prevents farmers from being self sufficient even in the case where no land is occupied by conservation structures, seem to have a stronger influence on the decision whether or not to invest in SWC (cf. Section 6.3.2 and Table 57).

Quite a different picture is presented in ***Mesobit & Gedeba***.[768] Here, farmers have invested in their land for generations and have constructed impressive stone terraces. Most farmers interviewed mentioned that they would strongly resist land redistribution. Their main argument was that they themselves or their fathers invested much labour in building and maintaining the stone terraces and are therefore not willing to hand over their land to others. Even when the question of compensation was raised they resisted. It was also often mentioned that a land redistribution would not help to alleviate poverty; on the contrary, it would simply spread poverty among more households. It was stressed that the young generation has to engage in other sectors than farming to relieve pressure on the land. Many households have reacted to the growing land scarcity by sending their children to school, even as far as Debre Birhan, and by exploiting other income possibilities such as growing high value market crops or being engaged in handicraft.

In contrast to findings from Andit Tid, from the information from Mesobit & Gedeba it can be concluded that there is a strong link between ***land tenure security and investments***. Whether land tenure security alone is already enough or whether it is merely one factor among others, remains open.

Interesting is the case of ***Maybar***. Here, SWC has a long history in flatter parts of the area, whereas on steeper slopes that have been used only for a relatively short time, there are not many traditional conservation structures. These areas will be used more intensely in future, as land scarcity is increasing. The 1997 land redistribution was not carried out in this area because of an unfavourable land-people ratio. Only few farmers, mainly returnees from resettlement areas and former soldiers, have received land, whereas about a quarter of the population of Maybar KA is landless. For those farmers who own land, the fact that no land redistribution has been carried out should be a positive signal. Unfortunately, the fieldwork for the present study was carried out too shortly after people heard about the decision that the land distribution was abandoned. It could therefore not be examined whether this increased land tenure security leads to a higher incidence of SWC. However, observations seem to support this hypothesis, as quite a number of farmers were seen constructing stone bunds in areas previously not conserved.

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[768] The interpretation is biased insofar as interviews were conducted only with farmers who own land. Like in other areas landless farmers would probably be in favour of a land redistribution.

## 8.3 Institutional Regulations Related to Religion

*"The real case is that holidays do not mean time that is exclusively allocated to pure leisure and recreation. [...] Activities which are emphasised during holidays are useful to the survival of the household and society at large. Some of them are socially useful; others are physiologically useful, and still others are economically useful."*
*(Dejene Aredo, 1991, 172)*

**Orthodox Christianity**[769]

In Christian areas, religion has a strong influence on everyday live of farmers in various aspects. Some authors argue that the Church is the ***focal point of social life***.[770] Parishes in pre-revolutionary times were equal to the property of a kin group. This is the major reason for the strong attachment of farmers to their parish, as this was the same area where they could realise their *rist* rights. Thus, farmers were not only bound to each other through religious contacts, but also their economic and political contacts were defined within the parish.

The Church and religious belief[771] have a considerable influence on farmers' activities: there are numerous ***social organisations*** with religious affiliations, church services are regularly attended, and religious holidays are scrupulously observed. In the local social hierarchy, priests are still at the top. This can be attributed to their function as intermediaries between man and God, and also to the informal power they exercise as representatives of the *Tabot* (a symbol of the saint to whom a church is dedicated).[772]

The Coptic Church has many ***religious holidays***, all of which are connected with a particular saint. These holidays fall into several categories:

- On a ***strictly observed holiday***, no work can be done except for cooking and caring for livestock.[773] Whether or not going to the market is allowed, is a disputed matter. The third, seventh, twelfth, eighteenth, twenty-first, twenty-third or twenty-fourth, twenty-seventh and twenty-ninth days of each month are included in this category.
- Among the ***less strictly observed*** holidays are the fifth, sixteenth, nineteenth and twenty-third or twenty-fourth and twenty-eighth days of each month. All types of work are allowed on these days, with the exception of ploughing, planting and weeding. The mill and the local shop remain open.

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769 The following paragraphs are based on Ludi, 1994, 134-141, and Ludi, 1997, 45-48.

770 Goericke & Heyer, 1976, 224.

771 Along with monotheistic Christianity, the Amhara believe in many supernatural spirits with pagan roots, which the official church has been unable to eradicate. Among these are *Zar* spirits; by contrast with the Christian God, it is believed that these spirits can punish humans directly. There is a patron-client relationship between human beings and pagan spirits: if homage is paid to the spirit in some way each day, it will offer protection. Feminine *Adbar* spirits protect the community from disease, misfortune and poverty, while their masculine counterparts protect against conflict, feuds and war. *Saytan*, which are personified as miniature devils and goblins, inhabit streams, ponds, swamps, forests, caves and the like, and bring harm to human beings. (Reminick, 1973, 31) *Saytan* can also have ecological and social impacts: people fell trees where they believe that *saytan* dwell, and potters who obtain clay near streams or swamps are avoided because people believe they have come into contact with *saytan*.

772 Reminick, 1973, 28.

773 Activities related to preparation of food, such as grinding grain or hauling water and collecting firewood, are forbidden in Anjeni, but allowed in Andit Tid. However, Dejene Aredo (1991, 166) also includes tilling fields, planting, weeding, mowing, winnowing, feeling trees, constructing houses, grinding or pounding grain with mortar and pestle (although grinding coffee is allowed), and handicrafts among the forbidden tasks. On the other hand, caring for animals, harvesting cereals, preparing food, and hauling water and gathering firewood are permitted.

- ***Saturday*** and ***Sunday*** are not actual holidays. Nevertheless, work in the fields is not allowed. Saturday is a market day, while Sunday is entirely devoted to religious ceremonies and meetings. The prohibition of work in the fields on Saturday stems from the year 1450, when it was decreed that all Ethiopians had to observe the Sabbath.[774]

| Month | Workdays with no restrictions | Less strictly observed holidays | Strictly observed holidays | Saturdays | Sundays | Total days |
|---|---|---|---|---|---|---|
| Meskerem | 11 | 4 | 7 | 4 | 4 | 30 |
| Tikimt | 10 | 4 | 6 | 5 | 5 | 30 |
| Hidar | 12 | 4 | 6 | 4 | 4 | 30 |
| Tahsas | 12 | 2 | 8 | 4 | 4 | 30 |
| Tir | 9 | 3 | 9 | 5 | 4 | 30 |
| Yekatit | 12 | 3 | 6 | 4 | 5 | 30 |
| Megabit | 13 | 3 | 6 | 4 | 4 | 30 |
| Miyaziya | 6 | 3 | 13 | 4 | 4 | 30 |
| Ginbot | 9 | 5 | 8 | 5 | 5 | 30 |
| Sene | 13 | 4 | 5 | 4 | 4 | 30 |
| Hamle | 8 | 2 | 12 | 4 | 4 | 30 |
| Nihase | 11 | 3 | 7 | 5 | 4 | 30 |
| Pagume | 3 | 1 | 1 | | 1 | 6 |
| Total | 129 | 41 | 94 | 52 | 52 | 366 |

*Table 62: Religious holidays in Christian case study areas by category and month (location specific differences are possible).*
*[Source: Own investigation 1992, 1997]*

Various ***religious-based associations*** are of great importance, not only socially, but also economically:

- ***Mahiber*** are religious associations that honour a particular saint. A group of 12 or more families meets at the home of a different member each month to pray and share a meal. *Mahiber* are usually composed of people who are related or who are friends. In addition to fulfilling religious duties, they also offer solidarity: members help each other when there is extra work to be done or when a death occurs, and richer members support poorer ones when the need arises (loaning oxen, sharing cereal, etc.). Despite this mutual aid, *mahiber* should not be confused with other types of co-operation. Members of a *mahiber* co-operate and offer aid only when there is an urgent need.
- The ***iqub*** is an association whose purpose is to collect money, which is then offered in succession to its member families. In another form of *iqub*, groups of several families set aside a certain amount of money each month, which they then use to purchase an ox for the Christmas celebration.
- The ***idir*** is a funeral association. Its members help each other in the event of death by providing funds to cover the heavy expenses of funerals and funeral ceremonies.

Most of these associations have members of comparable economic status, so that goods and services are redistributed to the benefit of the poor only on a small scale. Nevertheless, their functions are important, especially for poorer households, which can take advantage of the resources of better-off households during an emergency. Mutual aid – or direct support for poor households in the case of rich households – is a social obligation.

The Church also claims some of what each household produces, and offers social integration at the local level in return. In times of uncertainty this is a definite benefit. It seems that the Church is the most stable

774 Goericke & Heyer, 1976, 212.

institution in rural Ethiopia and therefore promises people a secure environment in comparison to the ever-changing governmental institutions. The role of the Church as a regulative institution therefore remains strong.

The ***status of farmers*** relative to groups with other occupations is determined partly by social norms. Because a particular occupation is frequently linked with religious affiliation (Jews are potters, while Muslims are smiths and merchants), certain types of work are not open to Christian farmers. This societal structure with regard to the status of different professions contributes greatly to the problem of increasing population pressure on the land. It also hinders the development of a society based on labour division in Christian rural areas, and thereby the creation of surplus value, which could be invested in productive sectors of the rural economy. Highest status enjoyed before the revolution titleholders and members of the higher hierarchy of the Church, today it is government employees and members of the clergy. In the second place come farmers with own land. Third in hierarchy are landless tenants, and on the last position are, among others, craftsmen, who are born into their profession and have hardly any possibilities of social mobility. This social hierarchy did not change much as a result of the revolution. Especially problematic is the case that craftsmen have such a low status. No farmer is inclined to change his profession, although there would be a good market for local products. Farmers often complained that they lack good quality ironworks or pottery.

**Islam**

In Muslim areas, the number of ***holidays*** is restricted to a maximum of two per week plus a small number of annual holidays. Hardly any taboos exist in relation to ***economic activities***. Similar to Christian areas, ***mutual aid*** has a high value in Muslim society. The *kire*, a burial association, is an important informal association found in many parts of Muslim-dominated Wello. All households of a village belong to a *kire*. Not being a member would mean total exclusion from social life.[775] Besides providing support in the event of a death, the *kire* also grants credits to its members. A further important function of the kire is to act as the lowest level of jurisdiction. The *kire* thus has similar community safety net function as the *mahiber*, *iqub* and *idir* in Christian areas.

### 8.3.1 An appraisal of the influence of religious institutions on the willingness of farmers to invest in the land

In no instance institutional regulations related to religion can be directly linked to discouraging investments. However, there are a number of ***formal and informal regulations*** which make it difficult for farmers to change their land use system or to invest in their land as an answer to changing ecological, economic or socio-political circumstances or new opportunities.

The Orthodox Church plays a crucial role in rural societies of the Ethiopian Highlands. On the one hand, ***religious-based institutions*** offer integration, support mutual help associations, and favour the development of a rural society characterised by limited wealth stratification. Compared to state institutions, which change with every shift in government, religious institutions are far more stable over time and therefore offer security. On the other hand, ***strict rules*** hinder the economic development of rural societies. Farmers have to strictly observe the numerous religious holidays with the imposed ban on farm work, otherwise they endanger their integration in the rural community, since they risk being denounced as belonging to another faith. Certain economic activities (e.g. blacksmith, potter) are considered a taboo. It is therefore not possible for a Christian farmer to engage in such handicraft to complement the income from farming. A factor that hampers profit-maximisation is that it is considered a sin to make profit, as this is associated with deceitful behaviour. Through the ***deep-rooted obligation to share***, even modest increases in the income of an individual household are distributed and can hardly be invested in more productive sectors of the rural economy. A similar institution is the ***rule of inheritance***. Each son receives a share of the father's land. In former times, when the land frontier was not yet closed, this hardly created any problem, as new land could be opened. Nowadays, sharing land

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775 Tarakegn Yibabie, 2001, 11.

equally among sons[776] without having the possibility to acquire additional land leads to holdings that are no longer big enough to sustain a family. It also leads to high fragmentation of holdings, since fathers divide the land also according to its quality. Each son should receive a parcel from the best and one from the worst plot. On the other hand, the social norm that each son receives at least some land from his father can be seen as a disincentive to search for employment opportunities outside the farming sector. Finally, the Church itself requests farmers to contribute to the support of priests and the Church, placing an additional burden upon the meagre production of subsistence farm households.

*Figure 56: Elders (Shimagele) sit together after the sermon to discuss local politics. Shimagele are an important stakeholder group and very influential in the village.*
*[Photo: E. Ludi, 1992]*

The most binding regulation in Christian areas is certainly the ***number of religious holidays***. Farmers are severely restricted in the organisation of their fieldwork. It is virtually impossible to till the land more intensely or to work fields at the most favourable time (e.g. co-ordinating ploughing with the start of the rainy season), although the real problem is the distribution rather than the actual number of religious holidays. It is well possible that in former times, when most households owned their own pair of oxen, the amount of days without restrictions was sufficient for carrying out fieldwork at the appropriate time. Nowadays, the situation is becoming increasingly difficult, especially for poor farmers who have to rely on sharing agreements to plough their fields. As the owner of the pair of oxen always ploughs his fields first and therefore at the most appropriate and convenient time, the farmer borrowing oxen has to wait and can plough his land only later, most probably not at the best time. On the other hand, holidays have a great ***social significance***. They are the occasion for important religious ceremonies and *mahiber*, for political gatherings, and for visiting relatives and friends. At the same time, they offer those who labour an important opportunity to rest.[777]

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776 In Anjeni, the rule of inheritance is as follows: when the eldest son separates from the father, he receives 1/3 of his father's land. When the second son separates, he will again receive 1/3 of the land with which the father remained. It could be clearly shown in the wealth ranking that with very few exceptions, the oldest brother is the richest and the younger brothers are in poorer wealth groups. (Ludi, 1994, Appendix 3)

777 The observation that institutions can have positive and negative effects corresponds with the analysis of social networks, which, on the one hand can provide a range of valuable services for the community members, but on the other hand cause costs, as the same ties can place considerable non-economic claims on members' sense of obligation and commitment with possible negative economic impacts. (Woolcock & Narayan, 2000, 7)

More than once, farmers complained that they lack the time to carry out all the necessary ***fieldwork*** at the right time. Any ***additional task*** that has to be carried out on working days, such as soil conservation, is difficult to accommodate without compromising fieldwork. In Section 6.3.2, Table 58, the labour demand for establishing SWC structures is presented. In the average, almost 440 days per hectare of arable land have to be invested in Maybar for establishing introduced SWC structures, or 160 days per hectare for adapted SWC. In Andit Tid and Anjeni, the investments amount to about 200 days/ha for introduced SWC and 50 days/ha for adapted SWC respectively. In Christian areas, the amount of working days without restrictions is in the order of 130 days. Additionally, 40 days are Saints' days with less restrictions. In Muslim areas, the amount of labour days without religious restrictions is around 230 days. Labour days for fieldwork vary between 40 and 135 days per adult household member in Maybar, 43 and 138 days in Andit Tid, and 70 and 180 days in Anjeni. It becomes evident that in Christian areas, where almost all available working days have to be devoted to farm work, only few days remain to be used for SWC. There are arguments between farmers and priests about whether or not it is allowed to carry out soil conservation activities on Saints' days. Priests usually argue that it is not allowed to do any work at all during the Saints' days. Farmers argue that especially on less strictly observed holidays, SWC activities should be allowed as long as they do not involve working with soil. Piling stones or planting trees does not constitute a violation of religious rules.

In sum, despite its integrative character, the role of the ***Orthodox Church*** seems to be that of an institution hindering the development and emancipation of farmers due to its own striving to regain more power, influence and control. The influence of the ***Islamic faith*** on rural society, especially with regard to economic activities, is much smaller. Taboos with regard to economic specialisation do not exist. Muslim societies generally show a higher degree of specialisation, and more farmers are engaged part-time in handicraft and trading. Potentials for economic development in Muslim-dominated areas are better than in Christian-dominated areas.

***Mesobit & Gedeba*** is an interesting case in this respect. Although the farmers of Mesobit & Gedeba are Christians, they have relaxed the strict rules imposed by religion considerably. It is no exception to observe farmers ploughing on Saints' days, several farmers are part-time engaged in handicraft, and growing of cash crops for the near-by market is quite frequent. A cash crop grown more frequently in the village by Christian farmers is *chat*, because of its good market price. Before, only Muslims were growing *chat*. This fact clearly shows that Christian farmers of Mesobit & Gedeba make use of market opportunities despite religious taboos. It is, however, difficult to state whether the farmers are forced to do so or whether they are liberal in their views because of their constant contact with members of other ethnic and religious groups living in the vicinity.

Scarcity and poverty form a kind of ***'society of fate'*** in rural villages. Individuals are bound to one and other through mutual self-help groups, through the obligation to share available resources as equally as possible even if the individual share becomes ridiculously small, and through their dependency on resources of others in times of need. The deep-rooted social norms and values shaping these bonds are supported both by the Christian and by the Muslim religion and correspond well with peasant societies and their socio-economic and socio-cultural system, which tries to ensure access to resources for all members. They are therefore aimed at preserving the status quo. As these bonds are necessary for survival, individuals do not question them, even if they reduce the individual's freedom to act. Ideologies supporting such behaviour are generally stable and can help explain the individual's behaviour of not breaching rules, despite the pressure from rising costs. This is the phenomenon known as cultural conservation or cultural lag.[778] ***Innovative farmers*** are considered by their fellow farmers as trying to break out of the 'society of fate'. As in their effort to change their current living situation they tend to violate certain values, innovative farmers pose a threat to the rural society as a whole. To prevent such innovative behaviour and thus the questioning of the rural society and local institutions, it is labelled as deceitful, or innovative people are affiliated to belonging to another religious group.

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[778] Ensminger, 1992, 11.

# PART IV

# SYNTHESIS

# 9 Conclusions and Recommendations

## 9.1 Review of Factors Influencing the Profitability of Soil Conservation

*"The degradation of land and water resources is a complex problem that does not lend itself to simple cost benefit analysis. While the bare hills and sediment-rich streams are obvious signs of soil erosion to most observes in the tropics, our scientific knowledge of its environmental, social, and economic impacts is dispersed and superficial"*
*(Craswell, in Enters, 1998b, i)*

### 9.1.1 Input parameters

Several input parameters are decisive for determining whether or not mechanical SWC is profitable in the research areas. These concern mainly:

- Annual soil erosion rates
- Efficiency of the SWC technology to reduce soil erosion
- Amount of land occupied by the conservation structures
- Opportunity costs for labour
- Annual crop production

***Annual soil erosion rates***

Soil erosion rates differ considerably in the three research areas (cf. Table 28). In Figure 38, the soil life for different slope gradient – soil depth combinations in the three research areas under mean annual soil loss rates as measured on test plots is modelled, assuming continuous cropping. It clearly shows that even without SWC, soil life in Maybar – despite rather shallow soils (cf. Table 31) – is much longer than in the other two research areas. This can be explained by the low annual soil erosion rates of only 28 t/ha*a measured on test plots (TP), which translate to an annual soil depth reduction of about 2.8 mm. Mean annual soil loss rates measured on cultivated TPs in Andit Tid and Anjeni are about five times higher than in Maybar. At 147 t/ha and 145 t/ha respectively, they are both in the same range. Because soil erosion in the past has decreased current soil depth much more in Andit Tid than in Anjeni, soil life in Anjeni is considerably longer than in Andit Tid.

The combination of current soil depth and annual soil erosion rates in the CBA has its greatest impact when a critical soil depth of 10 cm is reached. It is assumed that once the soil depth has reached 10 cm, crop production is abandoned. In Maybar, even on shallow soils it takes between 60 and 100 years of continuous cropping to decrease the soil depth to below 10 cm without SWC. In Andit Tid, without SWC the soil depth is reduced to below 10 cm within only 13 or 14 years, and in Anjeni within a time span of 23 to 32 years. With soil conservation, soil life in Maybar can be prolonged to about 140 up to more than 230 years, depending on the current soil depth. In Andit Tid, soil life can be extended to between 35 and 37 years with SWC, and in Anjeni to between 86 and slightly more than 110 years.

