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Sustainable Land Management

A textbook with a focus on Eritrea

First edition

Woldeselassie Ogbazghi
Brigitta Stillhardt
Karl Herweg

2011

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Abbreviations and Acronyms

ACED	Assessment of Current Erosion Damage
DoE	Department of Environment
CDE	Centre for Development and Environment
DFID	Department for International Development
DPSIR	Driving Forces–Pressures–State–Impacts–Responses
ERRA	Eritrean Relief and Rehabilitation Agency
ESAPP	Eastern and Southern Africa Partnership Programme
ETH	Swiss Federal Institute of Technology
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographic Information Systems
GoE	Government of Eritrea
GPS	Global Positioning System
HAC	Hamelmalo Agricultural College
IK	Indigenous Knowledge
IUCN	International Union for Conservation of Nature
MDG	Millennium Development Goal
MoA	Ministry of Agriculture
MoLWE	Ministry of Land, Water, and Environment
MoND	Ministry of National Development
NGO	Non-Governmental Organization
PLA	Participatory Learning and Action
PRA	Participatory Rural Appraisal
PTD	Participatory Technology Development
RLS	Rural Livelihood System
SLM	Sustainable Land Management Programme
SWC	Soil and Water Conservation
UoA	University of Asmara
WOCAT	World Overview of Conservation Approaches and Technologies
WRD	Water Resource Department

Preface

More than ever, land degradation is recognised as a global issue. It remains one of the most significant challenges facing nearly all developing countries. Land degradation causes immense costs at local, regional, national, and transnational scales. Their impact is felt in economic, societal, and environmental terms. The most obvious aspects include soil erosion, loss of biodiversity, and climate change. In Eritrea, land degradation has been recognised as a problem for many years. Severely degraded land is a ubiquitous feature of the country's rural landscapes. As a result, the yields of major crops are far below potential amounts even in years of good rainfall. The situation is aggravated by rapid population growth in what is still largely an agrarian society. While some people think that there is room for expansion of arable land, in actual fact Eritrea has no spare land to meet the needs of the growing population. Consequently, we must increase and intensify agricultural production on the land that is already under cultivation, and we must urgently embark on the restoration of degraded land. In an agrarian society such as Eritrea's, most livelihoods depend on land and land resources. Hence sustainable land management practices are important at all levels, including individual farms, farming communities, and the state.

Massive efforts are being made worldwide to stop land degradation and boost agricultural productivity. Sustainable land management (SLM) is the foundation of sustainable agriculture, and a strategic component of sustainable development and poverty alleviation. Although SLM is a relatively new term coined by international experts, the roots of SLM are well anchored in traditional land use and in the indigenous knowledge of many rural societies. For sustainable land management practices to be effective and efficient, it is thus essential to acknowledge proven local efforts in SLM, and to promote technologies, approaches, and practices that are technically feasible, socially acceptable, and ecological sound.

If SLM is a way forward, we must also focus on developing human resources in accordance with local needs to address the problems at hand. Training of qualified professionals and technicians in agriculture and natural resources management is, indeed, crucial for Eritrea. Such training requires qualified experts who hand on their knowledge to students, and who link up with farming communities to exchange experiences. It also requires relevant teaching materials. There is a vast amount of literature relating to SLM at the international level. However, most of these works lack relevance with regard to the specific situation in Eritrea. They are based on experiences from other countries with different socio-economic and environmental settings. Such materials cannot be used directly without major additional efforts to make them relevant to the local circumstances of Eritrean farming.

The present textbook was thus prepared to summarise the basic principles of SLM with regard to both Eritrean and worldwide experience. It is targeted for use by undergraduate and postgraduate students at universities and colleges in Eritrea. Many local publications – scientific and others, peer-reviewed and others – were consulted and used as major input. The experiences collected therein were complemented by state-of-the-art knowledge from international reference works to provide a broader perspective as it is deemed necessary for college-level education. Throughout the textbook, care has been taken not to assume that SLM practices can be transferred from one geographical area to another without making modifications to address specific local conditions. This is also reflected in the suggested topics for discussion found at the end of each chapter.

This textbook was initiated in 2006 with a view of using it at the then College of Agriculture and Aquatic Sciences at the University of Asmara. With expansion of higher education and its decentralisation to various parts of Eritrea, the book can now be used as teaching and reference material for courses at various colleges dealing with natural resources management, soil and water conservation, geography, ecology, and even rural sociology or anthropology. With its basic and yet detailed contents, its extensive coverage of topics and disciplines, including environmental and human aspects as well as methodologies of SLM, and extended lists of references in each chapter, we are confident that this textbook will make a significant contribution to education, research, and outreach in Eritrean training programmes dealing with rural development, including those of Hamelmalo Agricultural College.

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Introduction

Sustainable Land Management and Change of Paradigm: Where Do We Want to Go?

Sustainable land management (SLM) has emerged as an issue of major international concern. This is a result not only of increasing population pressure on limited land resources and the demand for increased food production, but also of the recognition that degradation of land and water resources is accelerating rapidly in many countries, including Eritrea. It is also becoming clear that the limitations on land suitable for agriculture are being reached in most countries. If land that is moderately suited or well suited for agriculture is already in use, then it follows that further increases in production to meet the demand for food from growing populations must come about through more intensive use of existing agricultural lands. Combating the often-cited deleterious effects of intensification, particularly with regard to environmental impacts, requires the development and implementation of technologies and policies that lead to sustainable land management.[1]

The growing interest in the concept of sustainability was given added stimulus at the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in June 1992. Agenda 21, a major action plan developed at UNCED, focused attention on the need to make development economically and environmentally sustainable as well as socially acceptable. Chapter 10 of Agenda 21[2] is concerned with the planning and management of land resources. For these reasons sustainable land management is now receiving considerable attention from development experts, policy makers, researchers and educators.

Sustainable Land Management, as understood in this manual, includes not only natural resources but also a focus on social and economic frameworks to define the range of possible actions and approaches. It considers lessons learned from research on sustainable land management (including scientific approaches and local or indigenous knowledge), undertaken world-wide as well as in Eritrea, and focuses on a compromise between top-down and bottom-up approaches. The complexity of the topic requires great methodological flexibility:

- Addressing complex societal problems requires a transdisciplinary approach, i.e. involving different scientific disciplines and scientific and non-scientific actors, and integrating their knowledge systems in a process of societal learning[3]. Transdisciplinarity[4] requires true participation. Recognizing the problem is a key issue in natural resources management research. Many organizations are still highly compartmentalized and hence their transdisciplinary work is poor. Others have multi-disciplinary teams in which the different disciplines are present but conduct business on their own rather than truly integrating. Given the complexities and multiple disciplines involved, do we have scientists who can perceive “the whole” or who can only use narrow disciplinary discourse to solve multifaceted problems related to sustainable land management? Do we have enough synthesizers such as ecologists or geographers? It will be essential for transdisciplinary teamwork that an appropriate level of integration is achieved. To ensure this, it is essential to establish some hypotheses at broader levels of outcome or impact that ultimately depend on integration for individual and team success.[5]

- We need fewer standards, more variety and creativity to adapt – not adopt! – particular measures to real life situations. Aspects to consider specifically in integrated natural resource management interventions, such as in soil and water conservation, are: integrating technologies, institutions and policies for implementation; establishing processes for improved and more straightforward adaptation of technological knowledge; increasing the testing of technologies in the production context (i.e. in the market/subsistence and policy contexts); and increasing the use of visualization, mapping and simulation tools to link research to farmers[6,7].
- Such holistic approaches require rethinking the roles of research, extension, land users, decision-makers and different stakeholders. Successful soil and water conservation interventions that integrate natural resources to achieve sustainable land management need to manage communication at different levels. Particularly important is communication at farmer-extension and farmer-researcher interfaces right from the beginning of the intervention. Researchers engaged in integrated resource management assume responsibility for ensuring appropriate communications media for different clients and partners. Communication with donors and local media, etc. is also important if a critical mass is to be achieved[8]. In most cases a well-intentioned and well-implemented intervention might go unnoticed by the external communities and stakeholders for lack of publicity and the provision of transparent information in a timely and predictable manner. According to Campbell and Hagmann[9], steps need to be taken from the beginning of a project in order to ensure documentation of the process and methodology, devise innovative ways of sharing, distil simple messages in local languages for use in appropriate media, draw lessons from past assessments of the effectiveness of different media, and instil stories for donors and policymakers alike.
- A shared problem and opportunity-driven focus is essential: the key to success of any multi-stakeholder action is shared understanding and a common perception of the problem and/or the opportunities[10,11,12,13]. Agreements need to be negotiated until all key players have the same understanding with regard to interventions in sustainable land management. In a study by Ludi et al.[14,15] specific aspects of integrated resource management were considered before implementation of the sustainable land management pilot project. These included, among others:

    1. Negotiating goals and visions among stakeholders;
    2. Establishing a negotiated action plan among stakeholders;
    3. Ensuring an appropriate and early baseline diagnosis to assess constraints and opportunities and to identify research needs;
    4. Understanding how people organize and participate;
    5. Articulating the needs and demands of stakeholders;

6. Devising better tools to prioritize problems, in a manner acceptable to all partners;
7. Facilitating understanding of the spatial extent of problems;
8. Ensuring exposure to opportunities.

Generally, situations prevail where agricultural and natural resource management advisors, who work in a team, make decisions on the basis of reduced information, with limited knowledge of the local situation, under time pressure, and then present an opinion to an audience.

The examples and exercises included in this manual try to depict real-life situations so that students will be able to work in groups in the classroom with limited time and information (tables, graphs, maps, photographs, transparencies, slides etc.) at their disposal for local appraisal of a situation. These exercises will simulate frequently occurring situations characterized by incomplete data sets (in a real-life situation data sets for decision support are scanty, patchy and dispersed in sectorally-oriented institutions). The results of the exercises will not lead the students in only one clear direction. Subjective and consultative decisions are needed in terms of role-play, methods from PRA (Participatory Rural Appraisal), SDA (Sustainable Development Appraisal), PTD (Participatory Technology Development), etc. Since all concerned stakeholders do not see the same problems with the same intensity and priority, village profiling, stakeholder analysis and discussion, and participatory approaches are emphasized. In most cases students may be required to defend unpopular decisions during their exercises and convince others during the presentation of group work, openly discuss results of their findings, give and accept constructive criticism, and participate in system analysis.

The goal of this manual is to equip students with appropriate framework knowledge of the issues of sustainability with regard to land management. After studying the text, students should be able to:

- Understand the most important factors in land degradation in the major agro-ecological zones of Eritrea;
- Design vegetative, agronomic and structural measures to reverse degradation;
- Understand sustainable land management in terms of holistic systems, and be able to include social and economic considerations in their approaches;
- Undertake applied research in sustainable land management;
- Work in interdisciplinary and transdisciplinary teams, and
- Train others in sustainable land management at different levels (extension agents, subject matter specialists, and farmers).

It is assumed that students have been exposed to other courses concerned with land resources as a basis for this instructional manual. This manual is thus intended as a collection of material for students who know the basics about the physical, chemical and technical context of sustainable land management and related topics.

In short, this manual will provide students with the basics for engaging in decision-making for more sustainable land management; specifically,

- They will know the indicators of unsustainable land management;
- They will be able to evaluate the importance of land problems (soil degradation), for instance where and when degradation processes occur and what possible causes and consequences are involved;
- They will know the possible starting points for soil and water conservation and agro-forestry measures;
- They will know about sustainable land management technologies and, more importantly, the principles of how they function;
- They will be able to critically evaluate the potentials and limitations of a local setting, including bio-physical, social, cultural, and economic aspects, and they will know about the potentials and limitations of indigenous approaches for situation-specific and sustainable soil and water conservation measures,
- They will be able to draw relevant conclusions from limited data sources and information, to present them in a convincing manner, and to represent them in front of other stakeholders;
- Last but not least, they will be able to use different tools and schools of thoughts to assess problems and find adapted solutions.

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Chapter 1

Approaches and Concepts in Sustainable Land Management – A Theoretical Overview

1.1 Use of terms in this manual

In Agenda 21[1] the preamble of Chapter 10 (integrated approach to the planning and management of land resources) gives the following actual definition of land, its use, and its response to human interaction.

Land is normally defined as a physical entity in terms of its topography and spatial nature; a broader integrative view also includes natural resources: the soils, minerals, water and biota that the land comprises. These components are organized in ecosystems that provide a variety of services essential to the maintenance of the integrity of life-support systems and the productive capacity of the environment.

Land resources are used in ways that take advantage of all these characteristics. Land is a finite resource, while the natural resources it supports can vary over time and according to management conditions and uses. Expanding human requirements and economic activities are placing ever increasing pressures on land resources, creating competition and conflicts and resulting in suboptimal use of both land and land resources. If, in the future, human requirements are to be met in a **sustainable manner**, it is now essential to resolve these conflicts and move towards more effective and efficient use of land and its natural resources. Integrated physical and land-use planning and management is an eminently practical way to achieve this. Examining all uses of land in an integrated manner makes it possible to minimize conflicts, to make the most efficient trade-offs and to link social and economic development with environmental protection and enhancement, thus helping **to achieve the objectives of sustainable development.** The essence of the integrated approach consists in coordination of the sectoral planning and management activities concerned with the various aspects of land use and land resources.

1.1.1 What is land?

"'Land' is not restricted to the earth's surface, but extends below and above the surface. It is also not confined to solids, but may encompass within its bounds such things as gases and liquids. A definition of 'land' along the lines of 'a mass of physical matter occupying a space' is also insufficient, for a landowner may remove part or all of that physical matter, e.g. by digging it up and carrying away the soil, but would nevertheless retain as part of his 'land' the space that remains. Ultimately, 'land' is simply part of a three-dimensional space, its position being defined by natural or imaginary points located by reference to the earth's surface. 'Land' is not the fixed contents of that space, although, as we shall see, the owner of that space may well own those fixed contents. Land is immovable and indestructible in terms of its legal significance. The contents of the space may be physically severed, destroyed or consumed, but the space itself, and thus the 'land', remains immutable."[2]

It is interesting that most of the common and well-known definitions of land reduce it to its physical and economic significance. Most often the social component is not formally described. In reality land in most countries also has high social value, e.g. as graveyards, holy sites, the domain of ancestors, as a meeting point, as a place of historical interest, as a banned area, etc. When land use planning takes place, it is important not to forget such cultural and social functions of land in order to avoid unexpected reactions from the local population.

1.1.2 What is land use?

"Land use" consists of the way in which land is used. It is generally described in terms of such things as the size of the plot, the size and location of structures on the plot, and the activities that take place within a structure. It is a general term to describe how a distinct piece of land is allocated - for what purpose, need or use (urban, rural, agricultural, range, forest). Often it is further subdivided into specific uses (in the case of agriculture this might be perennial crops, annual crops, intensive land use, extensive land use, grassland, gardens for vegetable production, etc).

The total of the selected options on the farm or the regional level defines the predominant land use system in a distinct area, i.e. mixed farming systems with livestock breeding and cereals or semi-nomadic pastoralists, etc.

1.1.3 What is sustainability?

Sustainability is a characteristic of a process or state that can be maintained at a certain level indefinitely. For planet earth, the intent of sustainability is thus to provide the best outcomes for the human and natural environments, both now and into the (indefinite) future. One of the most often-cited definitions of sustainability is the one created by the Brundtland Commission, led by the former Norwegian Prime Minister Gro Harlem Brundtland. The Commission defined sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainability relates to the continuity of economic, social, institutional and environmental aspects of human society, as well as of the non-human (natural) environment.

1.1.4 What is a livelihood?

The word 'livelihood' can be used in many different ways. The following definition captures the broad notion used in this manual: '*A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base*[3].'

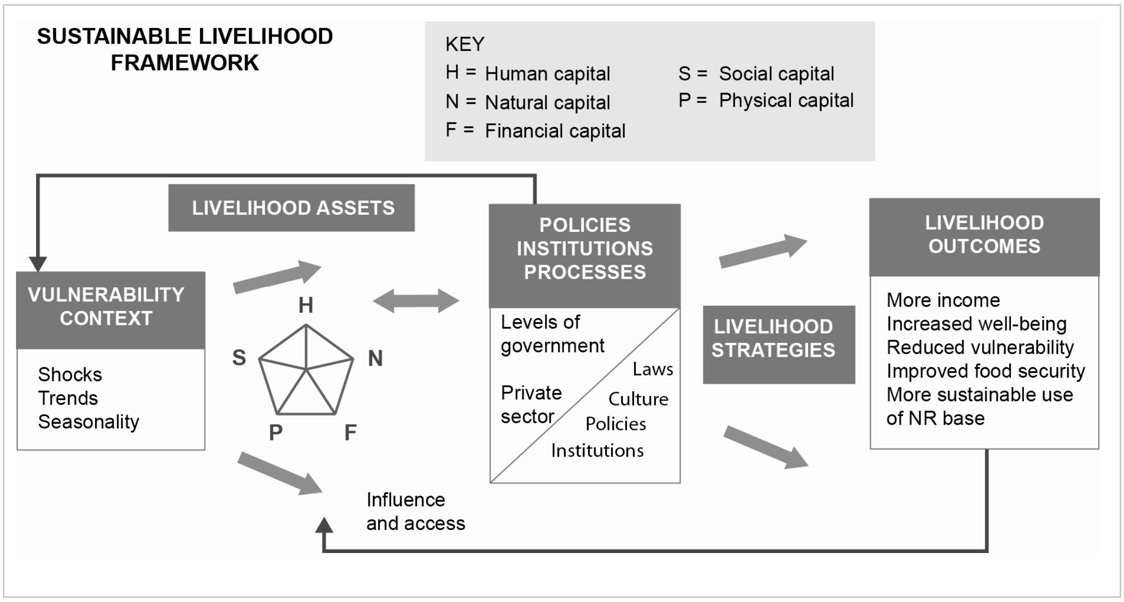

Figure 1.1 The framework of the livelihood approach as defined by DFID

The sustainable livelihoods approach (*Figure 1.1.*) is broad and encompassing. It can, however, be distilled to six core objectives. It aims to increase the sustainability of poor people's livelihoods by promoting:

1. Improved access to high-quality education, information, technologies and training and better nutrition and health;
2. A more supportive and cohesive social environment;
3. More secure access to, and better management of, natural resources;
4. Better access to basic and facilitating infrastructure;
5. More secure access to financial resources; and
6. A policy and institutional environment that supports multiple livelihood strategies and promotes equitable access to competitive markets for all.

1.2 Land degradation: causes and consequences

According to Blaikie and Brookfield[4], and Blaikie[5], land degradation is the reduction in the capacity of the land to produce benefits from a particular land use under a specified form of land management. On the other hand, according to Douglas[6] and Hurni,[7] the unhindered degradation of soil can completely ruin its productive capacity for human purposes and its capacity may be further reduced until steps are taken to stop ongoing degradation and restore productivity. This definition encompasses not only the biophysical factors of land use but also socioeconomic aspects such as how the land is managed or what yield can be expected from a plot of land[8]. Intensive agricultural use degrades soil in the long run and often reduces its fertility if it is not accompanied by conservation measures. Suitable cropping methods and more or less labour-intensive or capital-intensive measures can sustain soil fertility[9].

The speed and extent of land degradation depends on different factors such as soils, relief, climate, farming systems (e.g. intensity of use). Soil loss can be 20 to 40 times greater than the rate of soil formation, which means there is no hope of restoring destroyed soils within a time span that bears any relation to human history[10]. Information on the economic impact of land degradation by different processes on a global scale is not available[11]. Some information for local and regional scales is available and has been reviewed by Lal[12]. In Canada, for example, on-farm effects of land degradation were estimated to range between US$ 700 and US$ 915 million in 1984[13]. The economic impact of land degradation is extremely severe in densely populated South Asia, and in Sub-Saharan Africa[14,15,16,17]. On a plot and at field scales, soil erosion can cause yield reductions of 30 to 90% in some shallow soils of West Africa[18,19]. Yield reductions of 20 to 40% have been measured for row crops in Ohio[20] and elsewhere in the mid-western USA. Severe land degradation problems have been observed in the Andean region of Colombia. [21] Few attempts have been made to assess the global economic impact of erosion. The productivity of some lands in Africa[22,23] has declined by 50% as a result of soil erosion and desertification. Yield reductions in Africa[24] due to past soil erosion may range from 2 to 40%, with an annual mean loss of 8.2% for the continent. If accelerated erosion continues unabated, yield reductions by 2020 may be 16.5%. Annual reductions in total production for 1989 due to accelerated erosion were 8.2 million tons for cereals, 9.2 million tons for root and tuber crops, and 0.6 million for pulses. On a global scale the annual soil loss of 75 billion tons of soil costs the world about US$ 400 billion per year or approximately US$ 70 per person per year[25]. To satisfy the demand of the growing global population for agricultural land, additional agricultural land is needed each year. This results in the expansion into fragile or otherwise unsuitable areas. In Eritrea, for example, the landscape is mainly mountainous, characterized by steep slopes; this, together with the torrential nature of the rain and paucity of vegetation cover accelerates the washing away of soil. The net soil loss from cropland is estimated at 11.9 tons/ha/year on average, while that for barren land is 17.6 tons/ha/year. Assuming an average rate of decline in productivity of 0.3-0.6%/year, the gross discounted cumulative loss over 100 years is estimated to be circa US$ 18- US$ 36 million (Bojö, 1996).

Nutrient depletion as a form of land degradation also has a severe economic impact at the global scale, especially in sub-Saharan Africa. Stoorvogel and Smaling[26] and Smaling[27] have estimated nutrient balances for several countries in sub-Sahara Africa. Annual depletion rates of soil fertility were estimated at 22 kg N, 3 kg P, and 15 kg K per ha. In Zimbabwe, soil erosion results in an annual loss of N and P totalling US$ 1.5 billion. In South Asia, the annual economic loss is estimated at US$ 600 million for nutrient loss by erosion, and US$ 12,200 million due to soil fertility loss and depletion[28].

Globally there are an estimated 950 million ha of salt-affected soils in arid and semi-arid areas. Productivity of irrigated lands is severely threatened by build-up of salt at the root zone. In Asia, annual economic loss is estimated at US$ 1500 million due to salinization, and US$ 500 million from water logging[29].The potential and actual economic impact at the global scale is known neither for these degradation processes[30] nor for soil acidification and the resultant toxicity of high concentration of Al and Mn in the root zone, which is a serious problem in sub-humid and humid regions.[31]

Soil compaction is a worldwide problem, especially with the adoption of mechanized agriculture. It has caused yield reductions of 25 to 50% in some regions of Europe[32] and in North America, and between 40 and 90% in West African countries[33,34]. Land degradation and desertification are relevant in the context of these global economic and environmental impacts and in the context of numerous functions of value to humans. They are also relevant in terms of developing technologies for reversing land degradation trends and mitigating the greenhouse effect through land and ecosystem restoration. As land resources are essentially non- renewable, it is necessary to adopt a positive approach to sustainable management of these finite resources. Land degradation mainly caused by soil erosion has been one of the chronic problems in the Horn of Africa[35,36,37,38].The decline of early civilizations, migration events, recurrent drought, famine and dependency on food aid have contributed to this problem[39,40,41,42].

The main causes of land degradation are complex and attributed to a combination of biophysical, social, economic and political factors. There are different views of the causes of land degradation: many observers identify population pressure as the main cause of deforestation, overgrazing and expansion of cultivation into marginal lands. High population density is not necessarily related to land degradation; it is what a population does to the land that determines the extent of degradation. People can be a major asset in reversing a trend towards degradation. However, they need to be healthy and politically and economically motivated to care for the land, as subsistence agriculture, poverty, and illiteracy can be important causes of land and environmental degradation. On the other hand, there is increasing evidence that areas with high population pressure can also be centres of innovation and good land care.[43] Growing populations clearly mean more pressure on natural, human, economic and other resources, including soils. On the other hand, various studies indicate that food requirements can be met using current available technology and without doing excessive damage to the environment, even if the world population doubles. However, these studies do not necessarily include estimations of possible implications for global soil degradation and other environmental impacts[44,45]. Soil degradation has been a major cause of food shortages in many places. Higher population pressure on land may thus have negative effects if no proper corrective measures are taken. Yet higher pressure on land because of over-exploitation may also be induced by intensification of agriculture in countries, regions, localities and on farms with little population growth. Depending on many other social, political, economic and environmental conditions, population growth, development of innovation and the rational use of technology all go hand-in-hand and can lead to positive as well as negative impacts.

Worldwide, a large array of soil conservation measures and approaches are in use[46]. Although the immediate causes and impacts of soil degradation are generally well understood, it is far too simplistic to say that this understanding will lead to the reversal of soil degradation. There are many reasons why land degradation still occurs. An appraisal of different land rehabilitation technologies must therefore take into account not only the technological means involved but also the approaches used for implementation of measures, the socio-economic environment, markets, infrastructure, extension and other services, and socio-cultural conditions. Conservation issues are thus neither merely a technical matter, nor can they be resolved through legislation. It is also necessary to address socio-economic aspects of land use and to link incentives to sound land use practices[47,48]. Similarly, many have concluded that land degradation is a widespread problem with a widespread failure of interventions. As the causes of land degradation are perceived at different levels ranging from single plots to global scale, so can solutions be so perceived. In some cases it may be appropriate to seek solutions solely at household or community levels. In other cases, however, solutions identified at the local level need to be matched with national and global policies and actions[49].

1.3 Approaches to sustainable land management

1.3.1 Global aspects of soil degradation

Utilizing natural resources such as soils implies the risk of overusing and degrading these resources. The term **soil degradation** comprises a whole range of human-induced degradation processes, of which **soil erosion** by water is considered the most prominent one. The "Global Assessment of Human Induced Soil Degradation" (GLASOD, 1990[50]) of the United Nations Environment Program (UNEP) states that about one-sixth of the earth's terrestrial surface, including one-third of its agricultural land, is already affected by human-induced soil degradation *(Figures 1.2, 1.3, and Table 1.1*). GLASOD distinguishes four human-induced processes of degradation: water erosion, wind erosion, chemical degradation and physical degradation. According to Oldeman et al.[51] and Oldeman[52], worldwide 56% – in Africa 46% – of all human-induced soil degradation results from soil erosion by water, and 28% from wind erosion. The most important forms of chemical soil degradation are loss of nutrients and organic matter (South America, Africa) and salinization (Asia). The main reasons for chemical soil degradation are agricultural mismanagement (56%), and deforestation (28%). The most important causes of erosion by water are deforestation (43%), overgrazing (29%) and agricultural mismanagement (28%). The main causes of wind erosion, on the other hand, are overgrazing (60%), agricultural mismanagement (16%), overexploitation of natural vegetation (16%), and deforestation (8%).

Table 1.1 Soil degradation processes contributing to global soil degradation in percent

	World	Europe	N & C America	S America	Austral-asia	Asia	Africa
Category							
Erosion by water	55.6	52.3	67.0	50.6	81.0	58.0	46.0
Erosion by wind	27.9	19.3	25.0	17.2	16.0	30.0	38.0
Chemical deterioration	12.2	11.8	4.0	28.8	1.0	10.0	12.0
Physical deterioration	4.2	16.6	4.0	3.4	2.0	2.0	4.0
Causes							
Deforestation	29.5	38.3	11.3	41.3	12.0	41.0	14.0
Overgrazing	34.5	22.8	24.0	27.8	80.0	26.0	49.0
Overexploitation	6.7	0.2	7.2	4.8	–	6.0	13.0
Agricultural activities	28.1	29.3	57.2	26.1	8.0	27.0	24.0
(Bio-) Industrial	1.2	9.4	0.3	–	–	–	–

(Source: GLASOD, 1990)

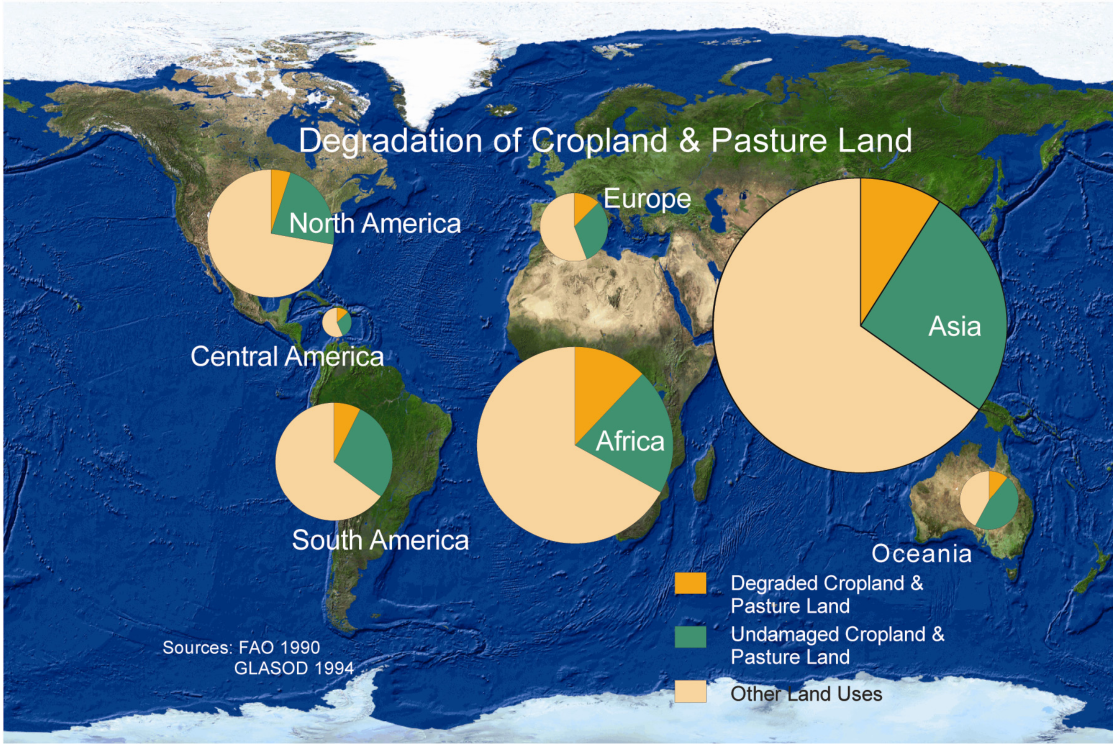

Figure 1.2 Global degradation of crop and pasture lands (Source: GLASOD, 1990)

Processes vary with climate and land management systems. Leaching, acidification and soil erosion by water are prominent processes in humid and sub-humid areas, besides nutrient depletion due to inadequate application of fertilizer and depletion of organic matter due to faster decomposition and insufficient application of organic fertilizer. Desertification, a process involving salinization (due to inadequate irrigation and drainage; 12% of all damage), erosion by wind and water, and compaction (4% of all damage), are typical of arid, semi-arid and drier sub-humid areas. Industrialized countries are facing high toxicity and compaction due to mechanized and industrialized agriculture with high fertilizer inputs, or due to waste as a result of urbanization, industry, infrastructure development and mining. The GLASOD maps show physical degradation particularly in the temperate zones, probably due mostly to compaction as a result of using heavy agricultural machinery.

The regional dimension of erosion was calculated by Morgenroth[53] by combining GLASOD data with own surveys and calculations. This product is one of the most current models dealing with the causes and dimensions of erosion processes. Nevertheless, all the above figures need to be used with care since the GLASOD results are not based on field studies but on the opinion of soil and water conservation experts. They give an estimation of the severity of soil erosion at the global scale.

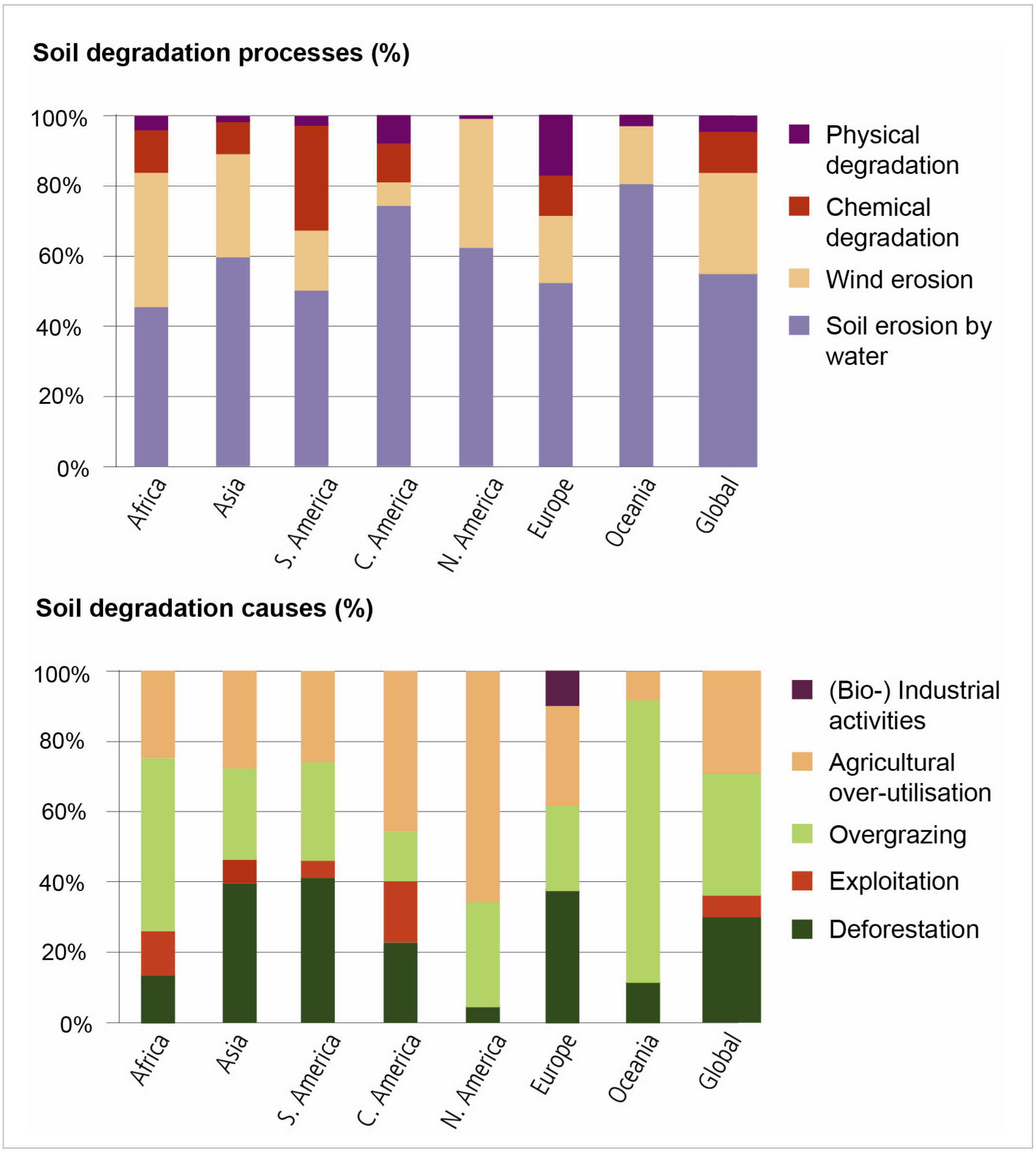

Figure 1.3 *Major processes and causes of human induced soil degradation (Source: GLASOD, 1990)*

On-site, soil degradation leads to declining soil productivity, which primarily threatens the livelihood of rural land users. This affects about 2.6 billion people worldwide who depend directly on agriculture, the majority of them being subsistence family farmers. Off-site impacts of soil degradation, such as flash floods, sedimentation of water reservoirs, water quality decline, mobile dunes and dust storms may affect society as a whole. Therefore, controlling soil degradation must involve all stakeholder groups in society, not only rural land users[54]. "Solutions" must thus be based not only on technologies but must also take account of socioeconomic, cultural and political aspects, such as population pressure, loss of indigenous knowledge, the effects of HIV-AIDS, inequity in global terms of trade, etc.

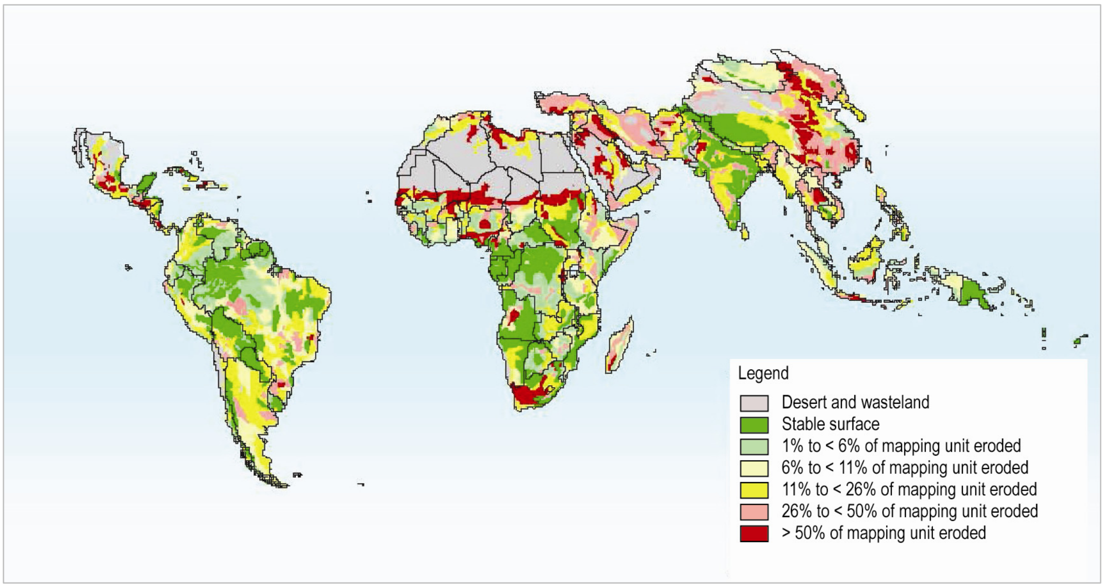

Figure 1.4 *Impacts of erosion processes on the land resources of the southern hemisphere: Percentages of eroded agricultural land area per mapping unit. (Morgenroth 1999)*

Rough estimates of soil loss in Eritrea are shown in Figure 1.5. However, the reliability of these estimates is subject to ground verification and should be used to stimulate further studies at local level.

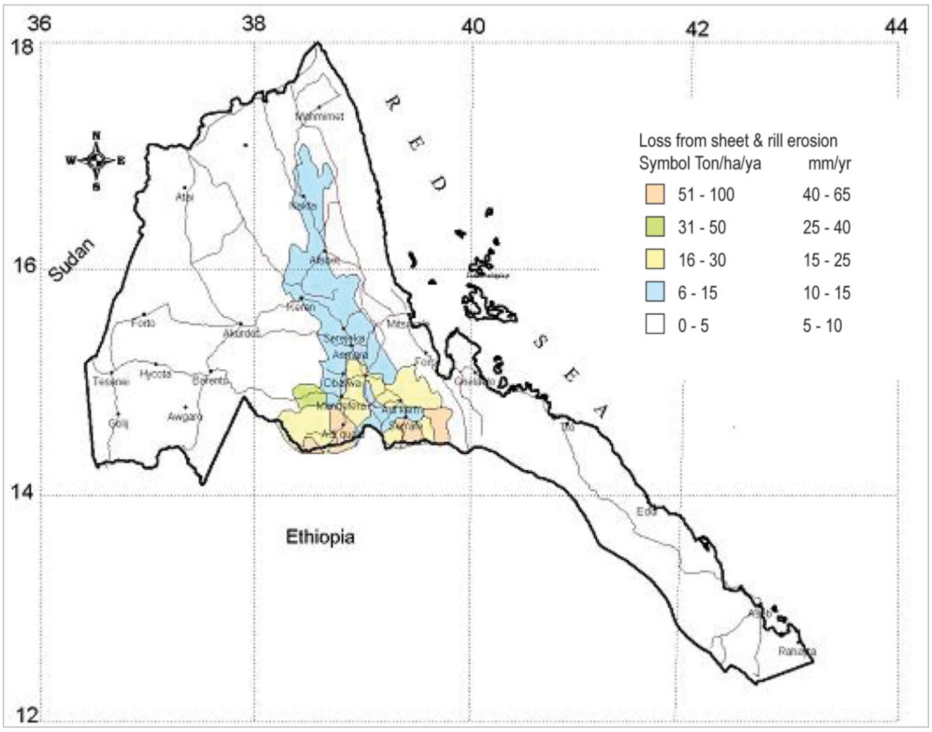

Figure 1.5 *Annual soil loss rates in different environments in Eritrea according to the Ministry of Land, Water and Environment 2005.*[55]

1.3.2 Approaches and concepts in the development of technologies

Diffusion of technologies began when people started to travel and to exchange knowledge. Promising approaches were copied in other places with similar environmental conditions, adapted to local needs and, where feasible, integrated into local land use systems. This evolutionary development process was slow and of course not all cultures gained access to the same knowledge, depending on travel routes. At the time when African countries were colonised by European countries, the implementation of technologies accelerated and semi-systematic international exchange of knowledge (mainly among the colonisers) took place. Technologies introduced at that time were the same as those in the country of origin (colonizers' country of origin), where the environmental conditions were rather different. It is, therefore, not surprising that many newly introduced technologies where neither effective in the new environment nor did local farmers have the means to adopt or adapt them. As a consequence, the adoption rate was low. Moreover, it was recognized 40 years ago (in the 1970ies and 80ies) that it was mainly resource-rich farmers who profited from agricultural research and its outcomes. As a consequence approaches developed in the 1980s and 1990s focused more on resource-poor farmers while simultaneously beginning to include local farmers (e.g. farmer participatory research and more prominent participatory technology development). Most success with such approaches was observed in African countries. In countries such as India, where the Green Revolution had a major impact on agricultural productivity and national development, the national research systems felt more secure with conventional approaches to agricultural research and experimented less with alternatives. In Africa, by contrast, where the effects of the Green Revolution were patchy and suffered major setbacks under policy reform aimed at liberalization of the agricultural sector, the need to try out alternative approaches was more widely accepted[56]. The results of projects using participatory approaches showed that the success rate was still not satisfactory. In the 1990s further research showed that especially resource-poor farmers in risk-prone environments live and operate in very complex livelihood systems and that purely technical solutions often do not fit into these systems. These findings led to holistic approaches such as those described in this manual, where the socio-economic and cultural environments are included in all steps in technology development, including different participatory methods to assess and develop promising practices (also known as best practices) in sustainable land management. The authors of this manual propose not to use the term "best practices" because there are always ways to further optimize the land use system - which would be literally redundant if the "best" approach or technology were already found.

1.3.3 Approaches and concepts in research and training

Research on sustainable land management in areas dominated by agriculture has been mainstreamed in the recent past by the organizations involved in the Millennium Development Goals. Goal number 7 deals with environmental sustainability:

- Integrate the principles of sustainable development into country policies and programmes; reverse loss of environmental resources.

Since the UN Millennium Project Task Force on Environmental Sustainability published their report in 2005[57] it has been widely accepted that goal number 7, which aims to protect the environment in a sustainable manner, is important to achieving all the other Millennium Development Goals. Therefore, a great deal of scientific effort has been made in recent years to understand the complexity of direct and indirect factors influencing environmental sustainability. Achieving a healthy, sustainable environment requires understanding the drivers of environmental change, assessing the state of the environment and people's dependence on it, and identifying the obstacles to ameliorating environmental degradation. The main efforts, therefore, were not made in the search for new approaches but in the process of understanding all aspects of such a difficult question. In its conclusion, the UN Millennium Project states that: "Environmental challenges are both complex and unique. Many institutions must act in concert to respond to them, and proposed solutions must be adapted to regional and local conditions. Neither structural changes nor technical interventions will succeed unless strong support for these changes comes from national governments, nongovernmental organizations, an informed citizenry, and the larger, multilateral community. Long-term success in meeting all of the Millennium Development Goals depends on environmental sustainability. Without it, gains will be transitory and inequitable. The paramount importance and clear urgency of environmental sustainability dictates immediate actions at all scales - and the political, social, and financial support will be necessary to sustain those actions."