In the CBA, it is further assumed that annual soil erosion rates differ according to slope gradient. Because not enough erosion plot measurements are available for different slope gradients, the following assumption is made (cf. Section 5.2.1): on gentle slopes with a gradient below 9%, annual soil loss is assumed to be mean soil loss as measured on cultivated TPs minus 1 standard deviation. On slopes with gradients between 9% and 30%, annual soil loss is considered equivalent to mean annual soil loss rates as measured on cultivated TPs, and on steep slopes with gradients above 30%, it is assumed to be mean annual soil loss as measured on cultivated TPs plus 1 standard deviation.

In addition to sheet erosion, also rill erosion is considered. It can often be observed that rills develop within a field because of a feature situated above the field, such as a footpath or an animal track collecting water, which then spills into the field. In other cases, water is channelled within a field because of a broken conservation structure or because drainage ditches are not well constructed. Since the factors leading to rill erosion are localised and stable, it is assumed that rills always occur in the same area within a field. Damage from rill erosion can be considerable. Based on an evaluation of rill mappings done in some of the SCRP research sites (cf. Section 5.1.6), it is assumed that rills develop in regular intervals, damage 10% of the field and reduce the soil depth by 120 mm. Farmers try to minimise the damage by ploughing in the rills. The damage is thus spread to about 30% of a field, and the soil depth reduction is decreased to 40 mm. Nevertheless, in the area affected by rills, soil depth rapidly decreases to less than 10 cm, and the area has to be given up for crop production.

***Efficiency of the technology to reduce soil erosion***

The efficiency of introduced mechanical SWC structures to control soil erosion varies between 55% in Maybar, 59% in Andit Tid, and 68% in Anjeni for the period of 5 years after the conservation structures have been established. In the case of introduced SWC, soil depth reductions are thus slowed down considerably. The efficiency of adapted SWC is assumed to be only half of the efficiency achieved with introduced SWC.

In the CBA, it is assumed that in the case without SWC, in years when crops are grown the soil depth is reduced annually by 2.8 mm in Maybar, by 14.7 mm in Andit Tid, and by 14.5 mm in Anjeni on medium steep slopes. With SWC, soil depth reductions in the case of introduced SWC are assumed to be reduced to 1.3 mm in Maybar, 6 mm in Andit Tid, and 4.6 mm in Anjeni in years when crops are grown on medium steep slopes. During fallow periods, no soil loss is considered, because the soil is protected by a closed vegetation cover. If one compares the three research areas, it becomes obvious that in Maybar, the negative effect of soil erosion on reducing soil depth is much smaller than in the other two research areas, because annual soil loss rates are lower. Comparing Andit Tid and Anjeni, where annual soil loss rates are similar, it shows that in Andit Tid, the critical soil depth of 10 cm is reached earlier than in Anjeni, because (i) soils are considerably shallower and (ii) the efficiency of the conservation technology with regard to reducing soil loss is almost 10% smaller.

***Amount of land occupied by the conservation structures***

Depending on slope gradient and soil depth, the amount of arable land occupied by conservation structures varies greatly (cf. Table 34). A maximum of 30% of a field is lost for crop production, although not for the production of grass on the conservation structure, which has been considered as a benefit of SWC in the CBA. In the case of adapted SWC, the amount of terraces is reduced and the maximum area loss is considered only 30% of the loss with introduced SWC. There are no big differences between the research areas with regard to average area occupied by conservation structures, which varies between 20% and 23% for introduced SWC and 6% and 8% for adapted SWC.

***Opportunity costs for labour***

Opportunity costs for labour are assumed to be EB 5 per day. This is about the amount a daily labourer receives for unskilled construction work or for employment on a commercial farm. A second case is modelled where it is assumed that subsidies are paid, which reduce opportunity costs for labour to EB 2.5 per day for SWC activities, both for construction works and for the maintenance. Other labour is not affected by this subsidy.

The sensitivity analysis, in which price changes in the order of ± 20% for crops, a change of the fertiliser price in the order of minus 100 EB/100 kg and plus 200 EB/100 kg, grass production on SWC structures of plus 3,000 kg/ha, changes of opportunity costs for SWC labour of minus 2.5 EB/day, and an increase of opportunity costs for all considered labour of plus 3 EB/day are compared to the standard situation, shows that subsidising labour has the biggest influence of all considered changes (cf. Section 6.1.5). Again, it must be stressed that subsidy payments are assumed over the whole period, i.e. covering the construction as well as the maintenance activities. However, compared to the effect of fertiliser applications and the associated yield increase on rising the profitability of SWC investments, the above mentioned changes of input parameters have an insignificant influence on the profitability of SWC.

***Annual crop production***

Annual crop production also plays a decisive role in determining whether SWC is profitable or not. To evaluate the effect of soil erosion on crop production, regression functions are calculated, whereby crop yields are related to soil depth and slope gradient. In most instances, yields diminish with decreasing soil depth and increasing slope gradient (cf. Table 16, 19 and 24). Anjeni is an exception, because several crops react the opposite way. Because annual rainfall is high and the soils have a high clay content, stagnant water is a problem especially on gentle slopes. With SWC, slope gradients are reduced and runoff barriers erected; this increases the incidence of damages to crop stands through stagnant water.

Crop yield declines resulting from soil erosion or soil depth reductions are quite small. In Andit Tid they are biggest at 0.62% per 1 cm soil depth reduction. In Maybar, yields decrease by 0.25% per 1 cm soil depth reduction, and in Anjeni by only 0.16% per each centimetre soil lost. Considering the measured mean annual soil loss on TPs and the soil loss reductions in the case of introduced SWC, annual yield reductions are in the order of 0.07% on unconserved land and 0.04% on conserved land in Maybar, 0.91% on unconserved and 0.37% on conserved land in Andit Tid, and 0.23% on unconserved and 0.07% on conserved land in Anjeni.

Because in Maybar and Andit Tid crops grown differ considerably according to altitude, two cases – an upper and a lower part of the study area – are differentiated. In Andit Tid, the upper part of the study area concerns the area above roughly 3,200 m asl; the upper limit of crop production is reached at about 3,600 m asl. Due to climatic limitations, only highland barley can be grown. Because no crop rotation is possible, long fallow periods of 3 to 4 years are necessary to allow the soil to regenerate and to control pests and weeds. In the lower part of Andit Tid, crop rotation of different grain crops and pulses can be practiced. In Maybar, the difference with regard to the cropping system is not as big as in Andit Tid. The main difference concerns maize and tef, which can be cultivated only in the lower part of the study area. These two crops are relevant because (i) the production of maize is much higher than that of any other crop, and (ii) tef is the grain crop with the highest value.

Yields in the Ethiopian Highlands are extremely low – often below 1 t/ha. In order to be able to pay back the investment costs for SWC, yields must increase considerably, or other benefits must be realised on the conservation structures. Therefore, a case is modelled, where artificial fertilisers are applied to simulate a situation where yields increase substantially. It is assumed that if artificial fertilisers are applied, yields increase by 50% on land that is conserved with introduced SWC, 40% on land that is conserved with adapted SWC, and 30% on land that is not conserved. In the CBA it is assumed that farmers pay the full costs of fertiliser and apply 100 kg DAP at EB 300 per hectare.

***Other model assumptions***

For the calculation of NPV's of the two considered conservation technologies and soil erosion forms, the following assumptions beside the ones presented above were additionally made: It is assumed that soil erosion on unconserved land remains the same for the whole period of observation. It is also assumed that soil erosion control in the case of SWC remains constant and is achieved already in the first year on that part of the field that is conserved. The soil erosion reductions between 55% and almost 70% mentioned above were observed in the first five years after the conservation structures have been established. It can, however, be hypothesised that after more years soil erosion reduction would further increase because terraces become flatter. This improved soil erosion reduction would be at the expense of arable area between two conservation structures, because the soil accumulated behind the terrace is lost from the area below the next upslope conservation structure. In the case of introduced SWC, the spacing between two terraces has been calculated based on slope gradient and top soil depth. Thus, there should be enough soil material available to build up sloping bench terraces over the years without decreasing the soil depth below the next upslope terrace down to the subsoil. In the case of adapted SWC, however, the number of terraces has been reduced considerably and the spacing does not allow the formation of sloping bench terraces without decreasing the soil depth on some parts of the plot down to the subsoil. In these cases it can be expected that after one or two decades small, almost flat terraces behind the conservation structures have been developed where soil erosion is reduced considerably, but that on a sizeable area the soil depth is diminished to almost nothing and crop cultivation has to be given up there. In the CBA, this reduction of soil erosion rates on conserved land at the expense of further loss of arable land has not been modelled. The percentage of land lost for crop production because it is occupied by conservation structures and the soil erosion rates have been kept constant over the whole observation period.

It can be expected that during a period of up to 50 years significant changes of conservation and farming technologies or land use practices will occur. Neither has been modelled. It is assumed that crop types, farming technologies, agricultural inputs and SWC technologies remain the same over the observation period. It has also been assumed that either fertiliser is applied in the first year to boost yields or never. A more realistic gradual shift to higher fertiliser application rates to compensate yield declines has not been considered.

Prices for crops and opportunity costs for labour have been kept constant as well over the whole observation period with the exception of the sensitivity analysis. It is difficult to foresee by how much in which direction prices might change in future. In the sensitivity analysis some of the input parameters have been changed (cf. Table 50), although starting from the first year of observation and not gradually over the years.

***Discussion***

The following Figure 57 to 61 present an overview of the Discounted Net Gains (DNG's) of physical SWC – either introduced or adapted measures – compared to the situation of uncontrolled soil erosion (sheet and rill erosion). According to the selection of fields measured, only some slope gradient – soil depth combinations are available. However, they represent the most common occurrence within the different research areas. Per slope gradient – soil depth combination, four cases are differentiated:

(i) Normal opportunity costs for SWC activities of EB 5/day, no fertiliser application (OCL: 5 EB, NF)
(ii) Normal opportunity costs for SWC activities of EB 5/day, with fertiliser application (OCL: 5 EB, F)
(iii) Reduced opportunity costs for SWC activities of EB 2.5/day, no fertiliser application (OCL: 2.5 EB, NF)
(iv) Reduced opportunity costs for SWC activities of EB 2.5/day, with fertiliser application (OCL: 2.5 EB, F)

Positive values indicate that the Net Present Value (NPV) achieved with SWC is higher than the NPV which is achieved without SWC. Only one time frame (50 seasons, i.e. 25 years) and one discount rate (12%) is presented. Other time frames and discount rates are also considered (cf. Section 6.1.2), but are not discussed here. The influence of the length of the time horizon of the analysis and of the magnitude of the discount rate are discussed in Section 9.1.2.

**Maybar**

In the lower part of Maybar, introduced SWC is not profitable, irrespective of slope gradient and soil depth, if normal conditions (no labour subsidy, no yield increment) are assumed. Only if fertiliser is applied and/or labour costs are subsidised, introduced SWC is profitable on slopes with gradients below 9%. Also on medium steep slopes (9-15%), introduced SWC is only profitable if labour costs are subsidised and fertiliser is applied. On steeper slopes, irrespective of soil depth, introduced SWC is not profitable. Since for adapted SWC the amount of land occupied by conservation structures is considerably smaller than for introduced SWC, adapted SWC performs better, despite the lower efficiency of SWC with regard to controlling soil erosion.

The fact that introduced SWC does not perform better in Maybar can mainly be explained by the low soil erosion rates on the one hand, which reduce soil depth only slowly, and by shallow soils on medium and steep slopes making many conservation structures necessary, on the other hand. Despite the fact that mean annual crop yields are considerably higher in Maybar than in the other two research areas, the value of avoided yield decline cannot compensate the high labour costs and the high area loss.

A comparison of fields with same slope gradients but different soil depths shows that soil depth has no decisive influence on the profitability of SWC. The major difference is the magnitude of the DNG.

The upper part of the research area presents a situation similar to the one in the lower part. On slopes below 9% gradient, both introduced and adapted SWC are profitable. Interesting findings result from a comparison of various soil depths on constant slope gradients between 9% and 30%. If the soil is deep, introduced SWC is not profitable, irrespective of the yield level and the labour costs. If soil depth decreases to between 21 and 30 cm, firstly the difference between introduced SWC and sheet & rill erosion decreases, and secondly introduced SWC becomes profitable if yields increase by 50% and labour costs for SWC activities decrease to EB 2.5. If erosion further continues and decreases the soil depth to a meagre 11 to 20 cm, a yield increase of 50% is sufficient to make SWC profitable, even without labour cost subsidies. This observation points at a very problematic situation. The shallower the soil, the earlier introduced SWC becomes profitable, because uncontrolled soil erosion can decrease the soil depth to below 10 cm and force crop production to be given up within a short period of time. From a farmer's point of view it would thus be wise to not invest in introduced SWC as long as the soil depth is above the minimum of 11 to 20 cm.

The fact that, under given circumstances, introduced SWC is only profitable on gentle slopes with a gradient below 9% and often only in combination with artificial fertiliser to increase yields and/or labour cost subsidies, is very problematic in Maybar. Only 3.4% of the research catchment (cf. Table 31) is flatter than 9%, thus introduced SWC is a profitable option only on a small area. Because Maybar suffers from considerable rainfall variability, artificial fertilisers are risky. The strategy of applying artificial fertiliser to boost yields and thereby compensate the high investment costs of SWC and yield decreases due to land occupied by conservation structures should not be promoted too vigorously without accompanying measures. Especially in the upper part of the study area, adapted SWC with smaller area loss is in many situations a profitable option and should be envisaged

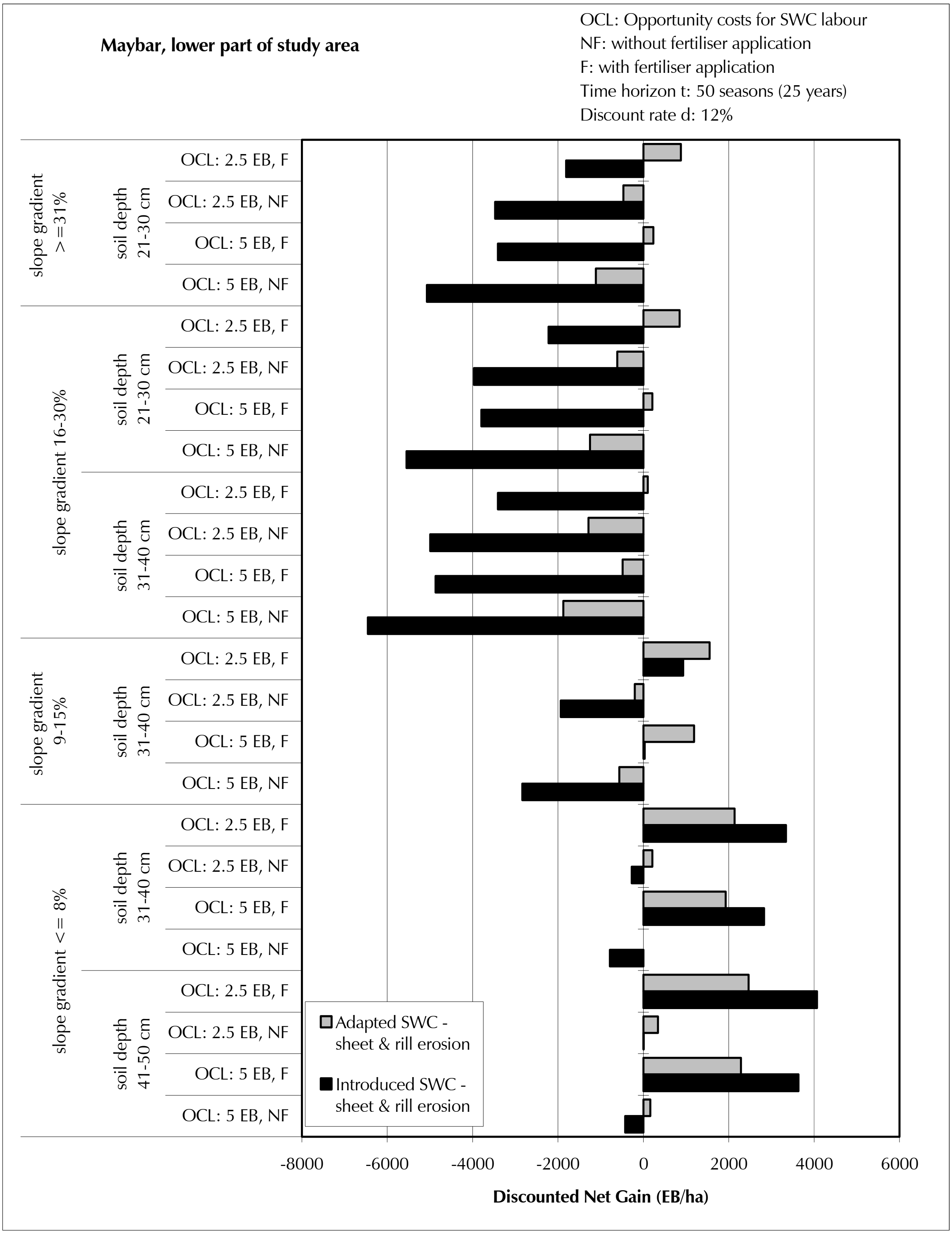


*Figure 57: Discounted Net Gain of introduced and adapted SWC compared to sheet & rill erosion in the lower part of the Maybar study area.*
*[Source: Own compilation]*

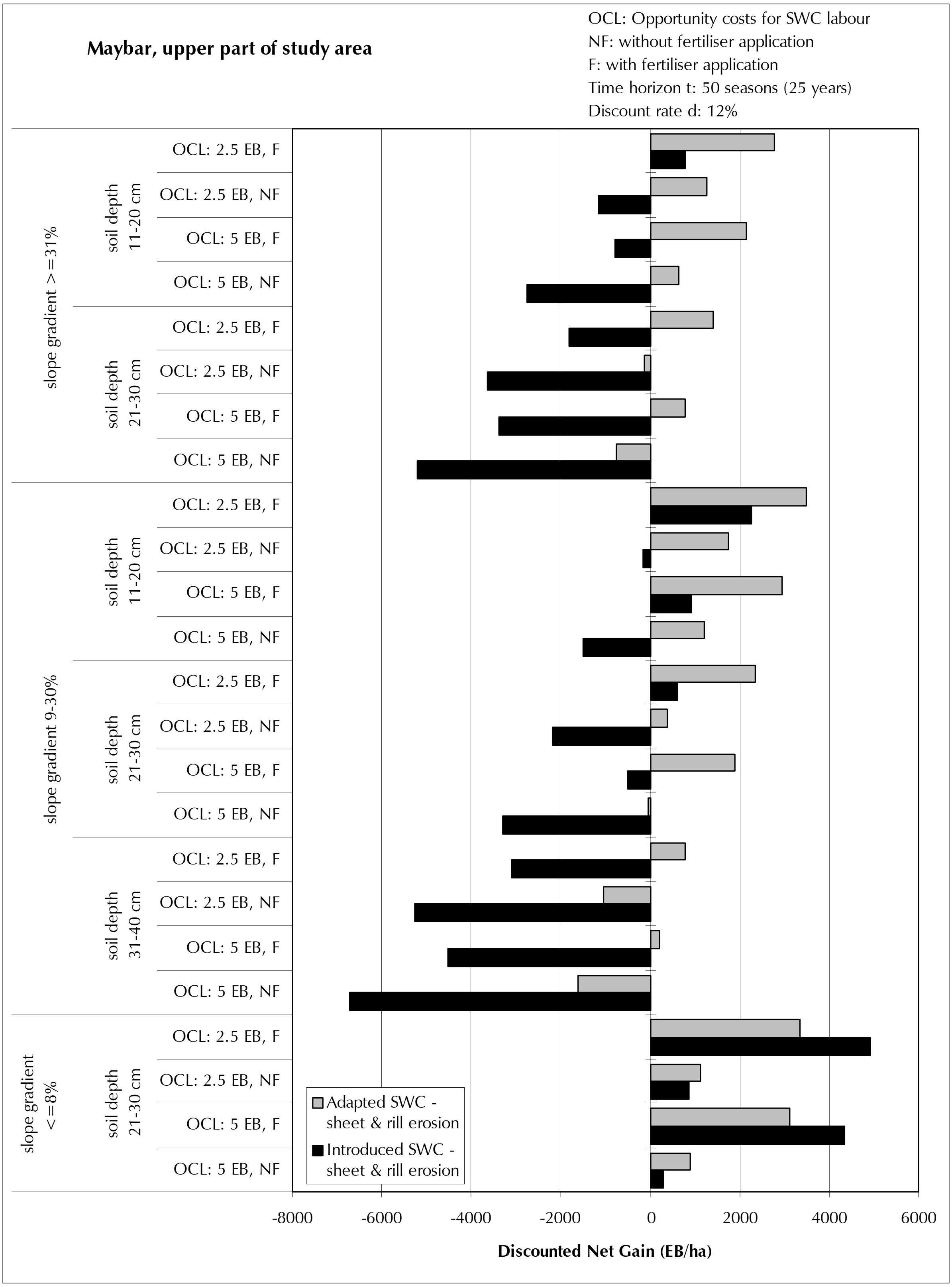


*Figure 58: Discounted Net Gain of introduced and adapted SWC compared to sheet & rill erosion in the upper part of the Maybar study area.*
*[Source: Own compilation]*

**Andit Tid**

Because soils are already very shallow in the lower part of Andit Tid and soil erosion rates are high, soil conservation is much more profitable here than in Maybar. Through soil conservation many years of possible crop production can be gained, whereas without SWC investments, crop production would have to be given up because soil depth would be reduced to a degree where crop yields drop so low that labour or seed investments are no longer justified. Because yields are generally low, the standard situation where no fertiliser is applied to boost yields and no subsidies are paid to lower labour investments in SWC is not profitable if slopes are steeper than 8%. In this situation, the yield loss due to land occupied by conservation structures outweighs the yield saved through erosion control. On slopes steeper than 15%, only a combination of yield increases and labour subsidies can make introduced SWC profitable.