This statement shows that:

1. At present, it is more important to understand complex systems and find appropriate, locally or regionally acceptable ways and solutions for sustainable resource management than to develop new approaches.
2. Without a strong institutional and political environment supporting the goals at the national level, it will be difficult to reach sustainable solutions.
3. Neither scientists nor economists nor politicians nor NGOs can act alone. Close collaboration is essential and all involved institutions have to focus together on national strategies. The scientific community could have a strong position as an agent acting between these different institutions.

As the central need is not to develop new scientific approaches but to learn to act in complex systems, understand holistic approaches and work in inter- and transdisciplinary teams, education must therefore focus on introducing complex (network) thinking, on the ability to work together with specialists of different backgrounds, on the capability to provide sound information to politicians and decision makers, and on supporting different stakeholders and combining limited information in such a way that the most promising approaches can be proposed and applied to the satisfaction of the local or regional population. This also involves proper project planning, monitoring and critical evaluation. The present manual offers concepts and methods based on the above needs and demands.

1.4 Global warming

There is much debate about whether long-term changes in climate have affected soils in the past. Hudson[58] and Reifenberg[59] have argued that no climatic change has led to drastic land degradation. By contrast, Parry[60] suggests that climate change may have been more important than previously assumed. However, whether or not climate has been a contributing factor, evidence from protected monastery and church forests suggests that land degradation observed today is a human-induced phenomenon. According to GLASOD (1990), deforestation, agricultural over-utilization and overgrazing are the major anthropogenic factors in soil degradation. A similar study in the Horn of Africa has also confirmed that human-induced mismanagement of natural resources is a root cause of soil degradation, together with the concomitant climatic change[61,62].

Nowadays, discussion of global warming is no longer about whether it is happening or not. It is accepted worldwide that climatic parameters have changed faster than ever since industrialization. Most scientists agree that human forcing has been a major factor in these changes. Today climate models project mean global warming by 2100 in the range of about 2°C to 4°C. Increasing temperatures will be accompanied by changes in rainfall and humidity, including a likely increase in the frequency of heavy precipitation events. Some areas will become drier because higher temperatures also increase evaporation. These changing environmental conditions will lead to a change in the whole ecosystem: Plant and animal habitats will undergo geographic shifts, diseases will spread and reach new places, and water will become increasingly scarce in many regions.

Although it has the lowest per capita fossil energy use of any major world region, Africa may be the most vulnerable continent to climate change because widespread poverty limits capabilities to adapt. Signs of a changing climate in Africa have already emerged: spreading disease and melting glaciers in the mountains, higher temperatures in drought-prone areas, and sea-level rise and coral bleaching along the coastlines. A selection of fingerprints and indicators are given in the following overview from the Union of Concerned Scientists:

- **Cairo, Egypt -- Warmest August on record, 1998.** Temperatures reached 41°C on August 6, 1998.
- **Southern Africa -- Warmest and driest decade on record, 1985-1995.** Average temperature increased almost 0.56°C over the past century.
- **Senegal -- Sea-level rise.** Sea-level rise is causing the loss of coastal land at Rufisque, on the South Coast of Senegal.
- **Kenya -- Mt. Kenya's largest glacier disappearing.** 92% of the Lewis Glacier has melted in the past 100 years.
- **World Oceans - Warming water.** The world’s oceans have experienced a net warming of 0.06°C from the sea surface to a depth of 3000 m over the past 35-45 years. More than half of this increase in heat content has occurred in the upper 300 m, which has warmed by 0.31°C. Warming is occurring in all ocean basins and at much greater depths than previously thought.

- **Mount Kilmanjaro, Tanzania - Ice projected to disappear by 2020.** 82% of Kilimanjaro's ice has disappeared since 1912, with about one-third melting in just the last dozen years. At this rate, all of the ice will be gone in about 15 years. Scientists hypothesize that less snow on the mountain during the rainy season decreases the surface reflectivity, leading to higher rates of absorption of heat and increased ice melt.
- **Rwenzori Mountains, Uganda - Disappearing glaciers.** Since the 1990s, glacial area has decreased by about 75%. The continent of Africa warmed by 0.5°C during the past century, and the five warmest years in Africa have all occurred since 1988.
- **Kenya -- Deadly malaria outbreak, summer, 1997.** Hundreds of people died from malaria in the Kenyan highlands where the population had previously been unexposed.
- **Tanzania -- Malaria expands in mountains.** Higher annual temperatures in the Usambara Mountains have been linked to expanding malaria transmission.
- **Indian Ocean -- Coral Reef Bleaching.** This includes the Seychelles; Kenya; Reunion; Mauritius; Somalia; the Persian Gulf, Madagascar; Maldives; Indonesia; Sri Lanka; Gulf of Thailand; Andaman Islands; Malaysia; Oman; India; and Cambodia.
- **Kenya - Worst drought in 60 years, 2001.** Over four million people were affected by a severely reduced harvest, weakened livestock, and poor sanitary conditions.
- **Lake Chad - Disappearing Lake.** The surface area of the lake has decreased from 25,000 km² in 1963 to 1,350 km² today. Modelling studies indicate that severe reduction results from a combination of reduced rainfall and increased demand for water for agricultural irrigation and other human needs.
- **South Africa - Burning shores, January 2000.** One of the driest Decembers on record and temperatures over 40°C fuelled extensive fires along the coast in the Western Cape Province. The intensity of the fires was exacerbated by the presence of invasive vegetation species, some of which give off 300% more heat when burned compared to natural vegetation.

1.5 Regional view: Approaches in SLM extension

Sustainable Land Management (SLM) is "the use of land resources, including soils, water, animals, and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and ensuring their environmental functions" (WOCAT, 2007). Accordingly, the aim of the present section is to build capacities that will enable analysis, design, planning and implementation of interventions to mitigate land degradation and create sustainable land management practices. Extension methods and tools should help extension workers to asses, quantify and analyze the nature, extent, severity and impacts of land degradation on ecosystems, watersheds, river basins, and carbon storage in drylands.

Over a period of 13 years (Between 1979 and 1992), about US$ 116 million of 'food-for-work' (FFW) assistance was allocated to soil and water conservation work in Eritrea. The output of such activities was, however, below the expected targets. One of the major problems was that farmers failed to adopt the recommended interventions or neglected them when the project ended (World Bank 1994[63], MoA 2002[64]).

The main SLM-extension approaches in Eritrea, aimed at catchment or watershed treatment and integrated agricultural development were based on Food for Work (FFW) before 1991, later on Cash for Work (CFW), and since 1994 on Local Level Participatory Approaches such as Employment Generation Schemes (EGS). These approaches are characterized by group work, provision of incentives such as cash and food, and campaign work. If dualisms such as participatory versus top-down approach, facilitation versus controlling, sustainability versus short-term benefits, and stimulation versus dependency are considered, gaps can be found that urgently need to be addressed. In actual terms, short-term benefits rather than long-term impacts were emphasized, but natural resources management is a long-term endeavour (Fetien et al., 1996[65], Haile et. al. 2006[66]).

In the above land management interventions, recommended land use practices were determined mainly by taking into account the biophysical capability of the land, with great emphasis on physical limitations (e.g. slope, soil texture, soil depth) and erosion risks, rather than on the needs and the social, cultural and economic circumstances of the land users. The overriding concern was to control runoff in order to prevent loss of soil. The conventional SWC extension approaches emphasized the use of structural SWC measures to stop runoff. In-situ moisture conservation structures were propagated using tied ridging, backward-sloping, contour terraces and Fanya juu, or by discharging the water into protected waterways using storm drains, diversion ditches, graded bunds and artificial waterways (Negassi et al, 2002[67]).

Historically, with reference to Eritrea, SWC extension approaches have been fragmented. Most of the planning and execution exercises emphasized tree planting and construction of SWC structures at watershed level. In most cases, there was little or no emphasis at all on including the aims of individual farms to boost agricultural production. Consequently, the boundaries of catchments have been used to demarcate the planning areas rather than the boundaries of administrative units (Mitiku et al, 2002[68]). Community participation has typically been dominated by the case study approach involving outsiders for data gathering, analyses and preparing plans, using Participatory Rural Appraisals (PRA) or Rapid Rural Appraisal (RRA). Once a report of a particular case was prepared, local communities were asked if they agreed with the planned procedure, and then local labour was mobilized for implementation. In such an approach, farmers have a limited chance to be actively involved in development and decision-making processes in the management of their own areas and even less in policy formulation at regional and national levels.

Conversely, the Rio conventions, such as the United Nations Convention to Combat Desertification (UNCCD), the United Nations Convention for Climate Change (UNFCCC) and the United Nations Convention on Biological Diversity (UNCBD) stipulate the sustainable utilization and use of natural resources. Specifically, they advocate active participation by local communities. In actual fact, however, sustainable land management is highly politicized and the role of scientific communities appears to be marginalized. Science and technology need to find their appropriate place in contributing to SLM. Science should identify the underlying causes of land degradation in different regions using inter- and multi-disciplinary methodologies to develop relevant scenarios for political decision-making (WOCAT 2007[69]).

1.5.1 Institutional set-up for land rehabilitation in Eritrea

Eritrea's first National Biodiversity Strategy and Action Plan (NBSAP), which was prepared in July 2000 (DOE, 2000[70]), builds upon the government's previous commitment to environmental protection, as continued in the National Environmental Management Plan - Eritrea (NEMP-E 1995[71]). At national level, the Ministry of Land, Water and Environment (MLWE) is committed to facilitate, promote and co-ordinate the implementation process of biodiversity conservation activities for sustainable use. The Department of Environment (DoE) of the MLWE coordinates all of the country's biodiversity- related activities.

Eritrea signed the UNCCD in 1994, and ratified it in March 1996. Pursuant to Articles 9 and 10 of the Convention, in 2002 a National Action Plan (NAP) to combat desertification and mitigate the adverse effects of recurrent droughts was prepared. The Eritrean NAP was developed in a participatory process. It was the result of interactive and decentralized approaches and addresses the global and local environmental problems Eritrea faces.

- The NAP has the following priorities for action:
- Exercising cautionary measures while expanding agriculture into dry woodlands and pasturelands;
- Encouraging community forestry with the aim of securing fuelwood and fodder plantations;
- Adopting moisture retention, groundwater conservation and water recycling measures;
- Expanding fuel substitution programmes through the introduction of renewable alternative energy sources;
- Creating a national database to monitor, assess and evaluate land degradation and use this as an input for an early warning system, and to increase awareness and shape policy;
- Mobilizing civil society through participatory processes

1.5.2 Facts on the ground

At present, Land Degradation (LD) has become a serious problem in most dry regions of the world. Millions of people put pressure on land through over-cultivation and overgrazing; often their land use practices do not allow for resilience of the land (Thompson 1994[72]). In Eritrea, serious LD has led to a marked deterioration in the living standards of the rural population. The progressive deterioration of land is the result of several factors, and its consequences have been harsh (Haile et al, 1996[73], Haile et al. 1998[74]):

Crop yield per unit area of land has declined drastically, and the vegetation cover is decreasing at an alarming rate. Water is becoming increasingly scarce. In many parts of the country, grass has ceased to grow due to loss of grass seeds and to the depletion of topsoil, even when there is sufficient rainfall (Haile, et al. 1998).

Land degradation is both a process and a phenomenon. As a phenomenon, it is the end product of a long process manifested by decreased cultivable land per farming household, decreased productivity of a unit of land per specified input, decline in livestock

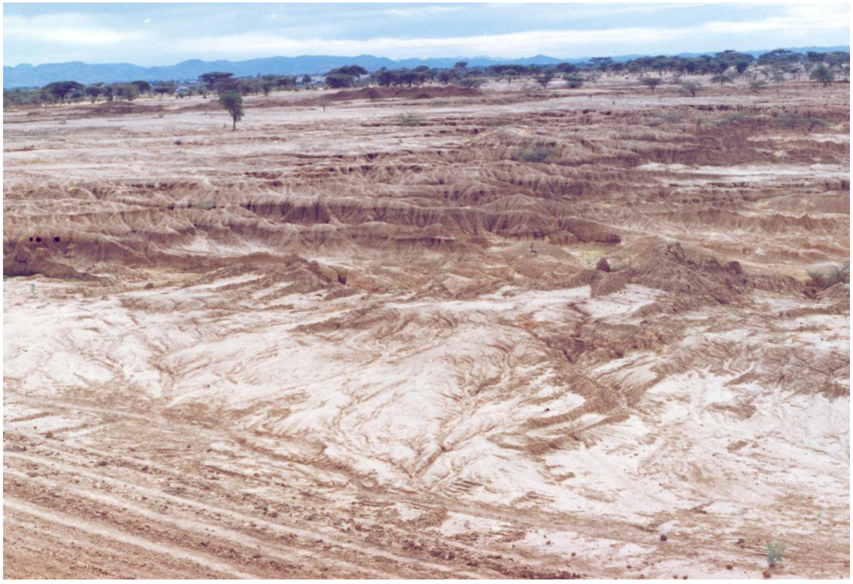

Figure 1.6 Degraded landscape due to soil erosion from water, Hazemo Plains, Zoba Debub (Woldeslassie Ogbazghi 1996)

population, loss of vegetation cover, shortage of fuelwood or timber, and loss of topsoil. This degradation reflects general ecological disturbance (Biswas and Biswas, 1980[75]). The proximate causes of land degradation are usually over cultivation, overgrazing and deforestation, preceded by mismanagement of soil, water and livestock. Heavy pressure on the land damages it beyond the capacity for resilience. Drought and other unfavourable climatic conditions are known to accelerate the land degradation process.

As a process, land degradation is continuous and incremental. The process is defined as an increased "weakening of the physical, biological, and economic potential of the land thereby severely reducing or curtailing overall productivity" (Odingo, 1990 cited in Thompson, 1994. Bojo and Cassellis (1995) defined land degradation as "a process that lowers the productivity of the land, assuming other factors such as technology, management and weather are held constant". There are six major factors in land degradation which can be reduced to human and physical categories (*Figure 1.6*). In Eritrea, the impact of human intervention on the environment increased with the advent of successive colonial forces (UNICEF 1994[76], Msghena 1988[77]). More efficient means of exploiting land resources triggered mass destruction of vegetation, which exposed soil to erosion. Moreover, the introduction of the Domeniale land holding system and the confiscation of land for concessions disturbed the customary regulatory mechanisms, leading to land scarcity and inappropriate uses of land, which in turn led to further over-cultivation and overgrazing. In physical terms, the landscape of Eritrea is characterized by steep mountains and slopes. The rains usually come in torrential downpours, accelerating the washing away of soils. Droughts cause crop failure and drying up of many susceptible trees, contributing to deforestation and further erosion.

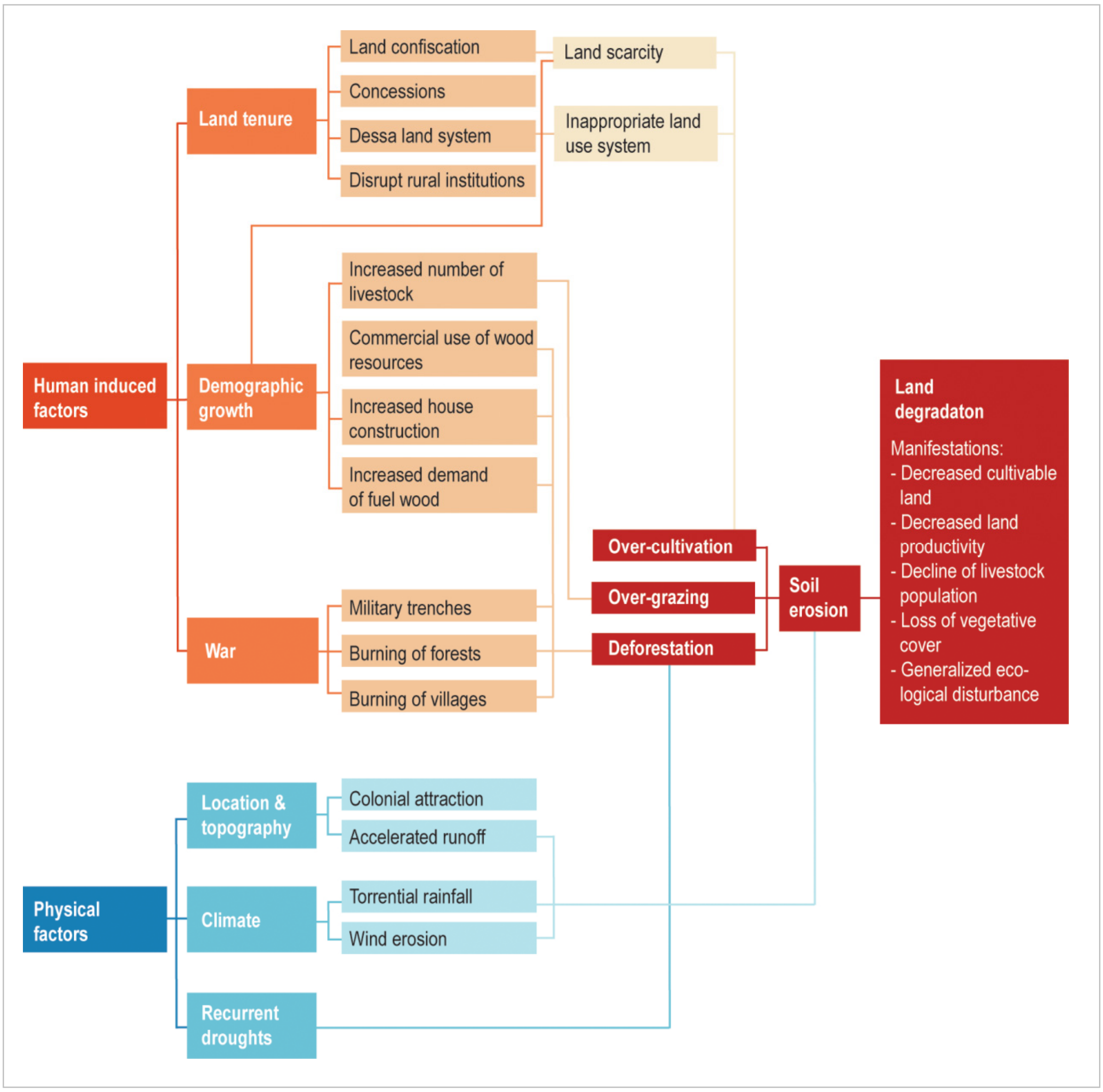

Figure 1.7 Conceptual framework of the process of land degradation from the causes and consequences (Adapted from Haile et. al 1998)

1.6 Solutions to land degradation

In most cases, land degradation is reversible if the land users actively participate in the rehabilitation process. Land degradation can be reduced and eventually controlled if a careful land rehabilitation plan of action is designed for this purpose and implemented. In many parts of the world, desert and arid lands have been reclaimed through sustained land management efforts using indigenous and improved modern technologies (WOCAT 2007). Good examples of how to combat land degradation exist. Globally, the techniques used are diversified but have one common denominator: the land user leading the way in "making the land greener". Important soil and water conservation technologies used include:

- Laying `trash lines' across the slopes to halt the flow of water;
- Water harvesting along dry river beds;
- Carpeting the ground with green mulch and rehabilitating terraces.

At the local level, the following land rehabilitation measures have proven feasible:

- Rehabilitation of degraded land through biological and technical soil and water measures. These include area closures and adaptation of appropriate SWC activities at the local level that maintain or enhance the productive capacity of the land in areas affected by or prone to land degradation.
- Adaptation of soil and water conservation technologies such as agronomic, vegetative, structural and management measures that prevent and control land degradation and enhance the productivity of the field.
- Adaptation of SWC approaches and means of support that help introduce, implement, adapt and apply SWC technologies on the ground.
- Restoration of ecosystem stability and enhancing the resilience of the ecosystems.

The main problems, coping strategies and possible solutions to these problems are summarized in Table 1.2.

Table 1.2 Major land degradation problems, coping strategies and possible solutions

Core problems	Underlying causes	Coping strategies and possible solutions
1. Deforestation	Tree cutting to make charcoal, construction of houses, diversion canals, recurrent droughts and war. Owing to lack of tree tenure, farmers consider area closure less important, as the land becomes less accessible for extraction of resources.	Tree planting, community-based area closure for natural regeneration widely practiced in rural areas. Raising farmers' awareness of biodiversity Encouraging individual farmers to grow multipurpose perennial trees and shrubs on private woodlots Procuring alternative construction materials at affordable prices Seeking renewable sources of energy Replacing temporary structures with permanent structures in spate irrigations systems Introducing area closure to promote natural regeneration of plants. Introducing and promoting cut and carry system of livestock management Allotting marginal lands to individual farmers to plant trees and use available resources privately
2. Soil Erosion	Sheet, rill and gully erosion is widespread. Soil erosion is accelerated by deforestation, poor ground cover and drought. Steep topography, poor land management in spate irrigation, and negligence related to the land tenure system also contribute. The constraints are related to current soil and water conservation practices and also to farmers' reluctance to look after the SWC structures constructed. Farmers lack incentives to maintain terraces constructed on community land on their own, due to the food for work syndrome and lack of land and tree tenure that discourage long-term investments in land.	Farmers construct earth bunds, stone bunds, check dams, terracing and embankments Tree and grass planting in cooperation with extension services Increase farmers' motivation by allowing them to have land and tree tenure ownership rights. Identification and provision of incentives to model farmers Raise farmers' awareness of the importance of SWC Training in effective SWC approaches and techniques Legislation and enforcement of SWC measures Country-wide SWC campaign (terracing, building of check dams and catchment treatment).

3. Shortage of Domestic Energy	Lack of firewood. Shortage of wood is one of the most serious problems	Farmers in general and women in particular, must travel long distances to collect a bundle of wood. As a last resort, farmers burn cow dung, crop residues (e.g. maize and sorghum stalks), and travel long distances to fetch wood (Haile et al. 1998). Possible solutions include: Introducing energy-saving technologies such as biogas, renewable energy (e.g. solar, wind energy) Introducing energy-saving stoves Improving the efficiency of traditional stoves
4. Population Pressure	Increasing pressure on land, depletion of underground water, and decrease in the cultivable land per capita (MoA 2002). Proximate factors that contribute to increase in population are early marriage and inadequate knowledge about family planning. The return of refugees from the Sudan and an internally displaced population also contribute to population pressure on land resources (Ogbazghi and Bein, 2004).	Increasing people's awareness of the consequences of population pressure on the environment Advocating family planning Introducing sex education in schools Raising literacy levels, especially for females
5. Decline of Crop Productivity	The decline of agricultural productivity is the most obvious indicator of land degradation. Yield decline is mainly caused by inadequate land management, drought, shortage of agricultural inputs, shortage of farm tools and implements, poor soil fertility, and crop and livestock pests.	Application of manure, use of local varieties. Low plant density with good rainfall when there is low pest infestation. Use of high seeding rate in case of low rainfall and high pest infestation. Conservation of seeds, multiple cropping and substitution of crops in response to rainfall intensity. Crop diversification: use of cash crops, crop rotation, and multiple cropping Crop improvement: identification of early maturing, drought-resistant and high-yield varieties Introduction of agroforestry systems Application of integrated pest management Identify and introduce forage species and delineate grazing areas.

6. Land Tenure	Traditional land tenure system (Dessa) has negative impacts on land. Short redistribution periods and land fragmentation discourage long-term investment in land. Cultivation of lands on steep slope with shallow soils exposes the land to erosion. Lack of incentives for farmers to improve their land use due to short redistribution cycle and progressive and scattered parcels of land discourage farmers from making long – term investments in land.	The equitable distribution of land among members of the village community is regarded as a coping strategy. Implementation of a land law that guarantees long-term investment in the land.

1.7 Challenges and opportunities

1.7.1 Opportunities at global level

The World Overview of Conservation Approaches and Technologies (WOCAT) is a global network of Soil and Water Conservation specialists initiated in 1992. WOCAT's mission is to support decision-making and innovation in sustainable land management by:

a Connecting stakeholders in SLM

b Enhancing the capacity of local populations

c Developing and applying standard tools for documentation, evaluation, monitoring and exchange of SWC knowledge.

WOCAT focuses on promising and innovative approaches and supports decision-making in the field and at planning levels. It concentrates on promising and successful approaches and technologies for sustainable land management in different social, economic and ecological contexts. It is based on the assumption that there are still many knowledge gaps, misconceptions and false assumptions regarding land management at all levels (e.g. country, regional, watershed and household levels), which must be addressed through training, evaluation and scientific monitoring. WOCAT offers comprehensive approaches to monitoring, evaluating and appraisal of soil and water conservation technologies.

1.8 Questions and issues for debate

1. Using participatory tools, select a small geographical area for assessment of the extent of land degradation. Describe current environmental conditions such as soil erosion, depletion of natural vegetation, groundwater, etc., and compare the situation with past conditions.

2. Identify the various human and physical factors contributing to the process of land degradation. Among the human factors are land tenure systems, population pressure, chronic conflicts, and crop and livestock production systems.

3. Based on your findings, suggest plausible interventions, strategies, and policies for reversing land degradation and for rehabilitating degraded lands, both at research sites and in the rest of the country.

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Chapter 2

Soil Degradation as a Driving Force of Land Degradation

Understanding the soil resource is important for sound soil and land management. In this regard knowledge of the nature and properties of soils is vital in regions where soil productivity is often limited by poor soil fertility and where the need for food production is great (Lal, 2004[1]; Sanchez, 2002[2]). In addition to low soil fertility, soil degradation is an increasing threat in many countries. There is an urgent need to understand the processes involved so that remedial actions can be put in place with a view to achieving sustainable land management.

In an attempt to address the issues of SLM, consideration must be given to the availability of research outputs, including results from the small SWC research station in Afdeyu run by the National Agricultural Research Institute (NARI) of the Ministry of Agriculture (MoA) in the Eritrean Highlands.

2.1 Soil functions

Along with water and biodiversity, soil can be considered one of the renewable natural or land resources. The term "renewable" is used if the time of regeneration does not take longer than the approximate lifespan of a human being. The term "resource" indicates that the soil is perceived in terms of functions that benefit society (*Figure 2.1*):

- **Production function**: capacity of the soil to produce food, fodder, fuel, fibre and construction wood; soil as a raw material and mineral resource to manufacture pottery, bricks, etc.
- **Physiological function**: value of the soil for producing nutritive plants, decomposing pollutants, filtering water, etc.
- **Cultural function**: soil as the dwelling place of ancestors, family and social security; "stemming from the soil", etc.
- **Ecological function**: soil as a value that controls energy, matter and water flows: storage of water, nutrients and pollutants, etc.

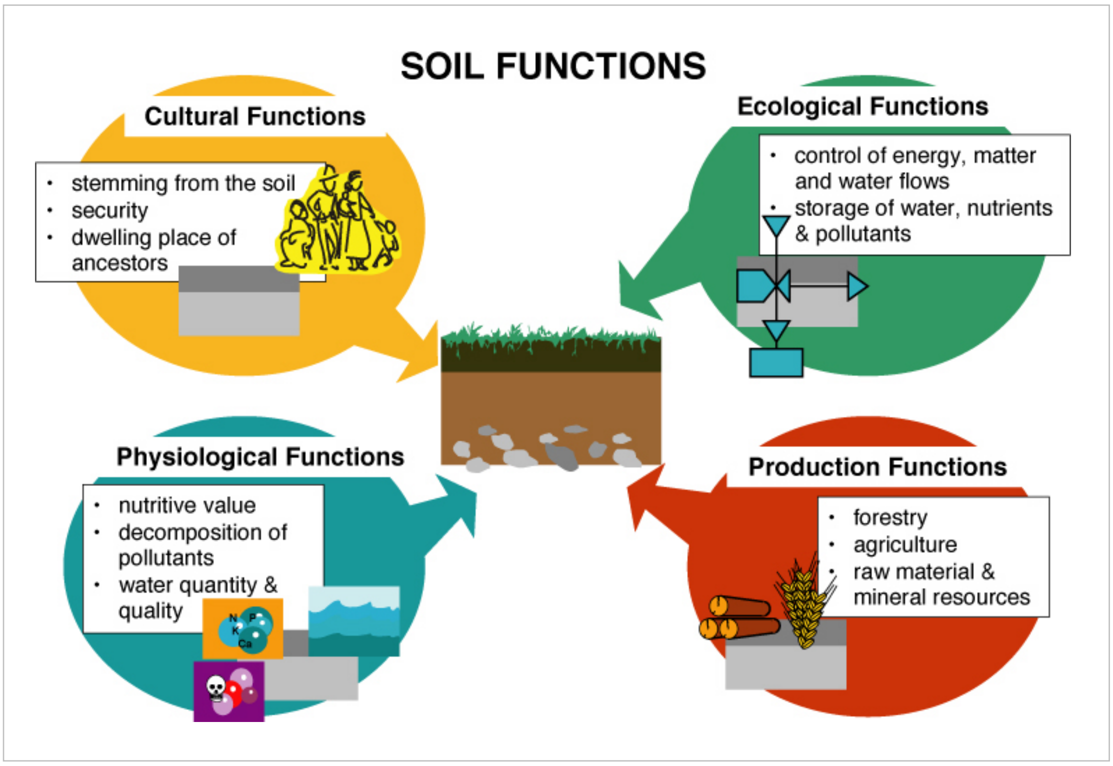

Figure 2.1 The different functions of soil (Karl Herweg)

2.2 Types of soil degradation

Processes vary with climate and land management systems. Leaching, acidification and soil erosion by water are prominent processes in humid and sub-humid areas, besides nutrient depletion due to inadequate fertilizer application, and depletion of organic matter due to faster decomposition and insufficient application of organic fertilizer. Desertification, a process involving salinization (due to inadequate irrigation and drainage; 12% of all damage); erosion by wind and water; and compaction (4% of all damage) are typical of arid, semi-arid and drier sub-humid areas. Industrialized countries are facing high toxicity and compaction due to mechanized and industrialized agriculture with high fertilizer inputs or waste as a result of urbanization, industries, infrastructure development and mining.

On-site, soil degradation leads to declining soil productivity, which primarily threatens the livelihoods of rural land users. This affects about 2.6 billion people worldwide who depend directly on agriculture; the majority of them are subsistence peasants. Off-site impacts of soil degradation, such as flash floods, sedimentation of water reservoirs, water quality decline, mobile dunes or dust storms may affect society as a whole. Therefore, controlling soil degradation must involve all stakeholder groups in society, not only rural land users (Hurni et al. 1996[3]). "Solutions" must thus be based not only on technologies but also take account of socioeconomic, cultural and political aspects, such as population pressure, loss of indigenous knowledge through HIV-AIDS, inequity in the global terms of trade, etc.

2.2.1 Physical (mechanical) soil degradation

Physical degradation basically involves a negative impact on physical soil properties, such as structure, texture, aggregate stability, porosity, permeability (compaction), and crusting. **Soil erosion** can be considered to be in this category because it physically reduces soil depth. Furthermore, **soil compaction** is an increase in bulk density due to external load, leading to the degradation of physical soil properties such as root penetration, hydraulic conductivity, and aeration. Compaction usually occurs in mechanized farming systems, where the soil has to support regular heavy loads. In the tropics, damage due to compaction is thus a particular problem with forest clearance machinery, and this problem also exists in agro-industry. However, compaction can be triggered through grazing, even with low stock (Mitiku et al. 2004[4]; Solomon, 1994[5]).

Hard-setting affects soils with extremely low structural stability that decompose into primary particles when moistened; when drying, the particles harden into a very compact, impermeable mass without structure. Unlike soil compaction, no external load is necessary so hard-setting also occurs in traditional farming systems with predominantly manual labour (Breuer, 1994[6]). Infiltration and water retention are very limited on hard-setting soils and plants cannot germinate or are seriously hampered. Tillage by hand or animal traction is often impossible and the land degenerates into badlands. **Crusting** occurs due to several factors, e.g. the destruction of aggregates in the topsoil by rain, which is closely linked to soil erosion, an upward movement of water and soluble salts under semi-arid conditions, and the development of algae at the soil surface. Crusting reduces infiltration and promotes water runoff. It inhibits germination and emergence of seedlings. Lower infiltration rates reduce water retention capacity and aggravate drought stress.

Without human influence, **geological (natural) erosion** occurs at all times due to the interaction of climate (weathering, precipitation), vegetation (nutrient uptake, protective cover), parent material, and topography. Nowadays, however, there is almost no part of the earth's surface that is not used by human beings (Eswaran, et al., 1997a[7]). This human "factor" can speed up erosion, which is, therefore, referred to as **accelerated (human induced) soil erosion** (*Figure 2.2*). With a view to more sustainable land management, it should be noted, though, that the "human factor" is also in a position to minimize soil erosion!

Soil erosion is defined as the detachment and transport of solid particles on the soil surface by water and wind. In the long term, this process leads to stable landforms with low erosion rates. From the point of view of production, however, erosion leads mostly to a less favourable distribution of soil properties due to the selectivity of soil erosion. Eroded topsoil particles contain a higher percentage of clay minerals, organic matter and nutrients than the remaining (sub-) soil itself. This means that even a seemingly minor loss of topsoil per year can reduce soil productivity significantly in the long run. In addition, spatial soil fertility distribution is easily changed for the worse: while fertility decreases by means of erosion on a relatively large area (e.g. ridges and slopes), the eroded fertile material is deposited in deep accumulations covering only a relatively small area (e.g. valley bottoms).

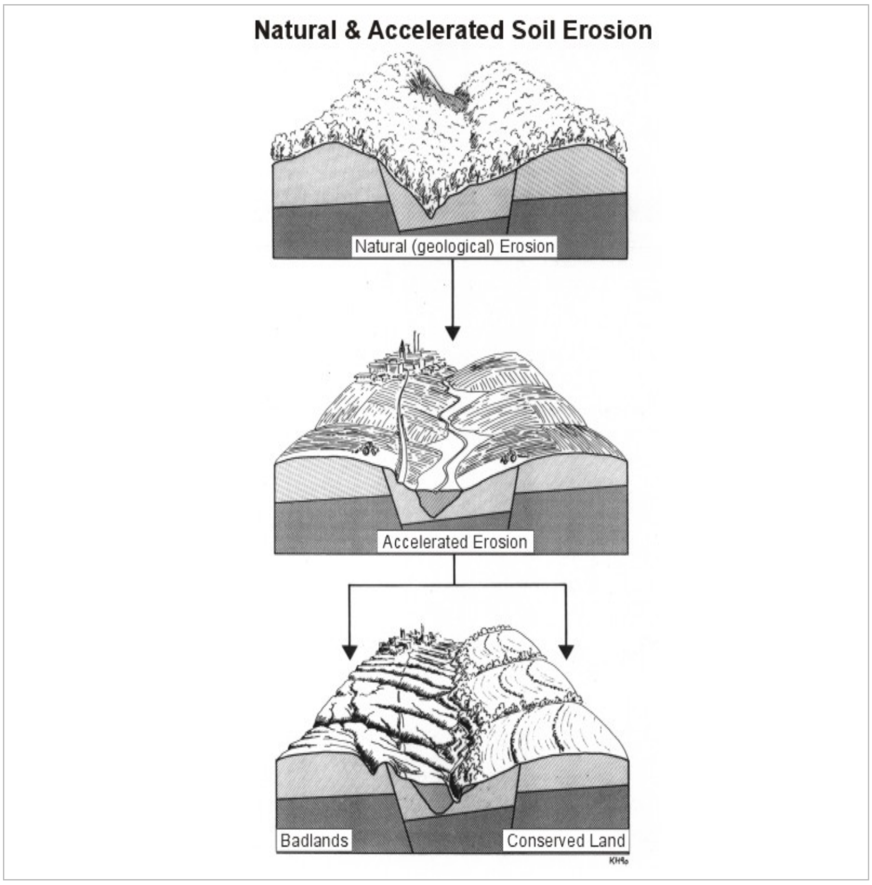

Figure 2.2 Natural soil erosion, accelerated soil erosion and possible effects on the landscape with and without human intervention (Karl Herweg)

In natural ecosystems undisturbed by man, erosion is triggered by a coincidence of natural tectonic events that alter the relief, natural disasters that destroy the vegetation cover, and climatic conditions that provide means of transport, such as water and wind. According to de Graaff (1993)[8], the determinants or direct factors that influence erosion are rainfall (erosivity), vegetation (ground cover), topography (surface forms, slope inclination and exposure to sun), and soil properties (erodibility) (*Figure 2.3*). Humans change three of these factors from their natural state – vegetation, topography and soil properties – and are therefore in a position to both accelerate and retard the process of soil erosion.

Erosivity is a complex indicator that refers to the potential of rainfall to cause soil erosion. It contains parameters such as amount of rainfall, intensity, energy, etc. Erodibility refers to the soil's vulnerability to erosion. It may include parameters such as soil texture, permeability, soil organic matter, etc. Some authors also include vegetation cover as part of their concept of erodibility.

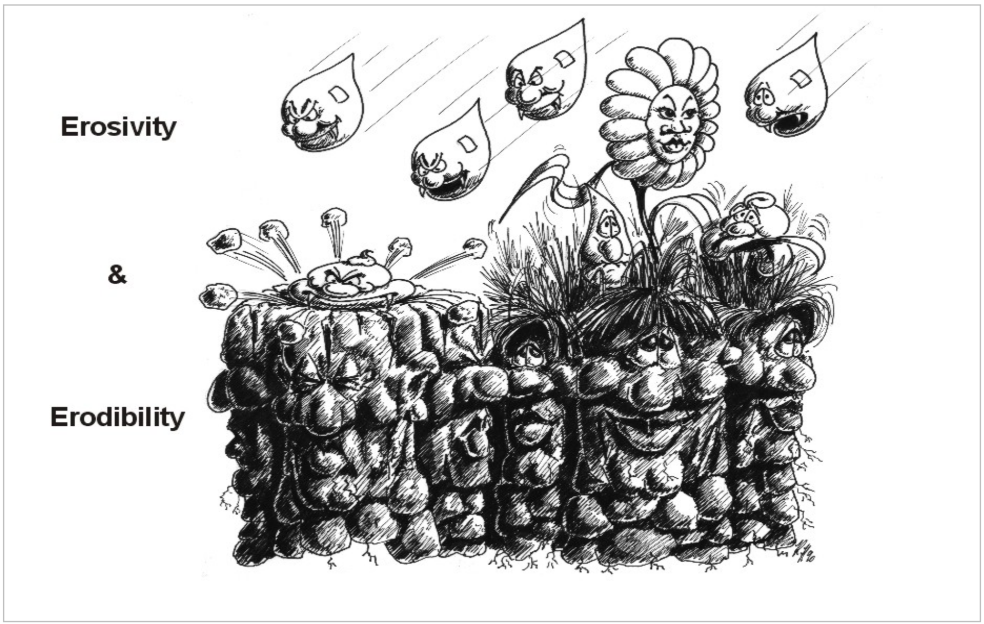

Figure 2.3 Erosivity and erodibility (Karl Herweg)

Soil erosion by water – a specific form of soil degradation

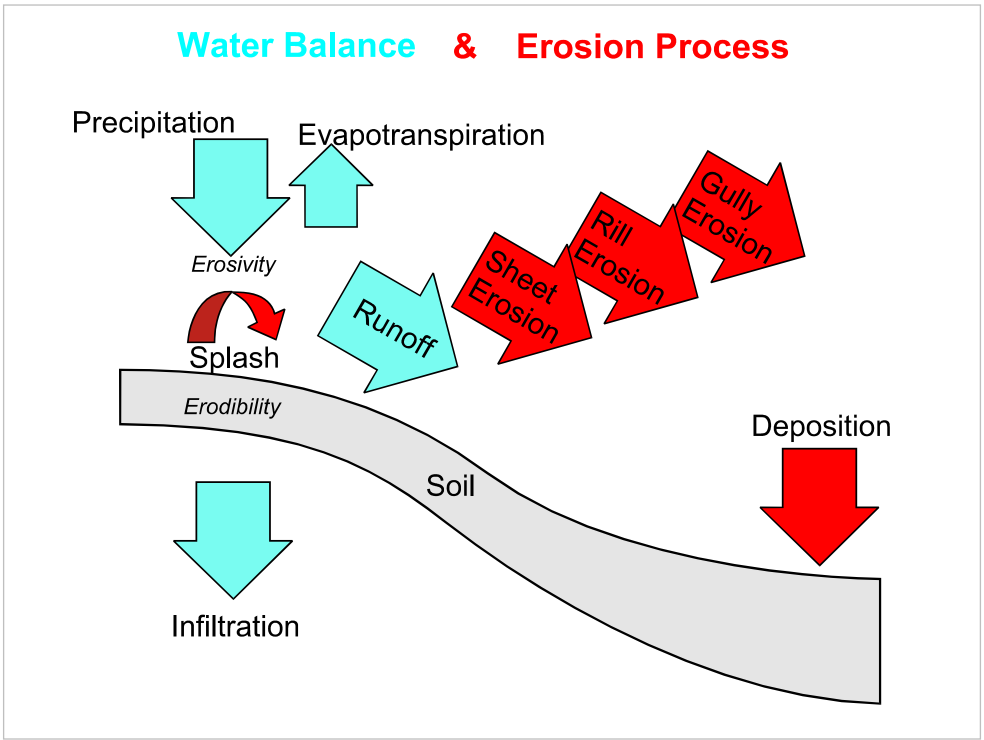

Figure 2.4 Water erosion is closely linked to the water balance (Karl Herweg)

Main erosion processes caused by water (*Figure 2.4*):

- **Rain-splash** detaches soil particles through the impact of raindrops and can move them several meters through the air. These particles are prone to be washed away by sheet erosion.
- Water that cannot infiltrate into the soil is called **runoff (overland flow).** Runoff that does not concentrate is referred to as *areal erosion*, or so-called **sheet flow** (sheet wash, inter-rill erosion), which moves particles loosened by rain-splash downslope. At the same time, runoff carrying soil particles loosens and picks up additional particles (entrainment). A freshly ploughed or harrowed soil surface is usually characterized by high surface roughness. After a number of rainstorms, splash, sheet erosion and diffuse accumulations smoothen soil clods and aggregates. **Low surface roughness (puddling effect)** is thus an indicator of recent erosion. This process is more rapid when aggregate stability is low.
- Particularly intense rainstorms lead to concentrated runoff that produces more obvious features of **linear erosion**, which often occur on steep slopes and in depressions. If water concentration and flow velocity exceed the soil-specific threshold of adhesion, **pre-rill erosion** forms small and shallow rills with a depth of several cm. Further development of pre-rills is called **rill erosion** if it forms channels up to 50 cm deep.
- **Gully erosion** may result from rill erosion. It forms channels deeper than 50 cm, which causes additional processes that destabilize the gully walls, such as small landslips. A riverbed, for example, can also be considered a permanent gully. Land that is dissected by gullies to the extent that any type of productive land use becomes impossible is classified as *badlands*.
- Precipitation in combination with infiltration may destabilize particularly steeper slopes and create mass movements such as **landslips** and **landslides** (Nyssen et al. 2002)[9].
- Material that has been transported by rain-splash and sheet wash may be deposited in **diffuse accumulations** only a few meters away from its origin. This process is often visible as a puddling effect, which contributes to sealing of the soil surface, reduced infiltration and increased overland flow.
- When runoff concentration and velocity diminish, the eroded material can be deposited in **concentrated accumulations** (“filter zones”). These are clearly visible in slope depressions with diminishing slope angle, on foot slopes and valley floors, along field borders, vegetation strips, and hedgerows, or above SWC structures.

It is important to keep in mind that data obtained with different measurement devices, such as test plots, sediment troughs, rill mapping, etc. always reflect a mixture of various erosion process.

Other physical soil erosion processes

- **Wind erosion**

The physical energy that causes wind (or Aeolian) erosion is similar to that which causes soil erosion by water: it consists of linear and turbulent flow. By contrast with water, air is less dense and has a lower viscosity. The same amount of energy can therefore only move comparably smaller amounts of sediment. Wind erosion is mainly active in areas with low plant cover, e.g. arid and semi-arid regions, but also along coasts and in sub-polar regions.

High-speed winds in arid and semi-arid areas such as those in Eritrea take up soil particles selectively, particularly from a dry surface. During transport, these particles have additional impacts on the surface and can thus mechanically loosen other particles. Wind erosion also creates a smooth and sorted-out surface (desert pavement) where the soil is eroded. Decreasing wind speed enhances deposition (accumulation), typically both in front of and behind wind breaks, such as trees, live fences, etc.

Once wind velocity exceeds the threshold level for initiation of erosion, the amount of soil it can move (termed the 'erosivity' of the wind) increases approximately with the cube of the wind speed.

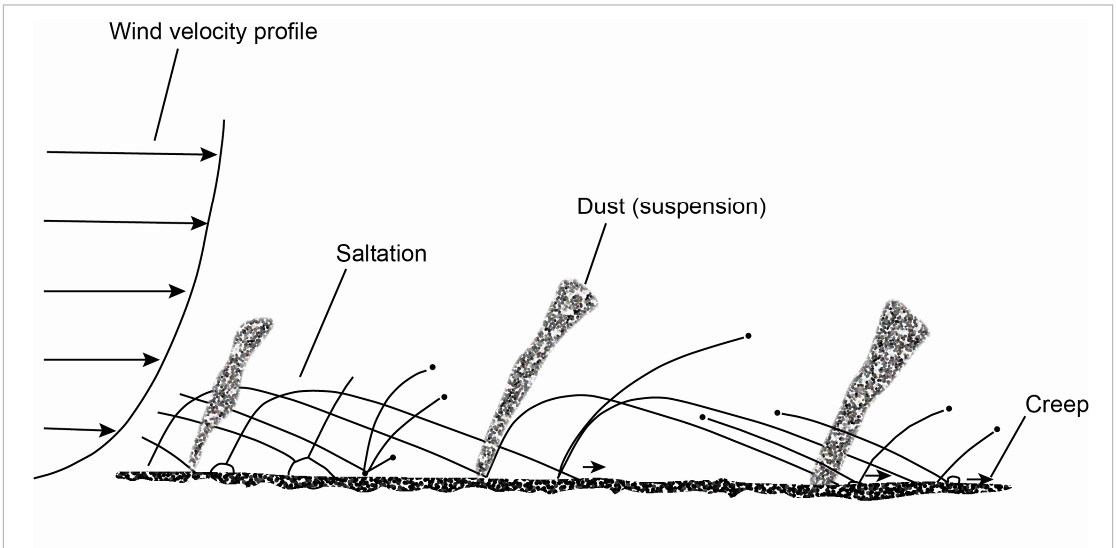

Figure 2.5 *Summary of processes within aeolian erosion (McTainsh and Boughton 1993)*

The process of soil erosion by wind involves three distinct types of movement: surface **creep**, **saltation**, and **suspension**, which usually occur simultaneously (*Figure 2.5*). Despite the highly visible impression of clouds of dust carried high in the air in suspension, most soil movement takes place within a few meters of the soil surface.

Soil movement is initiated by wind uplift and turbulence at the soil surface acting on loose, medium-sized particles (0.1-0.5 mm diameter), which are dislodged and moved by bouncing over the surface (termed 'saltation'). Saltating particles are too large to be carried higher in the air column in suspension. They are lifted and moved forward a short distance, then return to the surface, colliding with, dislodging and initiating movement of other particles, in a sort of 'chain reaction'. Finer soil particles (< 0.1 mm), which are already loose, or are dislodged from the surface, by saltating particles, are small enough that they can be carried by the wind high into the air in suspension. Most of the fine material carried in suspension during a wind erosion event comprises clay and organic matter, which together provide most of the nutrient storage capacity and structural stability of a soil. The largest or heaviest soil particles moved during a wind erosion event (0.5 to 2 mm) are too large to leave the surface by saltation or suspension, but are simply rolled across the surface by wind force and by impacts from saltating particles, in a process termed '**surface creep**'.

Wind erosion processes dislodge, transport and deposit soil particles with the result that coarser material is moved relatively short distances (meters to hundreds of meters) and deposited as sand drifts. Fine particles are carried for much greater distances (up to hundreds of kilometres) in dust, and are thus effectively lost for the farmer. The remaining sandy soils are greatly reduced in fertility by selective loss of clays and organic matter.

Two types of wind erosion are often described: '**Sweeping drift**' commonly refers to relatively gentle wind erosion where some loose soil fines go into suspension but with minimal development of drift banks. '**Active drift**' usually describes more vigorous wind erosion involving all three of the particle movement processes, with obvious development of drift banks or blow-outs. Both types, however, can result in significant soil degradation and off-site impacts.

The propensity of a soil for wind erosion (soil *'erodibility'*) is greatly influenced by the sizes of particles which are readily detachable from the soil surface, and by moisture. Soil particles or stable aggregates larger than 0.84 mm in diameter are effectively too large to be moved by most wind forces. A sandy soil type, with low clay content, generally has low cohesive strength between individual particles, and wind forces can readily dislodge particles and initiate the erosion process. More clay in a soil (and organic matter, to some degree) provides greater cohesive strength to hold larger aggregates (stable `lumps' of soil) together, and limits the exposure of finer particles to wind movement. These better-structured soils, however, can still be extremely vulnerable to wind erosion if they are left in a very fine, loose state by excessive cultivation or animal traffic. A moist soil will suffer very little from wind erosion as water in the fine soil pores provides strong cohesive bonds between individual soil particles. Even humid air conditions can reduce the degree of soil loss for a given wind strength.

- **Soil crusting and sealing**

Surface seal

The rapid drop in infiltration rate of most bare soils during rainstorms is due mainly to the formation of surface seal. The permeability of the seal is lower by several orders of magnitude than the subsurface permeability. Surface sealing, as well as most other crust formations, results from three processes (Agassi *et al.* 1981[10]; Morin *et al.* 1981[11]):

- **Physical disintegration** of soil aggregates and their compaction, caused by the impact of raindrops.
- **Chemical dispersion of the clay particles.** The low electrical conductivity of rainwater, and the organo-chemical bonds between the primary particles of the surface aggregates, dictate the rate and degree of dispersion.

- **An interface suction force which arranges suspended clay particles into a continuous dense layer.** Such almost impermeable layers form right on the surface of the soil or in the immediate subsurface washed-in layer, as discussed by McIntyre (1958)[12].

The separation above is artificial. The marked reduction in infiltration rate depends on the combined action of the three processes.

Hardsetting crusts

Hardsetting of cultivated soil is a process of compaction, with increase in bulk density that occurs without the application of an external load. In practice, it is difficult to distinguish between the effects of an externally applied load and the internal effect caused by the wetting of weak, unstable soil. In previously loosened topsoil, during and after wetting, hardsetting involves the collapse of some or all of the aggregated structure (tilth). The hardsetting processes can be divided into two physically distinct processes: slumping and uniaxial shrinkage.

Slumping: Slumping is not limited to hardsetting soils. It occurs during and after the wetting of a soil horizon formed of water-unstable aggregates. The aggregates soften and swell simultaneously, and some or all of the silt and clay-sized material becomes suspended. Under appropriate ionic conditions, some of the clay fractions disperse. Aggregates disintegrate because they have insufficient strength to withstand the stresses set up by rapid water uptake - caused by rapid release of heat on wetting, trapped air - the mechanical action of rapidly moving water (Collis-George and Greene 1979[13]) or by differential swelling (Emerson 1983).[14]

Uniaxial shrinkage: Shrinkage is a process often related to clay soils. Laboratory experiments show that, at least during the early stages of drying, uniaxial shrinkage occurs. Since uniaxial shrinkage is, by definition, anisotropic, it follows that it must be accomplished by realignment of the disrupted aggregates and/or the internal fabric of the soil.

- Compaction

Soil compaction occurs when soil particles are pressed together, reducing pore space between them. Heavily compacted soils contain few large pores and have a reduced rate of both water infiltration and drainage from the compacted layer. This occurs because large pores are the most effective in moving water through the soil when it is saturated. In addition, the exchange of gases slows down in compacted soils, causing an increase in the likelihood of aeration-related problems. Finally, a compacted soil also means that roots must exert greater force to penetrate the compacted layer.

Soil compaction changes pore size, pore distribution, and soil strength. One way to quantify the change is by measuring the bulk density. As the pore space is decreased within a soil, the bulk density is increased. Soils with a higher percentage of clay and silt, which naturally have more pore space, have a lower bulk density than sandier soils.

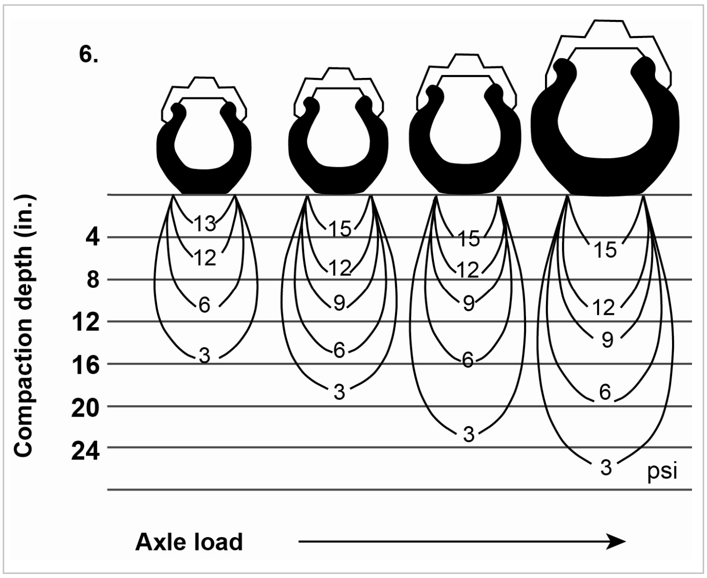

Figure 2.6
One important cause of soil compaction is mechanized agriculture. The heavier a machine is, the stronger the compaction and the deeper the effect. Axle load is a measure of the pressure exerted by a machine on the soil surface; it is expressed in pounds per square inch (psi)

Soil compaction can have both desirable and undesirable effects on plant growth:

- **Desirable effects**: slightly compacted soil can speed up the rate of seed germination because it promotes good contact between the seed and soil. In addition, moderate compaction may reduce water loss from the soil due to evaporation and, therefore, prevent the soil around the growing seed from drying out.
- **Undesirable effects**: Excessive soil compaction impedes root growth and therefore limits the amount of soil explored by roots. This, in turn, can decrease the plant's ability to take up nutrients and water. From the standpoint of crop production, the adverse effect of soil compaction on water flow and storage may be more serious than the direct effect of soil compaction on root growth (*Figure 2.7*).

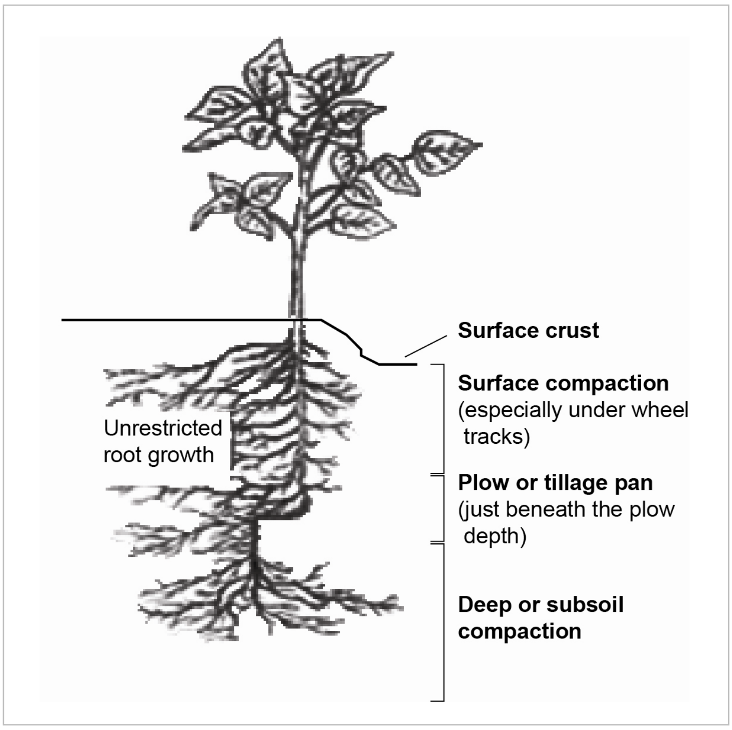

Figure 2.7
Reduced root growth due to compaction from raindrop impact, tillage, and wheel tracks. (Hughes et al. 2001[15])

In dry years, soil compaction can lead to stunted, drought-stressed plants due to decreased root growth. Without timely rains and well-placed fertilizers, yield reductions will occur. Soil compaction in wet years decreases soil aeration. This results in increased denitrification (loss of nitrate-nitrogen to the atmosphere). Reduced soil aeration affects root metabolism. There can also be increased risk of crop disease. All of these factors result in added stress on the crop and, ultimately, yield loss.

Soil erosion processes and features

Detailed information on soil erosion **processes** can be found in Bergsma (1996)[16] and Bryan (1987)[17]. Soil erosion **features** are evidence of numerous past erosion processes. The question is whether these processes took place recently (current erosion) or long ago.

Recent erosion features have rather sharp edges and are free (devoid) of vegetation. With time, the edges are rounded by rain splash and entrainment, and weeds and other vegetation start to cover the features. Other indicators of "old" or long-term erosion are exposed plant roots, or a lowered soil surface, e.g. visible along field borders. When erosion has removed larger parts of the topsoil and subsoil material (truncated B horizon) is ploughed up or weathered rocks become visible, the colour of the surface becomes lighter and more varied.

Changes in soil colour, as seen in Figure 2.8 (photo), often indicate loss or reduction of the darker topsoil and exposure of the lighter subsoil or parent material. In the centre of the photo, a relatively large area is affected by soil erosion. In the left part of the photo very light linear erosion features indicate a problem of uncontrolled drainage that originates from compacted footpaths and areas around the hamlets.

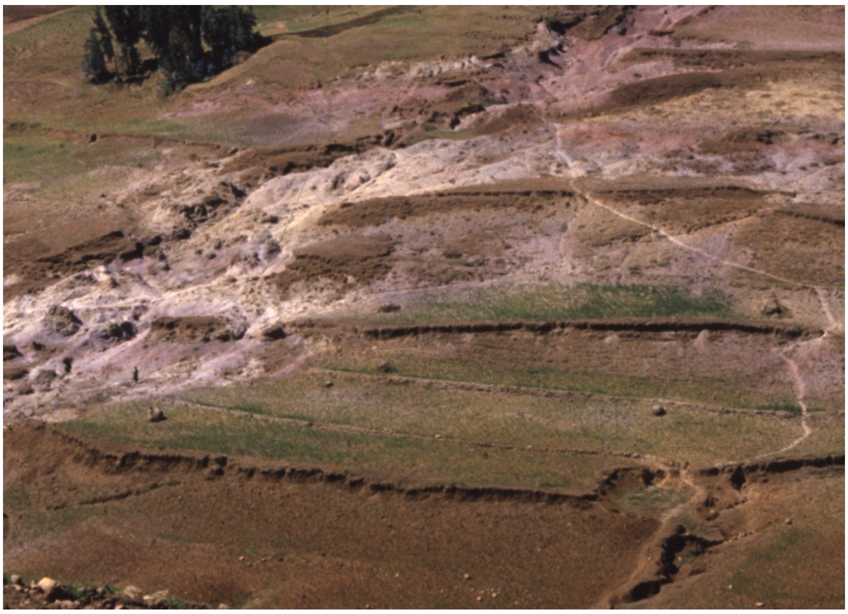

Figure 2.8 Soil colour as an indicator of erosion (Photo by Karl Herweg)

Different types of land use can lead to entirely different soil development, even if climate, parent material and the topography are similar. According to the Italian farmer who manages the land pictured in the photo, there was always forest (*macchia*) on the left hand side, and on the right hand side cropland every second year, alternating with pasture. He roughly estimated that this was the case for at least 150 years. The meter stick in the centre shows that the soil surface of the crop- and pastureland, which was exposed to soil erosion and accumulation processes, has been reduced by several 10s of cm during this period of time. Note that such “steps” in the landscape may occur for different reasons, and confirmation, e.g. by soil profile analysis, is required to determine whether they can be attributed to soil erosion, as it is the case here (*Figure 2.9*).

Figure 2.9 *Soil surface levels (Photo by Karl Herweg)*

Initially unspectacular rills can develop into gullies. The factors that cause this are manifold. The example shows surplus overland flow on the steep slopes in the background, from all types of land use and field border erosion, leading to an intensely intersected slope. In the foreground, the vulnerable soil type – in this case a Planosol – shows severe gully erosion. Very often, areas with compacted surface and low or zero infiltration also contribute to the development of such erosion features. Land management operations are severely hampered *(Figure 2.10)*.

Figure 2.10 Gully erosion (Photo by Karl Herweg)

If gullies cannot be controlled they become deeper and wider. When most topsoil and considerable portions of the subsoil are removed, vegetation growth is reduced to a minimum. Such severely eroded slopes of greater area coverage are called "badlands", as can be seen in Figure 2.11.

Figure 2.11 Badlands (Photo by Karl Herweg)

Direct factors of influence on soil erosion

Apart from land use activities that trigger soil erosion processes, a number of factors directly influence or steer these process. These factors are closely interlinked, which means they influence each other as well as erosion processes (*Figure 2.12*). Table 2.1 indicates how these factors and parameters can influence soil erosion processes directly or indirectly.

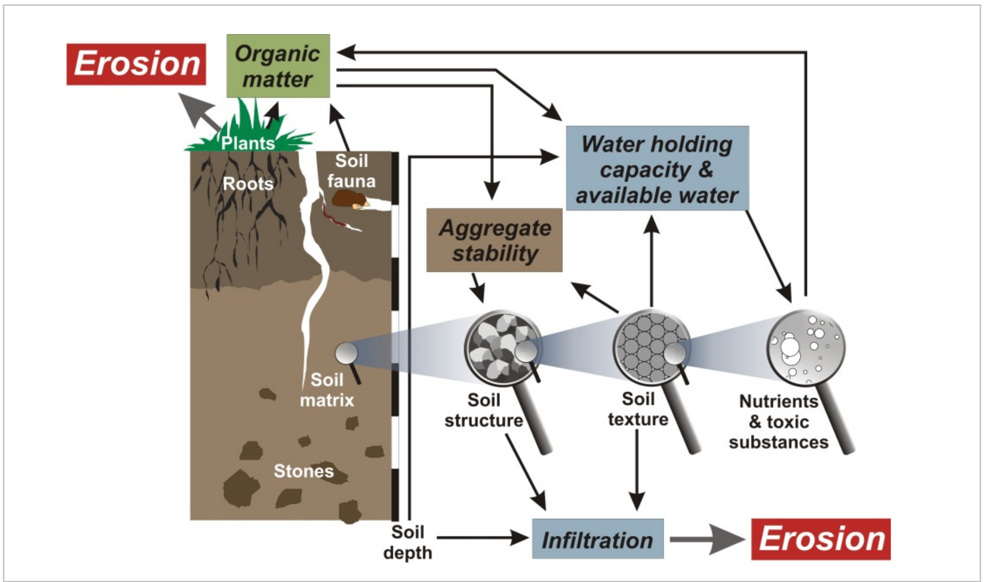

Figure 2.12 The influence of soil properties on soil (Karl Herweg)

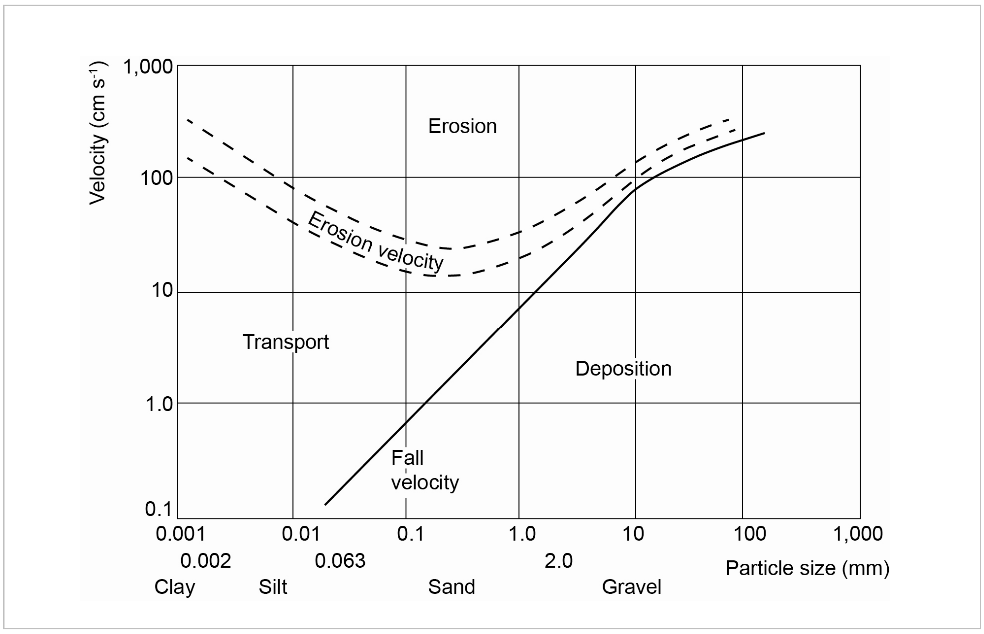

Figure 2.13 The relation between runoff velocity, detachment and accumulation

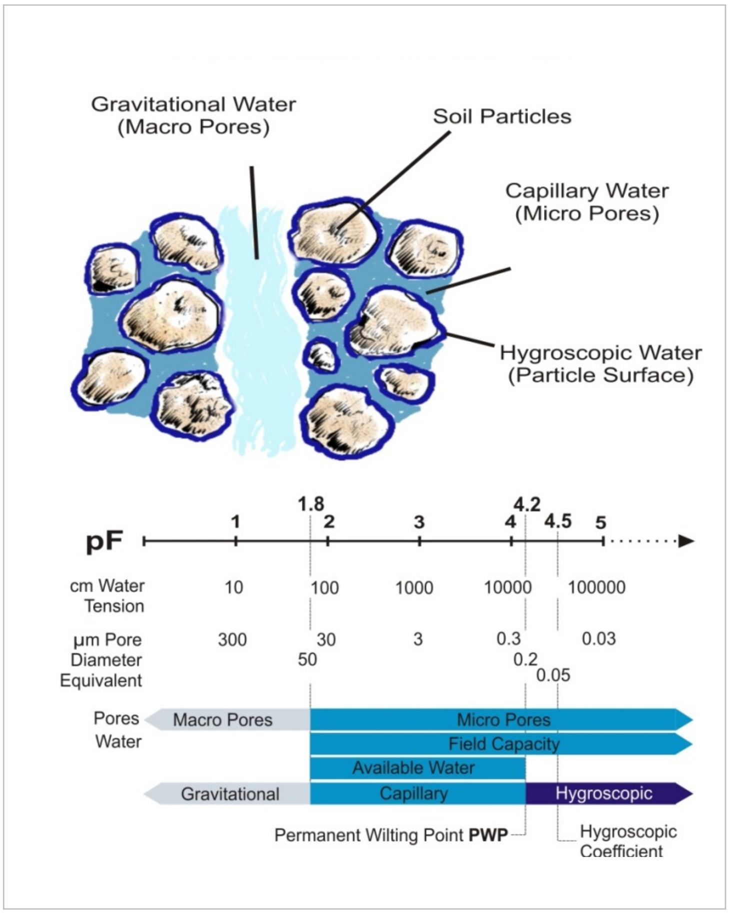

Figure 2.14 *Pore size, water tension and soil water (Karl Herweg)*

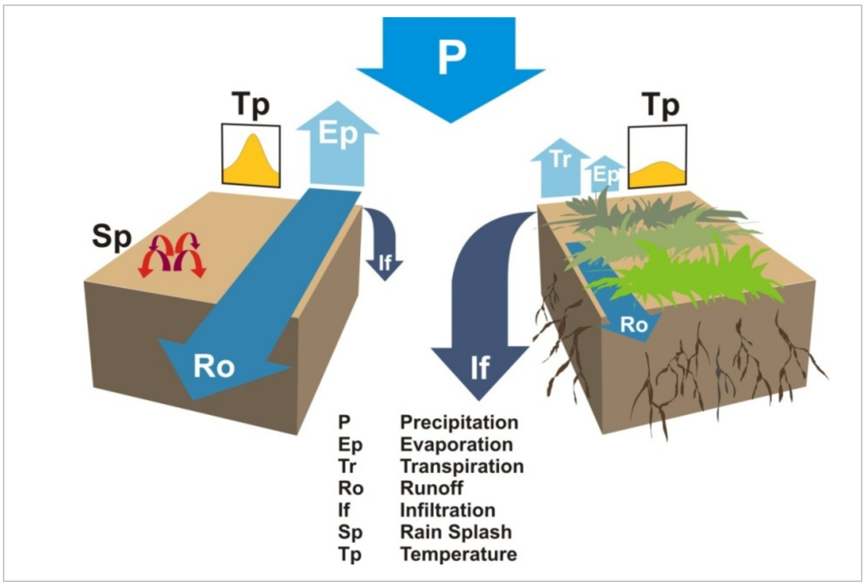

Figure 2.15 *The influence of vegetation parameters on soil erosion (Karl Herweg)*

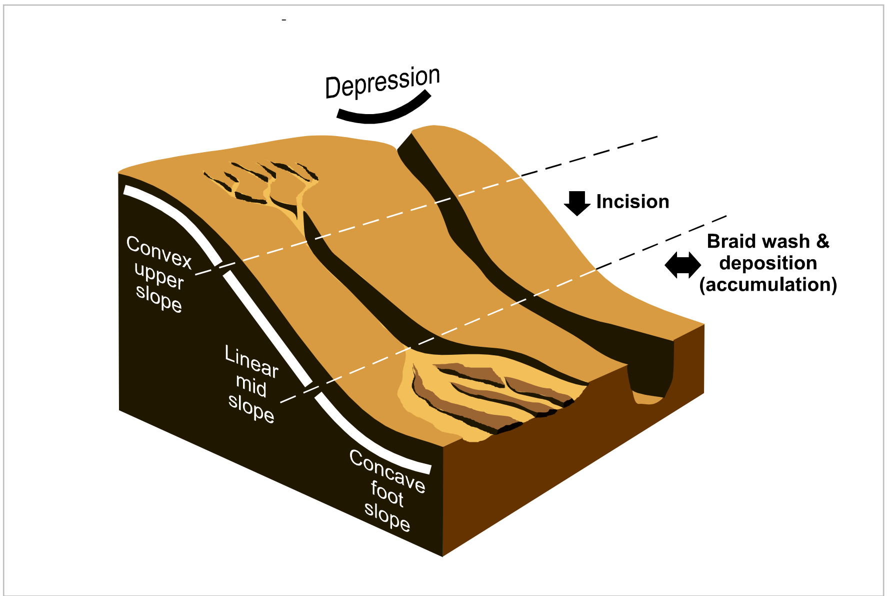

Figure 2.16 The influence of slope characteristics on soil erosion (Karl Herweg)

Table 2.1 The direct and indirect influence (in brackets) of different factors on soil erosion processes

Climate
Rainfall erosivity, amount, intensity, duration (detachment of soil particles)
Wind speed (detachment of soil particles)
Temperature (evaporation, soil moisture, infiltration / runoff))
Soil properties
Erodibility, texture, soil organic matter, permeability (detachment of soil particles, runoff)
Soil structure (infiltration speed)
Soil depth (volume of infiltration)
Surface roughness (runoff speed)
Soil moisture, soil water (infiltration / runoff)
Soil fertility and water holding capacity (protective plant growth)
Surface stone cover (rain splash)
Topography
Slope angle (runoff speed)
Slope length (amount and speed of runoff)
Slope shape (concentration and speed of runoff)
Exposition (soil moisture, infiltration / runoff)
Vegetation
Plant ground cover (splash, runoff velocity, accumulation)
Plant height (drip and splash)
Roots (infiltration)
Organic matter (erodibility)
Soil management
Crop rotation (fertility, ground cover)
Tillage direction (runoff)
Machines (compaction, infiltration)
Timeliness of planting (cover)
Fertilization (cover)

Indirect factors of influence on soil erosion

All changing conditions in the social, environmental and economic framework of an area can have an impact on soil erosion processes. Often the impact is negative, but under certain circumstances it can also be positive, e.g. in remote areas where land use becomes less intensive through time. Besides the rare positive examples, the best-known problems are, among others, changing climatic conditions due to global warming, increasing land pressure owing to population growth, land use changes caused by changing market demands, or other interactions. It is no trivial matter to understand the actions and interactions of indirect factors that influence soil erosion, and the complexity of such systems requires scientific approaches such as the DPSIR (Driving Forces – Pressure – State – Impact – Responses) framework developed by the European Environment Agency (EEA, 1999, 2000).[18] This is a holistic approach into which further extensions and reporting strategies can be built. The framework provides a basis for identifying the different factors influencing soil erosion, but it does not explicitly allow for the identification of actors in the DPSIR chain. On the assumption that the DPSIR framework is the best available framework to be applied to soil erosion, Gobin et al (2004[19]) have applied and revised it for soil erosion (*Figure 2.17*). Possible driving forces are grouped according to human activities and physical phenomena that in turn result in potential pressures on the land. The most important pressures related to soil erosion are land cover and precipitation. In this respect, population dynamics, tourism, agriculture and transport should be added to the list of driving forces.

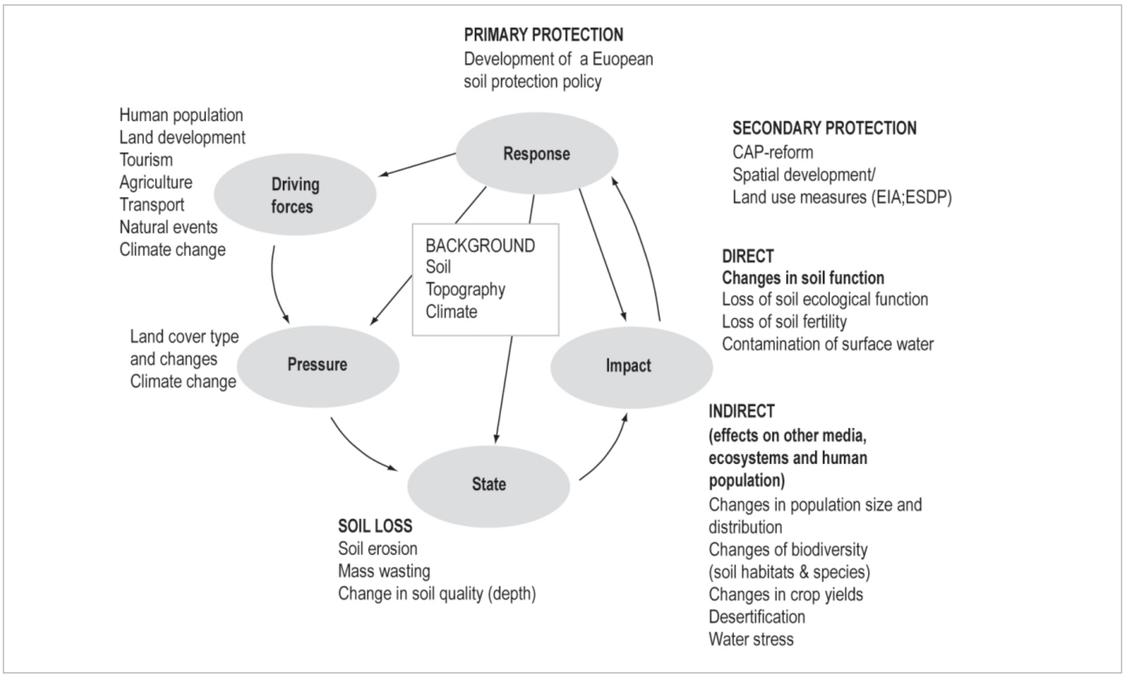

Figure 2.17 *This example of a DPSIR framework shows a cause-effect chain from driving forces (activities) to pressures, to changes in the state of environment, to impacts and responses (EEA, 1999[20], 2000). DPSIR is based on the assumption that economic activities and social behaviour affect environmental quality, and as such the framework highlights the complex connection between the causes of environmental problems, their impacts and a society's response to them (EEA, 2000[21]/Gobin et al 2004)*

The assessment carried out with the DPSIR framework does not aim to understand or analyze soil erosion as a process, but provides information to support policy-makers' actions so that the necessary measures can be defined and the effect of current measures assessed.

2.2.2 Chemical soil degradation

A number of chemical processes impair soil fertility; we can basically distinguish the **depletion** of plant nutrient reserves and **enrichment** of toxic substances (Dumanski et al., 1997a).[22] According to Sanchez and Logan (1992)[23] about 1.7 billion ha of tropical soils are low in nutrient reserves. These intensely weathered soils can supply only a limited amount of nutrients. Because of **leaching**, particularly in humid areas, soluble nutrients from the root zone can be washed out and transported into deeper soil layers. **Acidification** produces aluminium and ferrous oxides, leading to phosphorus fixation, which renders phosphorus unavailable for uptake by plants. Phosphorous *fixation* is more frequent in the humid tropics, but it also occurs to a significant degree in savannas and steep highlands. In Andosols, fixation is a major problem because allophane and volcanic soils in the humid tropics and tropical highlands are particularly affected.

In Sub-Saharan Africa substantial quantities of nutrients are removed from agricultural soils during harvest (Balesh, 2005;[24] Assefa et. al., 2004;[25] Smaling 1998;[26] Stangel et al., 1994[27]). If the removed nutrients are not replenished through the application of fertilizers, manure, compost, biological nitrogen fixation or subsequent delivery through weathering soil minerals, the nutrient content of the soil will decline rapidly, jeopardizing sustainable production. Soil acidification and aluminium (Al) **toxicity** are direct causes of leaching and nutrient export, decomposition of organic matter and root exudation. The use of acid-reacting mineral fertilizers, such as urea or ammonium sulphate, can speed up the process. Studies by Sanchez and Logan (1992)[28] show that about one-third of tropical lands have highly acidic soils, which contain plant toxic Al in the soil solution. The level of aluminium saturation is higher than 60% in the exchange complex. The aluminium ions in solution directly damage the plant roots and thus reduce nutrient and water uptake. In Oxisols, Inceptisols and Ultisols the Al concentration in the subsoil increases significantly. This is attributed to the decline of soil fertility resulting from the denudation of topsoils by erosion (Solomon, 1994[29]). One quarter of tropical soils are acidic, with pH values below 5.5 in the upper horizons. This does not necessarily mean that the plants are affected by Al-toxicity, because excess Al^{3+} concentration in soil solution is caused only by soil pH lower than 5. In addition, the concentration of Aluminium ions in soil solution depends not only on soil pH but also on the concentration of organic and inorganic compounds that can form complexes with Al, which cannot be taken up by plants. Low pH-soils occur across all agro-ecological zones. They require higher fertilizer rates and liming than soils with higher pH values. In addition manganese toxicity may be encountered in acidic soils with a tendency towards water logging.

Salinity

In the tropics, *salinization* poses a problem on 66 million ha. Of these alkaline soils, 78% contain a sodium saturation of more than 15% in the upper 50 cm of the soil. Globally, this problem affects less than 1% of the total land area but has a major local impact because the land concerned is often of high potential and capable of irrigation. However, in arid and semi-arid environments such as those in Eritrea, it is a serious threat to land. In some parts of Eritrea, there are indications of salinity in irrigation water Bereketsehay et al. 2005[30)]. Salinization can be classed as a specific form of chemical degradation. It is often the result of a combination of improper irrigation, high evapotranspiration, and human-induced changes in hydrological regimes. Due to the high osmotic potential of the saline soil solution, salinization reduces the amount of water available to plants. High concentration of some soluble salts will also have toxic effects on plants, and high soil *alkalinity* under the preponderance of high sodium levels creates a dispersed system damaging soil structure and impairing infiltration capacity.

Saline soils can also occur naturally, e.g. along coasts where salty sea water penetrates into the ground and evaporates from there, or in land-pans where the main water movement is upward (from the groundwater table to the soil surface). If the salt content of the groundwater is high and there is not enough rainfall to wash salt back into the groundwater, it will accumulate at the soil surface. Another possible natural source of saline soils is the parent material itself. Depending on the type of parent rock, many readily soluble salts are provided by the freshly weathered soil material. Accumulation through time can lead to poisonous salt concentration in the soil profile.

Organic matter

Organic matter ensures favourable physical soil conditions, including water retention capacity. It furnishes balanced and slow-flowing sources of nutrients and is a basis for cation exchange capacity (CEC). Particularly on soils with low-sorption clay minerals, organic matter plays an even greater role in CEC. In cropping systems involving repeated tillage, there is rapid decline in organic matter, often within a few cropping cycles. Nutrient retention declines below the necessary minimum and nutrient leaching increases by a large margin. Very low potential CEC is therefore gauged to be far more detrimental than a deficiency in particular nutrients, because, as estimates by Budelman and Van der Pol (1992)[31] show, even if additional fertilizer is applied, cropping ceases to be economically viable when the potential CEC drops below 30-40 mmol/kg soil. Many processes affect the delivery and decomposition rate of organic matter, which is why the equilibrium collates with different levels of “C” content depending on the site. In the tropics, organic matter decomposes about five times faster than in temperate climates (Sanchez and Logan 1992).

2.2.3 Biological soil degradation

Biological degradation is frequently equated with the *depletion* of vegetation cover and organic matter in the soil, but it also denotes the *reduction of biological activity*. It is a direct consequence of inappropriate soil management that also results in physical and chemical soil degradation. It is known that soil fauna is an indicator of soil fertility status and influences the structure of the soil. In the tropics termites play an important role in improving soil aeration and raising soil fertility (Swift and Sanchez, 1984;[32] Lee and Wood, 1971)[33]. Earthworms play a role in temperate soils and they can perform a function similar to that of termites in some tropical soils, but they are not comparable in number and biomass (Young, 1976).[34] The destruction of soil structure by compaction, water logging or crusting impedes aeration and thus the supply of oxygen to the aerobic soil organisms; conversely, this is conducive to the anaerobic organisms. Another component in this interaction is organic matter, which is itself beneficial to soil structure, while at the same time providing energy for most soil organisms.

2.2.4 Combinations of soil degradation processes

The degradation processes and phenomena listed above rarely occur in isolated forms but rather in combination. They can be accelerated or retarded, depending on the prevailing land management practices. For example, upslope-downslope tillage may cause soil erosion by water, which in turn affects physical, chemical and biological soil properties and thus triggers a series of different degradation processes. On the one hand, nutrients can be removed by soil erosion from the surface, and they can be transported into layers out of the reach of plant roots by leaching. They can also be diminished due to intensive farming without compensation of nutrients, e.g. under monoculture without adding fertilizer, organic matter, compost, and other organic material. A reduction of organic matter, e.g. due to erosion or chemical degradation, automatically leads to biological soil degradation. Decreasing plant cover and organic matter involves a decrease in soil biological activities (e.g. microbes, rodents, earthworms). A consequence of nutrient removal is acidification. On the other hand, overuse of fertilizer, herbicides and pesticides and improper management of irrigation schemes can contaminate the soils and lead to toxicity and salinity (Bruce, 2004[35]).

2.3 Questions and issues for debate

- Apart from the indicators of soil erosion mentioned in the text, do you know of any "indigenous erosion indicators" (i.e. local indicators used by farmers)?
- Vegetation, soil and slope parameters are, among others, major factors influencing soil erosion processes. (You can brush up your previous knowledge by scrolling through *Figures 2.12 – 2.16* and *Table 2.1*). Prepare a list of **which** parameters can be changed by human activities, and describe **how** they could be influenced in order to minimize erosion.
- Which of the above-mentioned factors of influence do you think have the most **dominant** impact on soil erosion rates, and why?

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Chapter 3

Agro-ecological/Agro-climatological Classification

3.1 Agroecological zones

An agro-ecological zone is an area of land where climate, landforms, soils and vegetation are relatively homogeneous. The constraints on and potentials for agricultural activities tend to be uniform within a given agro-ecological zone. Varying population density and variations in traditions, wealth and other socioeconomic factors may, however, result in the development of different farming systems within a given agro-ecological zone.

Importance of agro-ecological zone maps: The use of agro-ecological zone maps to guide agricultural policy has been a long-standing goal in Eritrea (DoE 1999[1]). Two recent agro-ecological zone maps exist for Eritrea (FAO 1994[2], FAO 1997a[3]). While the first was derived from the MoA Agricultural Sector Review and Project Identification, the second was developed by the Ministry of Land Water and Environment of the State of Eritrea.

Number of Agroecological Zones of Eritrea: FAO (1994) listed the following agro-ecological zones:

i. Central highlands zone (northern midlands)
ii. Central highlands zone (southern midlands)
iii. Central highlands zone (highlands)
iv. Western Escarpment zone
v. South-western lowland zone
vi. Green belt zone
vii. Coastal plain zone
viii. North-western lowland zone

For practical reasons, this section is based on the second most recent agro-ecological zone map of Eritrea. This map was developed on the basis of biological and physical characteristics of Eritrea. On this map, Eritrea is divided into six major agro-ecological zones (*Figure 3.1*). Owing to the diversity of environmental settings within the respective zones, these zones are further sub-divided into 55 agroecological sub-zones (Ghebru and Radcliff, 1997[4]). Ideally, soil and water conservation guidelines for sustainable land management should be specifically provided for each sub-zone, but for practical reasons only the major ones are explained in this manual (*Table 3.1).*

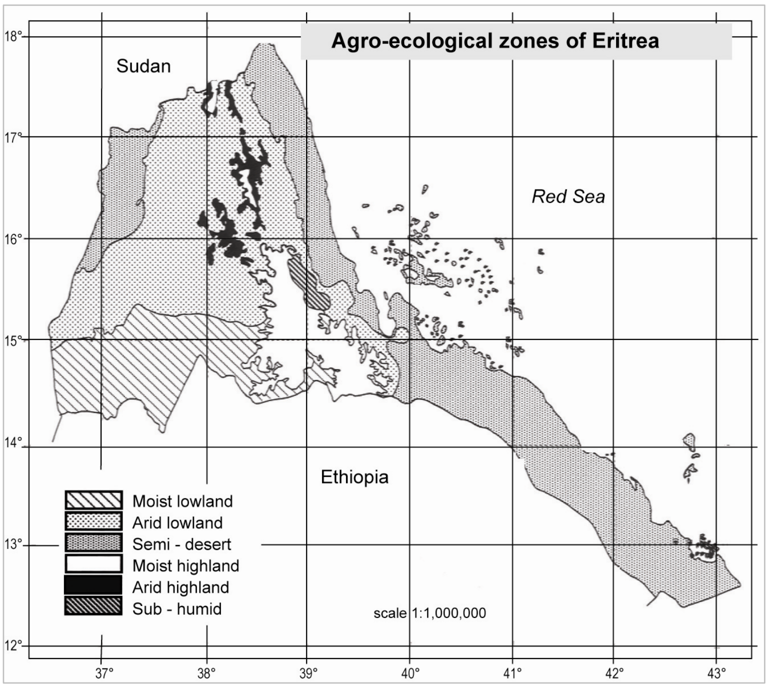

Figure 3.1 Agroecological zone map of Eritrea (FAO,1997a)

Table 3.1 Description of the six agro-ecological zones of Eritrea

Characteristics	Agro-ecological zone					
	Sub-humid	Arid high-land	Moist highland	Moist lowland	Arid low-land	Semi-desert
Nº sub zones (AEU)	3	3	10	8	12	19
Area (km^2)	1,006	3,143	9,302	20,363	43,115	48,772
Total area (%)	1	3	7	16	34	39
Slope range (%)	8-100	2-100	2-30	2-30	0-30	0-30
Altitude (m)	600-2,600	1,600-2,600	1,600-3,018	500-1,600	400-1,600	<100-1,355
Rainfall (mm)	700-1,100	200-500	500-700	500-800	200-500	<200
Temperature (°C)	16-27	15-21	15-21	21-28	21-29	24-32
PET (mm) (1)	1,600 - 2,000	1,600-1,800	1,600-1,800	1, 800-2,000	1,800-2,000	1,800-2100
DLGP range (days) (1)	60-210	0-30	60-110	50-90	0-30	0
MLGP range (days) (1)	90-240	30-60	90-120	60-120	30-60	<30

Source: FAO (1997a). (1) PET is Potential Evapotranspiration, DLGP is Dependable Length of Growing Period, and MLGP is Median Length of Growing Period

Three quarters of Eritrea is classified as arid and semi-arid agro-ecological zones. In most years, for most places, the mean rainfall is less than 500 mm and this combined with high-potential evapotranspiration (1,700-2,100 mm) results in dry conditions unsuitable for rainfed agriculture.