Unfortunately, no results are available for slopes with a gradient of over 30%. It can be expected, however, that introduced SWC becomes more profitable as the slope gradient increases, because the amount of area lost does not increase compared to the situation on slopes with gradients between 16% and 30%. On these slopes the maximum area loss of 30% is already reached, considering the generally shallow soils. The annual soil erosion rates, on the other hand, are considerably higher on very steep slopes than on medium steep slopes between 16% and 30%. Despite constant labour investments and area losses in the case of SWC, compared to the faster decline of soil depth in the case of no SWC and the earlier occurrence of the situation where crop production has to be given up that results from it, introduced SWC might again become an option.

In the upper part of the Andit Tid area, introduced SWC is only rarely profitable, whereas adapted SWC with less area loss and less labour investments is profitable in all cases considered. The unprofitability of introduced SWC in this area can mainly be explained by the fact that crops are only grown every 4$^{th}$ year. The overall income from crop production and overall soil loss over time are reduced accordingly, while the amount of investments and maintenance costs for SWC is the same as if crops were grown every year. Introduced SWC is therefore only profitable if yields increase by 50% and labour costs for SWC activities are subsidised, irrespective of soil depth and slope gradient.

Under normal conditions, introduced SWC is profitable on slopes with a gradient below 9% in the lower part of the research area. This area, however, makes up less than 5% of the research catchment (cf. Table 31). On fields with slope gradients between 9% and 15%, introduced SWC is profitable if either fertiliser is applied or labour costs are subsidised. These areas cover about 12% of the research catchment. Because rainfalls are less variable in Andit Tid than in Maybar, fertiliser application is less risky. A combination of introduced SWC with artificial fertilisers therefore seems an option for such areas.

Interestingly, adapted SWC is always profitable in the considered cases, irrespective of slope gradient and soil depth and even without increasing yields or subsidising labour costs. This is a positive signal, as it indicates options with regard to modifying the technology that would be profitable from a farmer's point of view.

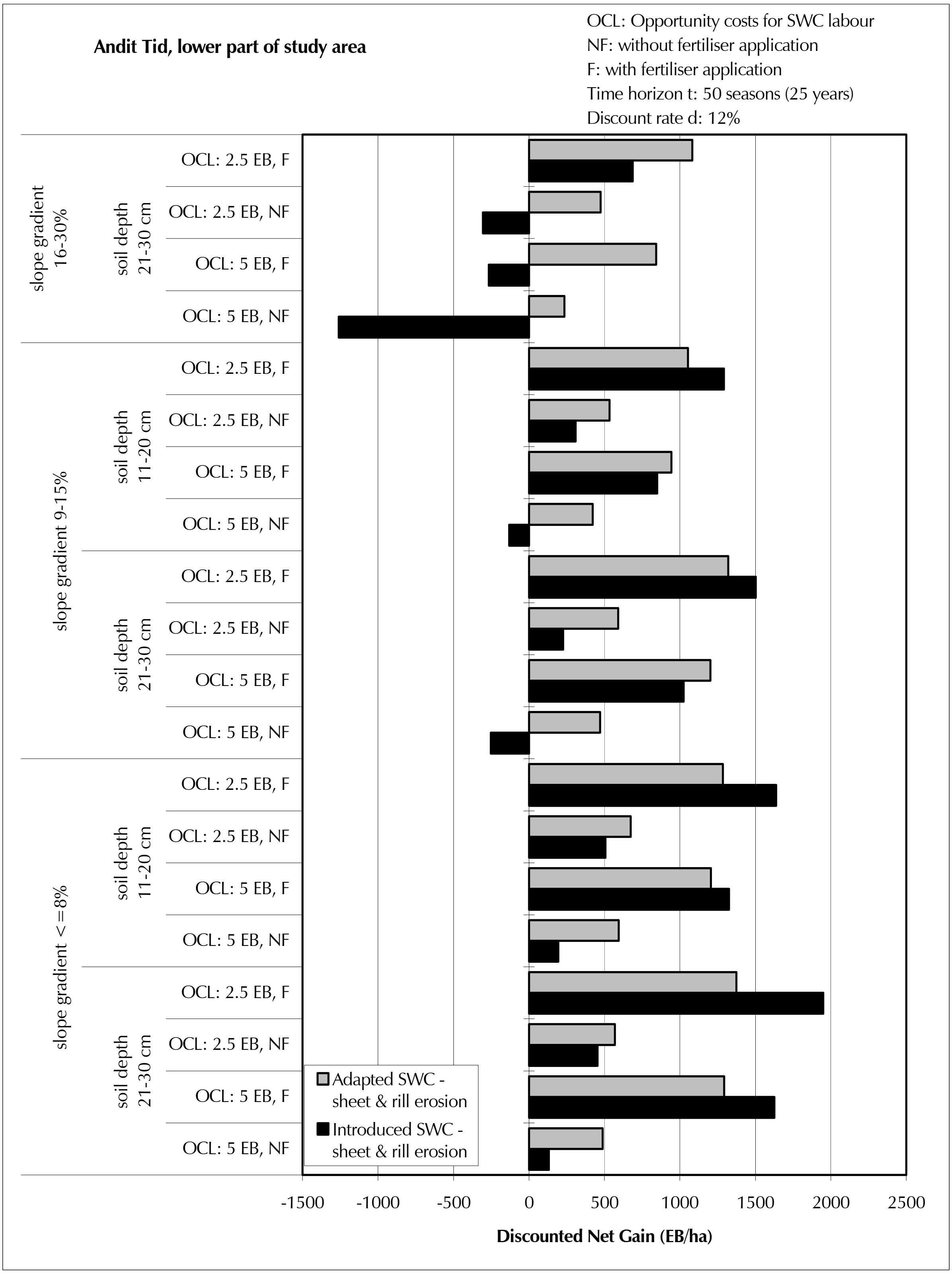


*Figure 59: Discounted Net Gain of introduced and adapted SWC compared to sheet & rill erosion in the lower part of the Andit Tid study area.*
*[Source: Own compilation]*

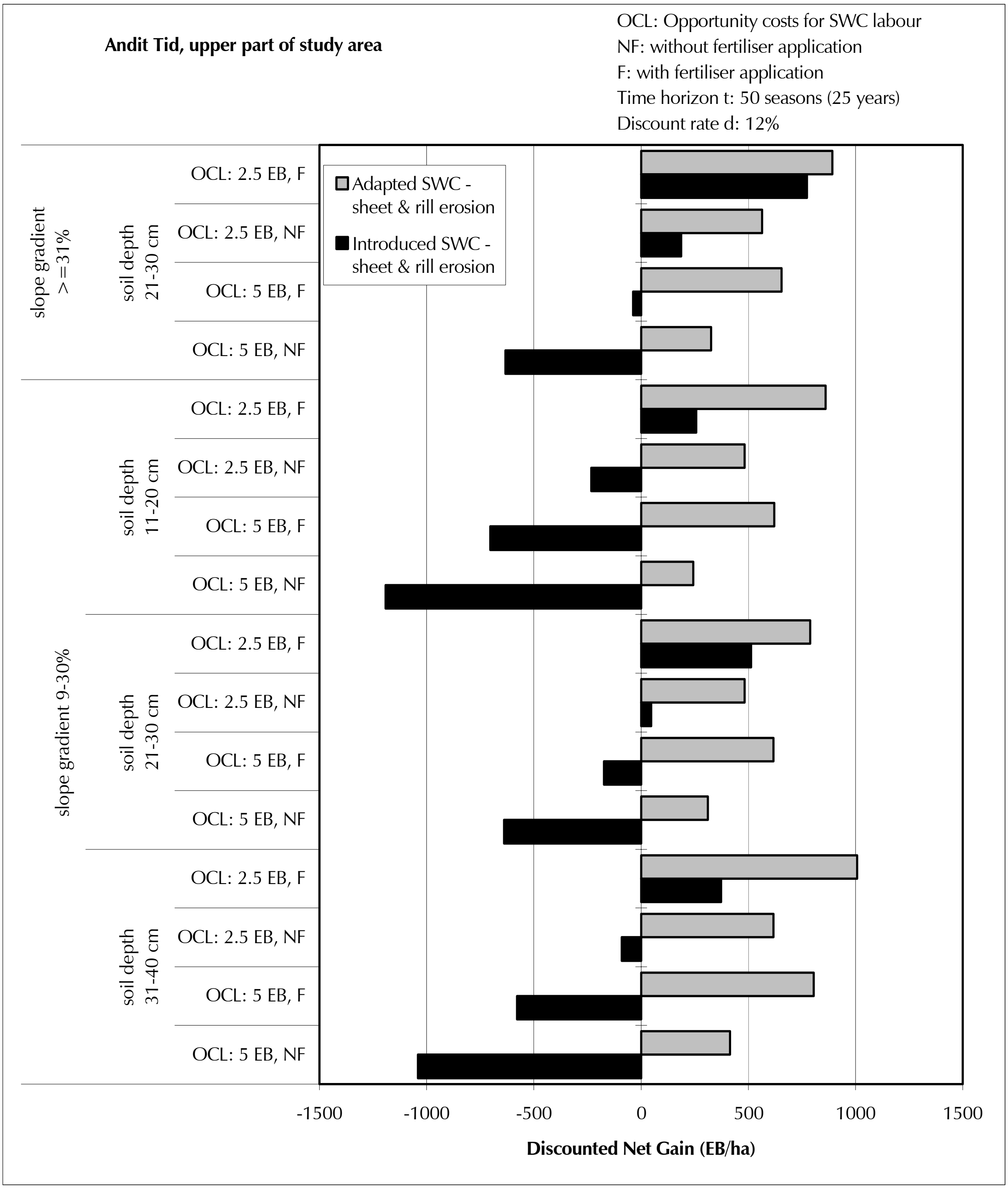


*Figure 60: Discounted Net Gain of introduced and adapted SWC compared to sheet & rill erosion in the upper part of the Andit Tid study area.*
*[Source: Own compilation]*

## Anjeni

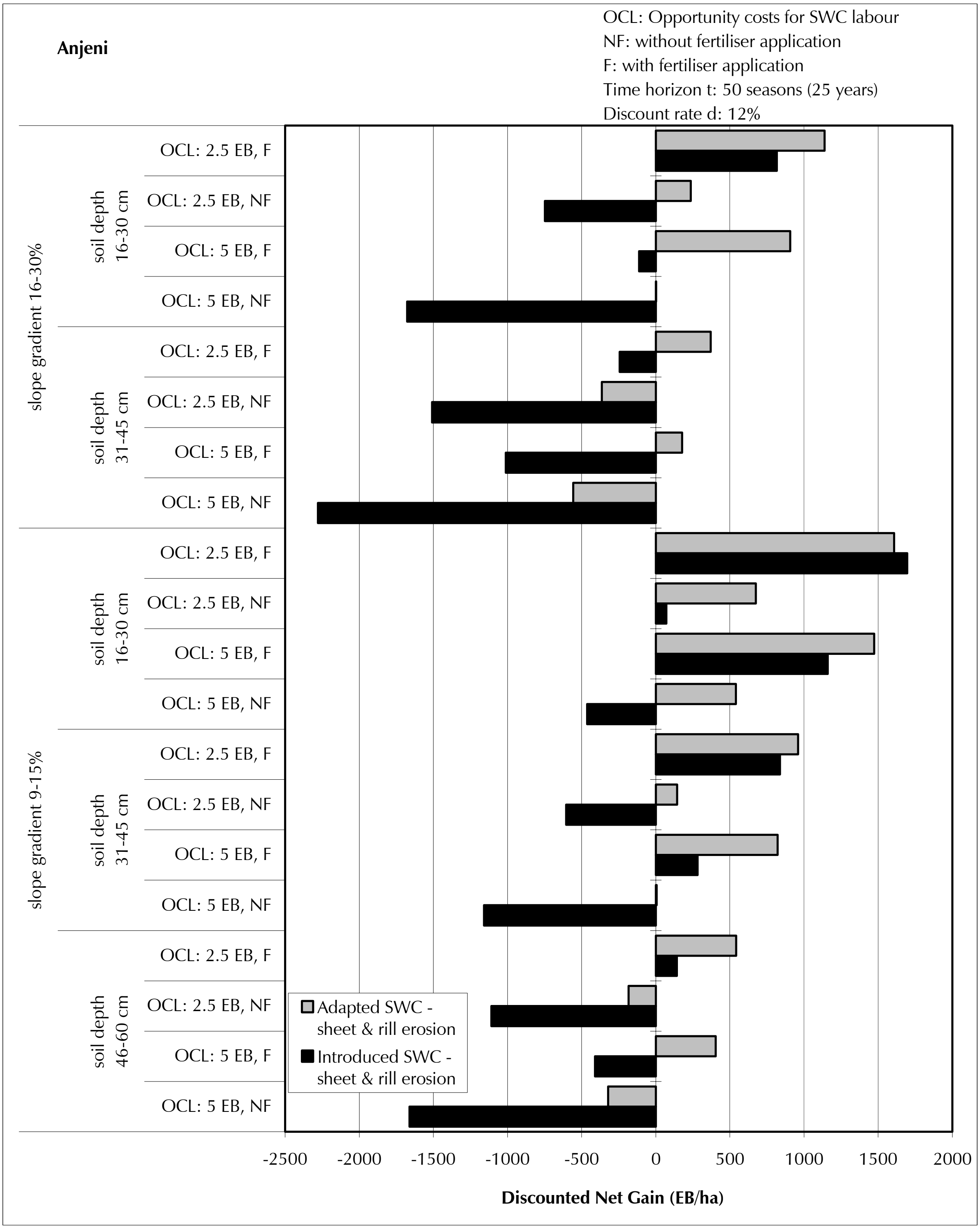


*Figure 61: Discounted Net Gain of introduced and adapted SWC compared to sheet & rill erosion in the Anjeni study area.*
*[Source: Own compilation]*

In Anjeni, the same observation can be made as in Maybar: SWC becomes more attractive with decreasing soil depth. On medium steep slopes with gradients between 16% and 30%, introduced SWC is never profitable if soils are deep. If the soil depth decreases to between 16 and 30 cm, introduced SWC becomes profitable, provided that yields increase and/or that labour costs for SWC investments are subsidised. Similar results occur for slope gradients between 9% and 15%. On deep soils, introduced SWC is only slightly profitable if yields increase by 50% and labour costs for SWC are subsidised. If the soil depth decreases to 31-45 cm, a yield increase is sufficient to make introduced SWC profitable. If the soil depth further decreases to 16-30 cm, introduced SWC is always profitable except in the case where yields are low and labour costs high.

50% of the Anjeni catchment is not steeper than 15%. On such fields, fertiliser application to increase yields by 50% could in most cases – where soils are deep – increase production enough to compensate the high investment costs and the yield decrease due to arable land occupied by conservation structures. In Anjeni, fertiliser application is already quite widespread. It could thus be an option to propose the combination of fertiliser application and SWC in order to convince farmers to continue investing in SWC also outside the catchment that is already conserved.

***Conclusions***

In summary, the results show that based on the model used here the profitability of SWC is highly situation specific with regard to

- location (which defines the climatic situation, among other things),
- farming system,
- current soil depth,
- slope gradient,
- annual soil erosion rates, and
- efficiency of the conservation technology.

There is thus no standard solution to be propagated for the whole Highland of Amhara Region. Neither is there a standard solution to be propagated within a single research area or watershed, as can be clearly demonstrated in Andit Tid and in Maybar.

In general, the results show that introduced SWC is expected to be profitable only as long as slope gradients are small (i.e. below 9%), because on such fields, the amount of land occupied, thus yield lost, and the amount of labour necessary to construct and maintain the conservation structures can be justified. On medium steep and steep slopes, introduced soil conservation is only profitable if annual soil loss rates are high and soils are so shallow that there is an acute danger of soils become too shallow for crop production within the period for which costs and benefits of SWC are calculated. Such a situation would correspond to the lower part of the Andit Tid area. In the upper part of Andit Tid, where soils are comparably deep and total soil loss over time reduced because of long fallow periods, introduced SWC already becomes unprofitable. This can be explained by the unfavourable relation between the high amount of invested labour and the considerable yield reduction, on the one hand, and the small amounts of yield saved thanks to the reduction of soil erosion, on the other hand. In areas such as Anjeni, where soil erosion rates are as high as in Andit Tid, but soils are considerably deeper, introduced SWC is again rarely profitable, because soil depth reductions are not yet as dramatic and do not threaten crop production within the considered time horizon.

Especially in high rainfall areas such as Andit Tid and Anjeni, which are characterised by high to very high annual erosion rates, but where introduced SWC is not profitable due to an unfavourable relation between costs and benefits, adapted SWC could be an option. It seems that on the one hand, costs in the form of labour investments and loss of arable land could be reduced enough so that in time, the saved yield could compensate these investments costs. In other words, under current conditions, from a farmer's point of view, a land loss of about 10% can be tolerated, if seen over a time horizon of 25 years. Similar observations, although less pronounced, can be made for areas characterised by much lower annual erosion rates, such as Maybar. On medium steep slopes, where soil erosion rates are average, even adapted SWC is not necessarily profitable. Only on steep slopes, where annual soil loss is considerable, adapted SWC becomes profitable.

The analysis further shows that on medium steep slopes, where the amount of arable land occupied by conservation structures is already substantial, yield increases in the order of 50% can make introduced SWC profitable over a time horizon of 25 years. Despite the costs for fertiliser, the additional yield can compensate the costs for invested labour and the yield lost through land loss. Furthermore, because soils are already shallow, introduced SWC can prevent soils from becoming shallower than 10 cm, which was assumed to be the threshold depth at which crop cultivation is abandoned. On slopes steeper than 30%, the yield increase resulting from fertiliser application can often no longer compensate the high costs of introduced SWC. It can thus be concluded that if yields can be increased by 50% – which is possible, as experiences from Anjeni clearly demonstrate (cf. Section 5.1.3) – introduced SWC becomes profitable. There is thus an urgent need to investigate in any possibilities of increasing yields. Artificial fertilisers, which are expensive and in moisture stress areas risky, should, if possible, be complemented by other technologies or management practices capable of increasing crop yields. Research should therefore be directed towards finding such alternatives.