3.1.1 Sub-humid zone

The sub-humid escarpment, which is commonly referred to as the green belt, is located on the eastern slopes of the highlands. The areas covered include Semenawi Bahari, and the central and eastern escarpments. The climate varies from mild at the higher elevation to hot in the lowest parts. There are two growing periods.

The natural vegetation is extensively influenced by human activities. The vegetation cover is dense or open forest dominated by remnant evergreen afromontane plant species such as *Olea europea sub sp africana*, *Juniperus procera*, and *Carissa edulis*. To some extent, the natural vegetation has been cleared for cultivation and grazing, but not as extensively as in the adjacent moist highlands.

The dominant soil types are Lithosols, Cambisols, Regosols, and Fluvisols. The commonest crops are maize, sorghum, coffee, barely and Irish potato. Cattle, goat, sheep, camels, donkeys and poultry are common. The people living in the lower part of the escarpment are mainly pastoralists, while those at higher altitudes are sedentary farmers with transhumance movement of people and livestock from the hot and dry coastal areas to the cooler higher lands during the months of May and August.

Due to the bimodal rainfall regime and the occurrence of mist during most parts of the year, maize, sorghum, coffee and barley are grown. Vegetables and fruit crops are grown along riverbanks or in areas where the water is abundant and soil conditions permit. The productivity of the area is moderate to high, depending on slope and soil depth.

3.1.2 Moist highland zone

The moist highland agro-ecological zone covers the central and southern highlands and the Rora and Hager plateaus further north. The topography of this zone is dominated by mountains and escarpments. The dominant natural vegetation is degraded forest with typical plant species being *Juniperus procera*, *Olea africana*, *Cordia africana*, *Acacia oregena, Euclea schimperi*, *Euphorbia abyssinica*, *Acacia etbaica*, *Ocimum grandiflorum* and *Dodonea angustifolia*. The dominant soils are Lithosols, Cambisols, Luvisols, and Vertisols. Lithosols occur on steep slopes and soil erosion is often high in these areas.

The people depend on crop production and raise livestock for their livelihood. The dominant crops are wheat (*Triticum aestivum)*, barley (*Hordeum vulgare*), sorghum (*Sorghum bicolor*), maize (*Zea mays*), taff (*Eragrostis teff*), finger millet (*Elusine coracona),* horse bean (*Vicia faba*) and chick pea (*Cicer arientinum*). The productivity is moderate, with potentially yields for barley ranging from 0.5 to 2 tons per ha, and 1.0-2 tons per ha (median). Cattle sheep, goats, donkeys and poultry are widespread.

3.1.3 Moist lowland

The moist lowland zone is located in the southern and south-western parts of Eritrea. It includes the south-western lowlands, and the upper Mereb River (Hazemo, Mereb, Ubel and Ala Plains), where the topography is dominated by plains. The land is mostly flat or undulating with few mountains, small hills and plateaux. The natural vegetation is bush-land savannah. The following tree species dominate most of the area: *Acacia senegal, Acacia mellifera, Acacia seyal, Ziziphus spina christi, Balanites aegyptiaca, Adansonia digitata, Dalbergia melanoxylon* and *Boswellia papyrifera.* The dominant soil types are Cambisols, Vertisols, Luvisols, Lithosols, Fluvisols, and Regosols.

This area is relatively flat and has potential for crop and livestock production. Livelihoods depend on a combination of cultivation and livestock production (agro-pastoralism). The major crops grown in this zone are sorghum, sesame, cotton, and pearl millet. Cattle, sheep, goats, camels, and donkeys are common. The productivity of the area is moderate to high for sorghum (2.5-3.0 tons per ha; 3.5-4.0 tons per ha (median). There is potential for irrigated agriculture from river flow in the Gash, Barka and Setit rivers. This area is also good for grazing livestock and wildlife.

3.1.4 Arid highlands

The arid highland agroecological zone covers areas in the northern highlands, except Rora and Hager uplands, and Mount Ramlu in Denkalia. The topography is mountain plateau. The vegetation consists of bushland with scattered relics of the original afromontane plant species. The natural vegetation is less degraded than in the moist highland zone due to rugged topography and inaccessibility. The dominant soil types are Cambisols, Lithosols, Xerosols and Regosols. Major crops grown in this area are barley, sorghum and pearl millet. The productivity is low for barley, 0-0.5 tons per ha, i.e. 5-1.0 tons per ha (median). The population density is low, and people depend on crop production and livestock husbandry. Goats, sheep, cattle, sheep, camels are commonly reared. The potential production of this area is low, mainly due to low and erratic rainfall.

3.1.5 Arid lowlands

The arid lowlands cover northern Eritrea, excluding the coastal plains and the extreme northwest lowlands, and most parts of the lower parts of the eastern escarpment. The topography of this zone is dominated by undulating plains and small hills. The natural vegetation consists of shrubs and bushes with some scattered trees such as *Acacia mellifera, Acacia nubica, Cadaba rotundifolia*, *Ziziphus spina Christi* and A*dansonia digitata*. Along the river beds *Hyphaene thebaica, Acacia nilotica* and *Tamrix aphylla* occur. The common soil types are Xerosols, Cambisols, Fluvisols, and Lithosols.

Major crops grown in this area are sorghum and pearl millet. Although this zone has very limited potential for rainfed agriculture, areas where surface groundwater is available can be productive with irrigation. The productivity is low, with yields for sorghum between 0.4-1.5 tons per ha, i.e. 1.0-2.5 tons per ha (median) on good soils. There is potential for localised irrigation. This zone is important for livestock rearing and households keeping goats, camels, sheep, cattle and donkeys as a source of livelihood and as security to bridge times of adverse climatic conditions.

3.1.6 Semi-desert

The semi-desert agro-ecological zone is located along the entire Red Sea coast of Eritrea and its islands. In addition, it occupies small areas northwest of Eritrea in the lower watershed of the Barka and Sawa rivers. The altitude of this area varies from -70 m (below sea level, in the Dalol depression), to 1,355 m on Mount Ramlu in the southern Red Sea region. In this zone, the natural vegetation is a sparse coverage of bushes and grasses with trees in wadis (e.g. *Acacia tortilis*, *Calotropis procera*), scrubs, and different desert species. Mangrove species including *Avicennnia marina,* as well as coastal species such as *Sueda monoica and Tamrix aphylla* grow along the watercourses.

The dominant soil types are Xerosols, Solonchaks, Lithosols, Cambisols, Fluvisols, Regosols and Andosols. In areas where water is available, salinity problems limit crop production. The agronomic and grazing potential of this zone is low, mainly due to low rainfall. However, in areas where flooding occurs as a result of heavy rains in the highlands, maize, sorghum, pearl millet and water melon are grown under spate irrigation. The productivity of crops is very low except under irrigated conditions. Consequently, most people depend on rearing goats, camels, cattle and sheep. Livestock productivity is low. Along the coastal areas, salt works, trade and fisheries contribute substantially to the livelihoods of the population.

3.2 Altitudinal zonation and agro-ecological belts

3.2.1 Eritrean classification system of altitudinal belts

The climate of Eritrea ranges from hot and arid adjacent to the Red Sea to temperate in the highlands in isolated micro-catchments in the sub-humid zone. Total annual rainfall increases from north to south and varies from less than 200 mm in the north-west lowlands to more than 700 mm in the south-western lowlands. The amount of rainfall tends to increase with increasing altitude. As to areas covered by the different rainfall regimes, about 50% of the country receives less than 300 mm, 40% between 300 and 600 mm, and 10% more than 600 mm of rain per annum (FAO 1994, Haile et al. 1998[5]).

Most of Eritrea (70%) is classified as hot to very hot with mean annual temperatures of more than 27°C; about (25%) as warm to mild with a mean temperature of about 22°C; and the remaining parts (5%) as cool, with mean annual temperatures of less than 19°C. Habtemichael (2004[6]) divided the climate of Eritrea into the following broad climatic regions:

- Coastal area climate
- Eastern lowland climate
- Eastern escarpment climate
- Highland climate
- Western escarpment climate
- Western lowland climate

There is great variation in the major climatic parameters across Eritrea. Table 3.2 provides detailed information on the major climatic zones of the country.

Table 3.2 Climatic data of the major meteorological stations in the major agro-ecological zones of Eritrea

Table 3.2.1

a.	Asmara: climate of the moist highlands						b. Nakfa: climate of the arid highlands					
	Temperature ºC						Temperature ºC					
Month	Max.	Min.	Mean	RH* (%)	Rainfall (mm)	PET* (mm)	Max.	Min.	Mean	RH (%)	Rainfall (mm)	PET (mm)
Jan.	22.7	2.7	12.7	41	5	91	21.0	9.2	15.1	73	4	73
Feb.	23.7	8.1	15.9	39	3	98	21.6	9.5	15.6	71	6	80
Mar	24.9	9.7	17.3	38	10	131	23.7	10.4	17.1	66	8	115
Apr	25.1	11.1	18.1	47	30	131	25.7	12.1	18.9	66	17	128
May	24.9	12.1	18.5	46	21	141	28.4	13.0	20.7	51	36	151
Jun	25.2	12.2	18.7	44	41	132	29.9	16.7	23.3	43	32	156
Jul	21.8	11.8	16.8	68	194	114	28.1	18.2	23.2	59	67	146
Aug	22.0	11.8	16.9	71	162	113	27.3	17.2	22.3	62	110	132
Sep	23.2	10.8	17.0	52	16	114	28.3	15.7	22.0	49	38	127
Oct	21.5	9.8	15.7	56	13	104	24.9	11.2	18.1	60	17	110
Nov	21.3	8.5	14.9	59	25	78	22.3	10.5	16.4	74	10	77
Dec	21.9	7.5	14.7	52	5	76	20.8	8.9	14.9	78	4	64

Table 3.2.2

c.	Barentu: climate of the western lowlands						d. Fagena: climate of the eastern escarpment					
	Temperature oC						Temperature oC					
Month	Max.	Min.	Mean	RH (%)	Rainfall (mm)	PET (mm)	Max	Min	Mean	RH (%)	Rainfall (mm)	PET (mm)
Jan	32.5	14.8	23.7	45	0	126	18.2	11.2	14.7	n.a	103	57
Feb	31.1	14.6	22.9	40	0	133	19.2	11.6	15.4	n.a	123	63
Mar	35.0	16.1	25.6	37	1	173	20.5	12.7	16.6	n.a	66	87
Apr	37.3	18.8	28.1	36	10	191	23.0	14.4	18.7	n.a	55	107
May	37.5	19.1	28.3	36	22	207	26.1	16.6	21.4	n.a	48	140
Jun	34.0	17.0	25.5	41	74	183	29.0	19.7	24.4	n.a	22	172
Jul	30.3	17.8	24.1	65	142	144	27.0	18.4	22.7	n.a	125	157
Aug	29.1	17.0	23.1	69	178	134	27.3	18.4	22.9	n.a	120	157
Sep	32.0	17.1	24.6	55	78	149	27.6	18.2	22.9	n.a	57	143
Oct	34.3	18.0	26.2	47	8	176	23.7	15.0	19.4	n.a	120	109
Nov	34.0	17.0	25.5	49	3	130	20.4	13.1	16.8	n.a	87	72
Dec	32.3	15.7	24.0	48	0	116	18.4	11.9	15.2	n.a	122	56

Table 3.2.3

e. Keren: western escarpment							f. Massawa (coastal area)					
	Temperature °C						Temperature °C					
Month	Max.	Min.	Mean	RH (%)	Rainfall (mm)	PET (mm)	Max.	Min.	Mean	RH (%)	Rainfall (mm)	PET (mm)
Jan	28.7	12.4	20.6	48	0	119	28.3	22.7	25.5	74	30	108
Feb	29.9	12.8	21.4	42	0	131	27.9	22.6	25.3	76	31	99
Mar	31.6	15.2	23.4	38	2	165	29.5	23.9	26.7	73	17	143
Apr	33.8	16.9	25.4	34	20	177	31.6	25.7	28.7	72	14	168
May	34.8	17.7	26.3	30	29	179	33.8	27.8	30.8	66	6	184
Jun	33.3	16.7	25.0	37	58	171	36.7	29.1	32.9	53	0	194
Jul	28.6	16.9	22.8	56	138	128	37.7	31.2	34.5	53	5	203
Aug	27.3	16.3	21.8	68	150	105	37.8	31.6	34.7	56	7	228
Sep	30.5	15.0	22.8	49	52	129	36.1	29.9	33.0	60	3	195
Oct	31.6	15.5	23.6	34	3	149	33.8	28.1	31.0	62	15	170
Nov	29.9	14.9	22.4	40	4	117	31.5	25.4	28.5	68	18	129
Dec	29.0	13.3	21.2	45	0	108	29.4	23.7	26.6	72	35	112

Coastal area climate

The coastal area extends from the Gulf of Zula in the south to the areas bordering the Sudan in the north. It stretches for 300 km along the Red Sea with a width of 20 km at its maximum. The region is characterized by two distinct seasons: a winter rainy season and a dry summer season. The rainy season occurs between November and January in some years, and between January and March in others. It is during this period that most of the annual rainfall takes place. This period is characterized by an average temperature of 25.2°C, with relative humidity of about 73% and persistent cloudiness. The summer season is between April and October. This season is characterized by a hot climate with extremely high temperatures. During the dry season, in Massawa the average temperature rises to 31.7° C with relative humidity of 62% (*Table 3.2.3*). A continuous and intense insulation occurs during the same period. Occasional downpours take place, coinciding with precipitation in the highlands. The coastal region can be described as sub-desert.

Eastern lowland climate

The eastern lowlands are found in an area located at an altitude between 200 and 700 m. They mark the beginning of the eastern escarpment. The climate is similar to that of the coastal area but receives a higher amount of rainfall with greater temperature variation between day and night and as well as lower relative humidity values for most parts of the year. In summer, the climate is torrid, characterized by frequent storms caused by the convergence of hot air streams *(Kamsin)* coming from the Red Sea with cold air streams coming from the highlands.

Eastern escarpment climate

The eastern escarpment covers steep areas that drop in a straight line not exceeding 25 km from an altitude of 2000 m to about 700 m. Consequently, the climate varies considerably in relation to differences in elevation. In this area, the rains occur from October to March. In contrast to the low-lying areas, it has greater rainfall amplitude and intensity (*Table 3.2.2*). The rains are brought about by humid currents from the Red Sea, causing clouds. In the afternoons, the likelihood of rain and fog events occurs when the mountains are positioned perpendicular to the direction of the air currents (Hailemichael 2004). When the position of the mountains is less perpendicular to the direction of the blowing humid streams, only raindrops from fog occur. The area comprising Ghindae in the south and Gheleb in the north is typical of the first situation, in which the mountains are more or less perpendicular to the currents from the east. This region has an approximate length of about 50 km and represents the so-called 'eastern slopes'. Locally the area is called *Bahri* and includes the localities of Filfil and Faghena. Both locations benefit from a good annual precipitation of about 1154 mm and 1047 mm respectively (Hailemichael 2004).

The highland summer rains from April to September also reach this region. About 37% of the total annual rainfall occurs in summer. In Faghena, the average annual temperature and the average relative humidity are 19.3° C and 35% respectively. The part of the escarpment that is less perpendicular to the direction of the humid currents includes the escarpment which is perpendicular to the blowing currents. Hailemichael (2004) mentions that the predominance of winter rains is 67% in Ghindae area, but the predominance of summer rains is 86% in Gheleb and Nakfa areas.

Highland climate

The climate of the highlands covers most elevated plateaus with an average altitude of 2300 m but with higher ranges such as at Emba-Soira (3017 m) in the south. Stretching for about 135 km along its main axis, the area covers Adi-Tekelezan in the north to Zala-Ambesa in the south. Becoming narrower toward the north, its width is variable. The general inclination of the plateau is towards the west. Normally, the climate of the highlands is characterized by two major rainy seasons: the small and big rains. The small rains, locally known as *Akeza*, start in mid-March and continue until the end of May. The big rains, locally known as *Kremti*, start in mid June and end in mid September.

The climate of the highlands is temperate, with considerable ranges between the day and night. During the first morning hours of the winter (dry season) the temperature drops to around 0° C (*Table 3.2.1*). Average annual temperatures in Adi-Ugri and Segeneiti are similar to those in Asmara. Along the Eastern escarpment, the end of the big rainy season is followed by mist and fog formation. These atmospheric phenomena create a perpendicular micro-environment suitable for late cultivation of cereals.

Western escarpment climate

This region is the area comprising the western edge of the highlands up to roughly 850 m. The amount of rainfall diminishes gradually from the north to the south until the border with Sudan, and from the west until the area of Barentu. For most of the region, the only data available regarding precipitation are those from Keren where the annual rainfall reaches 410 mm (*Table 3.2.3*).

Western lowlands climate

Comprising the largest part of Eritrea, the western lowlands cover roughly one third of the entire area of the country. 90% of the rainfall occurs between March and September, with peaks in July and August. During the dry season, there is conspicuous temperature fluctuation between day and night. The months preceding the beginning of the rainy season are hot, with relative humidity, particularly during the early afternoon hours, reaching very low values.

The lowlands are much drier than the highlands and eastern escarpment, with a hot semi-arid to desert climate. For instance, in Akordat the average annual rainfall is only 320 mm. The area to the north of Akordat is even dryer, with annual mean rainfall of less than 200 mm. Tessenei receives average mean annual rainfall of 349 mm. Around Barentu average annual rainfall is about 519 mm.

Climate of Danakil Region

The Danakil region covers an area 360 km long and 55 km wide in the southern Red Sea zone of Eritrea. It borders the Red Sea coast, until the frontier with Djibouti in the south and Ethiopia in the west. Some towns such as Tio, located approximately 190 km south of Massawa along the road to Assab, receive an average annual rainfall of 120 mm. At Assab, the average annual rainfall is about 67 mm. The seasons in this region correspond approximately to those in the northern coastal region of Eritrea. However, the amount of rainfall is considerably less, with very high temperatures. Occasionally, areas located towards the interior part of the region are confronted with violent thunderstorms, flooding vast areas that do not normally receive any rainfall for years.

3.2.2 Thermal zones in Eritrea

Traditionally, the altitudinal zones of Eritrea are divided into four major categories. These are:

Altitude zone	Altitude range
1. Kolla (lowlands)	100 – 1000
2. Weyna Dega (midlands)	1000 – 2000
3. Dega (highland)	2000 – 3000
4. Wirchi	> 3000

Traditional altitudinal zones have distinctive temperature regimes. Temperature is inversely related to altitude.

Table 3.3 Thermal zones of Eritrea based on regression values, and weather and climate of Eritrea

	Temperature °C					FAO 1994
Altitude	Min	Max	Mean	Hailemichael 2004	Mean PET	Temperature regime
< 500	23.6	35.5	29.5	>27.5 °C	2019.5	very hot
500 – 1000	19.7	32.8	26.3	27.5 – 24.5 °C	1910.6	hot
1000 – 1500	16.2	30.3	23.3	24.5 – 21.5 °C	1811.6	warm
1500 – 2000	12.7	27.8	20.3	21.5 – 18.5 °C	1712.6	mild
2000 – 2500	9.2	25.3	17.3	18.5 – 15.5 °C	1613.6	cool
2500 – 3000	5.7	22.8	14.3	15.5 – 12.5 °C	1514.6	cold
> 3000	3.6	21.3	12.5	<12.5 °C	1455.2	very cold

Source: FAO 1994 and Habtemichael 2004

Owing to the diversity of the country's topographic features, the climate of Eritrea is broadly classified into six major regions.

Cool area *(Korari):* mean annual temperature of 10°C or less; rainfall is sufficient for at least one crop season.

Cool temperate (*Dega):* mean annual temperature range between 10°C and 15°C. The amount of rainfall is sufficient for at least one crop season.

Temperate (*Weyna-Dega):* the mean annual temperature is between 15°C and 20°C and the rainfall is sufficient for at least one crop season.

Hot land (*Kolla):* the mean annual temperature is above 20°C and rainfall is adequate for one crop season.

Semi-desert (*Hawsi-Bereka):* the mean annual temperature is above 20°C and rainfall not sufficient for one crop season.

Desert (*Bereka):* the mean annual temperature is very hot and the rainfall is scarce and not sufficient for one crop season without irrigation.

Box 3.1 Regression equations describing the relationship between altitude and temperature regimes in Eritrea

Minimum temperature (°C)	=	25.3 – (0.007 * altitude in m)
Maximum temperature (°C)	=	36.8 – (0.005 * altitude in m)
Mean temperature	=	31.0 – (0.006 * altitude in m)
Mean potential evapotranspiration (mm)	=	2069 – (0.198 * altitude in m)

These equations were derived from regression analyses using temperature data from 10 stations in Eritrea and northern Ethiopia.

3.3 Agro-ecology and agro-climatology

The Agricultural Sector Review and Project Identification (FAO, 1994) identifies six major agro-climatic zones. These zones have been defined based on agro-climatic and soil parameters. They are: the coastal plains, eastern escarpment "green belt", highlands, western escarpment, south-western lowlands and north-western lowlands (Bein et al. 1996[7]).

3.3.1 Coastal plains

The coastal plains are hot and dry with less than 200 mm annual rainfall and a potential evapotranspiration of over 2,000 mm. They are found between the coast and an area located at an altitude up to 600 m. They include the Bada area depression (70 m below sea level). The main soil types are highly saline gleyic- and ortho-solonchaks, containing harmful soluble salts. Andosols have good agricultural potential, provided irrigation is possible. Crop production is impossible without irrigation, and natural pasture resources are poor.

3.3.2 Eastern escarpment

Located between the coastal plains and the highlands, the eastern escarpment stretches from north-east to south-west. It covers areas with an altitudinal range of 600 to 2,000 m, with peaks reaching 2600 m. In many respects, this zone is unique, as it receives rainfall approaching 1,000 mm in isolated areas. It encompasses numerous micro-ecological zones determined by the interrelationship of altitude, rainfall, exposure and soils. Microclimates in the green belt range from sub-humid temperate to humid tropical. The "green belt" differs from all other zones as it is able to support permanent cash crop production such as coffee without irrigation because of the bimodal rainfall pattern.

3.3.3 Central highlands

The central highlands lie at an altitude over 1,500 m with mean annual rainfall of 500 mm. They are an area with a warm-to-cool semi-arid climate and potential evapotranspiration ranging between 1,300 and 1,800 mm. In this area, the rainy season normally lasts about three months, beginning in June and ending in August or early September (the big rains are known as *Kremti,* a local name to refer the rainy season). Besides the big rains, occasional showers come in March and April (small rains, known locally as *Akeza*). The predominant soils are chromic, eutric and calcic cambisols of a strong brown and red colour and with good agricultural potential.

There are three sub-zones with many common features, in particular major crops, which are distinguishable by differences in altitude, annual rainfall, relief, soils, population density and degree of environmental degradation. The sub-zones are the highlands, southern midlands and northern midlands:

Highlands: over 2,000 m altitude, 500-600 mm rainfall, very high population density.

Southern midlands: 1,500-2,000 m altitude, more than 700 mm rainfall and generally lower population density.

Northern midlands: 1,500-2,000 m altitude, less than 400 mm rainfall and low population density.

3.3.4 Western escarpment

The western escarpment lies in an altitudinal range between 600 and 1,500 m and has a warm to hot semi-arid climate. This area is a transition zone between the highlands and the western lowlands. In terms of climate, population density and farming systems, the soils are similar to those of the highlands. The dominant production system is an agro-pastoralist one. Farm sizes are larger than in the highlands, averaging 2-3 ha. The main crops are sorghum, finger millet, taff, maize, sesame, cowpeas and chickpeas. Shortage of fuelwood is less acute than in the highlands.

3.3.5 South-western lowlands

Flat, hot and semi-arid, the south-western lowlands lie at an altitude between 600 and 750 m. Heavy vertisols are predominant. The population density, both of people and livestock, is low. Extreme climatic variations do not occur and the rainfall, though only 400-600 mm, is relatively reliable. Most of the livestock are kept under a highly mobile nomadic pastoralist system. Many of the animals from the highlands migrate to the area during the dry season. The herdsmen stay in the area to browse their livestock on the riverine vegetation or migrate further to neighbouring countries.

Camels are the preferred animals because of their resistance to drought and because they are easier to feed during dry periods. The semi-sedentary agro-pastoralist system is predominant in the area but it is not easily differentiated from the nomadic system. During the rainy season, most of the livestock are kept near the homestead, but at the beginning of the dry season people move with their herds to the dry-season sites, where drinking water for livestock and pasture is available. Later in the dry season, one male family member takes the cattle further south in search of pasture while the rest of the family (mother and small children and husband) stay at the dry-season site and later move to the rainy-season site to prepare for the cropping season (FAO, 1994, Bein et al. 1996).

Women keep donkeys for short-distance transport of water and firewood. In the crop/livestock mixed production system, people do not shift homes during the year and crop production is more important. The livestock herds are similar to those in the agro-pastoralist system but with a tendency to keep fewer camels and larger herds of cattle. The main crops are sorghum, pearl millet and sesame, which are all drought-resistant. Traditionally, farmers have developed an important complementary activity of irrigated small-scale horticulture. The most common crops are tomatoes, onions, *okra*, bananas and peppers, all irrigated by open shallow ditches along the river beds. Recently, commercial farming has developed as a result of a policy of land distribution in the form of medium- and large-scale land concessions. Concessions may be both for large-scale rainfed production of sorghum and sesame or irrigated production of fruit and vegetables to supply the major cities and for export.

3.3.6 North-western lowlands

Bordering with the Sudan, the north-western lowlands covers areas with altitudes between 400 and 1,500 m. The climate of this particular area is hot and arid, with an average annual rainfall of less than 300 mm. Evapotranspiration is between 1,500 and 2,000 mm. Sustainable crop production is impossible without irrigation. The pasture resources are poor to moderate. Lopping trees, and obtaining leaves as livestock fodder during dry periods by shaking the branches of trees and shrubs, are common practices.

3.4 Soils according to FAO

Some local studies on surface soils have been reported by Murphy (1968[8]) and Haile et al. (1998). Due to lack of up-to-date soil maps, the soils of Eritrea can only be considered in a general way, with reference to some of the soil groups described by FAO (1994). The updated version of the classification (FAO 1997a[9]) identifies nine major soil types distributed over six agro-ecological zones of Eritrea (*Table 3.4*).

Table 3.4 *Major soil types in the different agro-ecological zones of Eritrea. The + sign represents occurrence and the - sign means the soil does not occur in the respective zone.*

Soil type	Agroecological zone					
	Moist highland	Arid highland	Moist lowland	Arid lowland	Sub-Humid	Semi-desert
1. Cambisols	+	+	+	+	+	+
2. Lithosols	+	+	+	+	+	+
3. Fluvisols	-	-	+	+	+	+
4. Regosols	+	+	+	-	-	+
5. Xerosols	-	+	-	+	-	+
6. Vertisols	+	-	+	-	-	-
7. Andisols	-	-	-	-	-	+
8. Luvisols	+	-	-	-	-	-
9. Solonchaks	-	-	-	-	-	+

Source: FAO (1997)

Soils with the highest agricultural potential (e.g. Luvisols, Fluvisols, and Vertic Cambisols) are mainly found in the moist highland and lowlands. Limited soil depth and steep slopes limit their potential in many places.

3.5 Local soil classification

Having a wealth of local knowledge, farmers are capable of identifying various soils in relation to their suitability for crop production. Table 3.5 provides local names and the corresponding international ones (FAO).

Table 3.5 Traditional soil nomenclature of soils in Eritrea

Local name	Soil type (FAO classification)	Description
Keih Hamed Keih Chebel	Cambisol	Are found on sloping and undulating land. While the soils on steeper slopes are shallow and those on undulating and relatively gentle slopes are stony, they are deep and good for agriculture. The availability of phosphorus may be low and limit agricultural production.
Konterah Meraguzo	Lithosol	Are mineral soils less than 10 cm thick, developing over hard rock. Most Lithosols are found on steep slopes exposed to erosion
Ekub Hamed /Tswar Hamed	Fluvisol	These are young soils developed in recent alluvial deposits of river plains, deltas, former lakes and coastal areas. Sediments consist of materials eroded from uplands mountains. Fluvisols are good for agriculture.
Duka (Baekel)	Luvisol	These consist of the accumulation of clay minerals and iron in the upper soil layers. Some Luvisols have a strong brown red B-horizon. These are referred to as chromic Luvisols. In soils with a heavy textured B-horizon, permeability may be low and good root distribution can be hindered. Available phosphorus content is low to moderate. Most Luvisols are good for agriculture
Waleka Ke-mit/Tselim Chebel	Vertisols	Very heavy clay soils found on flat areas. In areas with a pronounced dry season, the soils shrink and develop large, deep cracks in a polygonal pattern. During the wet season, the clay soils swell and cause pressure in the subsoil. Vertisols are of limited use for agriculture as they make it difficult to prepare the land. Vertisols are subject to water logging since drainage is poor. The organic matter content is often less than 1%.
Chewam Meret	Solonchaks	Highly saline soils containing soluble salts. They are poor because most plants cannot grow at all. In saline soils that have moderate to rapid permeability to a depth of at least 3m, the harmful soluble salts can be washed out and carried away in drained water. When this is completed, these soils may have agricultural potential, although it is necessary to take care that salts do not accumulate in the rooting zone.
Mut Hamed	Regosols	Soils without profile development. They occur in areas with little precipitation and on slopes subject to severe erosion. They consist mostly of loose soil minerals. They have limited agricultural value.
Meret Bereka	Xerosols	Soils in arid and semi-arid areas with a weakly developed horizon. Calcic-Xerosols have a strong accumulation of calcium carbonate, while Luvic-Xerosols have an accumulation of alluvial clay.
Tfae Esate Gomera	Andosols	Occur in volcanic regions. They are formed in volcanic ash material which is very light. The bulk density of these soils is very low. They are very rich in mineral nutrients, permeable, and have poor water retention capacity.
Not available	Arenosols	Coarse-textured sandy soils, low water retention capacity, very permeable and low in natural fertility. Rooting depth is often restricted by limited soil depth. They are poor for agriculture

Source: Negassi et al 2002[10]

3.6 Geology, topography

3.6.1 Geology

Geologically, Eritrea is divided into two distinct regions: the central and northern highlands, and the coastal areas. The central and northern highlands consist of the Pre-Cambrian Basement complex of the oldest formations found in Africa. The western highlands, with their typical flat-topped mountains, are mostly covered by tertiary basaltic flows. In western Eritrea, the basement complex was later covered by young quaternary sediments, but locally rocky outcrops of the basement complex occur (Mohr 1970[11], Drury et al. 1994[12]). The formations along the Red Sea coasts and the southern Danakil plains (southern Red Sea) are younger and consist of tertiary and quaternary sediments and volcanic rocks.

3.6.2 Topography

Topographically, Eritrea can be divided into three major regions: the eastern coastal zone, the highlands, and the western lowlands. The highlands stretch from south to north dividing the country into the eastern and western lowlands. In the south, the highlands are predominantly a plateau, while in the north dissected hills, mountains, and escarpments dominate. The western and eastern lowlands are predominantly flat areas with dome-shaped hills (Haggag 1961[13]). The highland of Eritrea is an extension of the highland of East Africa.

3.6.3 Vegetation

Land cover classifications of Eritrea lack many details about the natural vegetation. These classifications describe the major vegetation types (i.e. forest, woodland, scrubs, bushland, and grasslands) and list a few dominant plant species. This limits the use of land use classification for detailed biodiversity planning, where the major goal is conservation of as wide a range of species as possible. Nonetheless, this is the first step towards identification of major land cover classes for sustainable land use planning.

A number of different studies have been completed providing more information on detailed species composition of different regions of Eritrea (DoE 1999). Some of the studies have been conducted at continental level or regional scale (e.g. Sharma 1988[14], White 1983[15]). Although these studies do not provide detailed information about individual plant species composition at the local level, they provide valuable insights which are not revealed by land cover classification systems. Some of the most important points revealed by these studies are the following:

- They provide an indication of the extent and distribution of the natural vegetation, which is likely to have been present before the most recent human influence; this can provide a baseline from which human influence can be assessed.
- They provide an indication of the significance of Eritrean natural vegetation types in terms of regional and continental conservation priorities.

- They provide access to descriptions of the species composition of similar vegetation found in adjacent floristically similar regions. Given the shortage of species botanical information in Eritrea, this can greatly assist ongoing efforts to better describe Eritrean natural vegetation in a broader sense.

FAO (1997b)[16] has produced the most recent, detailed analyses of the existing natural vegetation cover of Eritrea. This forest cover map provides the fine-scale detail which can be used to locate potential species-rich sites within which conservation management might be prioritised.

White's Vegetation Map of Africa

The Vegetation Map of Africa by White (1983) was originally made to document regions of the continent from which groups of associated unique species evolved – the so-called regional centres of endemism *(phytochoria).* This map listed 20 major regional centres of endemism, of which 4 (the Sudanian, Somali-Massai, Afromontane, and Sahel regions) are well represented in Eritrea (White 1983, Thulin 1983[17], Friis 1992[18]). The Sahara regional transitional zone is limited to an isolated area along the southern Red Sea coast. Within these regions, similar vegetation types are grouped into mapping units (*Table 3.6*). In Eritrea, there are nine mapping units, which represent nine vegetation types (*Figure 3.2*). Within these major regions, similar vegetation is grouped into mapping units, marking the geographic extent of essentially similar vegetation associations; i.e. where particular genera of species of plants are characteristically found growing together. Eritrea does not possess any of the high-altitude afromontane *phytochoria* (number VIII on *Figure 3.2*), but this regional centre of endemism cannot be separated from the number VIII region on the vegetation map (*Figure 3.2*).

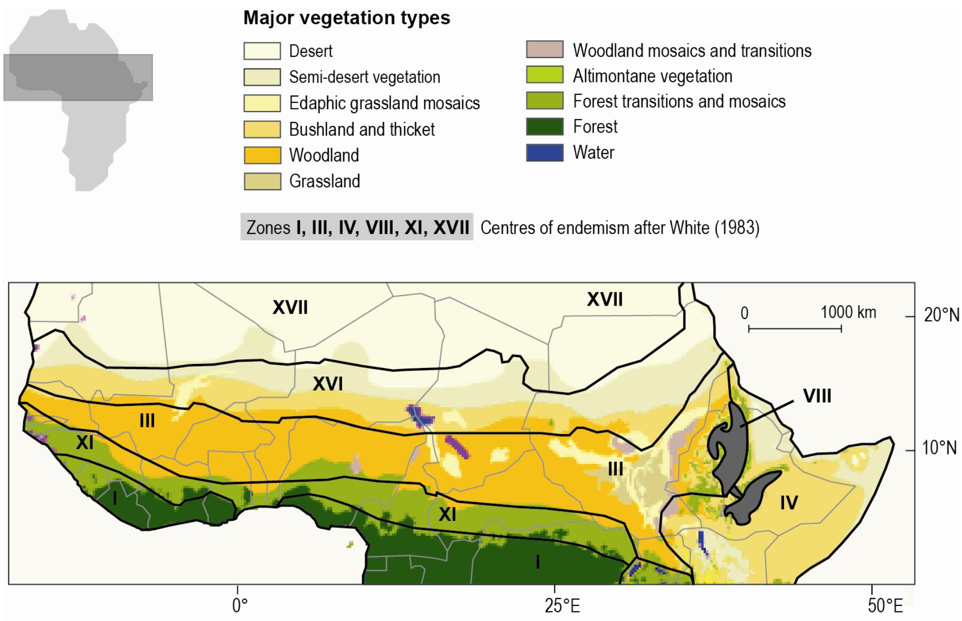

Figure 3.2 *Part of White's original vegetation map of Africa (1983) combined with the UNESCO vegetation map of Africa (after White1983), showing the main phytochoria as defined by White (Data processing: UNEP/GRID-Geneva)*

Table 3.6 *Vegetation mapping units and the main vegetation types present in Eritrea (White 1983)*

Phytochoria nº in Africa	Name of the centre of endemism (*Phytochoria)*	Vegetation type represented in Eritrea
VIII	Afromontane region (afro-alpine archipelago-like region of endemism)	Undifferentiated montane vegetation
III	The Sudanian regional centre of endemism	Undifferentiated woodland Ethiopian type
IV	The Somalia-Massai regional centre of endemism	i. East African evergreen & semi-evergreen bushland and thicket
		i. Somalia-Massai Acacia-Commiphora deciduous bushland and thicket
		iii. Somalia-Massai semi-desert grassland & bushland
	Sahel regional transition region	Sahel (Acacia) wooded grassland and Sahel (Acacia) deciduous bushland
		Sahel semi-desert grassland and transition to Sahara
XVI	Sahara regional transition	i. The Red Sea coastal desert
		ii. Wadis & bare/open desert

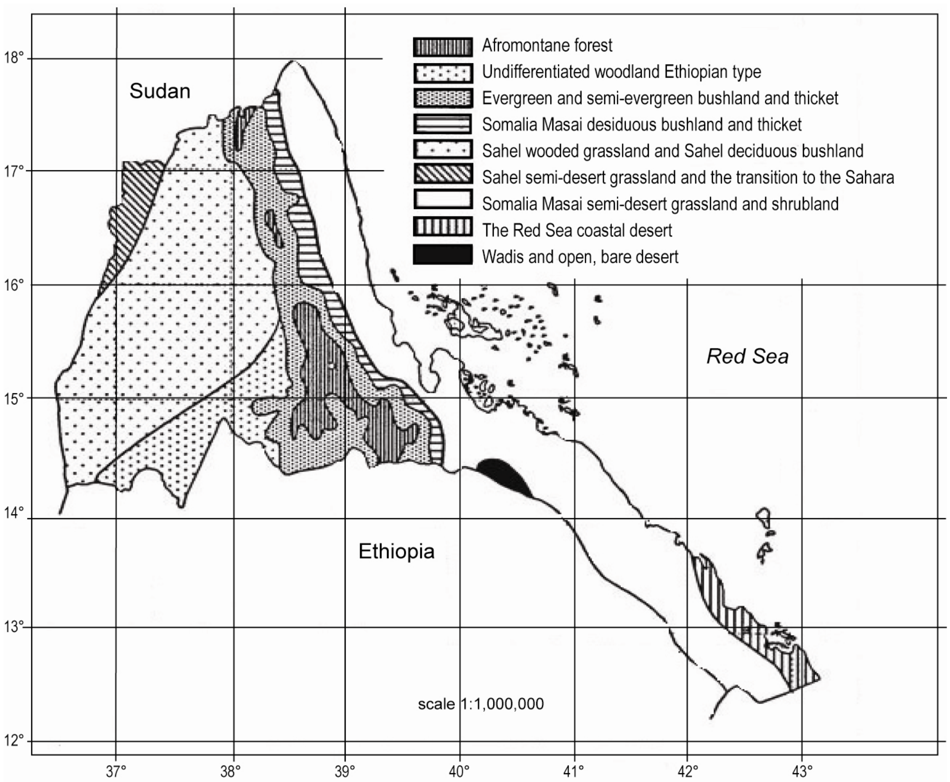

Figure 3.3 *The vegetation map of Eritrea based on the vegetation map of Africa (Ogbazghi 2001)*

The Afromontane region

The undifferentiated montane vegetation type is part of the larger *phytochoria* afromontane region (afro-alpine archipelago-like region endemism) and afro- alpine archipelago region of extreme floristic impoverishment. This area is part of a larger area that extends from the Loma Mountains and the Tinga Mountains in Sierra Leone in the west to the Ahl Mescat Mountains in Somalia to the east and from the Red Sea hills (17ºN) in the Sudan in the north, and to the cape (34ºS) in the south. The flora as a whole are estimated to contain over 4000 taxa, of which 75% are likely to be endemic to this regional centre (DoE 1999[19]).

The representation of this vegetation in Eritrea comprises the northern-most extent of the larger belt of this regional centre of endemism, which covers the Ethiopian highlands. This extension into Eritrea runs from the Ethiopian border northwards along the highland plateau and escarpment to the east of Adi-Keih Asmara road, broadens around Asmara, and then tapers into two isolated patches north of Keren at the Nakfa and Hager mountains. The Eritrean highlands plateau, notably drier than that of most of the afromontane regional centre of endemism, is represented here mostly by sub-type single dominant afromontane forest of *Juniperus procera*.

Juniperus procera has scattered distribution on the eastern side of Africa from the Red Sea hills in the Sudan, Eritrea (Jones, 1991[20]), and Arabia to the Nyika plateau in northern Malawi and Zimbabwe (Rendle 1969[21], Hall 1984[22]). *Juniperus* occurs mostly on drier slopes of mountains between 1800 and 2900 m, but it occasionally appears as low as 1000 m. In most cases, the amount of rainfall is between 1,000 and 1,150 mm per year, but well developed stands of forest more than 30 m tall occasionally occur where the rainfall exceeds 1,250 mm per year. *Juniperus* is also present as an emergent in scrub forest and evergreen bushland where the annual rainfall is as low as 650 mm, and this may represent its original habitat. *Juniperus procera, Nuxia congesta*, *Kigelia africana* (Bein et al 1996[23])

The Sudanian region: undifferentiated woodland

The undifferentiated woodland is marked as extending into Eritrea from Ethiopia and running through eastern Gash-Setit south of Barentu and up to Keren; it is bordered to the north by the Sahel regional transition region and to the east by east African evergreen and semi evergreen bushland and thickets. This vegetation type is found in the moist lowland agroecological zone of Eritrea.

Variations in soil types occur at the local level. On the plains, dark cracking clay soils dominate and the area is seasonally waterlogged. On sloping areas, which are well drained, the dominant tree species are *Anogeissus leiocarpus, Combretum collinum,* and *Combretum hartmannianum,* with *sporadic Sterculia setigeria. Balanites aegyptiaca, Boswellia papyrifera, Commiphora africana, Dalbergia melanoxylon, Erythrina abyssinica, Gardenia ternifolia, Lannea schimperi, Lonchocarpus laxiflorus, Piliostigma thonningii, Stereospermum kunthianum and Terminalia brownii* are common throughout the area.