The above-presented findings stand in marked contrast to observations made and comments recorded from farmers in the study areas. Soil conservation is much more widespread in Maybar than in Andit Tid or Anjeni, even on steeper slopes. In Andit Tid and in Anjeni, the attitude of farmers towards SWC is more negative than in Maybar. The results from the CBA, however, predict that in Maybar, SWC is in many situations not profitable, whereas it should be profitable from a farmer's point of view in Andit Tid and in Anjeni. This contradiction might be explained by the following aspects:

- Structural soil conservation has a longer tradition in Maybar than in Andit Tid and Anjeni.
- In rainfall insecure areas such as Maybar, structural soil conservation might contribute to reducing the risk of crop failure thanks to enhanced water conservation.
- Besides soil conservation, water management is an important issue. Especially in high rainfall areas such as Andit Tid and Anjeni, proper water drainage is essential. Conservation structures were designed in such a manner as to also drain runoff safely out of a field. However, when maintenance activities are reduced or even abandoned, conservation structures can begin to have the contrary effect of retaining too much runoff on the field, which leads to damage to susceptible crops through waterlogging.
- Because the stone cover is considerably higher in Maybar than in Andit Tid or Anjeni, the construction of stone terraces is a means of removing stones otherwise disturbing crop growth and field operations.
- Several important factors might have not been sufficiently taken into account in the CBA. These might include water conservation effects of SWC in dryer areas such as Maybar, the contribution of SWC to lowering the variability of yields from year to year, i.e. to risk reduction, or current nutrient levels in the soil and effects of soil erosion on this nutrient pool.
- Mean annual soil loss rates as used in the modelling were measured on erosion plots. They might only partly represent soil erosion on farmers' fields. It is possible that soil erosion on farmers' fields is higher than assumed in Maybar and lower than assumed in Andit Tid and in Anjeni.
- Farming technologies: The more the farming system is based on the ox-drawn plough, the more SWC structures are a hindrance to carrying out farm operations. In Maybar, manual land preparation is more widespread than in Andit Tid or Anjeni. On fields that are hacked instead of ploughed, a narrow spacing between two conservation structures is less of a problem.
- Labour availability: Because the inhabitants of Maybar are predominantly Muslim, whereas in Andit Tid and Anjeni most farmers are Orthodox Christians, religiously related labour restrictions influencing opportunity costs for labour might play an important role. Because Muslim farmers have many more labour days available, their subjective wage rate might be lower than the assumed opportunity costs for labour of EB 5 per day, whereas in Christian areas it might be much higher. In addition to the subjective wage rate, which would have to be included in the CBA as opportunity costs for labour, the labour availability over time plays an important role. Because the number of days and their distribution over the year is greatly restricted in Christian areas, farmers have to concentrate on field operations on those days when fieldwork is allowed. Any other labour demand which competes with fieldwork – and carrying out SWC activities certainly is such a demand – is rejected.

### 9.1.2 Time horizon of analysis and magnitude of discount rate

The length of the time frame for the analysis of discounted costs and benefits is especially important in situations where soil loss rates are rather small. In these situations, the unfavourable distribution of costs and benefits becomes clearly evident. Investment costs have to be borne in the first years, while the benefits of SWC only become visible after a long period of time. If the time frame for the analysis is short, these benefits might not enter into the calculation.

Despite this general rule, the effect of the time frame of analysis is not very pronounced. Only rarely do the considered technologies (i.e. introduced SWC, adapted SWC) become profitable if the time frame of analysis increases at constant discount rate of 12%. Increasing the time frame from 25 to 50 seasons can in some instances turn introduced SWC from unprofitable into profitable. Generalising these findings, one can conclude that with standard assumptions (i.e. no fertiliser application, no subsidies paid on labour for SWC activities), the technology is either profitable within a time frame of 25 years or not. With adapted SWC, the positive effect of soil conservation shows earlier. In the lower part of the Andit Tid study area, for example, adapted SWC becomes profitable already after 12.5 years. These findings vary slightly, depending on whether labour costs are subsidised, and on yield levels.

A good illustration for the role of the time frame of analysis is the comparison of the situation with sheet erosion only and the situation where sheet erosion occurs in combination with rill erosion (cf. Appendix 6.1). If the time frame of analysis is only 10 seasons, i.e. 5 years, the costs of rill erosion can hardly be felt. If, however, the time frame is increased to 50 seasons, the full costs of rill erosion usually become visible.

Decreasing the discount rate under standard conditions (i.e. no fertiliser application, no labour subsidy, time frame of analysis 50 seasons) from 12% to 5% would make introduced SWC in Anjeni profitable in 3 of the 5 cases considered, in Maybar in one of 12 cases, and in Andit Tid in four of 9 cases. These cases concern situations where soils are shallow, i.e. below 20 cm on medium steep slopes (9-30%) or below 30 cm on steep slopes (above 30%). By lowering the discount rate, the early costs of SWC, which are high on fields with shallow soils,[779] count more, i.e. the discounted net return in early years is smaller. However, at the same time, the benefits of introduced SWC, i.e. the gain in years of possible crop cultivation thanks to soil depth remaining above 10 cm, also weigh more than if discount rates were higher.

Considering the high to very high annual individual discount rates (cf. Section 5.3) of often more than 100% (in the CBA, a maximum annual discount rate of 149% was applied), shows that in Anjeni and Andit Tid, neither adapted nor introduced SWC would ever be profitable. In Maybar, introduced SWC is profitable even with such high discount rates if slope gradients are below 9% and soils deeper than 41 cm. On gentle slopes but shallower soils (31-40 cm), introduced SWC is no longer profitable under standard assumptions. On steeper slopes (9% and above) and with high discount rates, introduced SWC is not profitable either in Maybar. Adapted SWC is profitable as long as slope gradients are below 9%, irrespective of soil depth and even with extremely high discount rates. On steeper slopes, it takes additional yield increases in the order of 50% to make adapted SWC profitable.

Median individual discount rates are considerably higher in Andit Tid than in Maybar (cf. section 5.3.3). This could be an explanation for the observed lower acceptance of SWC in Andit Tid. However, to reduce individual discount rates, i.e. to lower the time preference, is a difficult task as it involves changing the perception of risk and the valuation of future benefits, or reducing overall poverty.

779 Because soils are shallow, the amount of conservation structures is higher compared to the situation where soils would be deeper. Cf. Section 5.2.1 for the formula to calculate the number of conservation structures in relation to soil depth and slope gradient.

### 9.1.3 Household characteristics

Although the technology might prove to be profitable, local land users might nevertheless reject its adoption, because profitability alone is not a sufficient incentive. Farmers often mentioned that SWC has negative side effects, which, in their opinion, outweigh the positive effects. Such negative side effects include waterlogging in high rainfall areas or pests and weeds spreading from the permanent conservation structures. It was further mentioned that farm operations are more time consuming on conserved land. These arguments are included in the CBA insofar as (i) yields as measured on farmers' fields are considered, thus damage to crops inflicted by pests or waterlogging is reflected, and (ii) the amount of labour invested in fieldwork is not adjusted in the case of SWC despite the smaller area to be cultivated. By considering these two aspects, an attempt is made to depict farmers' circumstances as accurately as possible. The results of the CBA show that even if such negative side effects are taken into account, SWC can, in certain situations, be profitable from a farmers' point of view. Other factors thus have an influence on the negative attitude of many farmers towards introduced SWC, especially in Anjeni and Andit Tid, where SWC is profitable in a number of situations.

It could be demonstrated in the CBA that introduced SWC is profitable only under specific ecological conditions (i.e. gentle slopes and high erosion rates in combination with shallow soils), as long as discount rates do not exceed roughly 12%, if planning horizons are adequately long (usually 50 seasons or longer), if yields are 50% higher than today, and in some cases where, in addition, labour costs are subsidised. Land users' situations are often quite different from these conditions. Firstly, subsidies on labour costs are not paid. They were paid during the Food-for-Work campaigns, but only for the construction of the structures and not for their maintenance, which can be very expensive. Secondly, farmers are often not in a position to purchase the artificial fertilisers necessary to increase yields by 50%. This is not only due to a lack of financial means; often, fertiliser is simply not available at the right time or in the right quantities. In addition, particularly in low rainfall areas, the application of fertilisers is risky, which is another reason why farmers avoid applying artificial fertilisers as far as possible. Farmers and extension staff further lack knowledge on alternative means to improve soil productivity, or they are no longer able to apply alternative technologies such as manuring. Thirdly, farmers' planning horizons with respect to investments in land are usually shorter than 25 years. This can mainly be explained by the insecure political and economic environment under which small-scale farmers in the Ethiopian Highlands operate. In order to invest in their land, farmers must be sure that they themselves will benefit from the investments, and not someone else. Fourthly, household-specific discount rates are often far above the assumed 12%. And lastly, although SWC is often profitable on gentle slopes, households usually have fields with different gradients. Because household labour availability is often restricted, farmers concentrate on specific locations where the erosion damage is highest. However, this will certainly not be gentle fields, where SWC would be profitable, but steep slopes, where rill erosion is visible.

Observations made in the research areas indicate that farmers often keep conservation structures if they consider the benefits to be adequate, but do not extend SWC to areas outside of the research catchments. Among other things, this shows that farmers perceive the amount of labour to be invested into the construction of new structures as being above their current capacities. If the conservation structures are built by the whole community and the individual's share of labour is therefore small, then the terraces are kept, except in specific locations. In Anjeni, farmers have kept and even maintained some of the soil conservation structures in the catchment where SWC activities were carried out as a campaign. In Andit Tid, maintained terraces can be observed in the lower part of the study area, especially on fields with a small or medium slope gradient. In the upper part of the research area, however, most of the conservation structures are not being maintained, and many of them are even ploughed under deliberately. Thus, farmers decide from case to case whether to keep SWC structures or not. The result is a situation similar to what was modelled and labelled as 'adapted' SWC. In this situation, the benefits and costs of SWC stand in a more favourable relation to each other, so adapted SWC is profitable in many more situations than introduced SWC. Nonetheless, land outside the catchment is only rarely conserved, except in Maybar, where it seems that SWC serves many other purposes than only soil conservation, which makes it more profitable from a farmer's point of view.

### 9.1.4 Economic conditions and institutional regulations

Production levels in all research areas are low to very low. Because farm sizes are small, households rarely have the possibility to produce and sell surplus; on the contrary, they have to sell livestock to purchase grain. Generally, their market integration is very low. Because the transport network is weak, it often takes farmers one day or even more to reach a market. High transaction costs force farmers to produce mainly for their own needs and not for the market. Because rural markets are underdeveloped, farmers offer only small quantities of grain to sell, which increases negotiation and quality control costs for traders. Many rural markets are not connected to the road network of if there is a road, it is often in a bad condition, which leads to high transport costs. It is therefore economically not profitable for traders to serve such rural markets. Because of high transaction costs both for traders and for farmers, the cash economy is underdeveloped. Farmers thus also lack the means to invest in production-enhancing inputs such as fertilisers, which make resource conservation necessary on the one hand and profitable on the other hand.

The fact that not more conservation activities are carried out in Andit Tid and Anjeni outside the already conserved areas might also be explained by labour shortages. Because the inhabitants are Christian, they are severely restricted with regard to the number of days they can invest for fieldwork. Because soil conservation is considered as a form of fieldwork, priests do not allow farmers to build SWC structures on Saints' days. On the remaining roughly 130 days without labour restrictions, farmers have to concentrate on fieldwork and cannot tolerate any other labour demand. Thus, for individual households with their family-specific labour availability, it is often impossible to divert labour to other tasks than fieldwork.

Land tenure insecurity must be considered a disincentive to farmers to invest in long-term projects such as soil conservation. Especially in areas where the most recent land distribution was carried out in 1997, several farmers have lost land and investments without compensation. They will be reluctant to carry out further investments if they cannot be sure whether the land they currently cultivate will remain theirs in future. In addition to maintaining tenure insecurities, the land distributions had another negative effect: farm sizes become smaller with every new redistribution. Current structural conservation technologies are unfortunately characterised by occupying a high portion of arable land and by not increasing total production in a sufficient amount. Farmers consider any technology which further reduces the size of their arable land as unacceptable, because current farm sizes are often no longer sufficient to produce enough to sustain a household throughout the year. Farmers from Andit Tid mentioned more than once that because they lost land they will be forced to plough under existing conservation structures and reclaim that land for crop production.

### 9.1.5 Conclusions

Whether soil conservation is profitable from a farmer's point of view depends on a broad range of factors:

- ecological characteristics: topography (e.g. slope gradient), climate (e.g. rainfall erosivity) or soil characteristics (e.g. soil fertility, soil erodibility)
- characteristics of the farming system: e.g. technology (ox-drawn plough), combination of crop production and livestock breeding, crop types
- economic characteristics: e.g. high transaction costs forcing farmers to remain in a subsistence mode of production
- institutional characteristics: e.g. land tenure insecurity, religious regulations).

Because these factors are highly interlinked, it is often not sufficient to change or influence only one of them to make SWC more profitable.

The results of the CBA presented in Section 6.1.2 show that ***introduced SWC is profitable only in few situations***, mainly if slopes are gentle, on steeper slopes if additional fertiliser is applied, and in some cases only if in addition to fertiliser application also labour costs for the construction and the maintenance of the terraces are subsidised. A special case is given in those situations where soil depth has already decreased to critical levels of 10 cm, and crop cultivation has to be given up. The construction of bunds to prevent sheet and rill erosion can be profitable already in the medium term. When farmers construct new terraces, it is done in such a manner that the relation between costs, such as the amount of labour and the amount of land lost for crop production, and benefits, such as perceived positive effects on yield through SWC, is optimised. Farmers thus try to find an optimal solution from their point of view. A similar conclusion can also be drawn based on the CBA. ***Adapted SWC*** is more often profitable because the amount of land occupied by conservation structures is smaller than it is in the case of introduced SWC, and less labour is necessary for construction and maintenance. For the interpretation of these results, one has to keep in mind the specific assumptions that underlie the model, such as the percentage of erosion reduction in the case of introduced and adapted SWC or the amount of arable land occupied. Nevertheless, the results from the CBA and the evaluation of SWC by farmers indicate that from both the internal and the external point of view, introduced SWC is only rarely a profitable investment under the given situation. The first hypothesis formulated at the beginning of this study – from the farmer's point of view, SWC is often an unprofitable investment because of the unfavourable distribution of costs and benefits – has thus to be accepted in many situations. Would other evaluation criteria than the NPV be included in the analysis, such as intergenerational equity, the results must be interpreted differently. For example, society may agree to maintain a minimal soil depth, so that crop cultivation remains possible also for future generations. In this case, SWC must be carried out in order to prevent soils from becoming shallower than the agreed threshold depth even if it proved to be unprofitable.

The case of Mesobit & Gedeba demonstrates that SWC is profitable, if certain conditions are met. Although not enough information was available to carry out a cost-benefit analysis, it can be concluded from observations made and farmers' statements recorded that SWC is, under the given situation, profitable. This situation differs from the situation in the other study areas in several aspects: Similar to Maybar, Mesobit & Gedeba is located on the eastern escarpment. Here, water conservation is probably an important positive effect of soil conservation structures. Thanks to the catchment's location at the foot slope of the mountains, river water and springs are available and allow small-scale irrigation. Due to its location bordering the Afar Region, market exchange has probably always been important. Because Mesobit & Gedeba is comparably well connected to the road network, the market in the nearby town of Aliyu Amba is much more developed than many other rural markets. Traders are involved both in purchasing locally produced crops and in supplying the area with agricultural inputs and other commodities. Farmers have diversified their farming system by integrating high-value market crops such as fruits, vegetables or spices. They invest quite considerable amounts in production-enhancing inputs such as fertilisers. In order to make best use of these opportunities, i.e. in order not to lose fertilisers through runoff, SWC has become an indispensable part of the farming system. Over the years, the local technology of stone terraces with high risers leads to the formation of level bench terraces in the lower and flatter part of the community, and to sloping terraces with a reduced slope gradient on the steeper hill slopes. The technology has not been introduced to the area recently; according to elders, it has been known for generations and has been gradually adapted to local ecological, economic and social circumstances. The current generation was therefore able to inherit considerable investments and does only have to finance maintenance and expansion of SWC structures. Because a variety of organic and inorganic fertilisers are applied, production levels are high for Ethiopian standards. The high investment costs and the yield loss due to land occupied by the SWC structures can thus be compensated.

Mesobit & Gedeba is thus an example, which demonstrates that relying more on the market for purchasing production-enhancing inputs and selling either staple food crops or specific crops grown for the market can lead to a more sustainable farming system. Because inputs are used, SWC is indispensable. Because part of the production can be sold on the market, enough financial means are available which allow purchasing such inputs. Farmers can rely more on the market because it is much more developed than in other regions. Nevertheless, simply having a market available is not yet sufficient. Farmers have to decide to participate in market transactions. Based on the conclusions that can be drawn from the example of Mesobit &

Gedeba, the second hypothesis formulated – unfavourable economic circumstances can be responsible for SWC being unprofitable – has also to be accepted. If the economic environment is favourable and farmers are better integrated in the market system, SWC can become a profitable investment.

Furthermore, institutional characteristics are different from other areas. With regard to the recently carried out land distribution in Amhara Region, farmers from Mesobit & Gedeba have clearly signalled that they oppose a redistribution of land. The main argument was that investments in the land are considerable and that farmers are not willing to loose them. By opposing land redistribution, farmers accept a growing number of landless young farmers. Elder farmers mentioned that this development would in any case continue in future, even if a land distribution were now carried out. Their proposed solution is that young farmers have to search for possibilities of occupation outside the farming sector. For this to happen, however, a change in the valuation of professions is necessary. In some parts in Mesobit & Gedeba, such a change can already be observed. Farmers seem to be much more liberal in their views and seem not to consider artisans to be per se of lower social status. Also with regard to restrictive religious regulations, especially in Christian areas, such as the ban to work on numerous Saints' days, have been relaxed considerably in Mesobit & Gedeba. The third hypothesis formulated – an unfavourable institutional environment can be responsible for SWC investments being unprofitable – has to be seen in a wider context. It is postulated that the institutional environment is decisive for the room for manoeuvre in general, but not necessarily with regard to SWC investments in the narrower sense. By expanding the possibilities of action through modifying certain constraining institutions such as insecure land tenure or limiting religious regulations, it can be expected that SWC becomes one of many different options farmers consider with regard to improving their livelihood conditions.

From this description, it becomes evident that a broad range of factors influences land users in whether they consider SWC profitable or not. This also means that if SWC is to be promoted in other areas, many aspects must be reformed or must change. This again calls for a co-ordinated approach, which focuses not only on the technology or on the farming system, but includes all other aspects of rural life.

In Section 3.1.3 different concepts of sustainability have been discussed. With this study, an attempt is made to make sustainability operational. As strong sustainability – which does not allow trade-offs between natural capital and man-made capital or between the ecological, the economic and the socio-cultural system – is hardly ever achievable, weak sustainability is the guiding principle. It could be shown that SWC, which contributes to sustainable land management through soil erosion reductions to tolerable levels, is in certain situations also profitable from the farmer's point of view. In other situations, however, the costs for SWC, such as loss of arable land and labour investments are too big compared to the benefits such as reduced yield declines. In order to make SWC investments not only sustainable in ecological terms but also in economic terms, certain conditions have to be met. The present study has attempted to show for particular situations in specific areas of the Ethiopian Highlands what these conditions are. It should thus allow evaluating future SWC investments also with regard to their economic sustainability and to propose measures, which would contribute to improve the profitability of SWC investments.

## 9.2 Changes Necessary to Make SWC Attractive and Profitable

*"It is not likely that a "magic formula" will emerge for sustainable development in fragile lands."*
*(Scherr & Hazell, 1994, 31)*

### 9.2.1 Modification of the SWC technology and approach

***Modification of the technology***

Runoff barriers in the form of stone and soil bunds are necessary in many parts of the Amhara Highlands, because agronomic or biological measures are not sufficient to control soil loss enough in critical times of the year or in critical locations. In some areas, biological or agronomic measures are not feasible at all because of climatic limitations of land use practices such as free grazing after harvest. As shown in the CBA, although introduced SWC is efficient with regard to reducing soil loss, it is characterised by high costs in the form of considerable labour inputs and a high portion of occupied arable land. The unfavourable balance of costs and benefits often makes introduced SWC unprofitable from a farmer's perspective. Adapted SWC, although less efficient with regard to controlling soil erosion, is less expensive. In the CBA, adapted SWC often produced positive results.

Modifying the technology might thus be an option. Because it is the land users who have to pay most of the expenses for SWC, their needs should be considered first. This requires that a compromise between the outsider's goal – maximum reduction of soil erosion – and the insider's need – maximum benefits – be found. Adapted SWC seems to go in that direction. Since not enough hard facts are available with regard to soil loss reduction, it was assumed that adapted SWC is only half as efficient as introduced SWC.

In areas where biological measures are not restricted by the climate, grass strips could be promoted. Results from erosion plots indicate that soil loss and runoff reductions through grass strips are similar to those achieved with earth and stone bunds,[780] while grass strips are much less labour demanding. The layout of grass strips is the same as for soil and stone bunds, as is the amount of occupied arable land. Grass strips might create other problems than bunds, such as higher incidence of weed infestation of cropland. Other than that, farmers consider them to have the same negative effects on carrying out farm operations because they are also constructed along the contour over the whole field width. Shifting from soil and stone bunds to grass strips would therefore probably not be sufficient.

Based on observations, it was assumed that adapted SWC leads to an area loss of only a third of that resulting from introduced SWC. Farmers mentioned that a combination of fixed structures stretching over the whole field width, at least at the top and the bottom of a field, and smaller, staggered structures in critical locations could be such a compromise. Further on-farm trials with soil loss measurements might be necessary to find an optimum of soil loss reduction and area loss.

The major challenge is to find ways of combining the necessary structural technologies, which control soil erosion in the most efficient manner, with agronomic and biological measures to raise overall production. Making use of available indigenous technologies and joint developing of improvements by concerned land users, extension staff, and researchers could be a starting point.

***Modification of the approach***

In the 70's and 80's, Food-for-Work approaches seemed an opportunity to combine the promotion of soil and stone bunds and supporting a rural population being affected by drought. Because it was assumed that the benefits of structural SWC on yields is sufficient to compensate the land loss, it was believed that by compensating the initial investment costs, structural SWC would be economically attractive enough for land

[780] Herweg & Ludi, 1999, 107.

users to continue maintaining structures on their own in later years. However, this assumption proved wrong. Not only are initial investment costs high, but the hoped-for positive effect on yields could not be achieved either. Not only this, but the general approach of applying the same technology throughout the whole country without consulting the land users beforehand proved rather unsuccessful. Upon realising this, the Ethiopian government invited the Swiss Agency for Development and Co-operation to help establish a research network through the University of Bern. In different agro-ecological areas, various adapted technologies were tested and their influence of controlling soil erosion assessed. More suitable technologies were developed; however, the approach applied by the Ministry of Agriculture with regard to implementing SWC remained the same. Only in Anjeni, a different approach was introduced. Instead of FfW, a social incentive in the form of a local clinic was financed. It seems that this approach was more successful, as both the clinic and the conservation structures exist to date. Although the FfW approach can be justified on the ground that it supports the population during times of food shortages, it did not lead to the desired outcome of the envisaged land use changes.

Upon realising this, the current government changed its approach. Food-for-Work is only to be used in areas suffering from chronic or episodic food deficits, but not otherwise. A system of compulsory group work has been designed, whereby farmers are expected to work in groups together. The DA responsible in the area designs the conservation measures and assigns the tasks to the groups. The major difference to the former FfW approach is that nowadays, no remuneration is paid anymore for the work carried out. Again, the selection of conservation technologies, the design of the layout, and the quality control is done by the DA without consultation of the concerned land users. And again, a catchment approach is applied, with a few simple technologies being promoted throughout the whole catchment without due consideration of varying ecological conditions or farming system requirements. Lastly, not the quality of the structures is decisive, but the quantity. At the end of the year, what counts is the total length of conservation structures built, and not the length of the conservation structures still maintained and eventually integrated in the farming system.

What could be shown in the CBA is that whether the considered SWC technologies are profitable or not depends not only on overall economic and political characteristics, but also greatly– on ecological factors, on the characteristics of the farming system in use, and on household characteristics. In a new approach, these factors have to be taken into account. A blanket recommendation, in which the DA informs the farmers what to do, would therefore be inappropriate. An individual assessment of needs and options of the land unit under consideration and the actor involved seems more promising. Much more flexibility is needed with regard to selecting appropriate technologies form a basket of available possibilities and of adjusting the technologies to land features and to constraints and opportunities of the concerned households. It might take a household many years to construct SWC structures on its land. A household might also choose different technologies for different fields according to the characteristics of the land or the specific crops grown. On the one hand, this demands knowledge and services from DA's, which they can currently not offer; on the other hand, a much slower pace will result with regard to promoting SWC throughout the whole Region. However, it can be expected that the survival rate and acceptance of SWC investments will increase tremendously with such an approach, as households will be able to choose the technologies that generate the highest returns under given circumstances.

### 9.2.2 Strategies and actions at the household and communal level

Although widespread poverty limits many households from adopting sustainable land management practices and especially mechanical SWC, there are nevertheless options also at the household and community level for achieving a more sustainable resource management system and increased production.

***Collective action to manage natural resources***

In all study areas, part of the community territory is classified as communal lands such as grazing lands, community afforestations or closed areas. With regard to the rules of use and management, communal grazing lands on the one hand and community afforestations and closed areas on the other hand have to be differentiated. Whereas hardly any restrictions exist on grazing land, clear regulations exist with regard to communal forests or closed areas, which are under direct control of the KA administration. Especially grazing areas are often severely overused because there are no incentives for households to restrict the number of animals. Communal grazing lands therefore show many of the problems of open access resources, such as the free-rider problem. Collective action is a strategy that should be promoted with regard to managing such communal properties. Because the lowest administrative unit, the KA, has become rather large, collective action at the village level seems appropriate. Village level resource management plans should be elaborated together with extension agents.

It was often mentioned by farmers that community afforestations are of no benefit to the community members. Pilot projects have been launched in ANRS, whereby communal forests and closed areas are distributed to individual households. It is clearly regulated what kind of land use is allowed on such plots. With this pilot project, a move is made towards private management of communal areas. Besides collective action, this could also be a possible approach to solving organisational problems in the management of communal resources.

In Mesobit & Gedeba, farmers have developed solutions with regard to grazing livestock. Roaming animals would damage the stone terraces used to conserve arable land, as well as the perennial shrubs grown on them. Farmers in the village of Mesobit & Gedeba have thus agreed to restrict free grazing on harvested land. Only the animals of the landowner are allowed to graze on private arable land, where it is the direct responsibility of the owner to protect his investments. Especially for farmers with small properties, this new livestock management system poses considerable problems. With less arable land to cultivate, they depend more on livestock for supplementing their household income, especially on small ruminants, which are now, however, no longer allowed to graze freely. Furthermore, the new system is problematic not only with regard to feed, but also with regard to labour. Since animals now have to be tended during the day, farmers with limited availability of family labour are no longer able to engage in off-farm income generation during the dry season. To balance some of the negative side effects of this new grazing system, poor households with small farm sizes are treated preferentially with regard to collecting grass from communal forest areas.

In Maybar, the KA administration has divided part of the grazing land near Lake Maybar into individual plots and distributed them to farmers. There are no restrictions with regard to what the owner is allowed to do. For those households that have no own grazing land and only small holdings, i.e. limited possibilities to produce enough fodder for their animals, this 'privatisation' of former grazing land is problematic. It is also questionable whether it solves the problem of overgrazing on the grazing land still under communal management. It must rather be expected that pressure on the remaining communal grazing land is increasing, because the total livestock density has not decreased, while the former grazing land near the lake has been converted to arable land.

Common property resources with collective protection and management may become the optimal strategy for managing scarce resources as long as population densities are moderate. With high population densities, the benefits and costs of collective action relative to private action may begin to change, because the need to organise larger numbers of people and the increasing scarcity of resources will make it more difficult to achieve collective action. Furthermore, the costs of monitoring and enforcement and the benefits of violating collective restrictions on resource use will rise. Eventually, as population grows, the net benefits of private management will exceed the benefits of collective management, promoting a shift in management systems. This shift may occur without a shift to private property – economics of scale in resource protection may favour keeping resources under communal ownership, even though they may be privately managed.[781]

A shift towards more privately managed natural resources can be observed in Maybar and Mesobit & Gedeba. This might be explained by the high population pressure in these areas and by the fact that before, only comparably small areas were under communal management. In Andit Tid, on the other hand, grazing land is not in short supply and it does not yet seem necessary to change the management system. Whether the

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[781] Pender, 1999, 45.

new system of private management will decrease resource degradation, needs to be demonstrated in future. It might well be that pressure on the remaining communal areas will increase, because no restrictions with regard to its use are yet in force.

***Diversifying household strategies***

Diversifying income sources can lead to lowering the dependency on income from agriculture, thus also lowering the dependency on natural resources. Diversifying income can also include diversifying the farming system. Examples from all research areas show that there are options to do so: in Andit Tid, growing Eucalyptus is economically very attractive, and in Maybar and Mesobit & Gedeba, a considerable income can be achieved with high-value crops grown with the help of small-scale irrigation. All these strategies, however, require an improvement of market integration. Because farmers have made bad experiences with the market during the revolutionary period, they are now reluctant to expose themselves too much to market risks. Although most markets are still very weak, they have improved to some degree. Producer prices and profit margins have increased considerably. However, to make best use of an increased and diversified production system, farmers must participate more in market transactions.

Those households with a comparably diversified household income are often innovators with regard to the farming system and land management practices, household and labour organisation, or social networks. In the Amhara rural society, innovators are considered a threat to the cohesion of the local society and are thus sanctioned. In Maybar, for example, the enclosed area where a household was experimenting with small-scale irrigation and new crops was destroyed three times. A new way of appreciating innovative behaviour must thus take root in the rural society. A change of attitude is also necessary with regard to accepting members of other professions as full members of the rural society.

***Joint action towards relaxing restrictive religious rules***

Especially in Christian areas, labour availability is limited by religiously imposed bans forbidding farm work on numerous Saints' days. Because most forms of soil conservation involve moving earth from one place to another, they fall under the religious ban just like fieldwork. On unrestricted workdays, SWC activities or other land improvements therefore often compete with normal fieldwork. Understandably, priority is given to normal fieldwork. Farmers often mentioned that they have difficulty in carrying out the necessary fieldwork at the right time. Only rarely, however, farmers ignored the ban on working on certain days, because this would endanger their integration in the local society. In light of the current economic and ecological situation in the Highlands of Ethiopia, such a strict regulation of when fieldwork is allowed and when not, must be reconsidered. It seems especially important that flexibility concerning fieldwork be increased. It is not to be expected that the Church itself will initiate the necessary changes. The pressure will have to come from the concerned farmers. This, however, requires joint action of all community members, as individuals trying to break out of religious norms have to expect sanctions.

### 9.2.3 Strategies and actions at the regional and national level

The government[782] must provide favourable frame conditions that allow farmers to adapt their farming system and adopt new or improved technologies, with the ultimate aim of increasing agricultural production, achieving sustainable land management, and reducing poverty. A wide variety of government interventions is possible, some of which are discussed briefly in the following paragraphs; this does not imply that the points mentioned form an exhaustive list of options. Interventions are necessary not only in the field of agricultural policies (e.g. agricultural, forestry, and livestock policies, agricultural extension system, price policy), natural

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[782] No distinction is made here as to whether the recommendations concern the Federal Government or the regional governments. Although the case studies all concern localities in the Amhara National Regional State (ANRS), situations are similar in other regions. Most of the policies will have to be formulated at the level of the Regions, however, national policies are necessary to guide the formulation of policies at the regional level.

resource policies, and research into agricultural and natural resources (e.g. crop cultivation, livestock production, natural resource conservation), but also in other sectors that have an influence on rural livelihoods, such as population and reproductive health, education, health, and industrial and infrastructural development. There are many indications that if rural livelihoods improve, chances increase that farmers are able to adopt more sustainable land management practices.

If aspects such as intensifying or diversifying agricultural production are mentioned in the following sections, this does not imply that the government has to do everything or even has to play a major role. In most instances, the government must initiate the process and provide favourable frame conditions. In the case of agricultural research, for example, the government must guarantee that funds are available, that working conditions are favourable, or that international networking among research organisations is possible. With respect to other options such as formulating appropriate and conducive policies or reforming the land tenure or the tax system the government has a much more prominent role to play.

***Initiating a multi-level and multi-stakeholder negotiation process***

In order to allow a sound development planning, including the proper consideration of the various below-mentioned aspects, which are believed to be important with regard to sustainable land management, a multi-stakeholder negotiation process[783] must be initiated. Such a process includes various actors or stakeholders, such as the concerned land users, local administrations, CBO's, local NGO's, traders, government personnel, project personnel, and other actors from the national and international arena. Multi-level refers to different spatial and organisational units, implying that sustainable land management cannot be achieved simply at the plot level, but that characteristics such as asset endowments and organisational forms of the household and the community are likewise important and that frame conditions at the national and international level also determine whether sustainable land management at a local level can be achieved or not. The following Figure 62 shows major intervention levels and activities in such a multi-stakeholder approach to sustainable land management.

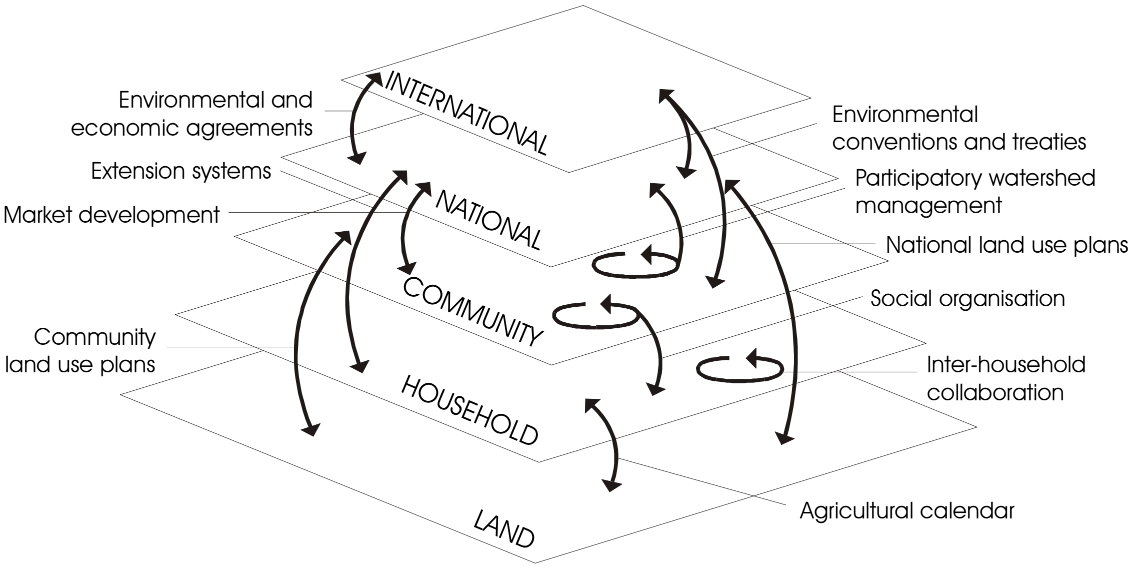


*Figure 62: Intervention levels in a multi-stakeholder approach to sustainable land management. [Source: Hurni et al., 1996, 34]*

783 Hurni, 1996; 1998; 2000a.

A basic principle of this approach is the acknowledgement that every society has its own perception of resources.[784] Thus, the starting point of every multi-stakeholder negotiation process at the local level is to define which parts of the ecological environment are considered resources and what sustainable resource use could be. Only after an agreement is achieved in this respect, activities can be discussed which would lead to a more sustainable resource management. Such negotiations combining local knowledge and more scientifically-based knowledge make it possible to design measures, which are acceptable to land users and at the same time lie within certain scientifically defined limits of sustainable resource use.

Major actors to be included in a multi-level stakeholder approach can be categorised broadly into three groups:[785]

(i) ***Local actors and communities***. On the one hand, through their specific land use system, local actors have the strongest influence on natural resources within a given region.[786] On the other hand, it is mainly they who will be involved when actions are undertaken to reverse negative trends. The perceptions, needs, and options of local actors and communities are therefore of paramount importance. The following aspects need to be considered: Firstly, rural societies are not homogenous. Different segments within the rural population (e.g. resource poor households, female-headed households, young families) have different problems, different needs, and different options available, based on their endowments with physical, financial, social and human capital. It will therefore be important to have these different segments represented in a multi-stakeholder approach. Secondly, even if sustainable land management is in the centre, other stakeholders from the rural society must be included. In the Christian dominated Highlands, for example, discussing sustainable land management and options for improvement without including the clergy will not lead to the desired outcome, because important constraints such as religiously related labour restrictions cannot be alleviated without the consent of the clergy. Other important groups include traders and artisans. Thirdly, to achieve sustainable land management, it is often not sufficient to rely on individual households. Local organisations are very important and must be addressed accordingly. In the rural society of the Ethiopian Highlands, many different forms of organisations exist. Although their purpose is usually not related to land management, they might nevertheless be important. For example, the traditional savings club *iqub* has changed from a mainly consumption-oriented into a more production-oriented savings club. And lastly, sustainable land management might not be the most urgent aim of local land users, thus other aspects of rural livelihoods, which can in turn create opportunities for sustainable land management (cf. Section 6.3.1), must be addressed first.

(ii) ***Scientists and researchers***: On the one hand, scientific approaches can help to determine whether current land use practices are sustainable or not compared to a predefined baseline situation. Scientific methods in monitoring can also help to shed light on positive or negative changes. Modelling and prospective impact analyses can show what possible outcomes could result if different input variables are changed. Such scientific approaches are not only necessary with regard to land use and natural resources, but maybe even more so in the field of socio-economic dynamics influencing the land use system. On the other hand, research might also help to find new land use options benefiting both the local land users and the environment.

(iii) ***National decision-makers and development agencies***: National decision-makers are responsible for creating a policy environment favouring sustainable land management. They will be responsible for balancing the needs of their population and the more trans-regional demands. Because national decision-makers often represent specific elites within a country, their role as mediators in the multi-stakeholder negotiation of sustainable land use can only be minor. International agencies and pressure groups might be better suited for that part. Nevertheless, even international actors have their very specific agenda, which must be clear to all involved parties at the beginning of a negotiation process.

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784 CDE, 1995, 12; cf. Section 3.1.4.

785 Wiesmann, 1998, 214.

786 Because in this case, the focus is on land use systems in an agrarian society, external negative influences such as air pollution, which in other situations can be the major source of resource degradation, will not be considered.

The multi-level stakeholder approach per se does not yet guarantee that sustainable land management can be achieved. The major problem, as in any negotiation process, is the distribution of power. In the Ethiopian case, for example, discussions between land users and government employees are often characterised by perceptions of superiority on the side of the government employees. In such a situation, the outcome of a negotiation is always that government employees dictate to farmers what they believe to be good for them. External stakeholders, on the other hand, might have their own agenda. Representatives from donor organisations, for example, must follow the policy of their organisation with respect to activities that can be funded. They might therefore push the discussion in a direction that suits the aims of the donor organisation, but not necessarily addresses the needs of the land users.

*Figure 63: Local land users, government employees and researchers come together in a multi-stakeholder negotiation to discuss issues of sustainable land management at the local level.*
*[Photo: E. Ludi, 1998]*

A multi-stakeholder approach could also serve to solve disputes over competence and responsibilities within the administration. Resource conservation cannot be separated from agricultural production. Agricultural production is not just a profession, but a way of life. Other aspects affecting rural livelihoods must thus also to be included. If responsible persons from different administrative levels and different sectors as well as researchers are brought together to discuss the issues of improving farming systems, achieving sustainable land and resource management, and improving rural livelihoods, chances increase that the problems faced by land users are addressed adequately and in a multi-sectoral and integrative way.

***Decentralising power and responsibilities and empowering society***

Decentralising power and responsibilities to lower administrative levels, developing human capital and empowering local people are important factors in a sound development approach. A decentralisation process has been initiated, in the course of which most responsibilities are delegated to the level of the Regional States. Unfortunately, the devolution of power and responsibilities was not accompanied by the necessary decentralisation of financial or human capital. Secondly, although many responsibilities have been handed to authorities at the regional levels, the decentralisation has not gone much further. Local communities have little funds and knowledge available for initiating their own activities, and usually the approval of higher administrative levels is necessary, which further delays planned activities. The concept of genuine participation of the local population in initiating, planning, implementing and monitoring development activities has not yet taken root in administrative procedures. Participation is more often understood as a free source of labour force for activities planned at a higher level. In order to empower the local population, a new appreciation of participation and of the role local populations and their knowledge base play in development has to take place in the administration, in research organisations and among policy makers.