The Somalia-Massai regional centre of endemism

In Eritrea, the east African evergreen and semi-evergreen bushland and thicket form a thin fringe around the upland forest undifferentiated montane vegetation, occupying large areas in the south around Senafe and Adi-Keih and then running along the east and west escarpment to the east of Keren and as far as the border to the Sudan. The vegetation type occurs on the drier slopes of mountains and upland areas in east Africa, from central Tanzania to Eritrea and beyond. It often forms an altitudinal ecotone between montane forest, especially *Juniperus* forest above, and deciduous *Acacia-Commiphora* bushland and thicket below. This vegetation type varies greatly in composition and richness, but certain genera and species are nearly always present, such as *Carissa edulis*, *Dodonea angustifolia*, *Olea europaea sub sp africana, Tarchonanthys camphorates*, species of *Acokanthera*, *Euclea*, *Sansevieria* and *Teclea* and succulent species such as Aloe and Euphorbia.

Somalia-Massai *Acacia-Commiphora* deciduous bushland and thicket

Deciduous bushland and thicket is the climax vegetation over the greater part of the Somalia-Massa region. Characteristically, the dominant Acacia and Commiphora species are spinous bushes 3-5 m tall and dense even in the more open types except along game and cattle tracks. In higher rainfall areas, especially on rocky hills, the emergent trees occur closer together and are a little taller, though scarcely over more than 10 m and might be considered woodland. Although most of the plant species are deciduous, evergreen contributes about 2.5 to 10% to the phytomass. Even when the bush cover is less than 40%, the bush remain physiognomically dominant and contribute to the phytomass. Although there is appreciable variation in floristic composition, species of Acacia, Commiphora, Capparidaceae and Grewia are nearly always present (DoE 1999). Overall, *Acacia mellifera, Acacia nilotica, Commiphora africana, Commiphora campestris, Commiphora erythraea, Commiphora mollis, Commiphora schimperi, Balanites orbicularis, Boscia angustifolia, Cadaba farinosa, Cassia spp., Dobera glabra, Euphorbia schefleri, Lannea spp, Salvadora persica, Sterculia africana, terminalia orbicularis, Grewia spp. Delonix elata, Adansonia digitata, Terminalia spinosa, Euphorbia candelabrum* are present.

Somalia-Massai semi-desert grassland and bushland

Where annual rainfall is between 100 and 200 mm, semi-desert grassland is dominated by *Eragrostis hararensis*, *Panicum turgidum* or *(asthenatherum) glaucum* cover on deep sand. On the coastal plains, the principal shrubby species are *Aerva javanica, Jatropha pelargoniifolia (glandulosa), and Farsetia longisiliqua.* Further inland, dwarf shrub lands on gypseous soils are composed of *Aloe breviscpra*, *A. rigens*, *A. scobinifolia*, *Euphorbia cuneata*, *Euphorbia multiclava*, *Ipomaea sultani*, *Kelloronia quadricornuta*, *Lasiocorys argrophylla, Lyceum europaeum, Ochradenus baccatus* and *Zygophyllum hilderbrandtii.* Shrubby species are most abundant in overgrazed and eroded areas; but it is possible that grasses including *Chrysopogon plumulosus* and *Dactyloctenium robecchii* were formerly dominant. Gypseous soils support a considerable variety of succulent endemic species such as *Euphorbia spp*. (*E. columnaris*, *E. sepulta*, and *E. mosaica)* and *Dorstenia gypsophila* and *Pelargonium cristophoranum*. Stapeliads, however, appear to occur on limestone rather than gypsum (DoE 1999).

Sahel regional transition region

In Eritrea, this vegetation type covers the entire western lowlands except for a small area in the north-western lowlands bordering the Sudan. The vegetation covers all the land to the west and north on a line running from Omhager and Barentu to Keren and then north along the western escarpment to the Sudan border. White's vegetation description of the area is heavily dependent on a few sites in West Africa Sahel and Sudan that may not be representative of the mapping unit in Eritrea. With the exception of the riverine vegetation, the vegetation is mainly dominated by acacia wooded grassland and deciduous bushland.

Acacia wooded grassland

Acacia tortilis, Acacia laeta, Commiphora africana, Acacia senegalensis, Balanites aegyptiaca, Boscia senegalensis, Maerua crassifolia and Leptadenia pyrotechnica occur on these grasslands. In the south they reach heights of up to 8 m with a stem up to 1.3 m. Further north, the vegetation becomes shorter and bushy and most of the species rarely exceed 4 m in height. Grass species include *Cenchrus biflorus*, *Schoenefeldia gracilis*, *Aristida stipoides* and *Tragus racemosus* and *Andropogon gayanus* are found in localized areas. In heavily degraded lands, *Boerhavia coccinea* and *Tribulus terrestris* are found.

Sahel *s*emi-desert grassland and the transition to Sahara

This vegetation type, widespread in the Sudan, covers the western section of the western lowlands in the areas drained by the Tuluki and Ali Mereb rivers. This is the driest vegetation type found in the western lowlands and should show strong affinities with the vegetation of the Sudan to Khartoum. This more or less corresponds to the western section of the semi-desert agro-ecological zone of Eritrea.

In this area, the amount of mean annual rainfall does not exceed 200 mm. Because of this, grassland is the most prevalent vegetation on deep sandy soils. It is usually a mixture of bushes and small bushy trees, the density of which is determined by local conditions such as moisture availability and soil characteristics. Today, like many parts of the country, the whole area has been subjected to intense human activity. Consequently, the extent to which treeless areas are natural is largely speculative (DoE 1999). The crown cover of woody species is usually less than 10%. Woody plants are sufficiently numerous to constitute bushland on rocky outcrops and water-receiving sites. Dominant plant species are *Acacia tortilis, Commiphora africana, Balanites aegyptiaca, Boscia senegalensis, Leptadenia pyrotechnica, Acacia laeta and Acacia ehrenbergiana.* All except the last occur throughout the southern Sahel region, where trees attain larger size. In the drier part of northern Sahel, these species never exceed 5 m in height, and often not more than 2 m. *Salvdoria persica* and *Tamarix appylla* dominate soils influenced by brackish water.

The most extensively occurring grasses are more or less similar to the Sahel deciduous bushland, and include *Cenchrus biflorus*, *Schoenefeldia gracilis*, *Aristida stipoides* and *Tragus racemosus*. They are characteristic of the southern Sahel. In northern Sahel, however, certain desert grasses, principally *Panicum turgidum* and *Stipagrostis pungens*, which are completely absent from the southern Sahel, are locally abundant and increase their abundance towards the north. The transition to the Sahara is not gradual, but is greatly modified by local edaphic factors, particularly the relief of the sand covering. The relation between rainfall distribution and species composition and cover requires much more detailed site-specific studies.

Red Sea coastal desert

The Red Sea coastal plain, which is 15 -20 km wide, receives very little rainfall. Apart from halophytic communities on the littoral itself, the plain is devoid of vegetation except in the wadis. Inland from the coastal plain a chain of rugged mountains with peaks over 2000 m high runs along the entire length of the Red Sea. Their summits intercept cloud moisture from orographic rain or condensation; this feeds permanent springs and contributes to the water supply of tunads and wadis associated with these mountains.

Littoral salt marshes are characterised by species such as *Arthrocnemum glaucum*, *Nalocnemurn strobilaceum*, *Zygophyllum album*, *Nitraria retusa* and *Suaeda monoica*. Ground cover varies between 5-100 % in the wadis of coastal plains. Saline areas have a dense growth of *Juncus arabicus* and *Tamarix spp*. Elsewhere in the wadis, *Acacia tortilis*, *Zilla spinosa*, *Capparis decidua*, *Galligonum comosum*, *Lasiurus hirsutus*, *Panicum turgidum* and *Retama retam* are characteristic species. Springs emerging from the mountainous areas provide habitat for fern species such as *Adiantum capillus-veneris*, bryophytes such as mosses and liverworts, and *Ficus pseudosycomrus*. Other marshy species such as *Phragmites australis* and *Imperata cylinderica* are also found. There are 13 species in the family *Moringaceae* (Price 2000[24]). The wadis in the mountains are rich in flora including the occurrence of *Moringa peregrine*, which produce excellent oil and fuelwood. These species are native to India, the Red Sea area and parts of Africa, including Madagascar. *Moringa oleifera* is the most widely known species but other species deserve further research.

Wadis and open desert

This vegetation type is represented by the northernmost part of the Danakil depression across the border between Ethiopia and Eritrea (Dalol depression). The vegetation description given by White (1983) is mixed and may not be particularly representative of the Danakil vegetation. The highlands of Danakil area, especially around Mount Ramlu in the south, possess richer more varied vegetation types. While these ecosystems are known to have richer fauna than the low-laying parts of the Danakil, detailed information is wanting on local biodiversity. Apart from the oasis, the wadis are the only desert habitat where trees and large bushes are found. There are four main vegetation types*:* *Tamarix* communities, *Acacia* communities; *Hyphaene* communities and those that are representative of bare deserts (*psammophilous* and Hamada communities). The agro-ecological zone map of Eritrea shows that this vegetation type falls within the coastal semi-desert agroecological zone and does not specify the existence of this particular vegetation type. It does, however, specify that Mount Ramlu in the southern Red Sea falls within the arid highland agro-ecological zone, but without making particular reference to unique vegetation types.

Shifting sand dunes are devoid of vegetation. Desert and sandy spots are dominated by ephemeral helophytes. Woody species include *Acacia tortilis* sub species *radiana*, *Acacia ehrenbergiana, Maerua crassifolia, Acacia nilotica Balanites aegyptiaca Capparis decidua, Salvadora persica, Ziziphus* spp; by and large the physiognomy of these communities is similar to that of the Sahel region.

3.7 Forest cover and its decline

Forest cover is dynamic, changing rapidly in response to changes in land use owing to increase in population, development and demand of the population for food, shelter, and clothing. Understanding the forest cover is an essential element in designing sustainable land management plans at small catchment area levels as well as on large watershed levels. It also provides valuable physiognomic information for much more detailed assessments of the dynamics of the vegetation cover over time. Preparation of forest cover map is a complex process. It requires knowledge of plant taxonomy, vegetation ecology and Geographical Information System (GIS) skills to create a uniform map.

A century ago, about 30% of the total land area of Eritrea is reported to have been covered by forests. This figure dwindled to 11% in 1952 (NEMP-E 1995[25], Bein et al. 1996). In 1960, it was estimated to be 5%. Today closed and open forest cover account for less than 1%, while about 60% of the country is covered by bushland.

A forest map of Eritrea (Scale 1: 250,000) has been prepared from GIS maps produced from LANDSAT-TM satellite imagery taken over the period 1984-1989 (DoE 1999). In a study carried out to support the forestry and wildlife sub-sector, aerial check-up of the major closed to medium-closed forest areas (FAO 1997a) confirmed that little change took place in closed forest cover between 1989 and 1999, with the exception of some vegetation losses in areas south of Asmara towards the Ethiopian border, in Gash-Setit, and in the area south and southwest of Nakfa. Recent studies on the causes of decline of forest show that several interrelated factors have contributed to it. Land clearing for commercial and subsistence agriculture, overgrazing, consumption of wood for fuelwood, construction of traditional houses, drought, and land clearing are the main causes (World Bank 1994[26], NEMP-E 1995, Haile et al. 1996[27], Bein 1998[28]).

During the long history of subsistence agriculture and especially after the introduction of commercial agriculture, many forests were converted into agricultural land. The seriousness of the problem was already noted during the Italian colonial period (Fiori 1912).[29] With the increase in population, land clearing was extended to steep areas unsuitable for cultivation. Furthermore, increased demands for firewood and the use of wood for the construction of traditional houses had adversely affected the forest cover (Haile et al. 1996). Licensed commercial exploitation of timber, fuelwood, and charcoal has further aggravated the problem (Jones 1991, Bein 1998). This situation is likely to remain as it is because the main source of domestic energy in the country is still wood (Habtesion 1997[30], FAO 1997b).

Grazing pressure has intensified during the last century. As a result of improved veterinary services, the livestock population has increased substantially. For instance, from

1946 to 1976, the number of goats, sheep and cattle increased by 46% (Bein 1998). Recent estimates were 1.65 million Tropical Livestock Units (FAO 1994, Haile et al. 1996). Grazing pressure is widespread throughout the country and is particularly severe during the dry season. There are no systematic data on the effect of the size of the livestock population on the forest cover but widespread degradation and lack of regeneration of many tree species due to overgrazing is evident everywhere. Land tenure, particularly the *'Dessa'* system with its periodic redistribution of arable land among villagers, provides no incentive for farmers to carry out permanent improvement to the land. Lack of tree tenure is the cause of neglect by the local communities to protect and plant new trees on their own farms (Kebreab 1996[31], Bein et al. 1996).

In recent decades persistent rainfall fluctuation has been recorded. For instance, the rainfall records in Asmara (1903-1932) show that of these 30 years, only in 13 years has rainfall exceeded the mean annual value of 518 mm, while in the remaining 17 years it was much less. Later rainfall records (1933-1962) for the same area and other meteorological stations in the country show a similar pattern. The effects of drought on the vegetation are not precisely known but areas affected by drought are usually followed by tree mortality (Ogbazghi 2001[32]). Many tree species were severely affected following the drought of 1968-1973 in the Sahel region and the drought cycle appears to repeat itself every 7 to 10 years. The effect of drought in this area was exacerbated by increased population pressure (White 1983, Workineh 1987[33]).

The negative effects of the 30-year war of liberation (1961-1991) on forest resources have been emphasised in the Environmental Management and Action Plan of Eritrea (NEMP-E 1995, Bein 1996). The most recent border conflict between Eritrea and Ethiopia (1998 - 2000) has had a tremendous impact on the forest cover. It is, however, difficult to give precise figures on the extent of deforestation caused by war. Frequent bombardment and fires killed trees, and many were cut to provide firewood and to construct trenches and military sheds. As the forest and woodlands were regarded as hiding places for combatants, they were regarded as a nuisance and recklessly cleared (Haile et al. 1998).

FAO (1997b) identified three broad forest/woodland cover types. These are the highland forests, *Acacia* woodlands, and riverine forests. In the highlands, the forests have been largely destroyed or degraded. Only remnant pockets of forests now survive in isolated grooves and ravines, sacred places, monasteries and religious sites. In the lowlands and lower parts of the escarpments, the *Acacia* woodlands occupy a quarter of the surface area of the country. Riverine forests are found along the Gash-Mereb, Setit and Barka rivers in the lowlands, where *Doum* palm (*Hyphaene thebaica*) is an important constituent. On the coastal plains, tree cover becomes increasingly sparse towards the sea. In some places, mangroves border the coast, the main species being *Avicennia marina and Rhizophna spp*. For practical purposes MoA (2002) classified the natural vegetation cover into six major categories. This classification does not strictly follow the definition of what constitutes a forest. The six categories are:

1. Highland forest: closed to medium-closed and open forest, composed of a mixture of coniferous species (Juniperus procera) and broad-leafed species African olive (Olea europea sub species africana) and associated species;

2. Mixed woodlands: Acacia (closed, medium-closed and open woodlands) and associated species, occurring mainly in the south-western lowlands, but also found in restricted areas elsewhere in the country;
3. Bush or shrub vegetation: which is the dominant cover in Eritrea
4. Grasslands to wooded grasslands: which occur in many parts of the country;
5. Riverine forest: composed essentially of Doum palm; it is common in the western lowlands and is frequent in the eastern lowlands;
6. Mangrove: occurring in many spots along the coast and concentrated mainly around Assab and between Tio and Massawa.

At the national level, the percentage of the various land cover categories is given in Table 3.7. Based on this classification and relating to the FAO 1997 categorization, the natural vegetation constitutes 0.8% highland forest, 11.3% close, medium and open woodland; 63.8% grassland/wooded grassland/bush land; and 1.6% riverine and mangrove forests.

Table 3.7 Vegetation types and area covered in Eritrea

Vegetation type	Area covered (km^2)	Percentage of total land area
Closed-medium forest	591	0.5
Open forest	410	0.3
Riverine forest	1,865	1.5
Mangrove	64	0.1
Closed-medium closed woodland	4,533	3.6
Open woodland	9,541	7.6
Wooded grassland	25,577	20.3
Bush land	53,824	42.7
Agricultural land	8,712	6.8
Barren land	18,265	14.4
Others	234	0.2
Not classified	2,172	1.7
	125,788	100.0

Source: FAO (1997b)

Table 3.8 Vegetation types and area covered in the six administrative regions of Eritrea

Land use category	Administrative region					
	Anseba	Maekel	Debubawi Keih Bahri	Debub	Semenawi Keih Bahri	Gash – Barka
Closed-medium forest	2.37	13.03	0	6.26	78.34	0
Open forest	32.44	0	0	3.66	63.9	0
Riverine forest	18.28	0	2.31	5.31	5.9	68.20
Mangrove	0.00	0	70.31	0	29.69	0
Closed-medium-closed woodland	11.54	0.18	0	9.88	18.35	60.05
Open woodland	9.44	0.19	12.95	15.42	16.30	45.7
Wooded grassland	54.52	0.20	14.38	3.55	2.62	24.74
Bush land	7.32	0.52	17.75	2.03	54.65	17.7
Agricultural land	10.23	0.02	56.63	0.63	24.81	7.68
Barren land	6.05	9.14	0	43.68	9.84	31.29
Others	1.70	16.6	49.36	0	3.83	28.51
Not classified	26.75	0	0	0	0	73.25
(%) of total area	18.11	1.01	19.89	6.35	30.79	23.85
Total area (Km^2)	22,785	1,275	25,017	7,992	38,724	29,994

Source: Eritrea support to forestry and wildlife sub-sector pre-investment study TCP/ERI/6712 (F). The data source was originally TM 1984-89 mosaic images produced by S. Drury and interpreted by M. Saket, based on 1: 250,000 topographic base maps (series EMA 3)

3.8 Crops

3.8.1 Agro-biodiversity

Agro-biodiversity is a new name for a very old phenomenon. It may be broadly described as the biological variety contained within those areas of land altered by mankind to enhance production of natural resources for human utilisation. This broad description helps to separate agro-biodiversity from natural biodiversity, although the boundary between the two is not easily determined.

3.8.2 Crops

A crop is any plant that is grown in significant quantities to be harvested as food, fodder, shelter, or clothing or for any other economic purpose. Eritrea has been a site for human settlement for several thousand of years (DoE 1998)[34]. For much of this time, the region has been almost completely isolated from the rest of the world, which enabled the evolution of independent agricultural production systems and the domestication of specific crops. Almost all of the seed crops from south-western Asia and the Mediterranean regions are represented in Eritrea. There is very high genetic variability in wheat and barley (Harlan, 1975[35], 1987[36]). The climatic and geographic variations of Eritrea create favourable local conditions for the growth of different cultivated crops. Following traditional farming systems for centuries, subsistence farmers have passed on the genetic diversity of their crops from generation to generation without major changes and modifications.

Due to man-made and natural calamities caused by war, drought, and plant and animal pests, ecosystems have been seriously affected by genetic erosion during the past 50 years. Thus the present capacity of ex-situ conservation in gene bank storage of crop genetic resources must be strengthened and supplemented by strong in-situ conservation in farmers' fields through rigorous and accountable programmes.

Eritrea as a centre of diversity of major crops

The Russian scientist N.I. Vavilov visited the highlands of Eritrea and Ethiopia, and in his writing confirmed that the Abyssinian plateau was one of the centres of origin and diversity for a number of crops (Vavilov 1926, 1951[37]). The terms "centre of origin", and "centre of diversity", should be well understood.

Centres of Origin: Centres of origin are areas where one or more plant species were originally domesticated by man. They are characterised by the presence of wild relatives in the wilderness portions of the same areas (*Figure 3.4*).

Centres of diversity: Centres of diversity are those areas where a wide range of varieties of one or more of particular species are found, although wild relatives are not found in the same area.

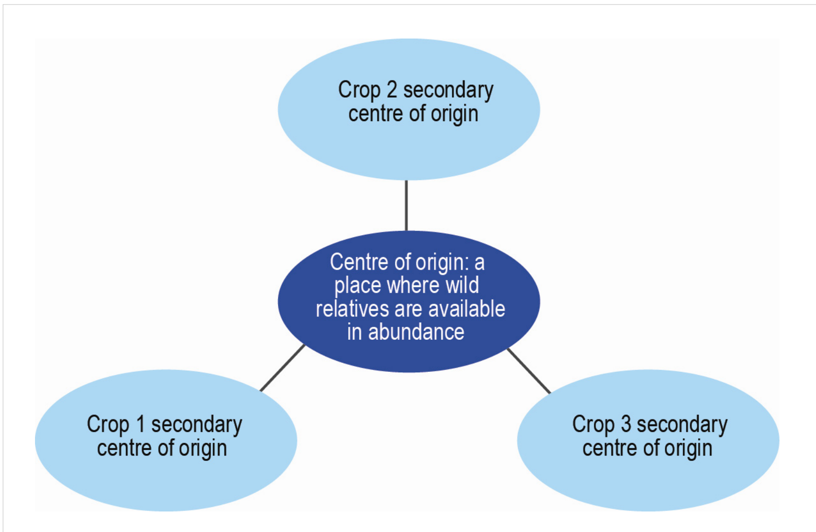

Figure 3.4 *Illustration of the concept of origin and secondary centre of diversity*

Eritrea is a globally significant centre of diversity for a number of crops (*Table 3.9*). For some species, notably sorghum, taff and pearl millet, Eritrea may be part of the centre of origin for the domesticated crops. In most cases, however, the crop diversity found in Eritrea reflects long-standing and widespread use of crops following their introduction from elsewhere. For such crops, the country represents part of the secondary centre of diversity (Harlan, 1987, Puseglove, 1966[38], 1968[39]), alongside the major crops which may have originated in the horn of Africa (Simonds 1976[40], Zeven 1975[41], Tivy, 1997[42]) *Table 3.9*).

Table 3.9 Eritrea as a centre of diversity and centre of origin of crops

Centre of origin	Crops	Crop species
Primary centre of origin	Cereals	Sorghum (*Sorghum bicolour*), Taff (Eragrostis taff), Pearl millet (*Pennisetum typoids*), Finger millet (*Eleusine coracona*), oats (*Avena spp*).
	Pulse	Chick pea (*Cicer arientinum*), Grass pea (*Lathyrus sativus*), Cow pea (*Vigna unuiculata*, fenugreek (*Trigonella foenum-graecum*,
	Oil Crops	Sesame (*Sesamum indicum*), Niger seed (*Guizotia abyssinica*), Safflower (*Carthanus annuus*),
	Fruits and vegetable crops	Okra (*Abelmoschus esculentus*), Mustard (*Brassica spp*), watermelon (*Citrullus lanatus* and others - the main crops for which Eritrea is part of the secondary centre of diversity.
Secondary centre of diversity	Cereals	Barley (*Hordeum vulgare*), Duram wheat (*Triticum durum*), Maize (*Zea may*),
	Pulses	Faba bean (*Vicia faba*), Linseed (*Linum usitatissiumum*),
	Oil crops	Groundnuts (*Arachis hypogaea*)
	Fruits and vegetable	Potato (*Solanum tuberosum*), Tomato (*Lycopersicon esculentum*), Banana (*Musa paradisca*), orange and lemon.

Information on local landrace diversity for most crops in Eritrea is lacking. Since 1991 collection and documentation of local Eritrean landraces has taken place at the Plant Gene Bank, which now holds more than 1200 accessions of cereals, legumes and oil crops (DoE 1999).

Crop production

In Eritrea, rainfed production accounts for about 95% of the national crop supply. Crop productivity is extremely low mainly because of the traditional nature of agriculture, pests and disease outbreaks, weeds, and low and variable rainfall. Average yields are in the order of 0.8 0.9 tons per ha (Mesghena and Bissrat 1997[43]). The national average for most cereals does not exceed 0.74 tons per ha (World Bank 1994). Enhancing agricultural production requires a thorough understanding of the major site-specific factors that define, limit or reduce yields.

3.9 Questions and issues for debate

1. Why are remnant forests confined to isolated habitats such as pockets and groves, monasteries, holy sites and steep slopes?
2. Why are remnant plant species useful for sustainable land management?
3. Discuss the concept of "centre of origin", and "centre of diversity". Based on your discussion, try to identify as many plants as possible and find out which of them were actually indigenous. Explain why you think they are indigenous!
4. In the context of sustainable land management, discuss in-situ versus ex-situ biodiversity conservation strategies, as well as their advantages and disadvantages
5. Taking time series satellite images, analyse the vegetation dynamics over the past 30 years

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Chapter 4

Making Experience Available at the Regional Level

4.1 Soil conservation research in the central highlands of Eritrea – an introduction

4.1.1 SWC research methodology

Soil conservation research in Eritrea is based at the field station at Afdeyu near Serejeka in the central highlands. The station is run by NARI (National Agricultural Research Institute), with some backstopping collaboration with the Centre for Development and Environment (CDE) at the University of Bern. The emphasis is on applied research; hence the station's research program was implemented on village (farmers') land, with as little disturbance of the catchments and farmers' fields as possible (Figure 4.1). The standard research program focused on monitoring runoff / river discharge and soil loss / sediment yield at different scales, on different slopes and soils, under various crops, land use types, and SWC treatments. Current soil erosion rates were measured on test plots and at a hydrometric station, where hundreds of events were recorded over the years on each site. This allowed determination of the average patterns of soil erosion, i.e. annual and monthly results. Extreme patterns of erosion were determined by analyzing the impact of the most severe rainstorms (critical times), and by mapping erosion rills at critical locations right after such extreme erosion periods. Concurrently, 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 erosion measurements. Land use was mapped for each cropping season. Throughout the catchments, crop yield and biomass samples were collected regularly to monitor production of the major crops. The general status of soil degradation was determined through soil surveys.

In addition to the standard program, site-specific research is also carried out if needed, with supplementary programs. Research was carried out on population and livestock dynamics, household land management strategies, attitudes towards and perceptions of SWC, effects of agronomic SWC measures, indigenous SWC measures and strategies, soil fertility mapping and erosion modelling.

Figure 4.1 *Afdeyu research station. Top photo: overview of the area with station building at the upper right and the river gauge in the middle right, on the valley floor (see gauging bridge crossing dry river bed). Bottom photos: agro-met station (left), and river gauge in detail (right). (Photos by Andreas Catillaz, 2009)*

4.1.2 What is measured in SWC research?

A focus on soil erosion requires the development of a specific erosion measurement methodology, which involves data collected on various levels and with different devices, levels of accuracy, possibilities and limitations of interpretation (*Table 4.1*).

- *Rainfall and erosivity* are measured for individual rainstorms using an *automatic rain gauge* located in the vicinity of the river gauging station.
- Close to the rain gauge, each research station maintains four *test plots* (TP, 2 m x 15 m) and two to four *micro-plots* (MP, 1 m x 3 m) on which *soil loss, runoff, and crop production data* are recorded. The impact of selected SWC techniques (usually grass strip, *Fanya Juu*, and bund) on soil loss, runoff and production is tested on four to six experimental plots (EP, 6 m x 30 m). All plots are on-farm plots; the farmer decides the crop rotation and timing of farm operations. The rugged topography involves frequently changing slope angles and soil properties. In addition, farm size is often below one hectare (ha) and a farm is further divided into numerous farm plots. This makes it almost impossible to find comparable plots of homogeneous soil, slope, crop type and farm management, and does usually not permit replications of plot measurements. Thus, over the years, each plot represents average soil loss and runoff "behaviour" in a specific situation. Herweg and Ostrowski (1997[1]) investigated the accuracy of plot soil loss and runoff values, as the result of a range of systematic and random data errors, parameter estimation errors, and model errors. For single erosion periods, the error ranges between ±2-5% for runoff and ±6-16% for soil loss, respectively. The error for annual data, by contrast, is lower, with ±0.1% for runoff and -3% for soil loss, respectively (*cf. Table 4.1*).
- *River discharge and sediment yield* are recorded with a *river gauging station* at the outlet of the research catchments (which has a size of 2 km^2). The estimated error of sediment yield and river discharge is ± 5 - 10%.
- If *rills and gullies* are formed, usually during the main erosive events, they are *mapped on-farm*. This methodology is known as the "Assessment of Current Erosion Damage" (ACED), and has been documented in a field manual by Herweg (1996)[2]. The estimated error of rill volume/soil loss (ACED) is ± 15 - 30%.

Table 4.1 Indications, limitations and estimated accuracy of different soil erosion measurement domains at Afdeyu station

Measurement level	Characteristics and possible interpretation	Limitations on the interpretation of results	Estimated error (± %)	Remarks and source of information
Hydrometric Station sediment yield river discharge	*Areal measurement device*, measuring outflow from a defined catchment; Long-term or permanent monitoring device; Results indicate possible downstream pollution (sedimentation) and flood risk	No differentiation of sources of erosion within the catchment possible; **Caution**: unreliable extrapolation without knowledge of channel characteristics	*Sediment yield* and *river discharge*: 5 – 10%	Original error was estimated to be 1-5%, without considering random errors during measurement (Bosshart 1996, 1997a)
Erosion Plots soil loss runoff	*Point measurement devices,* measuring soil transport over a defined slope length (e.g. a TP represents one average terrace spacing) during rainstorm periods; Long-term or permanent monitoring device; Results indicate soil erosion rates (mainly sheet and pre-rill erosion) under different soils, slopes, land management practices, SWC technologies, etc.; Results underline the importance of severe rainstorm periods	Negative balance: TPs consider only soil lost from the area but no deposition gained from upper slopes; narrow plot width encourages entrainment and pre-rill erosion: soil loss rates may thus be overestimated; **Caution**: without appropriate model the extrapolation of results is unreliable	*Soil loss*: annual – 3% storm 6 – 16% *runoff* annual 0.1% storm 2 – 5%	Accuracy is estimated for erosion plots which are well maintained, e.g. there is no interception of rainfall by canopies of high plants outside the plot; there are no further sinks or sources of sediment and water, etc. inside or outside of the plots (Herweg and Ostrowski 1997)
Assessment of Current Erosion Damage soil loss	*Point-linear measurement;* measuring rill and gully erosion losses at critical locations during severe rainstorms; Short-term monitoring method; Results indicate extreme soil erosion rates	**Caution**: no extrapolation possible; data are storm-based, annual data relatively uncertain	*Soil loss* 15 – 30%	The accuracy improves with the experience of the observer, while increasing vegetation cover and more complex rill systems increase the chance of error (Herweg 1996)

4.2 Management concept and data interpretation

In order to serve the needs of planners, researchers, trainers, students, extension agents etc., the data collected at the Afdeyu station need to be linked or combined in various ways. In a few cases, such links can be of a quantitative nature. For example, rainfall, runoff and discharge can easily be combined since they are all documented in the same unit (mm). Other data need to be transformed, such as soil loss and sediment yield (from t/ha into mm of topsoil loss) in order to be linked with rill mapping data. More often, however, different types of data cannot be combined quantitatively, but only semi-quantitatively or qualitatively through a combination of measurement, interpretation and judgment. For example, quantitative measurements of biophysical data on experimental plots can help identify suitable SWC measures. But qualitative information gained from socio-economic surveys regarding the viability and acceptability of SWC is equally important.

A basic data management concept was developed, from data collection in the field to analysis and final interpretation (*Figure 4.2*). The left side of the figure shows the general data management concept, while the right side indicates examples of the corresponding erosion data management (Herweg and Ostrowski, 1997). High accuracy measurement of soil erosion processes is very labour-intensive and costly. Therefore, before starting to collect data, it should be clear for what purpose they will be used, and how accurate the data should be. There are a number of options from basic research to applied erosion research, but in what follows, the focus will be on the aspect of application.

Four guiding questions can help identify a suitable research set-up (note that depending on the aims of research, not all questions may require scientific and costly investigation):

- *Where does soil erosion occur?* Locations with high erosion hazard – the so-called hot spots – can be detected easily through observation and mapping of current and/or past erosion features (rills, gullies, accumulations, etc).
- *When does soil erosion occur?* Concentrating on severe rainstorms with high erosion hazard, information can be obtained from long-term meteorological stations and from interviews with local land users.
- *Why does soil erosion occur?* Answering the first two questions reveals many direct causes or triggers of erosion, but also the indirect reasons for erosion.
- *How much soil is eroded?* Answering this question is usually time consuming and labour-intensive as well as costly. Corresponding methods and devices are of different quality and accuracy. Long-term (permanent) monitoring can be carried out on test plots (representing a farm plot) or river gauging stations (representing a catchment). Short-term methods such as observations and mappings of erosion features need to be carried out after several rainstorms each year. If there is no way to measure soil erosion directly, mean soil loss rates (erosion hazard) can be estimated using prediction models (USLE, WEPP). The empirical USLE and its derivates do not require many input data, but its results are of uncertain accuracy. WEPP and other physical models deliver better quantitative results but also require high inputs.

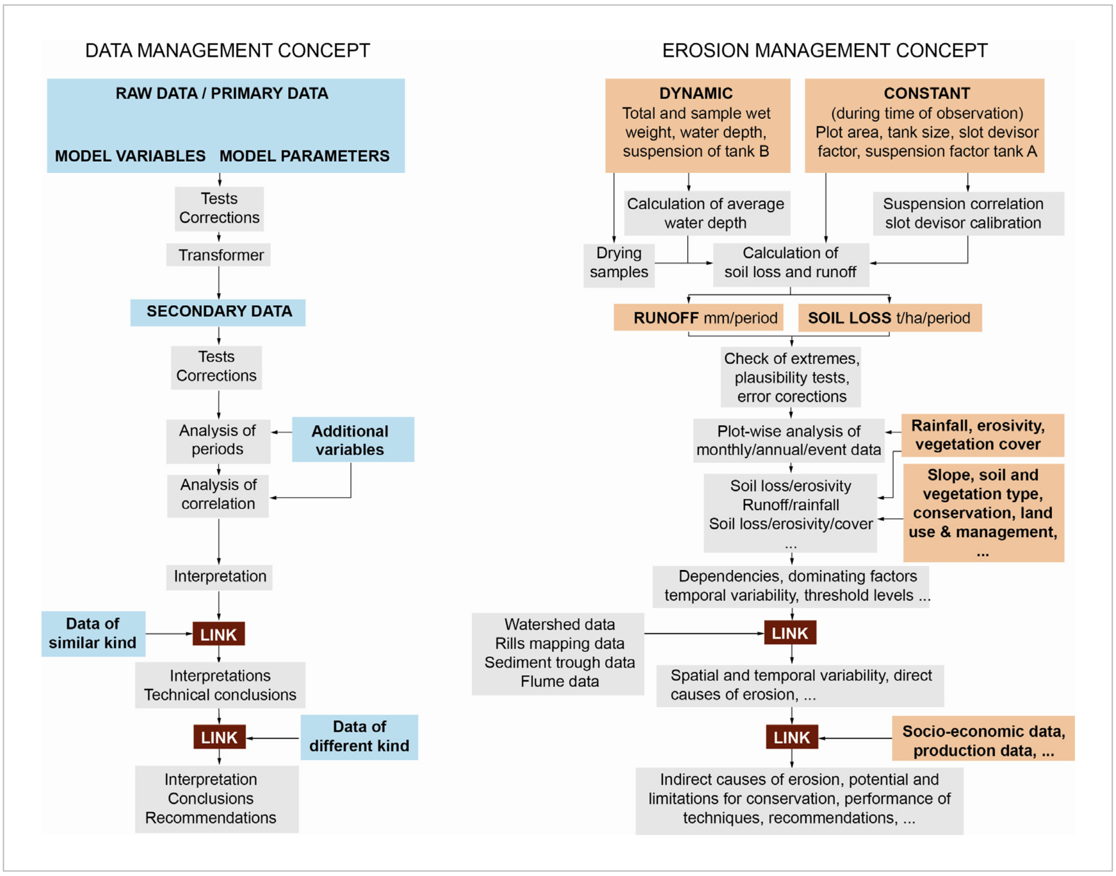

Figure 4.2 Data management concept, Afdeyu station

Primary or raw data are divided into two parts. The dynamic part contains all measurements of variables made during each erosion event, while the constant part describes parameters that are not supposed to change, at least not within one cropping season or year. Some of the parameters require a particular estimation procedure, such as slot divisor calibration or derivation of the sediment concentration in suspension. All field data, including average calculations of water depth, estimated parameters, and laboratory data are entered into the main transformer, in this case the plot soil loss and runoff calculation formula. The results of the calculation – output data of the test plot measurements – are considered secondary data (t/ha of soil loss, mm of runoff). They can be used as input data for a mathematical model (algorithm) of a higher order, passing through a series of tests (extremes, plausibility, error, etc) before they appear as monthly or annual time series for each plot.

Soil loss and runoff data can be linked (e.g. correlated) with additional variables, such as rainfall erosivity, and vegetation cover, allowing initial interpretation of the temporal variability of soil erosion. Then other parameters such as slope gradient, soil type, type and cover of vegetation, land use and land management, soil conservation practices, etc., can be considered in another correlation analysis, leading to an interpretation of interrelations and dependencies of factors, as well as causes and effects of soil erosion. At the next stage, plot results can be linked with data of a similar kind, i.e. erosion data from other measurement levels, such as gauging stations, sediment troughs, and assessment of current erosion damage (ACED, rill mapping). In this way, spatial and temporal vari–

ability, average and extreme patterns, as well as several direct causes of erosion can be assessed. It is then possible to draw certain “technical” conclusions, e.g. regarding the timing of SWC activities and critical locations that require special attention, what plant cover is necessary for effective soil protection, hazardous land use and land management, etc. Eventually though, erosion data must be linked with qualitative or semi-quantitative data of a different kind, i.e. representing the socio-economic, political, and cultural framework under which peasants implement SWC. When it comes to implementation, technical information about the impact of SWC measures on soil erosion is incomplete unless it is supplemented, e.g. by an analysis of the economic viability and cultural adaptability of SWC.

Expectations of what research can and should contribute to solving real-life problems are manifold, and not all of them are realistic. The experience gained at Afdeyu shows that practitioners – policy-makers, planners, farmers, etc. – are frequently not in a position to clearly express what their demands are. In addition, their demands and questions can change frequently and quickly. Furthermore, once a research set-up is designed and implemented, its flexibility to take up newly emerging research demands is limited. In practice this means that on-going research can only provide parts of the answers required. In addition, it is usually not only one measurement that responds to a specific demand, but rather a combination of quantitative and qualitative data sources. Figure 4.3 shows some common links of practical relevance between measurement, observation, assessment and interpretation. Some assessments and interpretations are useful to design protective and productive SWC measures together with farmers; others assist planners and decision-makers in developing supportive activities at the regional or national levels, such as identifying priority areas for SWC, designing legislative measures, and the like.

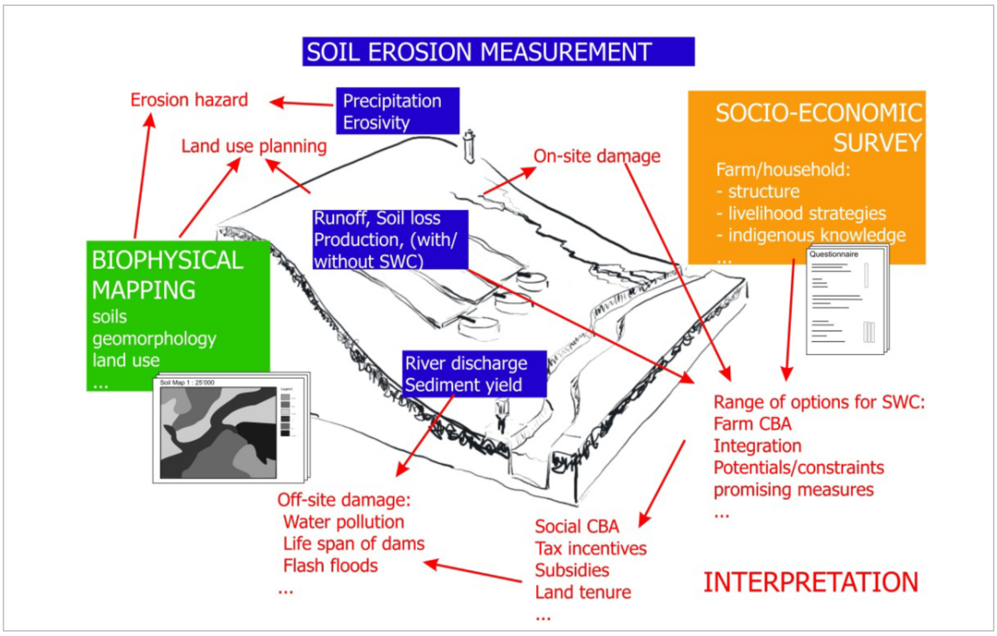

Figure 4.3 *Soil erosion measurement and survey and interpretation of results (Karl Herweg)*

4.3 Climatic conditions

Soil erosion is frequently quantified as soil loss from a given area over a specific period of time. It is expressed in standard units, usually tons per hectare and year (t/ha and y), as if net soil loss was independent of the size of the measured area (Nyssen et al., 2003b[3]; Van Noordwijk et. al., 1998[4]), which in reality is not the case. Although widely used, the term "soil loss" is slightly misleading and requires some explanation. Tanks at the lower end of a test plot collect soil that is washed from (and thus "lost" for) this plot area. What is not considered is that, on regular farmland without plot borders, the "soil in the tank" would be re-deposited somewhere further down, while at the same time this plot area would gain some sediment that was eroded upslope. River sediment yield values measured at most research sites suggest that a considerable part of the soil eroded on the slopes does not reach the river. However, great amounts of eroded soil are deposited in unfavourable positions, such as wet valley floors, along field borders, on footpaths, etc., where they are of little use for food production. Although not lost from the catchment, a lot of soil is lost for agricultural production.

Annual runoff and soil loss rates, computed from test plot measurements, are the most widely used values for underlining the severity of on-site erosion problems and emphasizing the need for soil and water conservation (SWC). Similarly, annual river discharge and sediment yield values indicate potential off-site effects. In turn, low annual soil loss values are used as an indicator of successful SWC. It is important to notice, though, that the magnitude of soil loss depends on the degradation processes taking place and thus to a great extent on the measurement devices and plot sizes used. Therefore, data cannot be appropriately interpreted without knowing the measurement devices or models that generated them. Direct measurement of soil erosion rates is rather rare because it involves high costs and time inputs. Many reports thus have to rely on quoting primary and secondary literature, often without mentioning the methodology corresponding to the data, let alone the measurement accuracy. As a result, there is a great potential for misappropriation of data. In particular, further statistical analysis of data taken from unknown sources can be critical, and the consequences of inappropriate decisions based on such analysis will finally be borne by the farmers, not those who interpret the data and write the reports!

Therefore, it is important to reflect on the possibilities and limitations of interpreting mean annual values or annual sums. Examples from the database at Afdeyu will help clarify what can be concluded from which data and what cannot. For example, mean annual overview figures can be important for decision-makers and planners who need to know where SWC priorities should be established, or more generally, where to intensify agricultural development. Such average erosion rates, however, tell very little about what type of SWC technology could be implemented to alleviate the problem. More detailed information on the temporal and spatial distribution of erosion events, and particularly on the extreme events, is necessary to design appropriate SWC measures on the local (field) level.

When interpreting the data it is important to note that test plots are located on different slopes and soil types with different crop rotations. The duration of measurement differs as well from site to site. Therefore, comparison of the data has to be made with care!

Nonetheless, a combined interpretation of annual and monthly plot data provides good insight into the orders of magnitude of soil erosion and its variability in the highlands.