***Supporting the intensification of the farming system***

In Section 6.1, it was demonstrated that, under given circumstances, mechanical SWC is profitable only in specific situations, i.e. if the ecological situation is favourable (e.g. gentle slopes), if labour costs are subsidised, or if fertilisers are applied and yields are assumed to increase by 50%. Thus, one reason for the low profitability of SWC are low yields compared to high investments costs.

With the ***Sasakawa-Global 2000*** (SG2000) project, the Ministry of Agriculture (MoA) has started to address low production levels as a major feature of overall poverty in Ethiopia. The objective of this programme is to demonstrate the productivity increases that can be achieved when farmers are provided with appropriate extension messages, adequate extension contact, and agricultural inputs such as improved seed, fertilisers, and agrochemicals delivered on time at reasonable prices. Participating farmers contribute a half-hectare demonstration plot. The MoA/SG2000 programme provides farmers with improved inputs on credit. During critical periods in the cropping cycle, participating farmers are closely supervised by extension agents. There seems to be strong evidence that average maize yields on plots under the SG2000 programme are much higher (e.g. maize yields in Jimma under the programme: 4.8 – 6.8 t/ha, traditional: 2.8 t/ha, national average: 1.9-2.1 t/ha). In contrast, tef yields under the programme do not differ significantly from those achieved with traditional cultivation practices.[787]

It seems that the SG2000 programme has been taken up readily by farmers and has also shown that with a right mix of improved land management practices, improved seeds, artificial fertiliser, and agrochemicals, the desired outcome can be achieved. However, the majority of these SG2000 plots are located in favourable areas with regard to rainfall, topography, road access, and DA-farmer ratio. The programme is also criticised for recommending a uniform fertiliser application rate throughout the whole country, irrespective of soil type, nutrient level, and potential moisture stress. A further problem mentioned by farmers is that the demonstration plot has to be half a hectare. In some areas, farmers are excluded from the programme because they do not have plots in that size. Moreover, even if they do have plots in the necessary size, some do not want to participate, because the risk associated with devoting half of one's farm to a programme with insecure outcome is perceived to be too big.[788]

Despite these problems, the strategy is heading in the right direction. However, there is a need to adjust the SG2000 programme to local circumstances by introducing several changes, such as different input combinations for different agro-ecological areas, a more flexible approach (e.g. smaller plots), and better integration with other farm management improvements (e.g. livestock improvement, manure, green manure and compost management, small-scale irrigation, integration of tree crops). The programme should be tailored to meet the needs of small-scale subsistence farmers. However, if it will not become more flexible, many resource-poor households will remain unable to participate. Also of great importance is the integration of the SG2000 programme with soil nutrient management.[789] The solution is not simply to supply artificial fertiliser; soil nutrient content must also be enhanced with input from organic sources. This in turn improves the efficiency of artificial fertiliser. More emphasis should be given to developing strategies to integrate external nutrients with available sources of organic matter, locally available sources of nutrients, leguminous trees and crops, manure, or compost.

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[787] Howard et al., 1999, 1.

[788] Fitsum Hagos et al., 1999, 35.

[789] Quinones et al., 1997, quoted in Fitsum Hagos, 1999, 52.

In many areas of Sub-Saharan Africa, with Ethiopia being no exception, nutrient mining is widespread, because formerly shifting cultivation systems have been transformed to continuous crop cultivation systems as a result of high population growth rates. As a promising strategy with regard to improving overall soil conditions and address nutrient deficits in areas dominated by soil fertility decline, annual crop cultivation, and resource-poor households with small farm sizes, ***organic fertilisers*** are proposed as a supplement or alternative to artificial fertilisers, because farmers lack the means for buying the latter. However, organic fertilisers are often unavailable, because animal dung is used as a fuelwood substitute. Furthermore, residues have competitive uses, such as fodder for livestock. And last but not least, the processing and application of most organic materials is highly labour demanding.

Most commonly, nutrients such as nitrogen, phosphorus and potassium are in limiting conditions. Technologies developed to transfer biomass and nutrients to arable land have shown promising results. In collaboration with the Tropical Soil Biology and Fertility Programme (TSBF), Kenyan agricultural research organisations have developed biological technologies that are available also to resource-poor farm households. Common shrubs and trees, which accumulate nutrients, have been identified. One of he most promising species is ***Tithonia diversifolia*** (Mexican sunflower), which is found as a roadside weed and common farm hedge plant, and can produce up to 275 tonnes of green material (about 55 tonnes of dry material) per hectare per year. It is easily propagated from seeds and stem cuttings, which are simply inserted into the soil, and grows rapidly after cutting, withstands repeated pruning, and decomposes rapidly after incorporation into the soil. It is not invasive, does not grow tall enough to become unmanageable, and has various uses ranging from fodder to fuelwood, building material, termite protection and animal and human medicine.[790] Nutrient concentrations in green leaves of Tithonia collected in East Africa were 3.5% N, 0.37% P, and 4.1% K on a dry weight basis. The N concentration is comparable to those found in $N_2$-fixing leguminous shrubs and trees, whereas the P and K concentration are higher than those typically found in shrubs and trees.[791] In experiments carried out in Kenya, 5 t/ha of dry matter of Tithonia were applied. In the season after the high quality residues were applied, the maize yield was tripled; moreover, a positive effect could still be felt in the next growing season.[792] This shows that green biomass of Tithonia is certainly a potential source of N, P and K for crops. However, the quantities of green biomass available from Tithonia growing near smallholder fields will most probably not be sufficient to supply all necessary nutrients and to eliminate nutrient deficiencies over large areas. Biomass from Tithonia must therefore be combined with artificial fertilisers. This combination is expected to have added advantages, because Tithonia biomass increases overall organic matter content of the soil and thus contributes to enhancing the efficiency of artificial fertilisers.[793]

Although Tithonia seems to be a promising option, it is not the solution to all soil fertility problems in the Ethiopian Highlands. First and foremost, results from experiments with Tithonia in Ethiopia are not yet available; the above quoted results were all measured in Western Kenya. It is thus unknown whether such positive results can also be achieved in the Ethiopian Highlands. Climatic limitations (annual rainfall, temperatures) might restrict biomass development considerably. Secondly, even if Tithonia grew in the Ethiopian Highlands and contributed to overcome N, P, and K deficiencies, the amount of biomass necessary to achieve significant results will be tremendous. Evidence from Kenya shows that per $m^2$ roughly 1 kg of dry matter of Tithonia can be produced.[794] A Tithonia hedge surrounding a one hectare plot would supply 0.4 t of dry matter, which is far below the recommended amounts of 4 to 5 t/ha. If the same plot were treated with mechanical SWC and Tithonia were planted on the conservation structures, additional biomass in the order of

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790 Wanjau, Mukalama & Thijssen, 1997, 25; Jama et al., 2000, 202.

791 Jama et al., 2000, 206.

792 Rao, et al., 1998, 6.

793 Jama et al., 2000, 212. Experiments for soil fertility recapitalisation in Western Kenya, in which organic and inorganic inputs were combined, showed that the integrated nutrient management strategy of 2.5 t/ha of Tithonia (organic) plus 25 kg $P_2O_5$ + 30 kg N per hectare of inorganic fertilizer (DAP) was an agronomically and economically promising strategy for recapitalising soils particularly depleted of phosphorus (and also nitrogen). (AHI information, 6-10-1999, [www.icraf.cgiar.org.sys_wide/programme/misp.html])

794 Jama et al., 2000, 216.

1 t/ha to 1.5 t/ha could be achieved. In this case, however, the nutrients would not really be an input, since the biomass would not be transferred from outside the considered land; on the contrary, such an arrangement would rather constitute a case of nutrient cycling or even nutrient mining. Furthermore, a considerable amount of labour has to be invested for cutting Tithonia and carrying it to the land. Since this has to be done during the time of land preparation and planting, labour capacities may not be sufficient.[795] Application of Tithonia thus seems promising either if carried out only on very specific locations within a field, or if used only for high-value crops grown on a small area (e.g. vegetables). These high-value crops could be used to generate income, which again could be invested to purchase artificial fertiliser for grain crops.

If ***phosphorus*** has reached critically low levels or is in a plant unavailable form (i.e. sorbed at the surface of clay particles), there is no other solution than to bring it to the soil from outside the system. In some cases, rock phosphate shows similar concentrations of available phosphorus as artificial fertilisers do, while it is considerably cheaper. One possibility is to apply rock phosphate in large doses of 250 to 500 kg/ha, which is enough to meet the needs of crops over the next eight to ten years. Highest crop yield increases were found where rock phosphate was combined with Tithonia.[796] However, due to the lack of transport infrastructure throughout most of the Ethiopian Highlands, this option is hardly feasible. Moreover, the costs of rock phosphate, although considerably lower than expenses for artificial phosphate fertilisers, are still above the capacities of most small-scale farmers. There are good arguments that justify supporting farmers in replenishing soil nutrients, as the benefits would accrue not only to the concerned land users, but also to society. Such a one-time concentrated investment would not be a hidden form of subsidies, but a true capital investment, which would be expected to generate profits in future. National and international investments can thus be justified as a cost-sharing arrangement between farmers and governments or the international community.

A further possibility to improve soil fertility levels is ***improved fallow***, which involves growing nitrogen-accumulating leguminous shrubs. However, throughout most of the Ethiopian Highlands, farm sizes are too small to allow a household to leave part of the land fallow, even though farmers know very well about the advantages. Trials in Western Kenya, where land scarcity is similar to land scarcity in Ethiopia, showed impressive maize yield increases after planted fallows of 6 to 12 months duration. Shrubs identified as suitable include different species of *Crotolaria*, *Sesbania Sesban* or *Tephrosia vogelii*. Fallow plants are sown together with maize between the rows. The shrubs start growing after the maize is harvested, and cover the land during the next short rainy season. The fallow is then cleared, fallow plants are worked into the soil, and maize is again sown in the long rainy season. Yields increased by 70%-80% compared to yields under continuous maize cultivation, and by 25%-33% compared to yields after a natural fallow.[797]

All of the above-mentioned technologies for boosting soil fertility to achieve a more intensive farming system face several ***constraints***. The SG2000 programme demands high financial inputs from farmers as well as a considerable area of their holding to be devoted to the trials. Furthermore, blanket recommendations with regard to fertiliser application do not consider differences in soil properties or plant requirements. Applying the same amounts of fertiliser in areas suffering from moisture stress as in moist areas is very critical, as the likelihood of total crop failure is considerable. Providing inputs exclusively on a credit basis does not take into account farmers' circumstances. Many farmers in the different research areas fear indebtedness if they have to buy fertilisers on a credit basis, because yields may not perform well. Furthermore, credits are culturally sanctioned. By not linking the programme with livestock production and organic means of increasing soil fertility and improving soil conditions, possible synergies are not exploited. Organic measures such as nutrient transfer or improved fallow have produced impressive results in Kenya, but there is no evidence yet that similar achievements are also possible in Ethiopian conditions. On-station trials with the proposed crops must first be carried out to study their impact and possible negative side effects. In a later stage, on-farm

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795 Results from Vietnam with mulch transfer to upland rice show that although the net return per labour unit was high and yield increases considerable, labour requirements for pruning *Tephrosia* and mulching was considered too high by many farmers. Additionally, labour for pruning and mulching collided with other farm operations. (Fagerström et al., 2001, 35)

796 Sanchez et al., 1997, 15.

797 Rao et al., 1998, 6.

experimentation will be necessary in order to find out under which conditions these biological measures contribute to improved soil fertility and thereby to improved production and household income. Constraints with regard to land, labour and cash availability of participating households, as well as community organisation with regard to access to communal land (e.g. for collecting suitable plants and bringing them to individually owned plots) and livestock grazing patterns (e.g. free grazing after harvest) have to be taken into account.

The fixed package programme as applied by the SG2000 project is under given restrictions due to the small number of DA's per KA probably the most efficient option. There are, however, possibilities of giving farmers more opportunities to ***experiment*** on their own with alternative mixes of inputs and to embark on a process of learning-by-doing. Farmer field schools[798] have shown good acceptance in many countries and have empowered farmers to experiment on their own, to collaborate with fellow farmers, to learn from experiences made by farmers in similar circumstances, to interact on a more equal basis with researchers and extension staff, and to communicate research questions relevant to resource-poor small-scale farmers. In the case study areas, it was time and again mentioned that with the package approach, not necessarily the right farmers participate. DA's have to fulfil a quota of participants. This forces them to persuade farmers to participate against their own will or to rely only on those farmers already convinced of the new technology. If the harvest is not as good as expected, the damage usually comprises more than the crop loss alone. What is requested both by farmers and by the DA is to continue with the programme, but at a slower pace (e.g. no quotas of participating farmers) and with more flexibility (e.g. smaller areas, flexible mix of improved seeds, variable rates of fertiliser application). Especially in moisture stress areas, where in unfavourable years fertiliser application can damage the crop totally, an insurance system should be established. It could be observed that because farmers have to buy agricultural inputs on credit and have to pay back the loan immediately after harvest, they are forced to sell assets (e.g. livestock) in order to repay the loan if the harvest failed. This acts as a very strong disincentive to participating in the programme.

Relying on artificial fertilisers to improve production masks the damage done to the soil by nutrient mining through harvested crops and nutrient loss through soil erosion. It must be clearly communicated that on sloping land, fertiliser should not be used alone, but only in combination with soil conservation and measures to enhance soil organic matter contents. Otherwise the costs of fertiliser can not be justified in future, as fertiliser efficiency will decrease dramatically if either the soil depth drops below what is necessary to grow annual crops, if water retention capacities are reduced so that negative consequences of fertiliser application become more frequent, or if soil organic matter content becomes so low that fertiliser can no longer be sufficiently fixed.

The supply of agricultural inputs for the demonstration plots even to remote areas does not pose too much of a problem. If, however, many more farmers were to participate in the SG2000 programme, the distribution of inputs would prove to be highly constrained. Not only are ***means of transport*** lacking, but many areas are not connected to the road network at all. In order to make inputs available on the one hand, and to allow farmers to sell their output on a competitive market, on the other hand, great efforts must be made to develop a functioning ***market*** system. On the input side, obstacles such as foreign exchange and import restrictions, price controls, and interventions by the local authorities in the private marketing of inputs must be removed.

In view of the constrained financial possibilities of the Ethiopian government and the tremendous needs with respect to infrastructure development, it is clear that many remote rural areas will also in future not be connected to the road network. ***Transaction costs*** for farmers to sell their goods and for traders to buy local products and to sell commodities are prohibitively high. It is argued that because one quintal of fertiliser yields three to seven quintals of grain, it would be cheaper to subsidise fertiliser transport to remote areas instead of delivering relieve food.[799] However, this strategy would only lead to positive results in comparably favoured areas where there are possibilities for increasing production.

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798 [http://dbtindia.nic.in/farm/page3_5.htm]

799 Fitsum Hagos et al., 1999, 53.

Whenever the high-input strategy is pursued, which relies on agricultural inputs, a functioning ***credit system*** is a prerequisite. On the one hand, it is necessary to enable farmers to purchase the necessary inputs. On the other hand, if the production of surplus is possible which can be traded on the market, marketing credits to allow farmers to store and sell crops during the dry season are also very important.[800] Furthermore, local storage facilities need to be developed.

In ***moisture stress areas***, where irrigation is limited, high external input strategies are not feasible. What is of paramount importance here is to conserve and use the available soil moisture as efficiently as possible. Limited inorganic fertiliser should be combined with organic nutrient management and SWC structures. Risks could be minimised by using artificial fertilisers in a targeted manner only above conservation structures, where moisture conservation is highest. Structures should also be supplemented with deep-rooting shrubs or trees in order to minimise water competition. Such deep-rooting shrubs and trees could also trap nutrients unavailable to annual crops and make them available through litter fall. Nevertheless, competition over water, nutrients and light has to be taken seriously. Furthermore, hedgerows or trees planted along field boundaries are often a reason for conflicts among neighbours.

A new policy with regard to ***degraded land*** has recently been launched in pilot communities of the Amhara Region. Degraded areas are distributed to individual households. Their use is clearly defined as for tree plantations and grass cutting only. It can be hypothesised that if this system will work and more trees will be available, the necessity to use crop residues and animal dung as fuelwood substitute will diminish. This again will make more organic material available to improve the soil nutrient pool. It will be important to promote not only fast growing Eucalyptus[801] trees for the rehabilitation of such degraded areas, but to put an emphasis also on local species, fruit trees, legumes, and fodder producing trees. This could help to improve soil fertility on the spot, to enhance biomass and nutrient transfer to farmland, to improve livestock production and to increase household income directly thanks to tree products sold on the market.

In all research areas, ***grazing land*** is heavily overused and shows clear signs of degradation. Often, area closures are recommended in such cases to allow natural regeneration. This, however, often leads to increased pressure on the remaining grazing land, so that the net impact on resource degradation is not necessarily positive. Cut and carry systems are a solution, however the labour demand is considerable, as well as the management necessities at community level with regard to distributing permissions to harvest grass from certain areas. Planting and managing improved grasses and trees could contribute to increasing the production of grazing areas in the long run.

Commonly, animals are only restricted to specific grazing areas during the growing period. After harvest, animals graze freely on farmland. With respect to biological measures to control soil erosion and improve soil fertility, this practice is very problematic. Improvements in the management of farmland may be restricted by the grazing system, which might therefore have to be changed.

Out of the research sites, ***Maybar*** is the one that belongs to the category of remote areas with – relative to the others – advantages, where the potential to improve agricultural production is still intact on selected areas. The rainfall pattern allows double cropping on medium steep slopes in combination with soil conservation investments, and thanks to the lake situated nearby, irrigated agriculture could be expanded considerably. There is the market of Dese in the vicinity, which is, however, currently not accessible by car.

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800 Fitsum Hagos et al., 1999, 54.

801 Ecological impacts of Eucalyptus are mixed. On the one hand, they produce more biomass on poor quality soils than local species (the annual increment of Eucalyptus is approximately 10 $m^3$, whereas for indigenous species it is only 1.2 $m^3$). Thanks to their strong root system, they halt mass wastages on steep slopes. They reduce wind erosion, and they can tap deep groundwater otherwise not available to annual crops. Furthermore, they are drought, fire and flood resistant and currently not threatened by pests. On the other hand, there is evidence that Eucalyptus can out-compete crops for nutrients and water, and allelochemicals in leaves alter soil mineral content and may be responsible for reduced crop growth. (Jagger & Pender, 2000, 45) In high rainfall areas such as Andit Tid and Anjeni, private Eucalyptus plantations on degraded lands are not expected to have serious negative effects, since the leaves are collected and water availability is not a limiting factor. In dryer areas such as Maybar, competition between crops and trees has been reported by farmers.

Input subsidies might be an option during the time the road is maintained. At the same time, the water pump needs to be repaired. The KA should discuss thoroughly how the irrigable land should be distributed among the farmers. This process might require outside assistance, as already now there is a conflict between different fractions within the community concerning the distribution of water, i.e. of irrigable land. This conflict is the major reason why the pump has been out of order since 1985.

Also in ***Mesobit & Gedeba*** and in some areas of the ***Simen Mountains***, small-scale irrigation is a possibility. It allows the production of high-value crops such as fruits, nuts, vegetables, spices, coffee, *chat*, and *gesho*. As the example of Mesobit & Gedeba shows, such small-scale irrigation does not have to be expensive, and furthermore, it is not dependant on imported technologies. The management of the numerous small springs is often sufficient to irrigate a small garden, the income of which can be considerable (cf. Section 6.3.3). However, to enable farmers to take advantage of such diversification opportunities, road infrastructure, agricultural extension services, local storage and processing enterprises and the market system need to be drastically improved.

***Anjeni*** is characterised by very low yields. Many of the dominant soil types (e.g. Nitisols) are expected to sorb phosphate, which is then no longer available to plants.[802] Climatic conditions and altitude are similar to Western Kenya, where experiments with nutrient transfer from Tithonia have shown substantial yield increases. Improved fallow with lupine (*Lupinus albus var. termis*) is already a common practice on degraded land in Anjeni. It would probably be worthwhile to launch a series of experiments combining improved fallows with Tithonia and $N_2$-fixing legumes with artificial fertilisers. Trials, in which lupine and other leguminous plants are grown in intercropping with cereals, might also be worthwhile.

In ***Andit Tid***, biological measures to improve soil fertility are limited because of the high altitude. Improved fallow is certainly an option, as on-farm trials with vetch (*Vicia sativa L.*) have shown. Several farmers have adopted the technology and rotate vetch on their land to improve soil fertility. They also mentioned that it is a favourable and very nutritious fodder crop. Since in many areas of Andit Tid crop cultivation is already impossible due to widespread degradation, conversion of plots to tree plantations seems a promising option to increase household income (cf. Section 6.3.3).

***Supporting the diversification of the farming system***

In addition to intensification, also a more diverse farming system would help improve the livelihoods of land users in the Ethiopian Highlands and reduce risks. If small-scale irrigation could be expanded, vegetables and fruit trees could be cultivated. On the one hand, a direct contribution to the nutritional status of the people can be expected. Currently, diets are rather monotonous, fruits and vegetables are almost totally missing. Products not marketed could be consumed directly. On the other hand, the income from high value market crops could increase the household income and could be used to purchase artificial fertilisers for grain crops. Most probably, however, food self-sufficiency has to be achieved before farmers embark on such a risky business as producing high-value market products. In areas where food security is achieved, longer maturing products such as coffee, *chat*, fruits and nuts or lumber could also become an opportunity.

Observations on the rural markets show that farmers all offer the same produces. This can lead to an oversupply and thus depress prices. With a more diversified production system, such situations could be more easily avoided.

Especially in moisture stress areas, the success of diversifying the cropping system heavily depends on ***irrigation*** possibilities. In many areas, water resources could be considerably optimised. Small-scale irrigation can be low-cost if water from small streams and springs is utilised to flood-irrigate nearby land. With irrigation, high-value horticulture crops could be produced either permanently or during the dry season on land that was used to produce rain-fed crops during the rainy season. In many areas of Tigray, the construction of micro-

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802 Sanchez et al. 1997, 11. Gete Zeleke (2000, 21) observes low to medium total N and very low available P contents.

dams has allowed to expand irrigated production, especially in areas near markets and roads.[803] But also in more remote areas, water conservation in the form of ponds and dams could show positive results with respect to improved diet and reduced labour (e.g. driving animals to distant watering places). Similar positive results from irrigation can also be expected for the drier study areas such as Maybar, Mesobit & Gedeba, and the lower parts of the Simen Mountains. In Maybar, a few farmers have started to utilise water from springs and produce a considerable income from a very small area. In Mesobit & Gedeba, small irrigated gardens are quite widespread. Goods produced include vegetables such as onions, garlic, lettuce, tomatoes, and pepper, sugar cane, and perennials such as coffee, papaya, oranges, and lemons. Usually farmers sell these products on the nearby market of Aliyu Amba; otherwise, they consume them themselves. Those farmers already practicing irrigated agriculture mentioned that it contributes a considerable portion to the household income.

Although irrigation could contribute significantly to improved agricultural production, it poses a number of problems. First and foremost, ***conflicts*** with regard to access to irrigable land and to water distribution have to be expected. Especially in areas where irrigation does not have a long tradition, institutions for managing water and solving water-related conflicts are missing. Support from outside might be necessary to promote and develop local institutions that could handle both the distribution of resources as well as conflict resolution. Conflicts might arise not only locally; if more water is used in the up-stream areas, less water will be available in down-stream areas, regions often depending heavily on irrigation. Water sharing arrangements that take into account the needs of both the up-stream and the down-stream inhabitants have to be developed. The construction of micro-dams and ponds could be a possibility to mitigate conflicts, as they retain peak runoff during the rainy season, thereby making the use of the base-flow during the dry season unnecessary. This could even produce additional off-site benefits, as peak runoff, which often leads to damage in down-stream areas, is reduced.

Both strategies, intensification and diversification, should in the end facilitate more ***sustainable land management practices***. This hypothesis is proved true by the situation in Mesobit & Gedeba, where a more intensive and diversified land use system can be observed, where market integration is considerably higher than in the other research areas, where high-input strategies are pursued in addition to low-input strategies that secure survival, and where investments in SWC are an indispensable part of the farming system. In an intensive and diversified farming system, investments in SWC will be more attractive to private farmers, since the value of the land and the need to minimise losses of valuable inputs through erosion and runoff will be increased. Terracing further improves water retention capacities, which together with improved organic matter content of the soil increase the efficiency of artificial fertilisers. Household income can be increased, if terraces are used to produce high-value crops such as *gesho* and *chat*. In addition to the direct benefits to the plots where intensified production is practiced and to the farm household, indirect benefits can be expected. Increased biomass production in the form of fodder plants might reduce pressure on grazing land. And lastly, if trees are part of the conservation system, this might contribute to lower the pressure on remaining forests. Perennial crops provide a better ground cover and can thus also contribute to overall soil loss reductions.

***Reforming the extension system***

Currently, the extension system is targeted towards promoting the SG2000 package in as many areas and among as many farmers as possible. A system of quotas fixes how many farmers per KA have to participate each year, and how many hectares of arable land have to be fertilised. Additional tasks include the construction of SWC structures on arable land and other SWC structures (check-dams in gullies, cut-off drains, etc.) on communal land. Extension agents are in very short supply. Currently, in the ANRS there is usually 1 DA per 1,000 households. As under such circumstances extension agents can offer little more than packages based on fertilisers, the system seems to take the form of a production campaign instead of proper extension activity. Agricultural extension has to be understood as a system of supporting farmers and not solely as a system of promoting specific technologies without involving the local land users in designing, implementing and monitoring the proposed technologies. This concerns both technologies aiming at increasing agricultural

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[803] Fitsum Hagos et al., 1999, 54.

production and natural resource conservation. There is considerable local knowledge available, which must be the starting point in the search for improvements.

With regard to the tremendous needs to reform the land use system and increase overall production, more weight has to be given to training DA's. Not only the number of DA's needs to be increased, but also their training needs to be enhanced qualitatively. DA's must be able to recognise various problems in their work area and analyse them properly, develop possible solutions together with the land users, and monitor the outcomes. In view of the limited financial means and the urgent need to increase the number of DA's, the current policy is to train as many DA's as possible within a very short time. Training courses last for 9 months only, and many DA's lack practical farming knowledge. Farmers, DA's themselves and employees of the ministry of agricultural mentioned that the training of DA's is not sufficient with regard to the multiple tasks they have to fulfil, ranging from crop production, livestock production, natural resource conservation and management and community planning and development to initiating co-operative movement. Furthermore, DA's spend a considerable portion of their time disbursing and collecting input loans. Because DA's lack the necessary training and knowledge, packet approaches are preferred, because their promotion does not require a very high level of basic agronomic, technical or socio-economic knowledge.

Instead of only focusing on artificial fertilisers to increase overall production, a combination of organic fertilisers from various sources (e.g. manure, green manure, improved fallow, crop residues) and artificial fertilisers should be promoted. This could contribute to (i) lower direct costs for farmers, as necessary amounts of artificial fertilisers could be reduced, and (ii) improved efficiency of artificial fertilisers because soil structures and organic matter content could be raised. Measures aimed at increasing production must be combined with mechanical SWC on sloping lands. With biological and agronomic measures alone, the problem of soil erosion cannot be solved. Mechanical structures are important in critical times of the year (e.g. at the beginning of the rainy season, when soils are not yet covered) and in areas with climatic limitations due to altitude or low rainfall, where crop growth is limited. It can be hypothesised that if overall production can be increased, the value of the land will increase, and mechanical SWC will become economically more profitable. Furthermore, more efforts need to be directed at searching for possible ways of using conservation structures in a productive manner. In this connection, it is not sufficient simply to search for appropriate species. On the contrary, it is at least as important to support local institutions in solving problems that will arise from new technologies, such as competition between neighbouring farmers or damages done by grazing animals.

Many farm households with small holdings are not able to achieve a sufficient income to support their household throughout the year. Farmers living near markets or major roads should be encouraged to produce not only staple crops, which are not very profitable, but to diversify their farming system. Of course resource-poor households cannot switch totally to the production of ***alternative goods***, but there is ample scope for combining staple crop production with alternative goods. The examples of small-scale irrigation in Maybar or Eucalyptus plantations in Andit Tid clearly demonstrate this. In order to enable farmers to embark on such a strategy of diversifying income sources, the extension service must provide the necessary information and technical knowledge. Currently, this is not possible, because the DA's themselves do not have the necessary knowledge. As rural societies are not homogenous but have different asset endowments and needs, one single alternative offered is not enough. A basket of different options must be provided, from which farmers can choose those that best fit their individual needs. Besides providing technical knowledge, there might also be a need of supporting ***local institutions*** in solving conflicts that may possibly arise out of such a diversifying strategy. It was mentioned in Maybar, for example, that in order to utilise water for small-scale irrigation, certain areas need to be allocated differently. Currently, suitable areas are used as grazing land by richer households. Young farmers would like to distribute this land to currently landless households in order to enable them to gain a minimal income. However, currently there is little hope for such a redistribution to be carried out. DA's could act as mediators in upcoming conflicts resulting from land use changes and as facilitators for creating new or reforming existing local institutions handling such conflicts.

There have been attempts to introduce the system of ***local level development planning*** (LLDP). This system involves a combination of rural infrastructure development and resource conservation. In a first step, the community identifies development needs such as an improved water system, protection of wells, improvement of the primary school or local clinic, or improvement of feeder roads and footpaths. At the same time, an inventory of natural resources and resource degradation is taken, and village or community maps are produced. Based on these maps, expert from the BoA propose resource conservation measures which are discussed with the village inhabitants. If the village agrees to carry out specific resource conservation activities, the BoA can invest funds (usually in the form of FfW) in the construction or improvement of local infrastructure. Judging from observations made during visits to several pilot study areas, the system seems promising. Also the experience from Anjeni supports this conclusion. Instead of FfW, a social incentive in the form of a local clinic was financed jointly by the SCRP and the government. Both the conservation measures and the clinic exist to date. It is unclear, why exactly this approach was abandoned. Most probably it is the result of a policy change that implies that FfW be used only in areas suffering from chronic or episodic food deficits, whereas in all other areas farmers are expected to carry out conservation activities without remuneration. This system of ***compulsory community group work*** for resource conservation activities, however, has to be evaluated as a failure. Farmers are expected to form groups of 10 adult people and work jointly for up to 15 days during the dry season. The DA designs the conservation structures, usually on communal lands or in small watersheds that were previously not conserved. The quality of the work has to be evaluated as insufficient. After one rainy season, most of the structures are destroyed or silted up. One exception could be observed in Mesobit & Gedeba, where farmers were jointly involved in upgrading an irrigation scheme. However, there was a direct interest involved on the side of the participating farmers, as it was planned for each hamlet to receive a section of the irrigable land and for profits from selling fruits and vegetables to be distributed to households. Many farmers mentioned that they would prefer the system of compulsory group work to be kept, but that groups should work in turn on the private land of the group members. Only this way, the benefit of their labour investments would accrue to those involved. Farmers also mentioned that because they have to invest considerable time in mandatory group work, they lack the time during the dry season to carry out SWC on their own land. It seems that public campaign work competes with individual efforts towards resource conservation. Of course, there are also considerable needs for conserving communal lands and cropland where no SWC campaign has been carried out previously. Fore these areas, the LLDP approach seems to be appropriate. In this approach, investments do not benefit only certain individuals, but the community as a whole. Certain incentives are absolutely justifiable, as a considerable social interest (e.g. intergenerational equity) and often also off-site benefits are involved. Such an approach would imply a cost-sharing arrangement between farmers, local communities, and the government.

***Strengthening research with regard to agricultural development and natural resource management***

In Ethiopia, agricultural research at the national level is mainly commodity research focussing on improving crop and livestock varieties. Cross-cutting themes such as natural resource conservation, sustainable land management or sustainable livelihoods, where agriculture is one of many different aspects, are clearly underrepresented in the research agenda. The Institute of Agricultural Research (IAR), which is the biggest of the different agricultural research centres under the umbrella of the Ethiopian Agricultural Research Organisation (EARO), has 72% of its researchers involved in crop programmes, 19% in livestock improvement, and only 9% are doing research on natural resources. The concentration of human and financial resources on crop research is explained by the government's development plans and strategies emphasising food self-sufficiency. In addition to the research institutes at the national level, there are nine Regional Agricultural Research Centres (RARC), which are located in Amhara (3), Oromiya (3), Southern Ethiopia Peoples Administrative Region (SEPAR) (2) and Tigray (1). These RARC's address specific needs of a particular region.[804] They are, however, severely understaffed and financial means are far from what is necessary.[805] Wages and working conditions in RARC's are unattractive, especially for senior researchers.

Major aspects mentioned in the "National Agricultural Research Policy" concern commodity research. Firstly, the policy states that agricultural research shall focus on generating and choosing technologies that will

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804 Getinet Gebeyehu & Tadesse Gebremedhin, 1999, 119.

805 Mulat Demeke, 1999, 42. He further calculates that in 1993/94 only 0.2% of the agricultural GDP was spent for agricultural research. International recommendations range in the order of 2%.

improve the agricultural production of the peasant sector, which constitutes the major part of agricultural production, in quality, quantity and diversity, in order to raise the productivity of the agricultural sector and to achieve self-sufficiency in food production. Secondly, in order to raise the productivity of the agricultural sector in all dimensions, private investors are encouraged to invest in large and modern farms. This means that agricultural research will also be conducted to supply the necessary technologies for large and modern farms. Thirdly, in order to meet the existing industries' demands for agricultural raw materials, research will focus on generating and choosing technologies enhancing the production of agricultural goods that are potentially used as industrial raw material. Fourthly, a greater emphasis is laid on raising the quantity and quality of exportable agricultural products that can generate foreign exchange earning.[806] There is no doubt that commodity research has to be strengthened. However, simply improving varieties without due consideration of the agro-climatic[807] and socio-economic circumstances of resource-poor farmers does not solve the problem of low agricultural production and continuing resource degradation.

Although the SG2000 project and other extension packages that are based on research results of the above-mentioned commodity research show significant results, they need considerable modifications. Firstly, modifications with regard to inputs, e.g. fertiliser application rates, are necessary in order to take into account different agro-climatic conditions and crop-specific parameters. Secondly, the approach must be much more flexible to suit the needs of different segments within the rural population. Thirdly, new approaches have to be developed, which combine the SG2000 approach with other agricultural aspects such as soil fertility management based on organic fertilisers, livestock production, niche production, and others. Fourthly, because SG2000 and similar approaches are based on the promotion of artificial fertilisers, they should never be propagated without mechanical SWC on sloping lands. Furthermore, positive results are also to be expected from improvements of farm management practices and improved farm implements. Fifthly, socio-economic considerations and policy-oriented research with regard to production, processing, marketing and consumption are likewise conducive. And lastly, agricultural research has to acknowledge the farmers' knowledge with regard to natural resource conservation and crop and livestock production. Agricultural research must therefore take the locally available knowledge as a starting point for developing improvements for specific technologies. Such modifications of extension packages cannot be the task of the extension system and the concerned land users alone; agricultural research institutes also have a prominent role to play.

In order to make the results of agricultural research more useful for small-scale farmers, researchers have to rethink their traditional roles. Not narrow disciplinary research is necessary for addressing land degradation and poverty, but interdisciplinary communication and ***transdisciplinary collaboration***.[808] This includes multi-disciplinary research, research partnerships between researchers and research organisations from Ethiopia and from abroad, and genuine collaboration of researchers and the concerned society. Not focusing on either participatory approaches or scientific methods alone, but combining the two knowledge systems equitably will be the key to finding options for sustainable land management and sustainable livelihoods. One methodological tool for participatory appraisal of sustainability from local to regional levels developed at CDE is the ***Sustainable Development Appraisal (SDA)***.[809] SDA guides the participatory assessment of baseline data relevant for development, and the evaluation of the local setting in relation to sustainable resource management and sustainable development from the viewpoint of different actors. It further serves as a baseline for monitoring (i) changes induced by internal development, as well as (ii) the impact of external action in the area. SDA provides the basic information and data, which can be used in a multi-stakeholder negotiation process to promote sustainable development and sustainable land management. SDA differs from 'participatory' approaches as commonly understood through its integration of the 'external' view, based on interdisciplinary science, with the indigenous knowledge base in a transdisciplinary manner. The SDA is based

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806 National Agricultural Research Policy, October 1994. [http://falcon.ifs.uni-linz.ac.at/research/masters/fisseha/policy.html]

807 For research purposes, 18 major agro-ecological units and 49 sub-units have been defined. (Mulat Demeke, 1999, 41)

808 Hurni, 1998; Wiesmann, 1998, 215; Hurni, 1999, 7; Hurni, 2000b, 272; Hurni, Lys & Maselli, 2001.

809 Hurni & Ludi, 2000.

on empirical information and data developed for pre-defined area units and sub-units at different scales. It is carried out as a field study by an interdisciplinary team. On the one hand, the team applies a transdisciplinary approach by combining external (scientific) knowledge with the indigenous knowledge of the local land users. On the other hand, 'shared' knowledge is enhanced by disciplinary assessment methods applied by individual team members. A comparison of the results of these two approaches can then show areas of contradiction as well as shared knowledge and evaluation. Identifying issues on which there is a shared opinion is a good opportunity for defining entry points for development activities (cf. Figure 64).

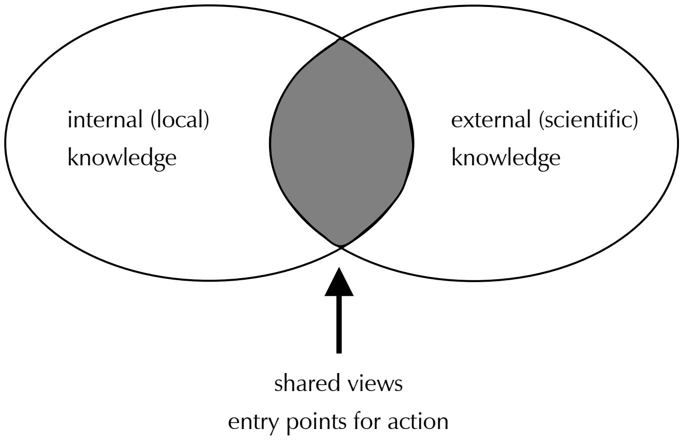


*Figure 64: Generation of shared knowledge in a transdisciplinary process is a basic principle of the SDA. [Source: Hurni & Ludi, 2000, 20]*

The major steps involved in an SDA are presented in Table 63 below.

| **Components** | | **Elements** |
|---|---|---|
| **Preparation** | Background and initial steps | |
| **Component I** | Participatory assessment and appraisal of current situation | **Element 1:** Characterisation of spatial units<br>**Element 2:** Characterisation of actor categories<br>**Element 3:** Appraisal of interactions |
| **Component II** | Participatory assessment and appraisal of dynamics | **Element 4:** Assessment of bio-physical dynamics<br>**Element 5:** Assessment of social, economic and cultural dynamics<br>**Element 6:** Appraisal of change |
| **Component III** | Participatory assessment and appraisal of development | **Element 7:** Assessment of development visions<br>**Element 8:** Assessment of needs, options and constraints<br>**Element 9:** Appraisal of development options |
| **Component IV** | Preparation of development profiles and synthesis | **Element 10:** Compilation of Local Development Profiles (LDPs)<br>**Element 11:** Compilation of a Regional Development Profile (RDP)<br>**Element 12:** Synthesis and recommendations for sustainable development |
| **Integration** | Initiation of multi-stakeholder negotiations | |

*Table 63: Major elements and steps in an SDA. [Source: Hurni & Ludi, 2000, 21]*

In the first component, the focus is on a participatory assessment of existing conditions in a given area, e.g. a community. Spatial units, different actors, and interactions among and between spatial units and actors are assessed. This is done not only by the research team, but also by the local community and by any other stakeholders invited to take part in the appraisal. In the second component, dynamic changes of spatial units and actors are assessed. Information of the first two components serves as a basis for the negotiations of development needs and options. The first element of this third component includes the formulation of development visions by the different stakeholders. These visions are then discussed in order to create a common vision which is acceptable to all stakeholders. The second element of component III is the assessment of needs, options and constraints. Again, it is important to assess needs, options and constraints for each stakeholder group separately. A synoptic presentation of the various needs – and if possible, their relative importance– reveals both similar and contradictory perceptions with regard to what is considered important, and points out possible hidden conflicts. The assessment of options and constraints by each separate stakeholder group reveals the assets (e.g. financial means, knowledge) that they have available for achieving a more sustainable land use or livelihood system. This also helps identify possible conflicts, which can already be addressed in this phase of the negotiation process. The third element synthesises needs, options, and constraints in order to determine concrete development options. Component IV includes the presentation of results in various forms such as reports or maps. These can be condensed Local Development Profiles (LDP) or more comprehensive Regional Development Profiles (RDP). Both LDP's and RDP's are valuable inputs into the multi-stakeholder negotiation process. Together with databases, they are also necessary for impact monitoring.