4.4 Different resolution of soil erosion data in time and space

4.4.1 Temporal resolution I: mean annual data

Figure 4.4 and Table 4.2 present mean annual data from Afdeyu station for the years 1984–2007. The left bar chart in Figure 4.4 shows annual rainfall versus runoff as measured by the rain gauge, and the river gauge respectively. It shows that rainfall is extremely variable from one year to the other, without any apparent pattern that would allow prediction from one year to the next. Run-off is of course linked to rainfall, but less clearly than one might expect. This is due to the distribution and intensity of rainfall over the year, which is not shown in the graph. For example, a very heavy rainstorm in one year might cause higher runoff than a series of smaller storms, which together bring more water in another year. The right-hand bar chart shows annual erosivity as against soil loss. Again, soil loss and erosivity of rainfall are linked, but less clearly than one might expect. This could be due to different onset of rainfall: a year with high rainfall intensity might be characterized by a crop vegetation cover not yet well established, which increases soil loss; a year with later heavy rainfall might be characterized by a better established vegetative cover and less erosion. This shows that annual values have their merits, but that data need to be broken down to monthly and even daily values.

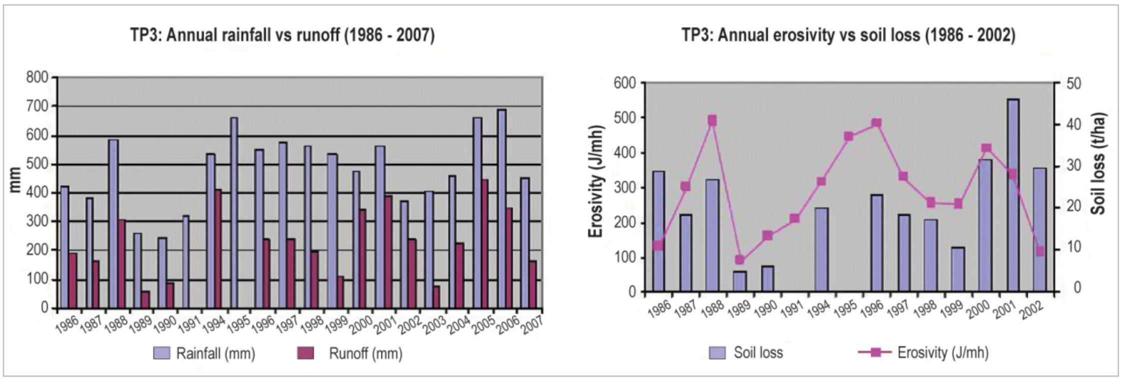

Figure 4.4 *Mean annual rainfall, runoff, soil loss and erosivity measured in Afdeyu (based on data analysis for 1984–2007). TP3 stands for Test Plot 3, which has a slope of 10% and is under annual crops (barley or wheat)*

As Table 4.2 shows, rainfall is low at Afdeyu on average for the 5-year reference period presented (1985–1990). With high coefficients of variation of annual rainfall (0.29), soil erosion becomes highly variable as well, and crop production very insecure. 28 to 38% of the annual rainfall leaves the cultivated test plots as runoff, but only 6% of the annual rainfall leaves the catchment as river discharge. This difference is a result of infiltration, refill of the groundwater aquifer, and evapotranspiration. On the slopes, structural SWC measures help reduce runoff and enhance moisture conservation for plant production. In the riverbed itself, farmers have dug a number of holes to fetch water for small-scale irrigation during the dry season. These holes also trap suspended sediment, which, together with well-developed vegetation cover on the flat valley floor can explain the relatively low sediment yield values during the rainy season. The months of highest erosion risk are July, August and to a lesser extent September, with a few erosive phases resulting in soil losses measured on test plots of 17–19 t/ha per year. Due to the long dry season, soil erosion on the “grass” test plot is not significantly different from that measured on cultivated plots.

Some important general conclusions can be drawn which go beyond SWC aspects – keeping in mind that the reference period is only 6 years (1985–1990) – which is very short, given the high annual rainfall variability in this semi-arid area:

- As annual rainfall is low on average, rainfed crop production is a risky enterprise, and difficult to plan for farmers.
- Run-off from all test plots (105–141 mm) is around one third of rainfall – and this is water that is lost for crop production! If SWC can reduce this amount, then more water is available for crop production
- River discharge is 6% of rainfall, and the sediment load in the river is 800 kgs per ha. These are important planning figures, for example, for reservoir dimensioning, as they indicate how much water is available for storage, and how serious siltation would be.

Table 4.2 Mean annual rainfall, soil erosion, run-off and sedimentation, Afdeyu 1985–1990

Years of observation	***Unit***	***1985-1990***
Rainfall	*mm*	382
Erosivity	*J/m·h*	233
Runoff	*mm*	105-141
Runoff	*%*	28-38
Soil loss	*t/ha*	17-19
River discharge	*mm*	21
River discharge	*%*	6
Sediment yield	*t/ha*	0.8

4.4.2 Temporal resolution II: mean monthly data

The high variability of annual soil loss values – even on the same slope and soil – results from a changing constellation of factors, of which the dominant ones are rainfall, erosivity, soils and vegetation cover. This constellation is not always critical, but it can become particularly hazardous in single years, single months or even single rainfall periods, which may then entirely distort the annual mean. Thus, interpretation of annual results should always be supported by interpretations of shorter period resolutions. For example, analyses on the basis of months or even days, or single rainstorms are sometimes also needed. Figure 4.5, for example, shows us in which period we might expect rainfall, and hence erosion to occur.

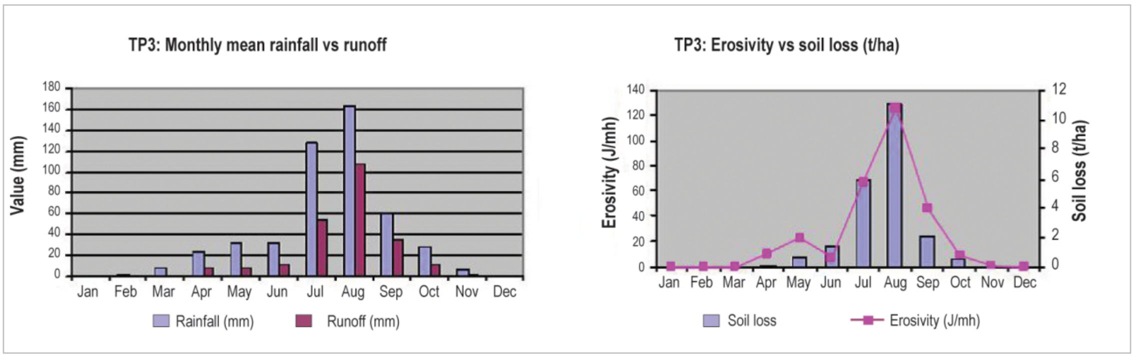

Figure 4.5 *Mean monthly rainfall, runoff, soil loss and erosivity measured in Afdeyu (based on data analysis for 1984-2007). TP3 stands for Test Plot 3, which has a slope of 10% and is under annual crops (barley or wheat)*

4.4.3 Temporal resolution III: Extreme soil erosion during rainstorms

In contrast to the average behaviour of soil erosion – expressed by annual or monthly data on rainfall, erosivity, soil loss, and runoff – the extreme patterns of erosion provide more detailed information about two aspects. (1) The **temporal** aspect refers to the variability or irregularity of soil erosion events within a year, focusing on heavy rainstorms that trigger high soil losses. (2) The **spatial** aspect is concerned with critical locations – the so-called "hotspots" – along a slope section that are visibly damaged mainly by rill and gully erosion processes.

Studies by Hagmann (1996) in Zimbabwe, Edwards and Owens (1991) in Ohio (USA), Chromec et al. (1989) in Hawaii, Schaub and Prasuhn (1993) in Switzerland, and Herweg (1988a, 1988b) in Tuscany (Italy)[5] state that a large proportion of annual soil loss occurs during a few rainstorm periods. Provided this is so, the effectiveness of a SWC measure depends on the extent to which it can resist such "extreme" rainstorm periods. Therefore, insight into such periods provides better information for SWC technology development at the field level than mean values.

Relying on average soil erosion data (t/ha per year) can lead us to think that soil erosion is evenly distributed throughout time and space. However, only a few heavy rainstorms usually cause the bulk of annual soil losses. The state and cover of the vegetation is then an important factor that determines whether or not a rainstorm period causes severe erosion. The literature evaluates the protective function of vegetation cover differently. On the one hand, Stocking (1998)[6] states that erosion decreases drastically to about 10% when vegetation exceeds a ground cover of 40%. He shows that the interactive process between soil and plants is sufficient to cope with erosion, provided, depending on the crop type, that vegetation is maintained at levels above 50 and 60% plant cover. Hudson (1995)[7] reports similar findings. Both authors refer primarily to studies in Zimbabwe. Young (1998)[8] assumes that a ground surface litter cover of 60%, maintained throughout the period of erosive rains, will normally reduce erosion to lower and acceptable levels, even without additional structures of the barrier type. Herweg (1988a)[9] observed drastically decreasing erosion in Tuscany, Italy, when cover exceeded a 50% threshold. On the other hand Cyr et al. (1995)[10] argue that cover must be at least 70% during erosive rains in the Quebec Appalachians. Thomas (1991)[11] qualitatively states that during heavy rainfall, vegetation cover is not too effective in controlling erosion in the south-eastern highlands of Ethiopia. It appears that the first group of authors is referring to "average" conditions, while the second group considers "extreme" conditions.

Analysis of the data collected at Afdeyu reveals that annual erosion rates are heavily dominated by single rainfall periods, as can be observed in Table 4.3. The occurrence of such periods is highly erratic, which explains the high variability of annual results. High soil losses result from a combination of many factors, for example, high erosivity, low vegetation cover, steep slopes and high soil moisture. The following average results were obtained on farmland, i.e. cultivated plots:

- 5% of the annual rainstorm periods caused 11.6% of the annual sediment yield and 26.5% of the annual soil loss.
- 20% of the annual rainstorm periods caused 83 % of the annual soil loss.

In exceptional years, a single rainfall period (out of a total of perhaps 50 periods for which rainfall was measured) may cause 60% or more of the annual soil loss, especially in a semi-arid environment such as Afdeyu with a generally lower number of rainstorms per year!

Table 4.3 The impact of rainstorms on soil erosion, runoff and river discharge at Afdeyu (based on 20 years of records). Reading the example for Table 4.3: 5% of all rainfall periods (say, 2 rainfall events -storms - out of a total of 40 events) bring 10% of annual rainfall, and cause 26.5% of soil loss and 11.6% of river sediment load

Afdeyu (17 - 20 t/ha x y)				
Percentage of annual rainfall periods	**5 %**	**10 %**	**15 %**	**20 %**
Precipitation	10.0	19.6	27.1	37.2
Erosivity	12.2	23.5	43.3	45.7
Runoff	10.0	22.2	54.3	
Soil loss	26.5	51.6	70.5	83.0
River discharge	6.4	15.4	42.8	
River sediment load	11.6	22.5	49.4	
Number of rainfall periods	(6)	(5)	(8)	(3)

One specific constellation that triggers high soil losses is a high erosivity rainstorm that occurs during times of low vegetation cover. Usually, the probability of such a coincidence is greatest at the beginning of a rainy season, when fields are freshly ploughed. Immediately after harvest, by contrast, there is usually sufficient ground cover available to provide protection. Open grazing, however, can contribute to reducing stubble cover after harvest up to the stage of exposing the bare soil. With respect to the influence of rainfall erosivity and vegetation cover on soil loss, data reveal that under low plant cover (0-30%), which is usually found during the onset of rains, to moderate plant cover (30 - 60%), all storm periods actually can cause erosion. The periods producing the highest soil losses recorded occurred under low vegetation cover at the beginning of the cropping seasons. The erosivity of these storms was exceptional (> 100 J/m·h), extreme (> 50 – 100 J/m·h) and very high (> 30 – 50 J/m·h). Under high plant cover (> 60%), only periods of extreme (> 50 – 100 J/m·h) and exceptional erosivity (> 100 J/m·h) caused a few but high soil loss events. It is important to keep in mind that these measurements were made under test plot conditions, implying that, due to the corrugated iron sheet borders of the plots, run-on from outside was prevented. On farmers' cultivated fields with run-on from above, erosion rates may well be higher.

4.4.4 Spatial differentiation I: the influence of plot length and steepness on erosion

The research set-up may include test plots of different size and length. The size of the plot determines what combination of erosion processes will take place (*Table 4.4*).

Experience at Afdeyu and elsewhere can be summarised as follows:

- Micro-plots (MP; length 3 m, width 1 m): no rills were observed on MPs, indicating that this length does not permit the build-up of the shear velocity necessary to form rills. The soil loss measured consisted of material detached by rain splash and entrainment of the sheet flow. MP results represent the amount of soil that is moved on an inter-rill erosion area.

Table 4.4 Soil erosion measurement levels and soil degradation processes (see text for explanation of terms)

Level/ Device	**Soil degradation processes**						
	Erosion					**Deposition**	
	Rain-splash	Sheet flow	Prerill erosion	Rill erosion	Gully erosion	Diffuse accumulation	Concentrated accumulation
*MP							
TP							
EP							
ACED							
Catchment							

Frequently observed   Rarely observed

- Test plots (TP; length 15 m, width 2 m): besides rain splash and sheet flow, pre-rills a few cm deep were observed on test plots. At the same time, diffuse accumulations of eroded material may occur, which partly refill the pre-rills. The TP situation represents, for example, the erosion on a terrace between two SWC structures, such as a soil bund or *Fanya Juu*.

- Experimental plots (EP; length 30 m, width 6 m): on the eroded part, rain splash, sheet flow, pre-rill and rill erosion may occur. On the deposition part, not only diffuse accumulations but also concentrated accumulations are found above the SWC structures. In contrast to TP, the EP represent a situation with a sequence of terraces and SWC structures interrupting both runoff and soil transport.

- The assessment of current erosion damage (ACED, see under Chapter 4.6) considers exclusively linear erosion features, such as pre-rills, rills, and gullies, as well as concentrated deposits.
- The sediment yield measured with *hydrometric devices* (river gauging station) at the outlet of a catchment is the result of all water erosion processes taking place in the catchment, including the erosion of the riverbed itself.

The influence of slope steepness on soil erosion also requires special consideration. The results observed in many research stations confirm that soil erosion increases with steepness. However, as other factors such as soil type, stoniness, vegetation, etc. vary, the relationship becomes more complicated. For example, lower soil loss rates were recorded on steeper slopes because more stony soils allow more infiltration.

4.4.5 Spatial differentiation II: hot spots of erosion

Micro and test plot data represent the average rain-splash, sheet flow and pre-rill erosion, balanced to a certain extent by diffuse and concentrated accumulations. Such a balance implies a rather slow down-slope movement of soil particles step-by-step, rain after rain. From the analysis above, it becomes clear that the bulk of a given annual soil loss value occurs during only 20% of the annual rainstorms. Similar to its uneven temporal distribution, the spatial patterns of soil erosion are also irregular, i.e. only part of a given area of cropland actually contributes to the bulk of soil loss. Those parts of an area that are seriously affected are called ***"hot spots".*** Visible erosion features, such as rills, gullies and concentrated accumulations, often indicate hot spots. Rill erosion, compared to sheet erosion, has an entirely different character. It removes a considerable amount of topsoil and it creates transport conduits for both water and soil (Nyssen et al., 2003a; Bryan, 1987[12)] originating from the rain splash and sheet wash of the inter-rill areas. Through rills, eroded particles are transported quickly over a large distance. Large particles are more effectively transported. Rills and gullies are embryo drainage systems, which will develop eventually into badlands if unchecked. This may involve irreversibility, meaning that the land cannot be put back into crop production in agricultural systems that are based on animal-drawn implements for cultivating the land, which is the case in most of the agro-ecological zones.

According to Hurni (1988) and Nyssen et al. (2003a), obvious signs of erosion such as gullies and rills can hinder or aggravate land management operations related to farming. In particular, current features indicate that tolerable amounts of soil loss must have recently been exceeded, even if the rills are small. Rill damage has a major impact because it reduces the area of production. It is possible that erosion may have a positive impact, for instance if it removes exhausted topsoil layers or if it causes reasonable accumulation of fertile layers on top of infertile soils. However, in most cases the disadvantages of erosion are predominant.

Several authors describe rill erosion damage in the African context. Hagmann (1996) from Zimbabwe, and Nyssen et al. (2000)[13] from Ethiopia, report that the major causes of rill erosion damage were related to influx of water from outside, non-effective contour ridges and drains, and concentration of runoff from within the field. In Lesotho, Wenner (1989[14]) found that many large rills and gullies on terraces were due to level terracing, and he refrains from advocating this measure. Von Gunten (1993[15]) and Thomas (1991)[16] come to similar conclusions, presenting detailed lists of rill erosion damage and its causes in Ethiopia. Regarding frequency of occurrence, they conclude that land management predominates over natural factors, triggering 81% of all cases of rill erosion damage. Defective and poorly maintained soil and water conservation structures alone are responsible for 36% of the damage observed in the study area. Hagmann (1996) also reports SWC failure to be a major cause of severe rill erosion in Zimbabwe.

Such failures in soil and water conservation structures suggest that more detailed information is required about appropriate design of structures – particularly where run-on and erosion occur – as well as the type of measure needed and exactly where. But this would imply that each field is continuously "monitored" over time – a task that can only be done by the land users themselves. If SWC is established on the basis of average erosion rates, assuming a homogenous erosion process, it will face several technical problems at locations where extreme erosion manifestations such as rills and gullies occur.

Since both the factors triggering and steering severe erosion and the order of magnitude of the resulting damage are highly site-specific and variable, generalizations must be made with care. An idealized pattern of the spatial aspect is the erosion topo-sequence that describes the "hot spots" of erosion damage along a topographic sequence of a slope (Figure 4.8). This could be a short checklist supported by a sketch or photo (*Figures 4.9 – 4.11*) that helps, for example, extension agents to search for possible signs of erosion damage, causes and effects (Herweg, 1996). The erosion topo-sequence contains obvious damage and direct cause-effect relationships. Asking why erosion occurred at a certain hot spot will also uncover the hidden reasons for unsustainable land management within the socio-economic framework. For example, a soil and water conservation structure broke and changed the flow of surface water, which resulted in severe erosion damage. Such an event not only indicates the need to improve the design of the structure, but even more importantly, to ask what went wrong in the first place. Did the structure break because the detrimental impact of an open grazing system on SWC structures was forgotten and not considered as an impediment while designing and planning the conservation measures? Did farmers stop maintaining structures after incentives were discontinued? Were extension workers inexperienced in soil and water conservation design? Answering such questions points to potential improvements which could pave the way for establishing more efficient soil and water conservation technologies, e.g. participatory planning, careful use of incentives, or better training and capacity building.

4.5 Assessment of current erosion damage (ACED)

4.5.1 Introduction to ACED

The method known as ***Assessment of current erosion damage*** (ACED) is based on the work of Schmidt (1979), which was further developed by Seiler (1983), Rohrer (1985), Vavruch (1988) and Schaub (1989) in Switzerland. For Mediterranean conditions, it was adapted in Italy (Herweg, 1987) and for tropical conditions in Kenya and Ethiopia. ACED was developed for two purposes. One is to supplement existing erosion measurement levels such as test plots and river gauging stations. The other is to provide practitioners with a more cost-effective tool to assess soil erosion and draw conclusions about implementation of SWC. Therefore, the ACED methodology has been separately published as a field manual (Herweg, 1996).

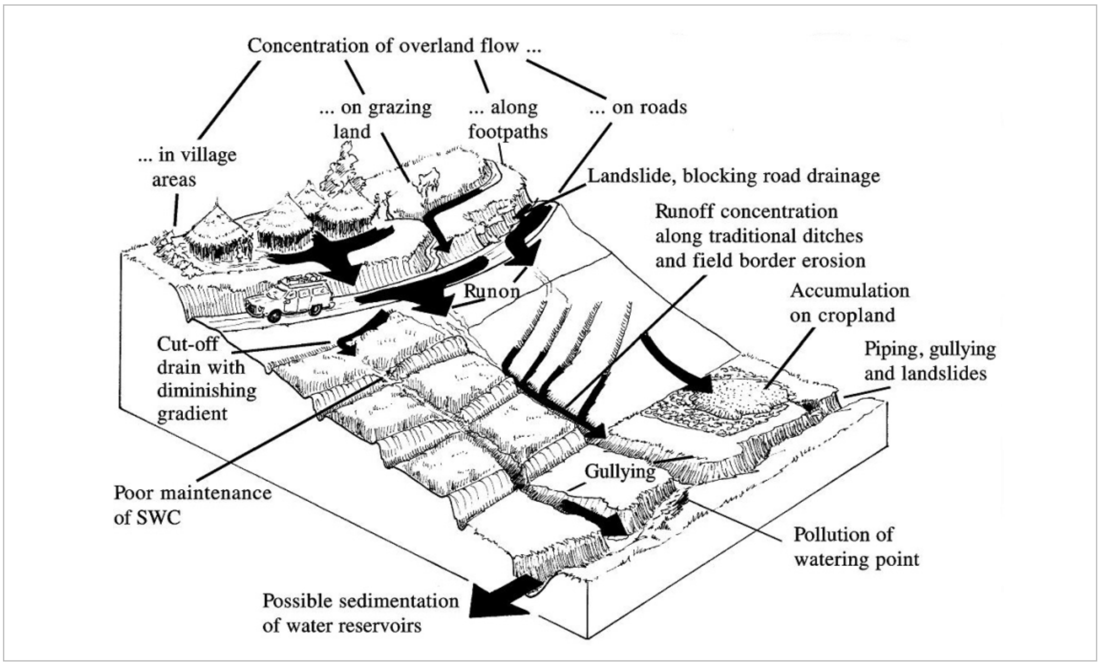

Figure 4.6 Erosion topo-sequences (Herweg and Stillhardt, 1999)

ACED is carried out in three steps after erosive storms, starting with the visible erosion features.

The first step is to measure the volume of the erosion features and the land management unit where they occur, in the so-called **damaged area**. Erosion damage may occur particularly on cultivated fields or other areas that are partly left without vegetation cover. Erosion features can often be linked to causes located on the damaged field itself, e.g. on steep slopes with high runoff velocity, in depressions and on long slopes with high runoff concentration, on silt soils, and on soils with low organic matter with high erodibility, and on fields which are ploughed upslope and downslope, etc.

The second step is to investigate the **upslope area** in view of its contribution to the features. The sources of runoff may be found outside the areas with actual erosion damage, i.e. above or upslope of the damaged area. Commonly, runoff is created on areas of low infiltration, such as the sealed surfaces of settlements, roads, footpaths and animal tracks. Interestingly, also grass and bush-land, which have much better infiltration, can “produce” considerable run-on if overland flow from these areas is not well drained. This is one of the most dangerous sources of erosion downslope. Where does run-on enter the damaged field, and where is it generated (along roads, small depressions or catchments, etc.)? The relevant answers to these questions can only be found if the mapping staff is in the field during a rainfall event!

The third step is to document the subsequent impact of the erosion features on the **downslope area.** Damaged areas can easily create consequent damage on areas downslope. For example, the eroded material accumulates and buries plants and seed-lings, or blocks roads and pollutes settlements. Field border erosion (gully) is a commonly observed phenomenon in humid areas where fields have to be drained. These gullies may also extend and destroy infrastructure such as roads or villages. Eventually, sediment that reaches the rivers can affect water quality and may lead to sedimentation of irrigation dams, while increased runoff can cause flooding or flash floods, a danger for downstream settlements.

Figure 4.7 *Rill erosion, accumulation and run-on (Photo by Karl Herweg)*

Rills as an indicator of considerable topsoil loss and long distance transportation often occur in slope depressions, alternating with accumulations on concave foot slopes (in the foreground). In this example, the very low vegetation cover shortly after germination has fostered the erosion process. However, the rill originates almost at the upper field border, which means that the conditions of the damaged field alone, such as vegetation cover, slope, soil, etc., cannot be the only reason for the rill. Overland flow in the upper parts of the slope was collected behind the stone wall that can be seen in the centre, a traditional conservation measure used by Italian smallholder farmers. Finally, concentrated flow broke the wall and caused the damage below. This phenomenon of overland flow entering a cultivated field is called “runon”. It underlines the fact that SWC should not focus on cropland only but needs to encompass the entire slope *(Figure 4.7).*

Figure 4.8 Footpath and soil erosion (Photo by Karl Herweg)

The photo shows a footpath crossing cropland and pastureland on a relatively steep slope. At several points there are indications of beginning gully erosion above the path (covered by grass), and a combination of landslips and advanced gullying along the path and in the field above (right-hand margin of the photo). Overland flow that concentrated along the path has merged with flow within the gullies above, and has created damage on the field below while entering as run-on *(Figure 4.8)*.

Figure 4.9 Roadside gully (Photo by Karl Herweg)

A frequently observed phenomenon is gullies that develop parallel to roads, particularly when the road crosses a slope depression or valley. The factors that contribute to this incident are manifold. The road itself and the village in the background of the photo build a compacted surface that does not permit infiltration. Such a sealed area is a source of tremendous overland flow. People and animals use the area adjacent to the road as "sidewalks" and thus add to the compaction of the soils. Drainage of the cropland also contributes to the concentration of overland flow. The role of the little Eucalyptus plantation on the right hand side is unclear and should be clarified. Were the trees planted to stop gully erosion, or has the gully below developed because of the plantation (keeping in mind that densely planted Eucalyptus trees and uncontrolled grazing and collecting of firewood prevent the establishment of ground cover) (*Figure 4.9*)?

Being a rough method, ACED cannot have the same accuracy as test plot or gauging station measurements (Herweg, 1996). Mapping of volumes and the number of rills and gullies can be carried out with an accuracy of ± 15%, but it may decline to ± 30% or more with inexperienced observers. The quantitative results become more inaccurate if vegetation cover and the number of rills increase, or if the form of the rills becomes more complex (Herweg, 1996). In contrast to controlled experiments under test plot conditions, the number of factors influencing rill and gully development varies considerably. Individual factors can produce drastic changes, particularly where "run-on" occurs. A footpath or a defective cut-off drain, for example, can greatly increase or shrink the catchment of a rill or gully. Concentration of runoff behind SWC structures, which is basically one of the desired effects of controlling erosion, can turn into a detrimental effect and create rills and gullies if the structure is poorly designed or if it is destroyed by grazing cattle. It is thus impossible to repeat rill measurements, both in time and space. However, as an important and often dominant part of erosion reality, these factors should not be ignored.

The results of ACED are indicative only, but they are helpful for improving SWC implementation. But they are not statistically significant, because it is hardly possible to carry out the mappings after each rainstorm. The sample considered only fields with rills and gullies, and did not include fields without damage. Therefore, the results do not represent an entire slope or a catchment, but only its critical locations. Consequently, certain patterns of damage may be over-represented, and a qualitative and semi-quantitative analysis is appropriate.

4.5.2 Important factors causing erosion

The following paragraphs summarise the lessons learnt about the key factors causing erosion; the experience was garnered by ACED and comes from Afdeyu as well as from case studies done in other parts of the Horn of Africa.

Land use and vegetation

Erosion damage usually occurs on cropland or on short-term fallow land that is under grazing.

- During seedbed preparation (0 cover) and under low cover (< 30%), high rill damage is frequently observed.
- Under medium cover (30 – 60%) less damage is observed. However, this may also be due to the lack of mapping during this stage of plant growth.

- Under high cover (60% and 70%) some cases of considerable rill damage were mapped. The highest soil losses were related to mixed cropping. This may occur at a stage when cereals already provide protection from rain splash, but the immediate ground cover of the pulses is not yet developed. Rill erosion under high plant cover mostly relates to run-on caused by parameters located outside the field under consideration.
- Fields with cereals seem generally more susceptible to rill erosion than those with pulses.
- The ground cover of fallow land, particularly under open and uncontrolled grazing, does not provide sufficient protection.

Soils and slope

The mappings selectively consider only fields where rills and gullies occurred. Since there is no area coverage of the mappings, no conclusions can be made about which soil types or textures might be more susceptible to rill erosion. Runoff concentration and rill erosion were observed on all soils, including those considered as having basically good drainage. Similarly, rills were observed in all slope classes and on all slope shapes. From the available data it cannot be concluded that, for instance, flat slopes are less susceptible to rill erosion, or that the highest soil losses occur along depressions. The impact of differences in soil properties and slope characteristics on rill erosion may also be outweighed by the impact of land management and conservation factors.

Land management/soil and water conservation

- Rills commonly develop where the gradients of cut-off drains diminish. This can lead to extreme soil loss.
- The collapse of SWC structures such as terraces is the most frequently observed case of SWC failure in many places. The collapse may be due to poor design of SWC, lack of maintenance, openly grazing livestock, concentration of rodents, or rejection by farmers. At the point of collapse, water is diverted through the structure and easily reaches a concentration that creates rills and affects downslope SWC structures.
- Waterways are subject to incision on steep slopes. If they cannot accommodate high runoff volumes during severe rainstorms, surface water is diverted to cultivated fields where it creates rills.
- Traditional drainage ditches can cause considerable rill erosion; if their gradient is too low or diminishing (cf. failure of cut-off drains), accumulations block the channel and runoff is diverted. If ditches are too steep, they cause incision (cf. failure of waterways).

Important factors influencing the upslope area

Very often, erosion on a specific section of a slope is due to run-on from above, which underlines the particular importance of this factor in the entire slope section. In addition, it stresses the need for an efficient and comprehensive drainage system (Hagmann

1996[17]). Bearing in mind that test plot measurements exclude run-on, it is obvious that damage mapping is an important supplement in erosion measurement such as that carried out at Afdeyu station, particularly for improving the design of SWC measures. Run-on can result from various sources located upslope, which contribute to a concentration of overland flow that consequently breaks onto cultivated fields. When several factors contribute to run-on simultaneously, it is usually not possible to determine the impact of a single factor. In the analysis, the respective soil loss value was divided proportionally among the contributing factors, and the results thus have a rather indicative character. In general:

- *Rill erosion rates* are high if areas with sealed soil surface such as footpaths, animal tracks, roads and settlements, etc. contribute to run-on.
- Other major areas of origin for run-on are *upslope cultivated fields*, fallow and overgrazed pastureland, particularly where SWC structures are not maintained or are broken down.
- It is surprising to see that rills are frequently associated with run-on from vegetated upslope areas such as grass or bushland. Vegetated areas themselves are well protected, but the overland flow they "produce" may still be sufficient to cause erosion downslope.

Beyond these general conclusions, SWC must respond to site-specific problems in order to be effective and efficient:

- *Village areas*, *fallow areas, and cultivated areas* with defective waterways deserve special attention.
- Tremendous rill and gully erosion can be observed along *roads and paths*
- *Grassland, bush land*, and *rocky sections devoid of vegetation* create run-on problems and require an effective drainage system.

As indicated earlier, controlling erosion is to a large extent a matter of controlling the drainage of an entire slope, not only the cultivated area. Only a properly designed and maintained drainage system of cut-off drains, terrace channels and waterways will be able to minimize erosion during times of low vegetation cover. It is therefore necessary to involve groups or communities of land users in the design and maintenance of the drainage system. Soil erosion is not only a consequence of intensive agriculture, but also of other land use factors such as settlements and roads. Thus, erosion problems can only be solved when farmers, planners, engineers and others work together.

Subsequent erosion damage on the downslope area

After mapping the damaged area and the influence of the area upslope, further signs of soil erosion may also be observed downslope. This subsequent damage is expressed in terms of frequencies of cases observed.

- *Rill and gully erosion* does not necessarily stop at the field border. It may create subsequent damage, such as erosion and accumulation on cultivated fields downslope. The accumulation of fertile topsoil as such may improve the fertility of the field that receives it. Often, however, infertile subsoil is deposited downslope, or deep accumulations bury germinated plants.

- *Field border erosion* results from runoff concentration and can easily develop into gullies that hamper farming operations and require special treatment. This usually involves high costs and labour input once the gullies are established.
- *The damage to grassland along valley floors* is another frequently observed phenomenon that may harm fodder and animal production.
- Rills and gullies, often results of piping, serve as transport channels and thus contribute *to river pollution and decline of water quality*.
- Footpaths, villages and other *infrastructure are easily damaged* or polluted by rill and gully erosion.

In addition to these cases observed on-site, other types of subsequent damage may *occur off-site,* for example, *pollution of watering points*. There is also a high probability of sedimentation of water reservoirs below areas with intense riverbank erosion.

4.5.3 Linking ACED with test plot measurements

In contrast to long-term monitoring on test plots and river gauging stations, ACED data are collected only during selected rainfall periods. The accuracy of the method decreases with increasing vegetation cover and networking of rills. Consequently, ACED results can only be linked to test plots on the basis of these selected rainfall periods. A comparison of ACED data with other spatial erosion data must thus be made with care.

- *Test plot measurements (t/ha)* suggest certain representativeness for a larger area, the "average rates and conditions" of erosion. This is because plot conditions are controlled and influencing factors such as soil type, slope angle, and vegetation type are few in number and rather homogeneous. Thus, test plot measurements simulate an areal element, and are theoretically replicable at any location in the catchment with the same conditions.
- *In contrast, rill mappings cover linear elements* – even if they occupy a small (damaged) area. They describe the extreme, not the average. Rills are not representative of a larger area, because often their influencing factors cannot be clearly defined. Therefore, rill mappings are not replicable.
- *To compare ACED mapping and plot results,* it thus appears appropriate to use the unit "mm topsoil loss" instead of “t/ha”. The latter unit would give the wrong impression that rill mapping results also imply area coverage, which is not always the case.

Overall, it is important to keep in mind that rill mapping represents the critical location of a field with "extreme" erosion, while the test plots represent an "average" erosion value. Comparison of these two levels of measurement always reveals differences, and these can reach several orders of magnitude (one order corresponds to an increase by a factor 10^1, two orders by 10^2, etc.).

4.6 Upscaling, downscaling, and temporal extrapolation of information

4.6.1 Upscaling

Upscaling refers to transferring information from a given scale to a larger one. Scientifically it is usually based on modelling: data from small reference areas should be chosen as representative of a larger territory of interest. Depending on the information needed, scientists have to select one model from among the most appropriate of innumerable different upscaling models to answer their questions. In general, upscaling is used to support professionals or politicians with information for decision making. A typical example of upscaling is a map of climatic data or soil data over a larger area. Measured information is only available for certain spots (where climatic parameters are measured or soil pits are analyzed), but on maps (e.g. the FAO soil map of the world) the collected data are upscaled until a complete area-wide map results.

At the national level, data are often upscaled to get policy-relevant information, data for planning or decision making, data for national statistics, etc. The larger the area covered by upscaled findings, the less accurate they are and the more site-specific information is lost.

The accuracy of upscaled data depends heavily on the factors included in the model: There are factors that change their properties within small areas (e.g. the field size and the slope in an individually terraced landscape). At the same time, the accuracy of the mean annual temperature is most probably within a tolerable range at the catchment level, and sometimes even at the regional level.

4.6.2 Downscaling

Downscaling refers to transferring information from a given scale to a smaller one. It is the inverse process of upscaling. The problem with downscaling is that findings valid for a larger area do not contain the site-specific information for a spot of interest. (Even in a very windy area, one finds sites in the wind-shade, which causes different environmental conditions for this site)

To obtain reliable results, downscaled data have to be verified on field level. Downscaling can be an approach for obtaining an initial impression of an unknown situation and can help in initial site selection.

Even if downscaling is an often insufficient approach scientifically, it is rather common in daily life: If no concrete information about a specific situation is available, we tend to take general information and use it for our purposes (e.g. rivers in semi arid environments are perennial -> the Nile is perennial).

4.6.3 Temporal extrapolation

Temporal modelling is also part of the scaling processes. It refers to transferring information from a given period to a longer time span. Most often it is used for forecasting processes, e.g. for weather forecasting. In the simplest case, the model is based on the assumption that natural phenomena are statistically normally distributed, independent of each other, and repetitive within a defined range. In such cases a simple trend calculation can be applied. But environmental data are usually not normally distributed and the common statistical procedures lead to worthless results.

Besides highly sophisticated models to compensate these deficits, the only way to get reasonable results is to depend on long-term data collections, as in the case of the SCRP data described above. The high natural variability within the data is compensated by the great amount of data, diminishing the influence of the extreme values occurring from time to time.

Box 4.1 A key lesson learnt

From the data and case studies presented, the key lesson to take home is that soil erosion is highly variable, both in time and space. We conclude with the statement that in general, and especially in the case of Eritrea, a few "key" rainstorms cause the bulk of soil erosion in every year, in particular at specific hotspots in a catchment. If SWC is not able to control erosion during these periods and at these locations, it will not be able to control erosion at all.

4.7 Questions and issues for debate

1. In this chapter you have "experienced" how greatly soil erosion rates depend on local specificities (hot spots, e.g. a slightly diminishing gradient of a footpath, artificial concentration of runoff along a field border, etc.) and the unpredictable irregularities of rainfall events. Taking this into account, what do you think is the use of generalized data such as annual values, mean soil erosion rates, etc.? For whom would they be useful?
2. As a decision-maker or extension agent at the regional level, what can you conclude and what interventions could you propose on the basis of the mean annual and mean monthly soil erosion values?
3. There is no standard research methodology for soil erosion and conservation research; the set-up of measurement levels and devices rather depends on the purpose of measurement. What research methodology would you design:
4. for monitoring the effects of soil and water conservation technologies, i.e. to estimate how well they control soil erosion, if they are economically viable, and if they are socially acceptable?
5. for developing an algorithm predicting the order of magnitude of soil erosion under various soil, slope, vegetative and land use conditions?

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Chapter 5

Information Technologies: Making Experience Available at the Global Level

5.1 Sustainable land management – scattered knowledge

The basic concept behind the term "sustainable land management" looks rather simple at first glance (*see Figure 5.1*). It is one of the most ambitious goals in real life, however, to implement a project that increases the overall sustainability of a natural resource system. While uncontrollable factors such as global changes, the destruction of the ozone layer, global overfishing, or a stock exchange crash might negatively influence an area, it is normally beyond the reach of a project to influence such factors. In a local context, problems such as very high population density, fast-growing herds, inflow of wastewater from an upper catchment, heavy windstorms and tornados may arise. As a consequence, sustainability in its pure form will remain an unreachable overall goal. At the project level, this goal is reached when none of the three dimensions of sustainability (see below) diminish as a result of project impact and at least one of the dimensions increases. Therefore, it is often more reasonable to refer at the project level to steps towards sustainability.

Generally, Sustainable Land Management refers to the use of **renewable** land resources (soils, water, plants, and animals) for the production of goods – to meet changing human needs – while at the same time protecting the long-term productive potential of these resources. SLM always refers to a concrete local land use context. As an approach, SLM is intended to produce a cross-sectoral view of the use of land resources in a given local context, including not only a single sector (e.g. the agronomic or forest sector) but also the inter-linkages between these sectors.

5.1.1 The ecological (environmental) dimension

Natural resources as defined for our purposes include the renewable parts of resources such as water and soil, all types of plants, animals and insects, and some forms of energy (non-renewable resources include stones, minerals and fossil energy).

Environmental resources have caught the interest of analysts more recently, and fairly well-developed tools are available for their analysis. In general, environmental resources provide services not only for immediate human consumption but also for use in connection with both production and consumption processes. The services sustain the biological basis of human life and well-being and provide for enjoyment of natural resources by people. These services are based on the absorptive capacities of the physical environment and as such also contribute to human well-being. The ecological dimension of sustainability requires careful consideration of the following three core elements:

- **Biodiversity**: the variety of plant and animal species, populations, habitats and ecosystems;
- **Ecological integrity**: the general health and resilience of natural life-support systems, including their ability to assimilate wastes and withstand stresses such as climate change and ozone depletion; and
- **Natural capital**: the stock of productive soil, freshwater, forests, clean air, ocean, and other renewable resources that underpin the survival, health and prosperity of human communities.

5.1.1 The economic dimension

The growth of economies and their structural transformation have always been recognized as being at the core of development. They still are the most important preconditions for the fulfilment of human needs and for any lasting improvements in living conditions. In addition to the quantitative economic aspects of development, an increasing number of qualitative aspects have come to be recognized too. The main argument is that neither economic growth in the aggregate nor growth of income at the personal level is sufficient to guarantee the progress of an entire society. Accompanying qualitative changes are needed as well.

5.1.2 The social / institutional dimension

There is one major argument for including social issues in the concept of sustainable land management. This is part of the general discussion on sustainability and can be described in the following way: equity considerations are vital to the notion of sustainable development. More precisely, inter-generational or inter-temporal equity is one of the cornerstones of the concept. As a consequence, the issue of intra-generational equity cannot be excluded from a comprehensive notion of sustainable development because to do so would be to destroy the symmetry of the equity argument on which the term 'sustainable' is built. Hence intra-generational equity – covering the whole range of social issues in development, such as regional and gender distribution – is rightly considered as an integral part of sustainable development[1].

The biophysical terms for sustainable land management technologies and approaches are not used consistently and mean different things to different people – and even to the same people at different times (Liniger et al. 2002[2]). In fact, no globally approved or endorsed system exists. Some of the names coined refer to the *appearance of structures* such as terraces, bunds, or ditches. Some combine the appearance with the *materials* used, e.g. stonewalls, earth bunds, grass strips, and some add the *slope or drainage,* e.g. graded ditches or infiltration ditches. Some refer to the *land management* such as enclosure, others to the method of construction, such as "*Fanya juu*" (an assimilated Swahili term describing the way soil is 'thrown upwards' to build the bund) or to the *function and impact,* e.g. cut-off drain, etc. Critchley 1999[3] showed that even amongst terraces there is a huge variety of names and much confusion about what 'terraces' actually are: names include, for example, bench terrace and step terrace (metaphorically derived), forward/outward sloping terraces (describing the inclination of the bed), *Fanyu juu* terraces, Puerto Rico terraces (site-derived) and Zingg terraces (named after a person). This makes common understanding and sharing of knowledge difficult. Such understanding is one of the aims of the World Overview of Conservation Approaches and Technologies (WOCAT) which was started in the 1990s as a global initiative to support better management of SWC knowledge (Liniger et al., 2004[4] Liniger and Schwilch, 2002[5]).

Historically the term "sustainability" is closely connected to improvement and maintenance of our bio-physical environment. But let us ask the question, for what purpose are we conserving natural capital? Is the society supported by this capital just and decent, worthy of preservation? Obviously, the work of sustaining a society raises the question of the moral worth of that society. This is clearly a question of ethics or values.

Values vary greatly in detail within and between cultures, as well as between academic disciplines (e.g., between economists and ecologists) (Tisdell, C. 1988, and many others[6;] Mats Gurtner et al.2006[7] Liniger HP, van Lynden et al 2008[8], FAO, 1990[9]). The integration of social values into sustainability goals implies a much more complex and contentious debate, and those focused on ecological impacts tend to strongly resist non-ecological interpretations.

Others see at the heart of the concept of sustainability a fundamental, immutable value set that is best stated as 'parallel care and respect for the ecosystem and for the people within'. From this value set emerges the goal of sustainability: to achieve human and ecosystem longevity and well-being together. Seen in this way, the concept of sustainability is much more than environmental protection in another guise. It is a positive concept that has as much to do with achieving well-being for people and ecosystems as with reducing ecological stress or environmental impacts. This kind of vision is of course much more debatable or subjective than the simpler definitions such as the Bruntland Definition or the "Daly Rules."

It is thus obvious that there is no well-defined, clear approach with added tools (like the livelihood-approach) for project planning. When using such a holistic approach for programme or project planning, it is therefore obvious that the planners must properly define their approach. The concept of sustainability also requires contributions from different specialists with different professional backgrounds (e.g. social scientists, economists, biologists, etc). This means that inter- and transdisciplinary teamwork is a precondition for success.