***Integrating natural resource conservation and agricultural development***

A major drawback in Ethiopia is the lacking integration of natural resource conservation and projects and programmes aiming at improving agricultural production. Often, separate and poorly coordinated programmes are carried out with different objectives and approaches.[810] This is problematic, since resource conservation and agricultural development are often complementary, if not dependent on each other. Productivity enhancing measures such as the application of artificial fertiliser or improved seeds only make sense if seeds and fertiliser remain on the field and are not washed away by runoff. On sloping lands, this can only be achieved by constructing structural or biological runoff barriers. On the other hand, structural measures such as earth and stone bunds are expensive and economically only justifiable if yields increase considerably compared to today's extremely low levels. Structural measures, especially in moisture stress areas, can also contribute to improving soil moisture, thus improving fertiliser efficiency. Similarly, organic measures for improving soil fertility can be a measure on their own with regard to reducing soil erosion. Thus, in order to gain maximum profit from the different technologies and approaches in the fields of resource conservation and crop and livestock production, they must be integrated, as only this allows positive complementarities and synergies to take effect. Furthermore, in order to realise these potential benefits, better integration is also required with regard to research and extension.

***Policy formulation***

Experts contacted, both from the administration and from research organisations, mentioned that one of the most serious problems is a lack of policies with regard to agriculture, forestry, and natural resource conservation. There seems to be a delay with regard to policy formulation at the national level, which impedes the formulation of policies also at the regional level. Regions have now taken the lead and have begun to formulate their own policies.[811]

Considering the diverse ecological, cultural and economic landscape of Ethiopia – even of the ANRS – it is unlikely that a "one-size-fits-all" set of policies will work in all circumstances.[812] The International Food Policy Research Institute (IFPRI) is, together with Ethiopian research organisations, involved in a policy research programme in the Ethiopian Highlands, which, among others, includes the following objectives: (i) to understand land degradation and its causes, (ii) to identify major pathways of development, their causes and their implications, and (iii) to identify and assess policies and strategies that facilitate more productive, sustainable, and poverty-reducing pathways for development.[813] They propose distinct pathways of development for different regions. These regions are differentiated according to production potential, distance to markets and urban centres, and population densities. The proposed policies vary accordingly. High

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810 Hurni quoted in Pender, Place & Ehui, 1999, 23.

811 Unfortunately, the English translation of agricultural or natural resource conservation policies of the ANRS was not yet available.

812 Pender & Ehui, 2000, 2.

813 Pender, 2000, xii.

potential areas with good market access, for example, should concentrate more on the production of high-input cereals, perishable cash crops, dairy production, or rural non-farm income, whereas low potential areas with low market access should rather concentrate on improved livestock production or low input cereal production.[814] Such differentiated policy approaches should be supported, as only they can guarantee that the specific problems of an area will be addressed properly.

Besides the above-mentioned policies concerning agriculture, forestry, livestock or natural resource conservation, macro-economic policy reforms are often considered important with respect to removing disincentives for sustainable land management.[815] In Ethiopia, major macro-economic reforms, such as currency devaluation, trade liberalisation, and removal of subsidies, were carried out in the mid 90's. Especially price liberalisations for agricultural crops have led to increasing income for rural households – if they are able to sell their products. Removal of subsidies on fertilisers, on the other hand, has led to decreasing ability of resource-poor households to purchase artificial fertilisers without participating in the extension package programme. Whether these policy reforms have had positive or negative effects on resource degradation and resource conservation is difficult to state at this early moment.[816] The increase in output prices may lead to increased resource degradation, as high-erosive grain crops become more attractive to grow. In the worst case, it may even lead to an expansion of arable land into marginal areas, if farmers opt for a profit maximisation strategy. However, increasing output prices may also lead to less resource degradation: if the income from currently cultivated areas increases, land use intensities may be reduced, or expansion to marginal areas may not become necessary.

***Improving the credit system***

Most of the above-mentioned strategies with regard to intensifying and diversifying the land use system depend on additional financial means. Resource-poor households do not have the financial means to purchase necessary inputs in cash. Credits are thus essential. Currently, there are mainly commodity credits at an annual rate of 12.5% available. Usually, a down payment of 25% to 50% is due when the inputs are received, and the rest of the loan has to be paid back immediately after harvest. Credits are disbursed and collected by the DA, who also selects the farmers who are to participate in the extension package. Because no securities are available, DA's usually select those farmers from whom they can expect that the loans will be paid back, since, if the recovery rate is below a certain threshold, the DA will be punished. In most areas, credits are only provided to buy agricultural inputs such as improved seeds and artificial fertilisers, because the BoA has only limited sums available to be disbursed as credits.

In areas where fertiliser can be bought on the market and farmers use it independently of the extension package, credits are available also for other investments. In Mesobit & Gedeba, for example, the DA can provide a limited number of credits to women's groups for purchasing improved chicken or sheep, which are then fattened for later resale. Such credits are usually not given to individual households but to groups in order to increase the recovery rate. It could be observed, however, that these credits were often used for other purposes. In some cases, they were spent for current consumption because families faced food shortages, and in other instances, the money was taken by the husband to buy a bull, which would be trained and sold when the loan had to be paid back. It is to be expected that the income generation effect for the household will in

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814 Lakew Desta et al., 2000, 21.

815 eg. Scherr & Hazell, 1994; Holden, 1997; Mulat Demeke, 1999; Moseley, 2001.

816 A finding supported by the IFPRI-led research project on *"Policies for Sustainable Land Management in the Ethiopian Highlands"*. They conclude that especially in Tigray (where the research is most advanced), broad improvements in access to infrastructure and public services can be observed, and that the adoption of resource conservation measures by communities and households and the adoption of modern agricultural inputs is widespread. They could, however, not observe yield improvements, on the contrary, food availability was declining in many communities. They conclude that uncertain rainfall and/or land degradation is limiting crop yield improvements despite considerable investments and the adoption of new technologies. (Pender & Ehui, 2000, 4)

this latter case be lower than if credits had been invested in chicken or small ruminants, which have a higher reproduction rate.

Fortunately, investments in SWC are not capital intensive. The inadequate credit system cannot be considered a major obstacle to adopting SWC. However, by limiting improvements of the farming system in general, missing credits and unfavourable conditions hinder SWC from becoming an economically profitable investment and a precondition for other production enhancing technologies.

The current credit system does not take into account the situation of resource poor farmers. There is no insurance system linked to credits. Farmers very often mentioned that they do not like to take credits because they fear being unable to pay them back if the harvest fails. There should be an insurance available for risk-taking farmers. Insurance fees should, however, not be added as a premium on the credit; instead, all KA members should contribute a minimal payment. This might act as an incentive also for poorer farmers to adopt a more risk-taking behaviour.

***Improving the marketing system***

If the strategy of intensifying and diversifying production is successful, more goods will be traded among different regions and rural and urban areas. In order to reap the highest possible benefits from these strategies, farmers must sell part of their production. Improving the marketing system and lowering transaction costs is therefore of paramount importance. Today, rural markets are underdeveloped with respect to both quantity and quality of goods demanded and offered. They are highly seasonal, are often not connected to the road network, or are dominated by a few monopolistic traders. In order to improve market integration of farmers, infrastructure development is necessary. This not only includes upgrading the road network and connecting rural areas to major centres, but it also includes the development of storage facilities to enable farmers to store their products until prices are most favourable. It also necessitates the support of traders. Credits must be made available for purchasing grain and means of transport. If traders are also engaged in the input and commodity trading, their interest to serve more remote markets might increase if their profit margin promises to rise. Besides infrastructure and financial support, information is of crucial importance. This concerns both information on production in various regions (i.e. identification of surplus and deficit areas) and information on prices. If they were better informed, both farmers and traders could profit from an increased exchange of goods.

High population pressure affects the labour intensity of agriculture by worsening the land/labour ratio. This may induce innovations in the agricultural and resource management sector.[817] Population pressure can increase the comparative advantage of labour-intensive production,[818] especially in areas where opportunities for off-farm employment are as low, as is the case in the study areas. Current farming practices in the Ethiopian Highlands relying on the ox-plough for grain crop production is not overly labour intensive. If surplus labour force cannot be absorbed in the off-farm sector, high-value agricultural products will be necessary to maintain returns to labour. In order to produce high-value products, a market is necessary for both inputs and outputs. If a market is available where goods can be sold, intensification and diversification of agricultural production becomes much more attractive, as is demonstrated in the case of Mesobit & Gedeba.

***Improving the land tenure system***

Although the current land tenure system cannot be made solely responsible for low adoption rates of SWC and other long-term investments, it certainly must be considered a hindering factor. It should be noted that there is no need to develop a land tenure system based on private ownership. What is necessary, though,

817 Scherr & Hazell, 1994, 7; Boserup, 1965, quoted in Pender, Place & Ehui, 1999, 38. However, Pender et al. (2001), in a study covering 198 villages in the Highlands of Tigray and Amhara Region, found that population growth had negative impacts on natural resources and did not lead to improved land management. Only better market access and improved access to credits and technical assistance were positively related to improved land management, resource conservation and welfare.

818 Birner, 1999, 78.

is ***long-term tenure security***. Farmers must be sure that they will be able to profit from the benefits of their investments, be it investments in improving soil productivity, in tree plantations, in irrigation systems, or in SWC. To achieve long-term tenure security, an essential precondition must be satisfied: Article 40, Section 4 of the Constitution of the FRDE must be reconsidered (cf. Section 8.2.1). In view of more or less exhausted reserves, tenure security of arable land can only be achieved if there are restrictions with regard to access to land. The constitution dating from 1994 states that Ethiopian peasants have the right to obtain land. Each new generation of farmers will make use of this right and claim land from their KA. Their claims can only be satisfied if other farmers surrender part of their holding. In light of the ideological background of the current government, which aims at avoiding a class of landless farmers who might become politically active, the right to land for all is understandable. Throughout Ethiopian history, the land issue has always been a crucial factor, and planned changes have often sparked off peasant revolts.

The right to obtain land has other negative consequences besides the insecure land tenure situation. Firstly, fragmentation of holdings will continue. Although fragmentation can have positive effects, especially in situations where different agro-ecological niches can be utilised and risks can be spread, there are clear limits. Farmers complained that they loose too much time because the distances from their home to their plots is increasing. Furthermore, plots are becoming very small, making farm operations difficult and uneconomical. And lastly, plots situated far from home are difficult to protect against birds and other wild animals, are often the target of theft, are worked less carefully, and because the return is expected to be smaller than on well tended plots nearby, they are seldom conserved. Another major negative consequence of the right to obtain land is the disincentive it presents to young farmers to search for income sources outside the farming sector. It is perfectly understandable that young men are not motivated to find an off-farm occupation if they know they are entitled to land, because even a very small farm guarantees a minimal income and, in the worst case, provides eligibility for humanitarian aid. If the system of guaranteed access to land was abolished, it can be expected that more young farmers would look for other sources of income. Of course, this would require considerable efforts by the government and the private sector with regard to creating off-farm employment possibilities.

***Reforming the tax system***

Currently, a flat rate tax of EB 20 for all households is applied. There are plans to change this and to apply a household tax depending on the amount of land owned. In Andit Tid, for example, it was planned to raise the tax for households with 4 *timmad* to EB 25, with 5 *timmad* to EB 35, and for households with 6 to 12 *timmad* to EB 45. With the objective of raising tax income for the government and balancing income differences within the community, such a move heads in the right direction. Tax reforms could even go further. One could think of using taxes and tax reductions as an incentive to achieve sustainable land management, i.e. to internalise negative externalities (Pigouvian taxes) in order to adjust for discrepancies between private and social marginal costs and benefits.[819] Taxes could be raised considerably for those farmers who do not invest in resource conservation. For farmers who take good care of their land, taxes could be lowered accordingly. However, tax reductions could only be used as an incentive to invest in land care if they were substantial enough. Furthermore, in order to avoid manipulation and corruption, tax inspectors independent from the local administration would be necessary to evaluate the investments carried out by farmers and determine the tax reduction.

***Improving physical infrastructure***

Ethiopia is characterised by one of the lowest supplies with physical infrastructure compared to other LDC's. The road network density, for example, is only 25 km per 1,000 km$^2$; 75% of the rural population is estimated to live more than a half-day's walk from an all-weather road. Also, per 1,000 inhabitants only 2.8

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819 Perich, 1993, 15; Holden, 1997, 30.

telephone lines are available.[820] The number of primary schools is throughout the whole country is 11,051, and only 24% of the rural population have access to safe drinking water.[821]

In its Plan of Action, the government intends to address the low supply with basic infrastructure. Sectoral development programmes envisage improving and extending the road network, improving communication and electric power supply, upgrading existing and building new schools in order to increase the gross primary school enrolment ratio from currently only 42% to 84% by 2010, improving the health system, and developing water for domestic purposes, irrigation or power generation.[822]

In must be assured that infrastructure development takes place not only in well accessible areas, which are already currently better served with basic social and economic infrastructure. Special emphasis has to be laid on connecting remote rural areas and on developing and improving infrastructure there as well.

***Creating off-farm employment***

In order to reduce pressure on existing natural resources and allow farmers to cultivate viable farms, the number of farming families has to be reduced in future. Only small areas are left which could be used to expand agriculture, and moreover, these areas are earmarked for the development of large-scale, capital-intensive agro-businesses. Thus, the only way to absorb the surplus agricultural labour force is to create off-farm employment opportunities. ADLI heads in this direction already as it states that the agricultural sector should also provide inputs for the industrial sector. It can further be expected that with growing income of the rural population, the demand for industrial products will rise.

There are good opportunities for expanding non-farm activities close to agricultural production. One of them is producing and maintaining farm inputs such as tools ('backward integration'). If production increases and farmers will be able to produce and sell surpluses, the trading sector will also gain importance. Locally produced goods (e.g. grain crops, oil crops, fruits, nuts, lumber, etc.) could then be processed locally ('forward integration'). The production and processing of perishable products such as vegetables, fruits and dairy products could gain importance in areas close to urban centres and roads. A manufacturing sector would require improved energy supply. Possibilities exist for local and small-scale hydropower generation. The biggest constraints expected to hamper rapid development of an off-farm sector are the lack of funds and the low level of education and training of the potential work force. Much more emphasis must be given to improving the educational system and to establish training facilities in areas where a potential for non-farm development exists. Credits are necessary to help finance small start-up enterprises such as workshops.

Nevertheless, not only local and small-scale manufacturing should be promoted. ADLI also envisages industrial development in the textile (cotton) and leather sectors. However, great care has to be taken with regard to national and international demand for such products. It must be expected that entering such markets will be extremely difficult for newcomers like Ethiopia. Furthermore, sectors such as leather industry or other sub-sectors that the government would like to develop (e.g. agro-industries, basic metals, and chemicals and engineering), pose a great risk of environmental pollution. Before investing in their development, environmental legislations as well as social standards have to be developed.

Economic growth outside the agricultural sector can have positive influence on sustainable land management. Often, economic growth is associated with infrastructure development, higher market integration of rural areas increasing the production of high-value products, and increased off-farm income of rural households. If part of the household is furthermore employed in other sectors, capital remittances to rural areas can be expected to increase. Such capital inflow to rural areas in combination with a favourable economic and policy environment can lead to more sustainable land management practices. However, better off-farm employment opportunities can also have negative effects if they reduce farmers' incentives to invest in

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820 UNCTAD, 2001, 27.

821 MEDaC, 2001, 10.

822 MEDaC, 2001.

land improvements because opportunity costs of labour increase. In most of the research areas, however, this is not to be expected, because the number of under- or unemployed people is considerable.

### 9.2.4 Strategies and actions at the international level

***Continuing debt relief***

Although in November 2001 Ethiopia has become the 24th country to qualify for debt relief under the HIPC Initiative and approximately US$ 1.3 billion in net present value or 47% of the total official external debt has been written down,[823] a considerable amount still remains, and debt service has to be paid. Further commitment of lender countries is necessary to reduce external debts. Saved debt services should be invested in development activities such as infrastructure development or improvements of social services.

***Supporting research organisations***

Research in the field of agricultural development and resource conservation is highly underfunded, understaffed and unbalanced. International support with regard to strengthening research organisations would produce considerable added value. Local experts would find working conditions that allow them to stay in the country. Increasing budgets for research organisations would allow employing more researchers and broadening the research agenda. International support could also contribute to networking among research organisations within Ethiopia and with researchers from other countries. This could lead to a knowledge transfer from which all involved actors could profit.

***Supporting recapitalisation***

Especially with regard to soil fertility recapitalisation there are strong arguments for outside assistance. It is argued that soil fertility is a form of natural capital. Benefits to farmers are expected to be large. However, resource-poor farmers will not be in a position to invest significantly in soil fertility recapitalisation. It is further argued that investments in soil fertility are capital investments that generate positive environmental externalities. Soil fertility recapitalisation is expected to produce future benefits, thus not only benefiting current land users, but also future generations. Such investments are thus distinctively different from paying subsidies, which only remove constraints in the short term. Because soil fertility recapitalisation is a long-term investment in improving the capital stock and produces positive social externalities such as reduced poverty and increased national food production and thus benefits society as a whole, society should cover some or all of the costs involved.[824] However, it is obvious that the Ethiopian government is not in a position to finance such large-scale capital investments. There is a clear need of outside assistance in such endeavours. A one-time investment is required, which – if properly designed and accompanied by the necessary additional measures such as SWC or improved land management practices – is expected to produce benefits in the long run. Such outside intervention can also be justified on the ground that each year, a growing number of resource-poor farmers depends on outside humanitarian aid. Although soil fertility recapitalisation is not expected to be successful in each and every situation, there is hope that in more privileged agro-ecological regions, substantial production increases can be realised which would lower the country's dependency on humanitarian aid and could be used to support areas suffering from production deficits.

Similar arguments could be put forth with regard to SWC investments. It was shown in the CBA that labour investments for the installation of mechanical SWC structures are considerable and often above the capacity of a household. In light of the positive externalities and off-site benefits SWC produces, one could justify financing at least the initial investments. There are, however, strong arguments against such an approach based on the experiences made with FfW during the large-scale conservation campaigns (cf. Section 6.1.6). Such reservations have to be taken seriously, because the same mistakes should not be repeated. Covering

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[823] World Bank Press release, Nov. 12, 2001. [www.worldbank.org/developmentnews/stories/html/111201a.htm]

[824] Izac, 1997, 249; Sanchez, 1997, 28.

initial investment costs is justified in cases where a positive contribution to agricultural production can be expected and where positive off-site effects – both in a spatial and in a temporal dimension – are expected to be substantial. This is the case if

(i) farmers are aware of the problem of soil erosion and the negative consequences and are ready to take action to reverse the negative trends, but currently lack the necessary means,
(ii) soil degradation has not yet reached the point of no return, i.e. soils are still deep enough to allow crop production,
(iii) mechanical SWC is combined with organic or artificial fertilisers to raise production levels considerably,
(iv) mechanical SWC structures can be used in a productive way,
(v) mechanical SWC fits into the farming system and has been designed together with the concerned land users,
(vi) employment opportunities outside the farming sector are available thus lowering pressure on arable land in the medium term.

If these conditions are fulfilled, it is expected that on-site benefits to the farmers and off-site benefits to society are big enough to justify both initial financial inputs from outside and maintenance investments by farmers in the following years.

In summary, unsustainable use of natural resources and its negative consequences such as soil erosion, among other things, is influenced by a broad range of factors from the ecological, economic and socio-cultural sphere, which are highly interlinked. There is thus no simple solution to achieve sustainable use of natural resources and to prevent soil erosions. Only a multi-level, multi-stakeholder, and multi-objective approach can contribute to developing solutions, which address the underlying problems adequately.

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# Appendices

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