5.1.3 Efficient management of existing knowledge about sustainable land management

As described above, there is no concrete tool to guide the implementation of sustainable land management practices, but conceptual frameworks such as "Sustainable Development Appraisal (SDA)" (*Table 5.1*) provide a collection of tools, methods and methodologies from different sciences to support planning and implementation of projects and programmes. Common to all the literature on sustainable land management or sustainable rural development is that all approaches cover the three dimensions of sustainability (ecological, economic and social/institutional) and include, besides disciplinary tools, participatory approaches, stakeholder analysis, local knowledge, involvement of local, regional and often also national power players and policy-makers, collective learning processes, etc.

Sustainable Development Appraisal (SDA) as an example of structuring and managing data

SDA makes it possible to address relations between human beings, nature and socio-political contexts. In particular, this approach

- Guides participatory processes to identify potentials and constraints inherent to the resources in a given physical and social environment;
- Facilitates determination and evaluation of development visions, needs, options, and constraints as seen by very different actors on all institutional levels;
- Provides an entry point for the initiation of processes involving multiple stakeholders on several institutional levels to develop development strategies and concrete activities;
- Provides a sound basis for subsequent strategic studies and for the formulation of scenarios, given that the data combine external and internal perspectives;
- Identifies entry points for action on the part of decision-makers and implementers on all levels;
- Can be used as a basis for impact monitoring;
- Facilitates the evaluation of a regional development plan.

Table 5.1 Overview of methodological components of the SDA procedure

Sustainable Development Appraisal: Overview	
PREPARATION:	Background and initial design
COMPONENT I:	Participatory assessment and appraisal of current situation
	Element 1: Characterisation of spatial units
	Element 2: Characterisation of actor categories
	Element 3: Appraisal of interactions
COMPONENT II:	Participatory assessment and appraisal of dynamics
	Element 4: Assessment of bio-physical dynamics
	Element 5: Assessment of social, economic and cultural dynamics
	Element 6: Appraisal of change
COMPONENT III:	Participatory assessment and appraisal of development
	Element 7: Assessment of development visions
	Element 8: Assessment of needs, potentials and constraints
	Element 9: Appraisal of development options
COMPONENT IV:	Preparation of development profiles and synthesis
	Element 10: Compilation of Local Development Profiles (LDPs)
	Element 11: Compilation of a Regional Development Profile (RDP)
	Element 12: Synthesis and recommendations for sustainable development
INTEGRATION:	Initiation of multi-stakeholder negotiations

Source: Hurni and Ludi 2000[10]

Methodological elements of the SDA procedure

Element 1: Characterisation of spatial units

In Element 1, the study analyses the physical environment and identifies the spatial units important to the study. The delimitation of spatial units is done in a participatory way.

Spatial units are homogeneous analytical units that contain information about a) natural resources, and b) natural resource use. Thus homogenous spatial units can be discussed, defined and visualised according to:

- **Bio-physical aspects**: especially topography (altitude, slope, exposition), relief and land cover (land cover already includes cultural aspects as it has developed out of a land use system over time), (geo-)morphology, climate, soils, hydro-geography, vegetation, fauna etc.; elements that modify the productivity of resources (climatic elements, atmospheric moisture, soil fertility, availability of water resources, vegetation, aspects of soil management, social and cultural functions of resources, etc.).
- **Aspects of land use**: general resource use (forests, pasture, fields, settlements, etc.), land use management (cycles, intensity, technologies, etc.). In addition, information on trends can be included (for example, intensification, innovations, and limitations on land use management).
- **Cultural aspects**: (see also land cover), patterns of land ownership and access to resources, administrative units, rules and regulations, economic and social strategies, infrastructure.

Element 2: Characterisation of actor categories

In Element 2, the study team creates an overview of actors who are direct and indirect resource users and who affect and are affected by the environment. This differentiation is necessary, as people use resources and the environment differently and also have different strategies and powers to realise their interests.

By analogy to spatial units, actor categories are defined as analytical social units that make sense for the scope of the intended study. In addition, each actor category is also actively integrated in and shapes the appraisal process. For this overview, actors and actor groups – individuals that have common interests, influence and impacts on natural resources – are arranged in categories according to criteria such as:

- Livelihood strategies (e.g. land use strategies, land management strategies, access to resources, impacts on the environment);
- Economic, political and organisational power (e.g. social status, formal or informal power, legitimacy, economic status);
- Position in decision-making processes (e.g. decision-making power over resources, production and distribution, and land use strategies).

Preliminary information about actors and actor groups already appears during the initiation phase. Yet, whereas dominant groups are easy to recognise, other groups are less visible. Socially and economically marginal groups or groups only indirectly connected to the resource use system need special attention (absentees, day labourers, women, old people, lower casts, migrants, urban consumers, etc.). Thus, in interaction and discussion with local informants during the process, additional information about actors usually comes to light and a need to include additional actor categories arises. On principle, a complete range of actor categories must participate in the appraisal.

Element 3: Appraisal of interactions

In Element 3, interrelations and exchange between actor categories and spatial units are discussed in order to get a joint description of the status of the strategic sectors and the study area.

Thus, actor categories and spatial units are again joined together, revealing clear aspects of resource use and cooperation, as well as conflicts over resources and social tensions. Discussions are held with actor categories separately, focusing on strategic sectors. The perceptions are put together by the study team and checked again by each actor category. At the end, a clear picture emerges of the status of the strategic sectors that also reflects the status of the study area.

Element 4: Assessment of bio-physical dynamics

In Element 4, dynamics resulting from the interrelations and interactions between spatial units are analysed.

Such interactions can be analysed by:

- Flow of biomass and energy: Use of natural resources always affects the natural cycle. Within a system, flows of material and energy reveal surpluses and deficits (for example firewood, dung, water). In addition, flows of material and energy reveal the degree of autarchy and the room for manoeuvre in a system within a broader system (e.g. markets, flow of money, migration, upland-downstream)
- Systems of natural resource use: The economic strategies of social units are linked to the environment in a specific manner. The analyses show the dependencies and conflicts that arise between spatial units (e.g. pasture land in forests and fields).
- Temporal aspect: Information from the past makes possible further description of changes in the natural resource base as they emerge within a spatial unit, as well as their interactions (e.g. changes in use of forests, water resources and soil, erosion, discharge).

Element 5: Assessment of social, economic and cultural dynamics

In Element 5, the dynamics taking place between actor categories are analysed. The way they interact – in a competitive or cooperative way, no interaction or mutual exchange, for example – influences environmental change.

Interaction can be analysed according to:

- Ecological aspects (collaboration and conflicts in space, etc.);

- Economic aspects (cooperation and synergies, trade and exchange, markets, competition, etc) and,
- Social aspects (synergies, patron-client-relationships, castes and classes, social status and decision-making powers, etc.).

The result of Element 5 is a range of perceptions and appraisals of the environment, of strategies and room to manoeuvre, of dependencies, synergies, and dynamics between actors. This makes it possible to appraise negative and positive interactions between groups and interpret their impacts on the environment.

Element 6: Appraisal of change

In Element 6, an analysis is done of how humans affect their environment and what kinds of dynamics take place. This allows appraisal of changes related to sustainable development. Change is experienced by people in as much as it affects daily life and forces them to change their livelihood strategies. People are thus able to give concrete information about change from their perspective. Thus, in Element 6, actor categories appraise trends in the environment and the strategic sectors separately. Appraisal of change by actor categories clearly outlines where development options must be sought.

Element 7: Assessment of development visions

In Element 7, people develop visions vis-à-vis the dynamics taking place in their environment. The particular interests of people and their daily strategies often contradict the visions they have of their environment. Those visions often include a healthy social and ecological environment.

A dialogue may show common interest in sustainable resource use and sustainable development. It can outline necessary adaptation processes, identify new livelihood strategies, and make clear the need for outside support (higher levels of organisation, research, development cooperation). In such a dialogue, negative trends are not treated separately but located and understood in the social and ecological context. It is very helpful to have development visions (expression of negative visions is an impressive tool). This results in description and appraisal of positive visions that different actors have about their environment. As visions contradict the change appraised by different actors, entry points for discussion and entry points for development strategies emerge.

Element 8: Assessment of needs, options and constraints

The objective of Element 8 is identification of room to manoeuvre in the livelihoods of actor categories. Often it becomes obvious that trends appraised as negative within a certain actor category are actually pushed to be perceived as negative by this category. Especially in case of scarcity, a trend is pushed unintentionally as long as no alternatives exist. The differences that different actor categories face in their daily lives become obvious in the way they express specific needs, options and constraints.

Element 9: Appraisal of development options

In Element 9, development options are deduced from the information collected and the appraisal done in the preceding elements. Thus Element 9 draws conclusions and looks to the future. Different perceptions are again put together in a matrix, and discussed and checked in different actor categories.

The proposed way of identifying development options in a sound bottom-up process ensures broad acceptance and very specific ideas for concrete actions. In addition, it is made clear who can take over responsibility for the implementation of strategies and what kind of support from higher levels is necessary. On this basis, subsequent procedures such as negotiation or implementation processes can be organised according to need (SDA procedure: integration (*Figure 5.1*).

Elements 10 to 12: need no further description. These are the steps in interpreting and synthesizing the available information.

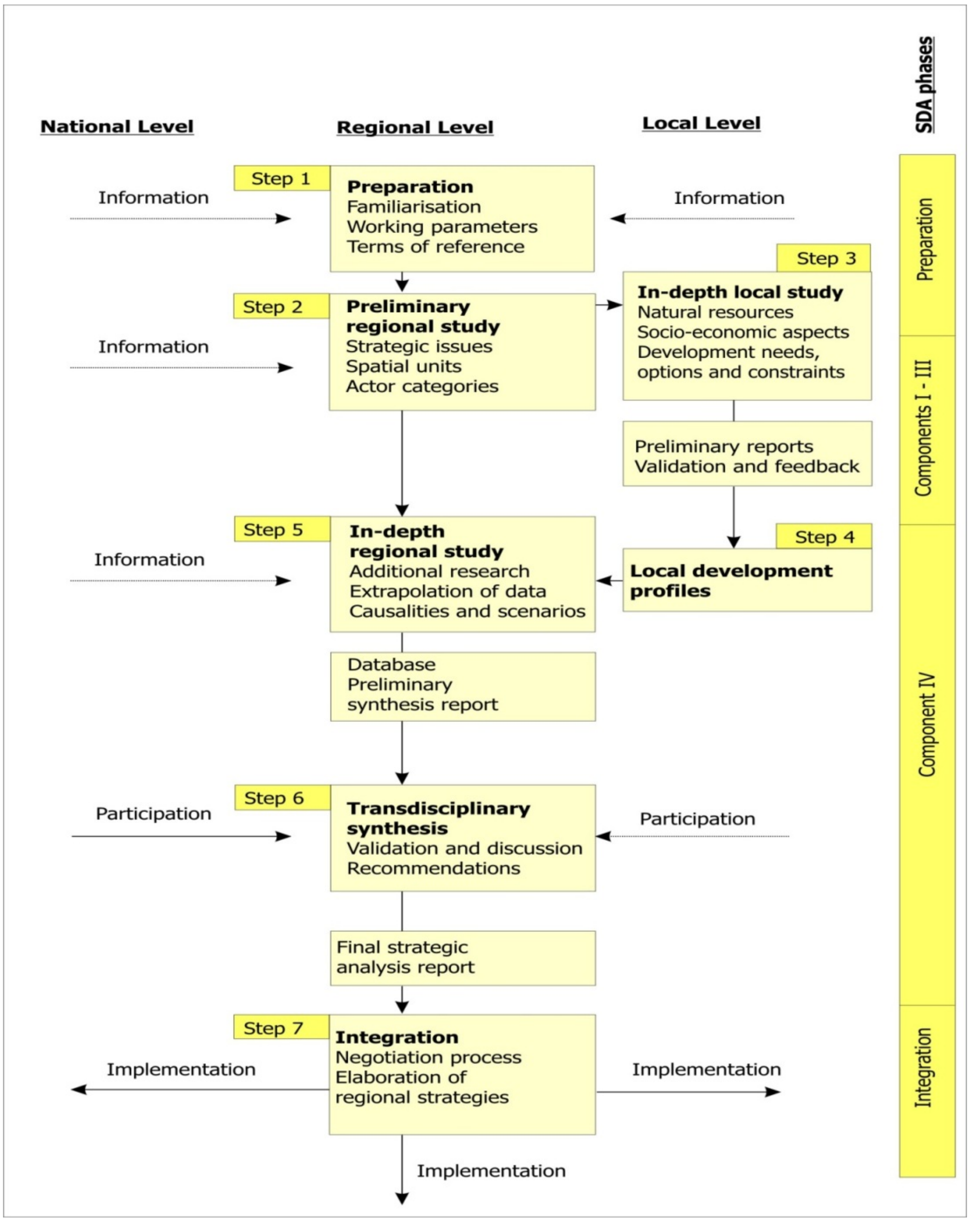

Figure 5.1 Implementing steps in an SDA (Hurni and Ludi, 2000)

5.2 The World Wide Web as a source of information

Today almost everything can be found on the internet. The major limitations are computer capacity, the capacity of the line to the provider, the quality of the search engine, and, not least, brain capacity.

It would grossly inflate the volume of this textbook to offer guidelines on how to best use the internet and search all the information provided on the World Wide Web, because almost all information sought can be found. The greatest problem is that one often knows nothing about the reliability and the quality of data or statements found in the World Wide Web. The ground principles when using the web are, therefore, to crosscheck the findings, to critically review the content and to search what other information is available from the same internet sites. The URL (uniform resource locater; some form of the address of the document), can give clues to the authority of a source. A tilde (~) in the URL usually indicates that it is a personal page rather than part of an institutional web site. Also, users should make a mental note of the domain section of the URL, as follows:

- .edu: educational (anything from serious research to student pages)
- .gov: governmental (usually dependable)
- .com:commercial (may be trying to sell a product)
- .net: network (may provide services to commercial or individual customers)
- .org: organization (non-profit institutions; may be biased)

To structure the search for information, so-called search engines have been introduced (*Table 5.2*). In a search mask, words or expressions of interest are typed in and the search engine provides thousands or millions of links to documents, institutions, etc. Normally the size and type of the file are also available. It is important not to open resources that are too big for a personal computer. This can lead to a lot of lost time and trouble. Particular care must be taken when downloading a .pdf file including high resolution graphics or pictures.

Search engine databases are selected and built by computer robot programs called spiders. Although it is said that they "crawl" the web in their hunt for pages to include, in truth they stay in one place. They find the pages for potential inclusion by following the links in the pages they already have in their database (i.e., already "know about"). They cannot think or type a URL or use judgment to "decide" to go look something up and see what's on the web about it.

If a web page is never linked to any other page, search engine spiders cannot find it. The only way a new page - one that no other page has ever linked to - can get into a search engine is for its URL to be sent by some human to the search engine companies as a request that the new page be included. All search engine companies offer ways to do this.

Some types of pages and links are excluded from most search engines by policy. Others are excluded because search engine spiders cannot access them. Pages that are excluded are referred to as the "Invisible Web" - what is not seen in search engine results.

Table 5.2 The most popular search engines (status 2008)

Search Engine	Google www.google.com	Yahoo! Search search.yahoo.com	Ask.com www.ask.com
Size, type	HUGE. Size not disclosed in any way that allows comparison. Most probably the biggest.	HUGE. Claims over 20 billion total "web objects."	LARGE. Claims to have 2 billion fully indexed, searchable pages.
Noteworthy features and limitations	Popularity ranking using PageRank™. Indexes the first 101KB of a Web page, and 120KB of PDF's.	Shortcuts give quick access to dictionary, synonyms, patents, traffic, stocks, encyclopaedia, and more.	Subject-Specific Popularity™ ranking. Suggests broader and narrower terms.
Sub-Searching	At bottom of results page, click "Search within results" and enter more terms. Adds terms.	Add terms.	Add terms.
Results Ranking	Based on page popularity measured in links to it from other pages: high rank if a lot of other pages link to it. Fuzzy AND also invoked. Matching and ranking based on "cached" version of pages that may not be the most recent version.	Automatic Fuzzy AND.	Based on Subject-Specific Popularity™, links to a page by related pages.
Truncation Stemming	No truncation. Stems some words. Search variant endings and synonyms separately, separating with OR (capitalized): airline OR airlines	No truncation. Search with OR as in Google.	No truncation. Search with OR as in Google.
Language	Major Romance and non-Romance languages in Advanced Search.	Major Romance and non-Romance languages.	Major Romance languages. Use Advanced Search to limit.
Translation	Yes, in Translate this page link following some pages. To and sometimes from English and major European languages and Chinese, Japanese, Korean.	Yes.	No.
Boolean logic	Partial. AND assumed between words. Capitalize OR. - excludes. No ( ) or nesting. In Advanced Search, partial Boolean available in boxes.	Accepts AND, OR, NOT or AND NOT, and ( ). Must be capitalized. You must enclose terms joined by OR in parentheses (classic Boolean).	Partial. AND assumed between words. Capitalize OR. - excludes. No ( ) or nesting.

Google is at present recognized as the most comprehensive general web search engine, for the following reasons:

- Google is the BIGGEST search engine database in the world

- PageRank™ often finds useful pages. It is one of the defaults that cannot be turned off in Google and is not for sale. It works on a unique combination of factors, some of which are:
- Popularity – based on the number of links to a page and the importance of the pages that link
- Importance – traffic, quality of links
- Word proximity and occurrence in results
- Google has many useful ways to limit searches
- Google offers special "fuzzy" searches that are useful to search synonyms, find definitions, and find similar/related pages, and more
- The shortcuts and special Google databases can enhance certain types of research
- Google Books and Google Scholar have great potential for university-level research using the web.

The World Wide Web is developing rapidly and is very dynamic. Major changes within a short time may occur; new specialized engines may open at any time. This requires that the user be permanently informed about the major changes. A page that offers a great deal of reliable high quality information about the World Wide Web, how it functions and how to use it is:
http://www.lib.berkeley.edu/TeachingLib/Guides/Internet/Google.html[11].

5.3 The World Overview of Conservation Approaches and Technologies (WOCAT) as an example of a global database

5.3.1 Introduction

Both land users and Sustainable Land Management (SLM) specialists have developed a wealth of know-how related to land management, improvement of soil fertility, and protection of soil resources. Most of this valuable knowledge, however, is simply not evaluated and documented – or if it is, it remains poorly accessible, and comparison of different types of experience is difficult. Such knowledge therefore remains a local, individual resource, unavailable to others working in the same areas and seeking to accomplish similar tasks. This is one of the reasons why soil degradation persists, despite decades of effort throughout the world and high investments in SLM. In this context, the World Overview of Conservation Approaches and Technologies WOCAT (www.wocat.org) was established in 1992 as a global network of SLM specialists. It is organised as an international consortium, coordinated by an international management group and supported by the secretariat which is located at the Centre for Development and Environment, at the University of Bern, Switzerland. Apart from compiling knowledge and making it available, methods and tools have been developed in collaboration with many national and international institutions.

The aim of WOCAT is to monitor and document global experiences in Sustainable Land Management (SLM). This is expected to support global exchange between actors and researchers in SLM, thereby enriching local activities with global experiences. Making use of WOCAT means benefiting from a range of important professional opportunities. Most important among these are:

- The opportunity to intensify the professional international connectivity of one's own institution to other institutions worldwide and vice versa.
- Defined and internationally compatible monitoring and documentation tools like WOCAT can help to promote the vast range of Eritrean traditional and current knowledge and actors in this field throughout the world.

5.3.2 WOCAT's field of expertise: SLM

The main objective of SLM is to promote human coexistence with nature with a long-term perspective so that the provisioning, regulating, cultural and supporting services of ecosystems are ensured. SLM is an essential prerequisite to sustainable development; progress should be made simultaneously at all levels. In terms of such concerns as food security, poverty alleviation, livelihood improvements, water conflicts and ecosystem services, SLM is an important local issue that is also a global concern.

Within the framework of SLM, WOCAT focuses mainly on efforts to prevent and reduce land degradation through Soil and Water Conservation (SWC) technologies and their implementation approaches. The use and sharing of information related to these efforts is a key asset of WOCAT. Training enhances capacities for better SWC implementation. This leads to improved knowledge management. The aim of WOCAT, as a network, is to increase the awareness and motivation of planners and decision makers as well as land users and agricultural advisors. WOCAT hopes to reduce investment failures by providing knowledge-based support about the advantages and disadvantages of available alternatives, based on a wide range of experience in the field.

The extent and effectiveness of SLM / SWC today, be it within a given region or even less on a worldwide, scale is not known. There is, therefore, a pressing need to assess these issues, not least in view of the heavy investments being made in this sector. By providing the appropriate tools and networks required for conducting such an assessment, WOCAT can play an important role in this domain. (WOCAT Strategy 2008 – 2012[12])

5.3.3 WOCAT's vision and mission[13]

WOCAT's vision is that land and livelihoods are improved through sharing and enhancing knowledge about sustainable land management.

WOCAT's mission is to support innovation and decision-making processes in sustainable land management, particularly in connection with soil and water conservation (SWC). This is done by:

- Connecting stakeholders;
- Analysing and synthesising experiences and setting direction;
- Enhancing capacity and knowledge;

- Developing and applying standardized tools for documenting; monitoring, evaluating, sharing and using knowledge

WOCAT's target group is SLM specialists:

- At the field level, including agricultural advisors, project implementers, and land users;
- At the (sub-)national level, including planners, project designers, decision makers, and researchers;
- At the regional and global levels, including international programme planners, and donors.

5.3.4 WOCAT – the four dimensions of knowledge

"Knowledge" – a crucial aspect of WOCAT – has multiple dimensions:

1. Knowledge related to SWC/SLM: innovative methods and an extensive network of both land users and soil and water conservation specialists have enabled WOCAT to accumulate a wide base of knowledge;
2. Knowledge related to documentation and evaluation tools and methods: through the process of refining its methodology and tools, WOCAT has developed substantial experience and know-how on documentation and evaluation procedures;
3. Knowledge related to information sharing and networking: the establishment of an intellectual environment conducive to sharing and networking simplifies the dissemination of acquired knowledge to others working in the same areas and seeking to accomplish similar tasks;
4. Knowledge related to research, training and education: Due to requests to use the WOCAT methods and tools, WOCAT has conducted a large number of training workshops throughout the world. Due to emerging knowledge gaps, WOCAT has become more and more involved in research. These experiences have enabled WOCAT to gather a wealth of knowledge related to research, training and education methods.

5.3.5 WOCAT's activities and achievements

WOCAT tools provide a unique, widely accepted and standardised method of application. They include three comprehensive questionnaires and a database system that cover all relevant aspects of SLM technologies and approaches (as case studies), as well as an assessment of area coverage of degradation and conservation. WOCAT's database currently comprises datasets on 440 technologies and 280 approaches from around 50 countries, of which a subset of 250 technologies and 140 approaches are quality-assured. Many of these have not been reported comprehensively elsewhere. A selection of 42 technologies and 28 approaches are documented in the global overview book *where the land is greener* together with an analysis and with conclusions and policy points (Liniger and Critchley 2007[14]). An interactive and scale-independent mapping methodology has been developed and used in pilot countries.

Furthermore, WOCAT is a very active and successful network of soil and water conservation specialists. The annual workshops are usually attended by 30 to 50 participants from around 20 to 25 countries. Over 80 institutions worldwide have thus far been involved in WOCAT. The methodology has been jointly developed with these participants and institutions.

At the national and regional levels, WOCAT is often included in ongoing projects, moves into the mainstream in local programmes, and becomes part of a national strategy. Its tools are used to document and evaluate local conservation successes and to help share them among others. WOCAT enables practitioners to make informed choices rather than following blueprint prescriptions of 'what to do'. The successful use of WOCAT in SWC implementation at the field level has, for example, been reported from many countries (e.g. Nepal, the Philippines, and Central Asian countries as well as China). It is likely that others have also used WOCAT's knowledge base and its methodology to implement SWC technologies and approaches, but have not yet reported it to the network. Likewise, many technologies and approaches are stored in local WOCAT databases and in local languages.

Documentation of scattered knowledge is demanding for the collector as well as for the resource person. But an important effect of this process is self-evaluation and self-teaching among all persons involved. This is often reported as an enriching and stimulating process. On the other hand, data quality is a concern. This requires a thorough and interactive review process that involves the joint efforts of land users, technical specialists and researchers. Research is also conducted to better understand the ecological, social and economic causes of degradation, to analyse what works and why, and how to modify and adapt particular technologies and approaches to locally specific circumstances and opportunities.

WOCAT has also been used in training and education at various levels (from land user level to university). Over 500 SWC specialists from 40 countries have learned about the WOCAT methodology in WOCAT training workshops so far. Training and capacity building can today be counted among the major aims of WOCAT. Overall, WOCAT is a process: it is demand-driven, on-going and continuously refining its tools and expanding its networks.

5.3.6 WOCAT methodology

As mentioned above, comprehensive questionnaires and a database system have been developed to document and evaluate all relevant aspects of technical measures, as well as implementation approaches, by teams of researchers and specialists together with land users (Liniger and Schwilch 2002; WOCAT 2007). This process allows better understanding of the reasons behind successful local experience – whether introduced by projects, or found in traditional systems – and how to share it among various sites. Work with these questionnaires also helps to critically review often fragmented knowledge, to identify the gaps and contradictions in what one already knows, and to question and evaluate one's own current perceptions and field experiences. This process ensures systematic recording and piecing together of local information, together with specific details about the environmental and socio-economic setting in which the information was obtained.

Experiences documented contain technological measures as well as implementation approaches. **Technologies** are understood as agronomic, vegetative, and structural and management measures that control land degradation and enhance productivity in the field. **Approaches** are ways and means of support that help to introduce, implement, adapt and apply SLM technologies on the ground. The questionnaire on technologies addresses the specifications of the technology (purpose, classification, design and costs) and the natural and human environment where it is used. It also includes an analysis of the benefits, advantages and disadvantages, economic impacts, acceptance and adoption of the technology. The questionnaire on approaches focuses on implementation, with questions on objectives, operation, participation by land users, financing, and direct and indirect subsidies. Analysis of the approach described involves monitoring and evaluation methods as well as an impact analysis.

Many local, national and regional initiatives have worked with the WOCAT questionnaires, have helped to improve them, and have confirmed their effectiveness. Recently, a new methodology has been developed in which the global database is used as a source of information for local implementation of SLM. The main aim of this methodology is to provide a framework for a **participatory process for the appraisal and selection of SLM options.** The process starts with initial co-learning among stakeholders about degradation and conservation, continues with a participatory appraisal of existing field experience, and ends with the agreed selection of a solution for field trial. The methodology consists of three main parts:

In the first step, SLM measures already applied at the respective local site are identified and listed during a workshop with representatives of different stakeholder groups (land users, policy makers, researchers). The participatory and process-oriented approach initiates a mutual learning process among the different stakeholders by means of sharing knowledge and jointly reflecting on current problems and solutions related to land degradation.

In the second step, these identified, locally applied SLM measures are assessed with the help of the WOCAT questionnaires in a joint effort by researchers and land users.

The third step consists of another stakeholder workshop where promising options for sustainable land management in the given context are selected, based on the WOCAT database, including the evaluated locally applied measures. These promising solutions are then assessed with the help of a selection and decision support tool and adapted for implementation at the local site.

5.3.7 WOCAT at university level

WOCAT should not be seen as an aim in itself, but used within a broader context, and presented as a powerful tool in planning, evaluating and researching SLM. The potential of WOCAT for a university institution is manifold:

Integration into curricula: WOCAT methodologies and products can easily be integrated into curricula at undergraduate and postgraduate levels and be used to improve teaching of SWC / SLM in the form of lectures and student exercises. Experience in this respect has already been gained in universities in Central Asia, the Philippines and through the Swiss National Centre of Competence in Research (NCCR) North-South; the available material can also be shared (www.wocat.net/educat.asp[15]).

Research: The comprehensiveness of the WOCAT tools for documenting and evaluating SLM technologies and approaches helps to interlink knowledge in SLM. This may, in turn, lead to the definition of new research themes. WOCAT allows for the building up of disciplinary and transdisciplinary research capacity to identify key research issues, and makes it possible for different target groups to use the findings in order to achieve a comprehensive pathway for SLM efforts.

Network: WOCAT offers an international network and all collaborators can join in and profit from its vast connections and knowledge exchanges. A research organisation can use the network to further professional profiles and to engage in international exchange.

Evaluation: WOCAT methodologies can be applied in evaluation of land management measures. The uniform and proven WOCAT tools allow for evaluation over a wider range of socio-economic and biophysical spheres.

Implementation tool: In the implementation of global Conventions (e.g. the UN Convention to Combat Desertification), universities can play an important role supporting the implementation process of government programmes in conjunction with international conventions. WOCAT can be used in this context to show the efficiency of land management measures in combating desertification and to provide an overview of achievements in this area so far.

5.3.8 WOCAT's land conservation measures – constituents of SLM

According to WOCAT, conservation measures fall into four categories: agronomic, vegetative, structural and management measures. Measures are components of SLM technologies. Each Technology is made up of one or – very commonly – a combination of measures: For instance, terraces – a typical structural measure – are often combined with other measures, such as grass on the risers for stabilisation and fodder (vegetative measure), or contour ploughing (agronomic measure) (*Figure 5.2.a-e*).

SLM Technology

Description

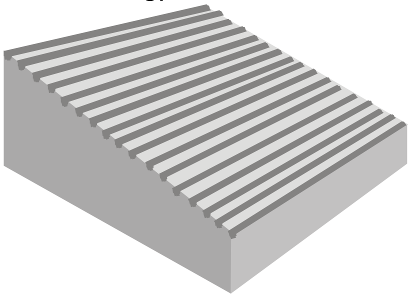

Figure 5.2a

Agronomic measures such as conservation agriculture, manuring / composting, mixed cropping, contour cultivation, mulching, etc.

are usually associated with annual crops
are repeated routinely each season or in a rotational sequence
are of short duration and not permanent
do not lead to changes in slope profile
are normally independent of slope

A1: Vegetation / soil cover
A2: Organic matter / soil fertility
A3: Soil surface treatment
A4: Subsurface treatment
A5: Others

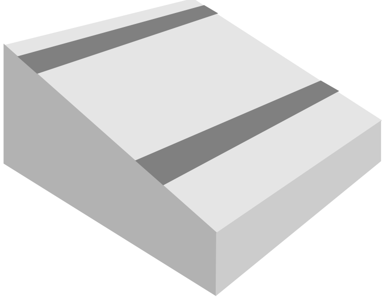

Figure 5.2b

Vegetative measures such as grass strips, hedge barriers, windbreaks, agroforestry etc.

- involve the use of perennial grasses, shrubs or trees
- are of long duration
- often lead to a change in slope profile
- are often aligned along the contour or against the prevailing wind direction
- are often spaced according to slope

V1: Tree and shrub cover
V2: Grasses and perennial herbaceous plants
V3: Clearing of vegetation (eg fire breaks/reduced fuel)
V4: Others

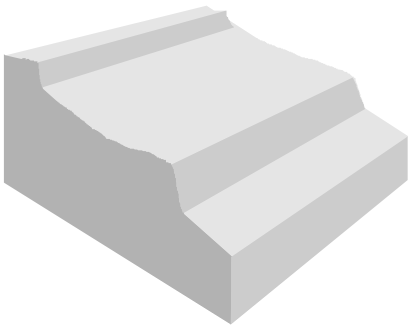

Figure 5.2c

Structural measures such as terraces, banks, bunds, constructions, palisades, etc

- often lead to a change in slope profile
- are of long duration or permanent
- are carried out primarily to control runoff, wind velocity and erosion and to harvest rainwater
- often require substantial inputs of labour or money when first installed
- are often aligned along the contour / against prevailing wind direction
- are often spaced according to slope
- involve major earth movements and / or construction with wood, stone, concrete, etc.

S1: Bench terraces (slope of terrace bed <6%)
S2: Forward sloping terraces (slope of terrace bed >6%)
S3: Bunds / banks
S4: Graded ditches / waterways (to drain and convey water)
S5: Level ditches / pits
S6: Dams / pans: store excessive water
S7: Reshaping surface (reducing slope)
S8: Walls / barriers / palisades
S9: Others

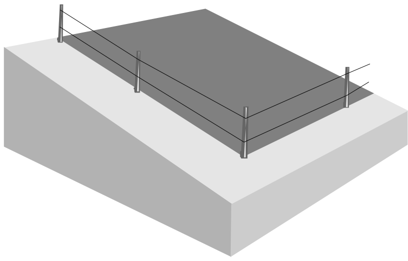

Figure 5.2d

Figure 5.2e

Management measures such as land use change, area closure, rotational grazing, etc.
involve a fundamental change in land use
involve no agronomic and structural measures
often result in improved vegetative cover
often reduce the intensity of use
M1: Change of land use type
M2: Change of management / intensity level
M3: Layout according to natural and human environment
M4: Major change in timing of activities
M5: Control / change of species composition (if annually or in a rotational sequence as done eg on cropland -> A1)
M6: Others

Combinations in conditions where different measures are complementary and thus enhance each other's effectiveness.
Any combinations of the above measures are possible, eg:

- structural: terrace with
- vegetative: grass and trees with
- agronomic: ridges

Example: S1,V1, V2, A3: bench terraces with tree and shrub cover, grasses and perennial herbaceous plants, and soil surface treatment

Figure 5.2a -e SLM technology classification (WOCAT)

M: Overall management

Management measures (such as land use change, area closure, rotational grazing, etc., see *Figure 5.2d*) involve a fundamental change in land use; involve no agronomic and structural measures; often result in improved vegetative cover; and often reduce the intensity of use.

- *M1: Change of land use type*: e.g. enclosure, resting, protection, change from crop to grazing land, from forest to agroforestry, from grazing land to cropland, etc.
- *M2: Change of management / intensity level*: e.g. from mono-cropping to rotational cropping, from continuous cropping to managed fallow, from laissez-faire to managed, from random (open access) to controlled access (grazing land, forestland, e.g. access to firewood), from herding to fencing, adjusting stocking rates, etc.
- *M3: Layout* according to natural and human environment: exclusion of natural waterways and hazardous areas, separation of grazing types, distribution of water points, salt-licks, livestock pens, dips (grazing land)
- *M4: Major change in timing of activities*: land preparation, planting, cutting of vegetation
- *M5: Control / change of species composition*: reduce invasive species, selective clearing, encourage desired species, controlled burning / residue burning

A: Agronomic measures / soil management

Agronomic measures (such as mixed cropping, contour cultivation, mulching, see *Figure 5.2a*) are usually associated with annual crops; are repeated routinely each season or in a rotational sequence; are of short duration and not permanent; do not lead to changes in slope profile; are normally not zoned; and are normally independent of slope.

- *A1: Vegetation / soil cover*: better soil cover by vegetation, early planting, relay cropping, mixed cropping / intercropping, contour planting / strip cropping, cover cropping, retaining more vegetation cover, mulching, temporary trash lines, others.
- *A2: Organic matter / soil fertility*: legume inter-planting, green manure, applying manure / compost / residues (organic fertilizers), applying mineral fertilizers (inorganic fertilizers), applying soil conditioners (e.g. use of lime or gypsum), rotations / fallows (associated with M), others.
- *A3: Soil surface treatment*: conservation tillage (zero tillage, minimum tillage and other tillage with reduced disturbance of the top soil), contour tillage, contour ridging (crop and grazing land), done annually or in rotational sequence,
- *A4: Subsurface treatment*: breaking compacted subsoil (hard pans): deep ripping, "subsoiling", deep tillage / double digging, others.

V: Vegetative measures

Vegetative measures (such as grass strips, hedge barriers, windbreaks, etc., see *Figure 5.2b*) involve the use of perennial grasses, shrubs or trees; are of long duration; often lead to a change in slope profile; are often zoned on the contour or at right angles to wind direction, and are often spaced according to slope:

- *V1: Tree and shrub cover*: dispersed (in annual crops or grazing land), aligned (in annual crops or grazing land): e.g. live fences, hedges, barrier hedgerows, alley cropping), in blocks (e.g. woodlots).
- *V2: Grasses and perennial herbaceous plants:* dispersed, aligned (grass strips).

S: Structural measures

Structural measures (such as terraces, banks, bunds, constructions, palisades, etc., see *Figure 5.2c*) often lead to a change in slope profile; are of long duration or permanent; are carried out primarily to control runoff, wind velocity and erosion; often require substantial inputs of labour or money when first installed; are often zoned on the contour / against wind direction; are often spaced according to slope; and involve major earth movements and / or construction with wood, stone, concrete, etc. There are many terrace types:

- *S1: bench terraces* (<6%) (if combined with S3, S4 and S5 indicate the combination): level (incl. rice paddies), forward sloping / outward sloping, backward sloping / back-sloping / reverse

- *S2: forward sloping terraces* (>6%): (if combined with S3, S4 and S5 indicate the combination)
- *S3: bunds / banks* (if combined with terrace, combination is indicated): level (tied, non-tied), graded (tied, non-tied), semi-circular, v-shaped, trapezoidal, others.
- *S4: graded ditches, waterways* (to drain and convey water): cut-off drains, waterways
- *S5: level ditches, pits:* infiltration, retention, sediment / sand traps
- *S6: dams / pans:* store excessive water
- *S7: reshaping surface* (reducing slope) */ topsoil retention* (e.g. in mining, storing topsoil and re-spreading
- *S8: walls, barriers, palisades* (constructed from wood, stone concrete, others, not combined with earth)
- *S9: others*

These categories allow a better overview of a number of more or less different single SWC technologies or measures. However, such classification is to a certain extent arbitrary because, in practice, these components always occur in combination. For example, a terrace (structural measure) involves a ditch and a small dam that is stabilized by grasses and trees (vegetative measure), and the area of cereal production can only be ploughed along the contour (agronomic measure). The most effective erosion control component is certainly a dense plant cover, and thus, agronomic and vegetative SWC are given highest priority in soil protection. At the same time, these measures provide direct economic return mostly in the form of biomass production. However, after a dry season of several months, there is hardly any vegetative cover to protect the soils from intensive rains. Therefore, a well-designed system of structural SWC measures provides protective function until the plant cover takes over. Structural measures also gain importance when runoff from roads, settlements, etc, enters and damages cropland. In arid areas, plant cover might always be low so that soil protection always relies on structural measures. Optimal conservation effects can be achieved if all components are integrated into one farming and protection system.

5.3.9 Principles of SWC

Attempts to systematize SWC terminology and the enormous variety of technologies have produced innumerable SWC handbooks and guidelines. The systematic description of a technology, however, has another side effect: an SWC expert without much field experience – i.e. at the beginning of his/her career – will not question the design and technical details of a technology and will try to implement it as it is described in the reference book. A predetermined mind, however, can seriously hamper participatory approaches and prevent experts from considering farmers' opinions, indigenous knowledge and thus site-specific experience. In the past this has led to great problems of acceptance and adaptation of SWC.

Therefore, before focusing too early on one specific technology, a definite construction material, a fixed spacing, one type of plant, etc., it is recommendable to initiate an open-minded discussion with the land user. The "conservationist's mind" could be kept relatively open, for example, by focusing on the "principles of functioning" that are required to respond to a set of challenges. For example, when a long slope showing negative effects due to uncontrolled surface drainage is observed, the first thing that often comes to mind is "terracing". But before this "solution" arouses too much excitement, thought should first be given to whether terracing is the only way to diminish runoff velocity, or if there are other alternatives such as vegetation, ditches, trash lines, etc. Another example is the term "soil bund". Since "soil" is a precious resource, why waste it by constructing bunds instead of using stones, residues or other materials that are locally available? Being equipped with the principles of functioning *(Figures 5.4a-e*) and a pool of SWC technologies, a conservation expert should be in a good position to be a competent partner in assisting land users in practicing more sustainable land management. To describe these principles, it was found useful to regroup the above-mentioned SWC categories into four groups with similar functions: (1) vegetative and agronomic SWC (2) structural SWC in humid areas, (3) structural water conservation in arid areas, and (4) wind erosion control.

(1) ***Vegetative and agronomic measures*** create effects both above and below the soil surface. Plants and plant residue but also stones, coarse clods (soil aggregates), ripples etc. form an increased surface roughness that in turn enforces a reduction of runoff velocity and accumulation of eroded particles, and also provides an extended time of infiltration. In addition, plants and mulch reduce the effect of rain splash, decreasing the amplitude of the surface temperature, thus helping to reduce evaporation losses. Plants also help increase infiltration in many ways: (1) directly through their roots, and (2) indirectly by increasing organic matter and thus improving aggregate stability and soil structure. Selected plant types improve soil fertility by fixing macronutrients such as Nitrogen. Improved soil fertility, in turn, again serves for better plant growth. The soil-plant system may thus stabilize itself, ensuring both production and protection functions.

(2) Catchments in humid areas often face a general problem of surplus overland flow. The first task may therefore be to protect the uncovered cultivated parts from external sources of water - so-called run-on. Particularly at the beginning of a rainy season, when there is less protective vegetation available, it is mostly drainage channels or ditches, so-called cut-off drains that serve as a run-on control. On cultivated fields, structural measures such as ditches, terraces, bunds etc. help interrupt (decrease) slope length. With time, the slope angle will also be diminished when structures gradually develop into terraces. To safely drain excess water, these structures are graded. Both reduced slope length and slope angle help to retard runoff velocity, encourage accumulation of eroded particles, and extend the time of infiltration. Vegetative strips, hedgerows, etc. can achieve the same effects, provided that sufficient water and controlled grazing are available to maintain a certain plant cover. Cut-off drains and terrace channels collect a lot of runoff that needs to be safely drained out of the cropping area and out of the catchment. Such waterways can be natural or artificial drainage lines that should be protected from erosion themselves, for example by dense ground cover (grass, stones) or wooden / stone check dams. Waterway - or gully - protection measures also focus on reducing runoff velocity and enforcing accumulation of eroded material.

(3) ***In arid areas*** rainwater is commonly insufficient for production. A first measure is, therefore, to split the area into different functions. Only a certain part of a slope, e.g. 50%, will be used as cropping area, while the remaining part serves as external "catch-

ment" for collecting / harvesting rainwater to be drained onto the cropping area. The latter requires both runoff and infiltration management. Soil crusts must often be broken to enable infiltration. Mulching can minimize evaporation losses. With time, soil structure (aggregate stability) and organic matter content can be gradually improved. At the same time, structures of different shapes – half moon and rectangular forms – will keep overland flow in the cropping area as long as possible. Excess water will be drained around or through these structures (via spillways) onto the next cropping area and structure downslope. In this manner, slope length is reduced to minimize erosion risk during heavy rainfall events. Consequently, runoff velocity is reduced, accumulation of eroded particles is enhanced, and infiltration increased. The management of run-on is an important aspect of this land management. This is similar to the spate irrigation system carried out in the western lowlands or Eritrea.

(4) *Controlling wind erosion* can be separated into prevention of detachment and re-accumulation of already eroded material. In both cases, wind speed must be diminished. It needs to be kept in mind that eroded soil particles blown over a surface with high-speed work like sand paper to destroy the surface by detaching further material. Increased surface roughness, either by plants or large soil aggregates and clods, reduces wind speed near the soil surface; eroded particles accumulate in diffuse accumulations, and detachment is largely decreased. Barriers, so-called windbreaks, consisting of higher trees, bushes and ground cover, reduce wind speed in the first several meters above ground. Typically, accumulations of eroded material concentrate immediately before and after the barrier.

5.4 Other Global Databases

5.4.1 5.4.1 The FAO soil map of the world

Reference: www.fao.org/ag/AGL/agll/dsmw.htm[16]

The World Reference Base for Soil Resources (WRB) is an initiative of FAO, supported by the United Nations Environment Programme (UNEP) and the International Society of Soil Science, dating back to 1980 (FAO 1998[17]). The intention of the WRB project was to work toward the establishment of a framework through which existing soil classification systems could be correlated and through which ongoing soil classification work could be harmonized. The final objective was to reach an international agreement on the major soil groupings to be recognized at a global scale as well as on the criteria and methodology to be applied for defining and identifying them. Such an agreement was meant to facilitate the exchange of information and experience, to provide a common scientific language, to strengthen the applications of soil science, and to enhance communication with other disciplines.

The project to create an International Reference Base (IRB) for Soil Classification was initiated in 1982 as one of the programmes proposed to implement a World Soils Policy through UNEP. It was envisaged that the IRB was to be used as a basis to revise the legend of the Soil Map of the World (FAO-UNESCO, 1974[18]).

In 1988 FAO issued the revised legend of the Soil Map of the World (FAO, 1988[19]). The number of major soil groupings in this legend was increased from 26 to 28 and that of the soil units from 106 to 153. Some of the main changes included the amalgamation of Lithosols, Rendzinas and Rankers into Leptosols, the split of Luvisols into Luvisols and Lixisols and, similarly, the separation of Acrisols into Acrisols and Alisols, the deletion of Xerosols and Yermosols, and the introduction of Anthrosols, Plinthosols, Calcisols and Gypsisols. Some diagnostic criteria were adapted, and others were newly defined (e.g. argic and ferralic B horizons, and andic, fluvic, gleyic, stagnic, nitic, salic and sodic properties).

When comparing the Kyoto list of 20 International Reference Bases for Soil Classification (IRB) units and the 28 FAO major soil groupings of the revised legend, the question arose as to whether it was justifiable to develop two systems side by side. If a further split of some IRB units took place, one would end up with almost identical lists of units. Furthermore, as both IRB and the Soil Map of the World were co-sponsored by the ISSS, it was deemed inappropriate to pursue two separate programmes which essentially had the same goal, namely to arrive at a rational inventory of global soil resources. An early motive for doing so had been that the 1974 FAO-UNESCO legend was meant only to serve the sole purpose of the 1:5000,000 Soil Map of the World. Since then, the legend has progressively been developed to encompass the major soils of the world at three levels of generalization and is presently used widely for surveys both in developed and developing countries. Moreover, the terminology is well known and generally accepted. Therefore, it was decided that the IRB should adopt FAO's Revised Legend as a framework for its future activities. It would be IRB's task to apply its principles of definitions and soil relationships to the existing FAO units, providing greater depth and background. The merger of the two efforts was launched under the name: 'World Reference Base for Soil Resources', an ISSS/FAO/ISRIC undertaking.

5.4.2 Objectives of the world reference base for soil resources

The main objective of the World Reference Base for Soil Resources (WRB) is to provide scientific depth and background to the 1988 FAO revised legend, incorporating the latest knowledge relating to global soil resources and their interrelationships. To include some of the most recent pedological studies and to expand use of the system from an agricultural base to a broader environmental one, it was recognized that a limited number of important changes to the 1988 legend were necessary. These changes are:

- To develop an internationally acceptable system for delineating soil resources to which national classifications can be attached and related, using FAO's revised legend as a framework;
- To provide this framework with a sound scientific basis so that it can also serve different applications in related fields such as agriculture, geology, hydrology and ecology;
- To recognize within the framework important spatial relationships of soils and soil horizons as characterized by topo- and chrono-sequences; and

- To emphasize the morphological characterization of soils rather than to follow a purely laboratory-based analytical approach.

The WRB is also a tool for identifying pedological structures and their significance. It serves as a basic language in soil science and facilitates:

- Scientific communication;
- Implementation of soil inventories and transfer of pedological data, elaboration of different systems of classification having a common base, interpretation of maps;
- Acknowledgement of relationships between soils and soil horizon distribution as characterized by topo- and chronosequences;
- International use of pedological data, not only by soil scientists but also by other users of soil and land, such as geologists, botanists, agronomists, hydrologists, ecologists, farmers, foresters, civil engineers and architects, with the particular objective of improving:
- The use of soil data for the benefit of other sciences;
- The evaluation of soil resources and the potential use of different types of soil cover;
- The monitoring of soils, particularly soil development, which is dependent on the way soils are used by the human community;
- The validation of experimental methods of soil use for sustainable development, which maintain and, if possible, improve the soil's potential;
- Transfer of soil use technologies from one region to another.

5.4.3 Principles of the world reference base for soil resources

The general principles of the WRB can be summarized as follows:

- The classification of soils is based on soil properties defined in terms of diagnostic horizons and characteristics, which to the greatest extent possible should be measurable and observable in the field;
- The selection of diagnostic horizons and characteristics takes into account their relationship with soil-forming processes. It is recognized that an understanding of soil-forming processes contributes to a better characterization of soils but that they should not, as such, be used as differentiating criteria;
- To the extent possible at a high level of generalization, an attempt is made to select diagnostic features of significance for management purposes;
- Climatic parameters are not applied in the classification of soils. It is fully realized that they should be used for interpretation, in dynamic combination with soil properties, but should not be part of soil definitions;
- WRB is meant to be a comprehensive classification system which enables people to accommodate their own national classification system. It comprises two tiers of categorical detail:

1. The "Reference base" which is limited to the first level only, having 30 reference soil groups; and
2. The "WRB Classification System" consisting of combinations of a set of prefixes as unique qualifiers (or modifiers) added to the reference soil groups, allowing very precise characterization and classification of individual soil profiles;

- The reference soil units in WRB should be representative of major soil regions so as to provide a comprehensive overview of the world's soil cover (see *Figure 5.3*);
- The reference base is not meant to substitute for national soil classification systems but rather to serve as a common denominator for communication at an international level. This implies that lower-level categories, possibly a third category of the WRB, could accommodate local diversity at country level. Concurrently the lower levels could emphasize soil features which are important for land use and soil management;
- The Revised Legend of FAO/UNESCO Soil Map of the World has been used as a basis for the development of the WRB in order to take advantage of the international soil correlation work that has already been conducted through this project;
- Definitions and descriptions of soil units are to reflect variations in soil characteristics, both vertically and laterally, so as to account for spatial linkages within the landscape;
- The term 'Reference Base' is connotative of the common denominator function which the WRB will assume. Its units should have sufficient width to stimulate harmonization and correlation of existing national systems;
- In addition to serving as a link between existing classification systems the WRB may also serve as a consistent communication tool for compiling global soil databases and for the inventory and monitoring of the world's soil resources.
- The nomenclature used to distinguish soil groups will retain terms which have been traditionally used or which can easily be introduced in current language. These terms are precisely defined in order to avoid the confusion which occurs when names are used with different connotations.

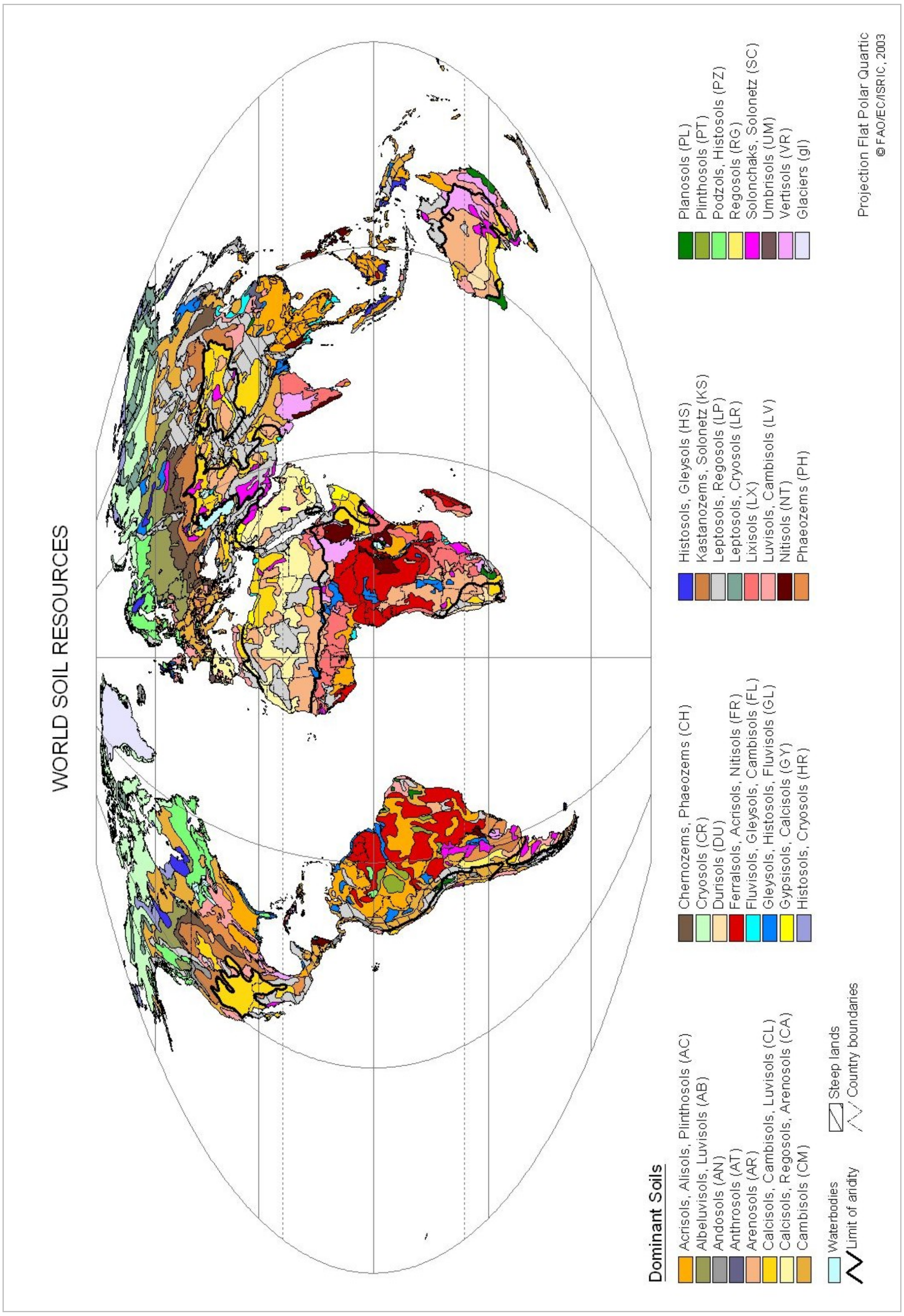

Figure 5.3 The WRB reference soil groups. 30 reference soil groups were identified to constitute the World Reference Base for Soil Resources (Map: Google Earth)

5.5 Questions and issues for debate

1. Considering traditional land use knowledge and practices in Eritrea (identify two or three of these practices), are they consistent with our comprehension of SLM today? Should they be promoted in future, or rather not?

2. Is it important to include socially or/and economically marginal groups such as day labourers, women, old people, lower casts, migrants, poor urban consumers, etc. in SDA?

3. Try to identify key differences between SDA and WOCAT. How would you integrate the two knowledge systems in your SLM work?

4. The World Soil Resource Base map of FAO is assumed to be very useful at the level of national and international scientific communication. Do you think it could be helpful at the local level, too?

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Chapter 6

The Livelihood Approach

The term "livelihood" emerged in development cooperation and research in the 1990s. A livelihood is what allows people to sustain their lives (see definition below). The Sustainable Livelihoods Approach (SLA) as developed by the UK Department for International Development (DFID) has become the most prominent framework among various concepts developed by other agencies. Basically, DFID subscribes to a system approach that attempts to capture the many factors that influence people's livelihoods and helps to identify priorities for action based on the needs and interests of people.

> *"A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base.*"(Chambers 1992[1])

The SLA was originally developed for poverty reduction. But it can also be used to promote sustainable land management, which is why it is included in this manual. Moreover, poverty and unsustainable land use are often linked.

The following paragraphs present an overview of the livelihood approach and discuss two specific frameworks dealing with sustainable livelihoods.

6.1 Why a livelihoods perspective?

6.1.1 Livelihood approaches and core principles of application

Sustainable Livelihood Approaches (SLA) are **conceptual frameworks** that promote people-centred development. They are responsive and participatory, and they favour multidisciplinary and multilevel development interactions. Livelihood approaches generate a deeper understanding of the wide range of livelihood strategies pursued by people to sustain their lives. Such an understanding is important, whether our aim is to reduce poverty or to promote sustainable land management.

Livelihood approaches acknowledge the connections and interactions among the microcosmos of the livelihood of individuals, household and/or communities with the larger socio-economic, cultural and political context at the meso- and macro levels. Livelihood approaches help to reconcile a holistic perception of sustainable livelihood with the operational need for focused development interventions. In other words, they give access to the complexity of livelihoods while acknowledging the need to reduce this complexity in a responsible way for drafting policies and designing programmes and projects.

As mentioned above, the principles of SLA were originally designed to address poverty. But they can equally well be used to address sustainable land management. According to these core principles, development activities should be (Ashley & Carney 1999[2], p. 7):

1. **People-centred**: sustainable poverty reduction will be achieved only if external support focuses on what matters to people, understands the differences between groups of people and works with them in a way that is congruent with their current livelihood strategies, social environment and ability to adapt.
2. **Responsive and participatory**: poor people themselves must be key actors in identifying and addressing livelihood priorities. Development agents need processes that enable them to listen and respond to the poor.
3. **Multi-level**: poverty reduction is an enormous challenge that will only be overcome by working at multiple levels, ensuring that micro-level activity informs the development of policy and an effective enabling environment, and that macro-level structures and processes support people to build upon their own strengths.
4. **Conducted in partnership**: with both the public and the private sector.
5. **Sustainable**: there are four key dimensions to sustainability: economic, institutional, social and environmental sustainability. All are important - a balance must be found between them.
6. **Dynamic**: external support must recognise the dynamic nature of livelihood strategies, respond flexibly to changes in people's situations, and develop longer-term commitments.

Table 6.1 shows how poverty and livelihoods are linked, and how the livelihood approach allows poverty issues to be effectively addressed.

6.2 The DFID livelihood framework

Among the many approaches offered for livelihood-oriented development cooperation (see Hussein, 2002[3]), we opt here for a blend between the UK Department for International Development (DFID) approach (Carney, Drinkwater, Rusinow, Neejes, Wanmali, & Singh, 1999[4]) and the livelihood framework (RLS) developed in the context of an Indo-Swiss research project on rural livelihoods in semi-arid India (Baumgartner & Högger, 20045).

More details on the DFID livelihood approach can be found in Annex 1.

6.2.1 Origin and principles

Sustainable livelihood approaches were first used in DFID poverty reduction efforts in the 1990s. The guiding assumption of the DFID approach is that people pursue a range of livelihood outcomes by which they hope to improve or increase their livelihood assets and reduce their vulnerability. The five types of assets that form the core of livelihood resources in the DFID SL framework are financial, human, natural, physical, and social capital. These constitute the actual building blocks of livelihoods (see *Figure 6.1*).

The livelihood strategies applied for achieving livelihood outcomes evolve in interaction with a context of vulnerability and transforming institutions. The actual framework has been considered, from the beginning, as one of many possible ways to conceive a livelihood framework. DFID therefore attached more importance to the underpinning principles of a poverty-focused and livelihood-oriented development.

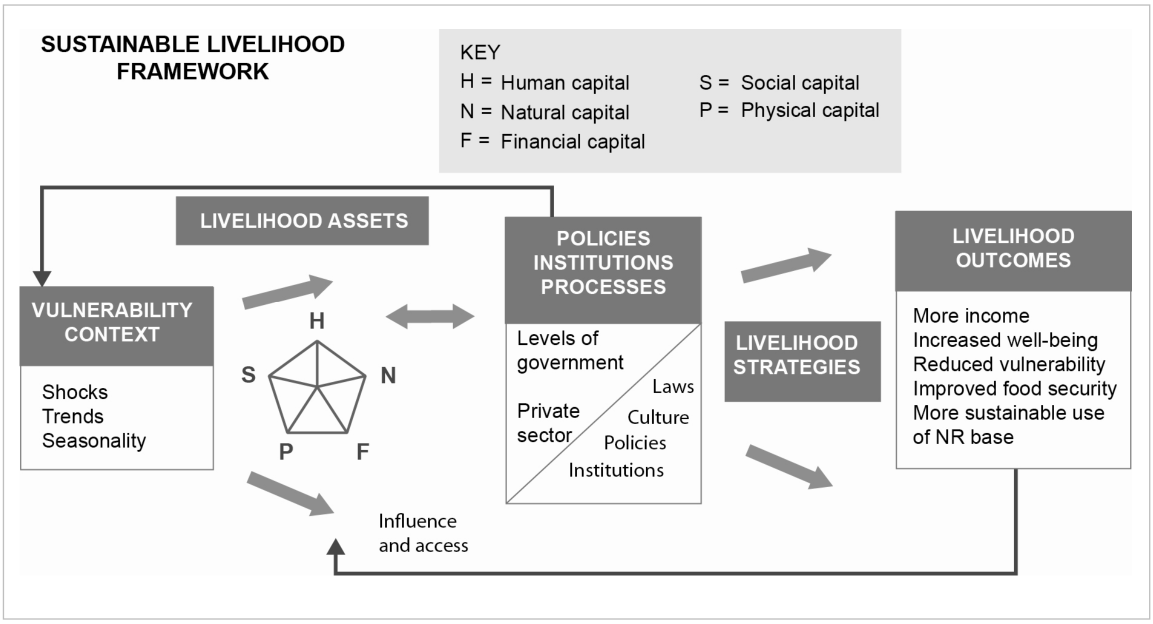

Figure 6.1 The DFID sustainable livelihood framework (DFID 2001: livelihoods@difd.gov.uk[6])

Based on the above concept, DFID differentiates between three groups of components in the livelihood framework: (1) the asset portfolio, which forms the core element of livelihood, (2) the Vulnerability Context and Policy, Institutions and Processes, and (3) the loop linking livelihood strategies and livelihood outcomes.

The Vulnerability Context of livelihoods refers to shocks, trends and seasonality, with their potential impact on people's livelihoods, while Policies, Institutions and Processes on the other hand comprise the context of the political and institutional factors and forces in government and the private and the civil sectors that affect livelihoods.

DFID stresses the illustrative purpose of the framework as providing a structure and focus for thinking. It emphasises the necessity to adapt the framework flexibly to the requirements of the actual situation under analysis and underlines the need to respect and follow the guiding principles in application. Poverty-focused development activities should be people-centred, flexible, responsive and participatory. They should be conceived as multi-level approaches and be conducted in partnership with both the public and private sectors. Finally, they should strike a balance between key dimensions of sustainability and recognise the dynamic nature of livelihood strategies. SL approaches must be underpinned by a commitment to poverty eradication. Although they can, in theory, be applied to work

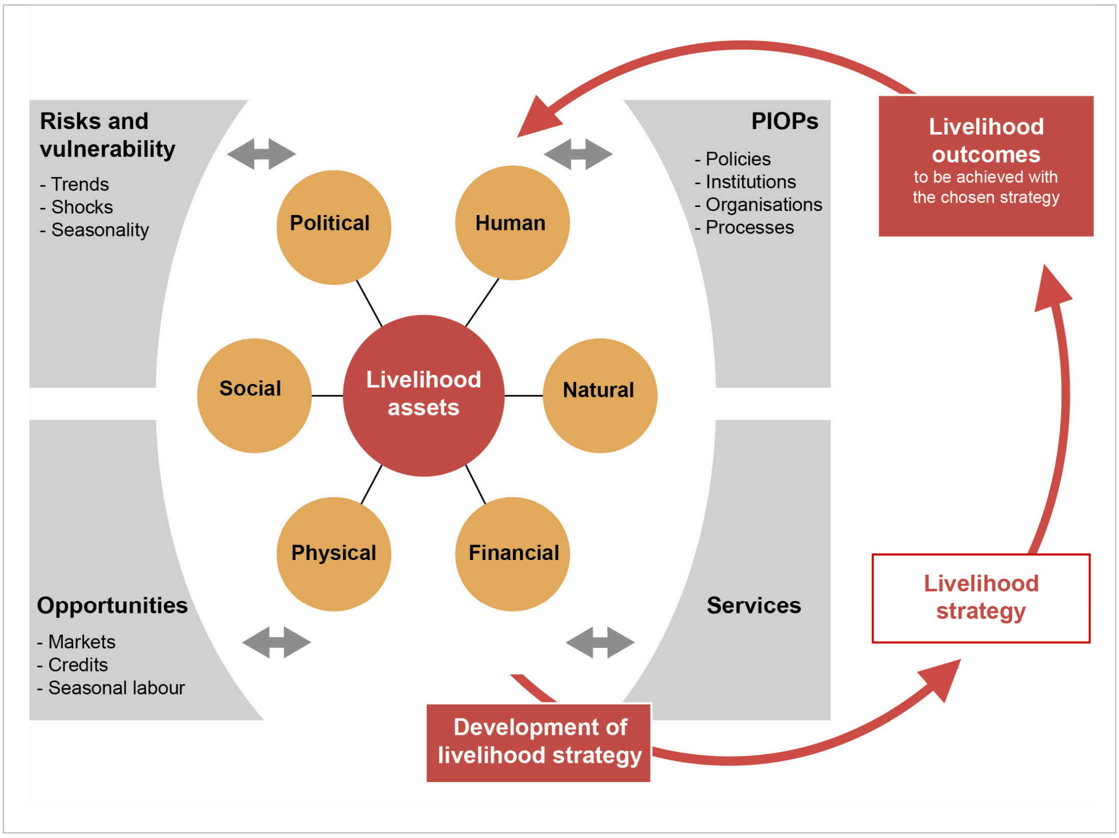

Figure 6.2 *The DFID approach to livelihood, modified for the purpose of this manual (NADEL, ETH Zurich and SDC, Bern 2007[7])*

with any stakeholder group, an implicit principle for DFID is that activities should be designed to maximise livelihood benefits for the poor.

6.2.2 Need for integrating further dimensions: a modified framework

Some important dimensions appear to be under-emphasised in the SL framework or are not made explicit enough in the underlying principles. For the purpose of this manual, for example, the "vulnerability context" is being extended by the "context of opportunities". Current areas of concern also include power relations and gender issues. When it comes to understanding the development of livelihood strategies, the DFID framework does not offer an explicit platform for dealing with crucial elements of decision-making, such as people's individual orientations and collective worldviews or their experience and emotional attachments. It is clearly important to remember these 'missing' aspects and to use different tools to ensure that they feed into development planning and our overall understanding of the driving factors behind livelihoods and poverty reduction (*Figure 6.2*).

6.3 Vulnerability and risk

Vulnerability is an important concept within livelihood frameworks. What does living in a state of vulnerability mean? To a farming family in coastal Bangladesh, it could mean being unable to cope with tidal floods. To a slum dweller in a *favela* (slum area) of Sao Paolo, it could mean being helplessly exposed to violence and corruption. Vulnerability stands for a crucial dimension of livelihoods, and, therefore, the term needs to be clarified for application to poverty reduction measures.

6.3.1 Clarification of terms and definitions

According to one dictionary (Collins, 1986[8]) vulnerability means "the capacity to be physically or emotionally wounded or hurt." Vulnerability is thus susceptibility to physical or emotional harm or injury. In other words, vulnerability emerges when human beings, as individuals or as a social unit, have to face a harmful threat or shock with an inadequate capacity to respond effectively. This understanding is reflected in the two examples above, namely, exposure to tidal floods without access to a flood shelter in Bangladesh, or exposure to violence and corruption in a favela without recourse to effective protection by the rule of law. Obviously, mere threat or risk alone is not a sufficient cause of vulnerability – not even if the threat has a high probability of occurrence. It is, ultimately, the combination of risk and inadequate capabilities to respond that leads to a state of vulnerability.

The above understanding is captured and refined in the definition of vulnerability proposed by the OECD Development Assistance Committee (DAC) Network on Poverty Reduction (POVNET[9]): *"Risk is defined as the likelihood of occurrence of (external) shocks and stresses plus their potential severity, whereas vulnerability is the degree of exposure to risk (hazard, shock) and uncertainty, and the capacity of households or individuals to prevent, mitigate or cope with risk."* This differentiation of the term "vulnerability" is of crucial relevance for assessing the causes of poverty and for conceiving poverty reduction measures.

6.4 Frequent misunderstandings regarding a livelihood orientation in development collaboration

6.4.1 Holistic analysis versus focused interventions?

CARE submitted the following statement to DFID's Livelihood Approach: *"A frequent misconception concerning the livelihoods approach is that holistic analysis must necessarily lead to holistic or multi-disciplinary projects. Although projects with a strong livelihoods approach may often work across a number of technical disciplines, applying a livelihoods approach does not preclude projects being largely sectoral in nature. What is important is that a holistic perspective is used in the design to ensure that cross-sectoral linkages are taken into account, and that the needs addressed in project activities are really those which deal with the priority concerns of households and build upon the experience and traditional coping mechanisms they have evolved" (Drinkwater & Rusinow, 1999, p. 9).*[10]

Oxfam illustrated the above statement using a convincing metaphor: *"A useful analogy is the 'acupuncture approach': a good acupuncturist uses a holistic diagnosis of the patient followed by very specific treatment at key points. Holistic diagnosis does not mean needles everywhere!" (Oxfam, cited in Ashley & Carney, 1999).* The assessment of the outcome of such a focussed treatment, however, calls again for a holistic perception, especially also for tracing unintended effects. The two statements illustrate the need for a holistic perception in development planning and as well as in monitoring the outcome and impact of development interventions.

6.4.2 Livelihood approaches: Are they models – theories – frameworks?

Livelihood approaches, be they from DFID or other agencies (see Hussein, 2002[11]), do not offer models or theories of livelihood systems. Instead, they suggest conceptual frameworks in line with Rapoport's (1985[12]) definition and understanding:

"Conceptual frameworks are neither models nor theories. Models describe how things work, whereas theories explain phenomena. Conceptual frameworks do neither; rather they help to think about phenomena, to order material, revealing patterns – and pattern recognition typically leads (thereafter) to models and theories". Conceptual frameworks of livelihood systems, therefore, do not substitute subject matter-based theories and methodologies for analysing economic, social, or religious dimensions of development issues. Rather, they suggest applying such subject matter competence in conjunction with a holistic perception of a livelihood system.

6.5 The Rural Livelihood System (RLS) approach

6.5.1 Origin and guiding assumptions of the RLS approach

Originally, the RLS approach to livelihood was the outcome of a research effort (funded by the Swiss National Science Foundation) to achieve better understanding of rural people's perceptions of what sustainable management of natural resources means in semi-arid areas of India. Over centuries, farmers and their communities have obviously developed culture and location-specific perceptions of sustainable management of natural resources. Yet, *sustainable land use* represents just one element, however important, of a much wider concern of farm communities with sustainable livelihood and the constant adaptation of their survival strategies towards this goal. It follows that rural households will participate in sustainable resource management projects only if the projects connect meaningfully with their concerns about *sustainability at the level of their livelihoods*. Therefore, the guiding assumption of the RLS research project was that effective strengthening of the self-help capacity of rural households calls for a shift from sustainability concerns about single natural resources, such as land, water, pastures, etc., to the meta-level of sustainable livelihoods.

Not surprisingly, when interviewed about the local meaning of sustainability, farmers in the Indian state of Gujarat summarised their notion of sustainable rural livelihood with the expression "Ghar chalava", meaning, "to keep the house(hold) going". "Keeping the house going" obviously implies more than just a narrow bundle of different income sources or assets; it points to the almost countless number of factors, forces and efforts on which the life of a family depends.

6.5.2 Principles and elements of the RLS framework

Inspired by interactions of the above type with farm communities in India, the RLS project found a suitable answer in the interface of two powerful images useful for a holistic perception: the ***mandala*** as a cross-culturally accepted symbol for wholeness and a centred universe, and the rural house as a metaphor for livelihood (*Figure 6.3*).

The metaphor of a rural house suggests a three-tiered perception of livelihood: The foundation represents the material and non-material resource base, including the emotional resource base of livelihood. The walls metaphorically shape the room for three different notions of 'space', putting the family space of decision-making into the centre. The roof, finally, points to the three-fold orientation of a livelihood system, (1) collective orientations, (2) orientations held by the family and (3) orientations in the mind and heart of the individual.

The RLS approach to livelihood subscribes to the same core principles established by DFID. In practical terms, the RLS framework, represented as a nine-square mandala, advocates looking first through a multi-focal looking glass in order to gain a holistic perspective. It is therefore a *heuristic tool*, a framework, for discovering the properties of a livelihood system. Any of the nine squares of the RLS mandala qualifies as an entry point. The purpose of the assessment, at times also the dynamic of the process, determines the usefulness of starting, for instance, with elements belonging to the "base" or to the "orientations" of a livelihood system.

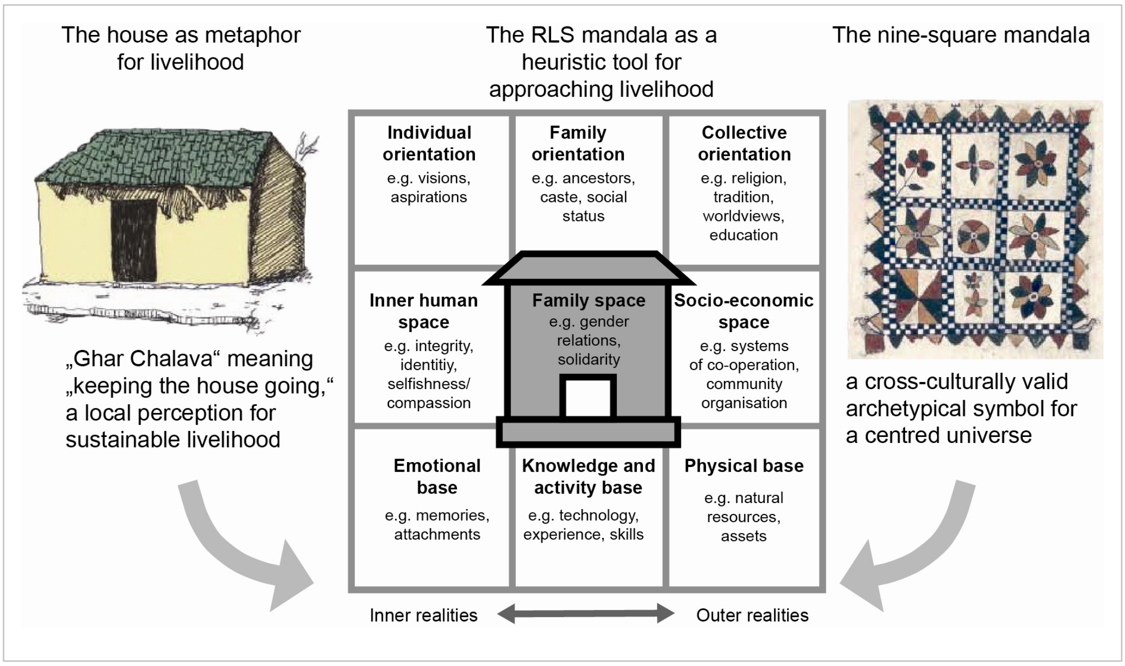

Figure 6.3 *Rural livelihood system framework: Capturing Meanings of Livelihood. The nine-square mandala for livelihood. The RLS mandala as a heuristic tool for approaching livelihood (NADEL, ETH Zurich and SDC, Bern 2007)*

6.5.3 The need to integrate further dimensions into RLS

The RLS framework lacks an explicit reference to important factors and forces in the wider context of livelihood. For this reason, it does not explicitly invite investigation of processes and impacts resulting from an interaction with policies, an institution, etc., as DFID does. However, the RLS framework addresses gender dimensions in the core of the nine-square mandala. Both approaches lack a clear reference to power relations, which very often are at the core of sustained poverty in rural and urban contexts.

6.5.4 Common features of the livelihood approaches of DFID and RLS

- Both the DFID SL approach and the RLS approach offer a "heuristic" tool in the form of a framework for exploring and analysing livelihood. They propose neither "models" nor "theories" of livelihood.
- Both approaches to livelihood can only produce meaningful results if the application of the frameworks (here DFID SL framework and or the RLS Mandala) respects the respective set of guiding principles explained in the guidelines to these two approaches.
- Both approaches advocate a clear distinction between the application of a holistic perception for analysis and better understanding of poverty on the one hand, and the need to adopt a focused approach for the design and implementation of development support for poverty reduction on the other hand.
- Both approaches provide orientation for a livelihood-focused application of methods and tools, as they are made available by social and technical science, including the development of specific instruments such as Participatory Rural Appraisal (PRA).
- Both approaches are a work in progress and not finalised products. They are not conceived as recipes but instead offer conceptual inspiration for development efforts aiming at more sustainable livelihoods. They are complementary to other development approaches in use.
- Most importantly, combining both efforts has the potential to provide a more comprehensive picture of livelihoods than each one alone (*Table 6.1*).

Table 6.1 The frameworks of DFID and RLS compared: A blending of elements of both frameworks generates added value for understanding livelihoods

DFID Approach	Issues	RLS Approach
Predominantly deductive reasoning. Systemic and dynamic linkages in time and space, inspired by New Institutional Economics	Conceptual approach	Predominantly inductive reasoning based on practical experience. Applying metaphoric and symbolic representation of livelihood
Proposing explicit linkages between micro and macro contexts of livelihood, both in the field of Policy, Institutions and Processes and the Vulnerability Context	Linking micro and macro perspectives	Addressing micro-macro linkages only implicitly through the square called "Socio-Economic Space" in the RLS Mandala
Addressing poverty explicitly with the reference to vulnerability and its linkages to assets for coping	Poverty orientation	No explicit conceptual orientation towards poverty
Focusing on the constellation of assets of livelihood systems, with an economic bias	Addressing psychological aspects of livelihood	Acknowledging inner and outer realities of livelihood, including emotional dimensions
Focusing on changing asset portfolios of livelihood systems and on interaction with institutions (value system) and policy context.	Decision-making at household level	Embedding decision-making into inner and outer realities of livelihood and its gender-related dimensions
Strategies explicitly addressed as a systemic loop, inviting exploration of livelihood activities and outcomes	Role of livelihood strategies	Strategies implicitly addressed, heuristic approach, stressing forces and factors relevant for strategy
Applicable for rural and urban livelihoods. Not bound to project-based development efforts. Can be integrated into PCM (Project Cycle Management)	Scope for application	Originally conceived for a rural context but adaptable to urban livelihoods as well. Not bound to project-based development efforts Can be integrated into PCM (Project Cycle Management)

6.5.5 Blending elements of the livelihood frameworks of DFID and RLS

Blending elements of the livelihood approaches of DFID and RLS combines the strengths of the two frameworks, as it integrates their key elements into a new integrated framework (*Figure 6.4*). This integrated framework allows not only a comprehensive analysis of the context of local livelihoods but also directs attention to people's decision-making with regard to their own livelihood strategies and their personal motives. These motives are crucial for decision-making for livelihood strategies, while the assets, vulnerability/opportunity contexts, and the policy contexts will largely decide whether the livelihood outcomes are sustainable.

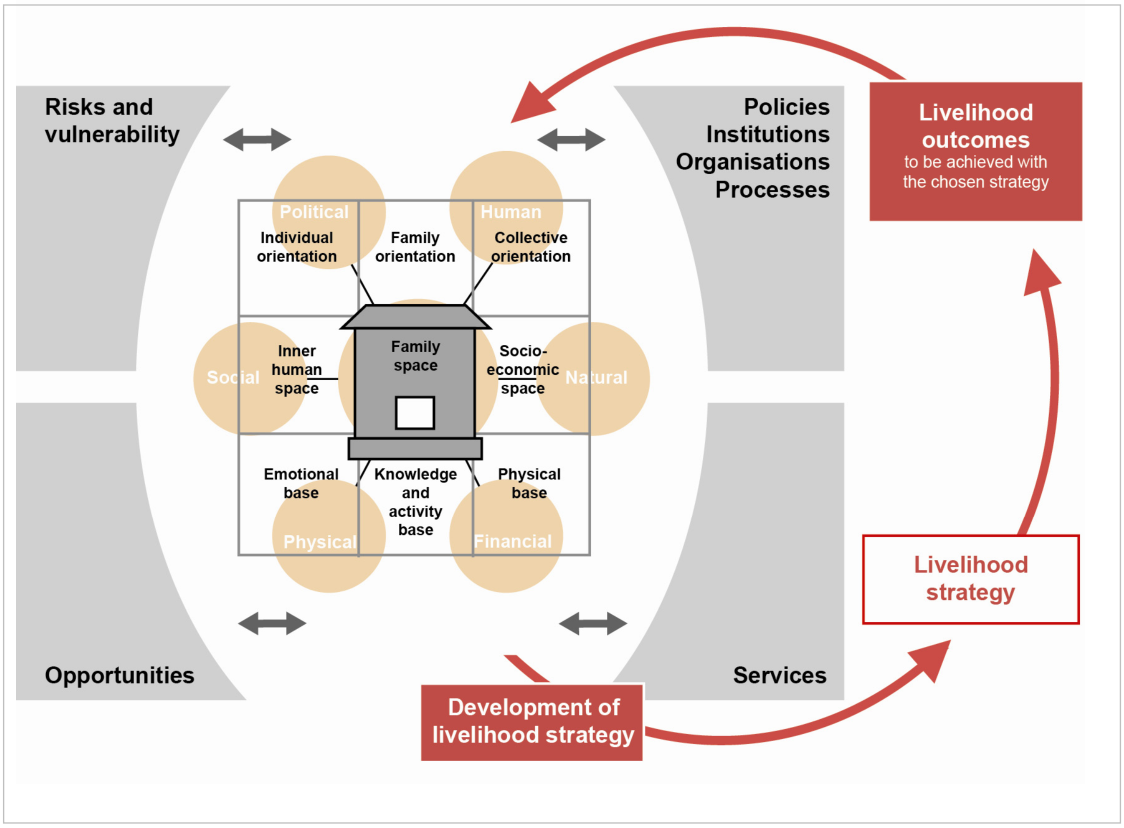

Figure 6.4 *Combining the livelihood approaches of DFID and RLS (NADEL, ETH Zurich and SDC, Bern 2007)*

6.6 How livelihoods can be analysed in practice

6.6.1 Fields of observation and methods: a threefold focus

The livelihood approach offers a framework for a structured and goal-oriented analysis of livelihoods. It allows identification of patterns of livelihoods with their constraints and potentials.

Figure 6.5 suggests a distinction between the context and the core of a livelihood system under investigation. Whether to approach first the core or the context of local livelihoods depends on the purpose and frame conditions of an analysis. For the sake of clarity, the approach in this manual is guided by a threefold focus.

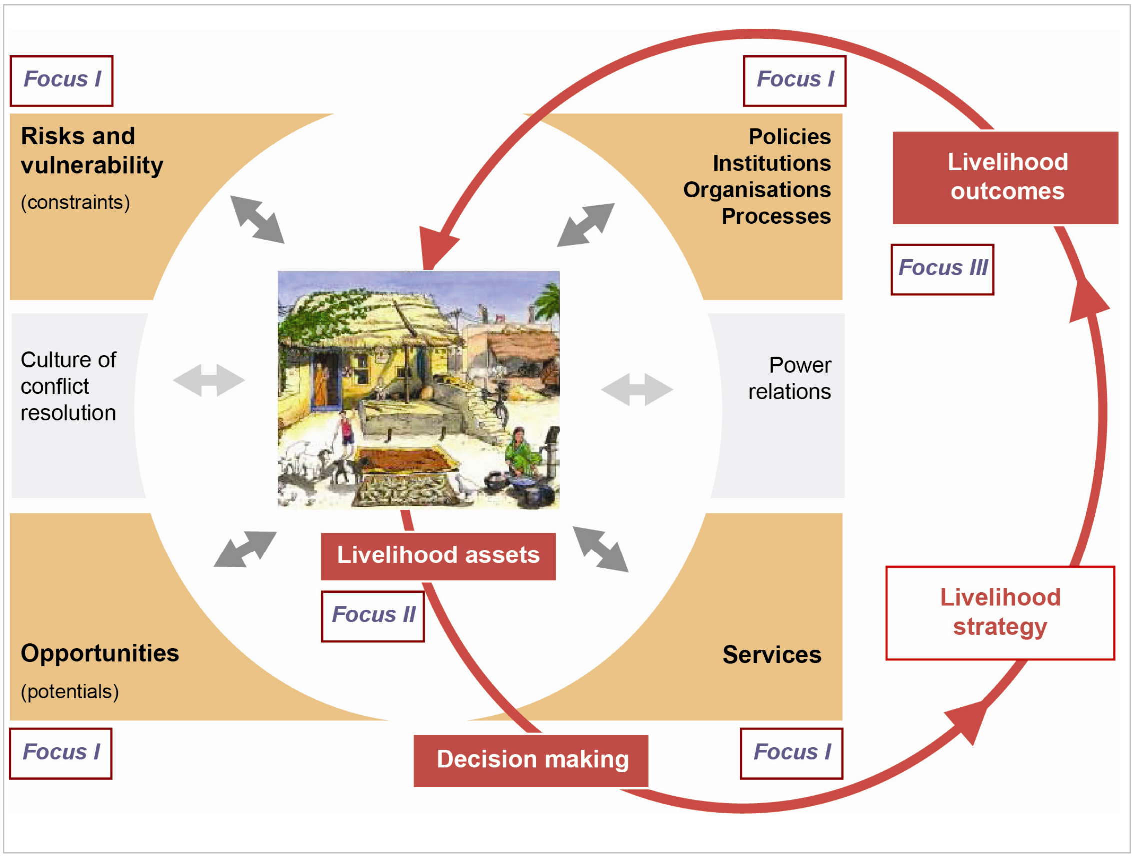

Figure 6.5 *Approaching livelihoods using a threefold focus (NADEL, ETH Zurich and SDC, Bern 2007*

Focus I is on the four key elements in the context of a livelihood system. Focus II concentrates on the asset portfolio. Focus III is on the decision-making space in which people develop and/or adapt their livelihood strategies and strive for outcomes with their own perception of the inner and outer realities of their livelihoods. External support becomes meaningful if they succeed in making their livelihood strategies more sustainable.

6.6.2 Focus I – the livelihood context

Focus I invites exploration of four crucial dimensions of the **context** of a livelihood system. Four key questions are used to address these dimensions (*Figure 6.5*):

1. **Risks and vulnerability: What renders people's livelihoods vulnerable?**

Risks and shocks (hailstorms, political unrest), adverse trends (decreasing market prices, climate change) and seasonality (rainy-dry season) have a bearing on people's livelihoods. Yet a livelihood becomes truly vulnerable when it lacks adequate coping or adapting capacities on the micro-level of livelihood. The level of these capacities is explored with Focus II (asset portfolio) and Focus III (livelihood strategies). These two focuses help to clarify the following question: "Should poverty reduction measures tackle an observed risk and reduce an assessed vulnerability in the context of poor people's livelihood, or should they target the core of livelihood and aim to increase people's coping capacity?"

2. **Opportunities: What opportunities offer potential for improving livelihood?**

Opportunities are as much part of the context of a livelihood as risks and threats. They may take the form of markets, credit facilities, education, social networks, etc. The task here, however, is to identify constraints that explain why these opportunities are outside the reach of poor people's livelihood strategies.

3. **Policies: How do policies support or constrain people's livelihoods?**

Exploration of the policy context and the way policies are implemented is crucial and highly livelihood specific. Do we address pastoralists, or urban slum dwellers, or marginal farmers? Are we inquiring into the effects of an overarching policy, such as pro-poor growth, or of measures targeting poverty more directly, e.g., services like rationing schemes? It can be beneficial to review both supporting and constraining policies.

4. **Institutions: How do institutions favour or constrain livelihood?**

In livelihood frameworks "institutions" have two important elements: on one hand, the rules and normative frame conditions that govern social interactions; on the other hand, the way that organisations operate in both the public and private sector, against the background of explicit and implicit values. Political participation, market systems, and concepts of social orders (such as castes, clans, etc.) belong to this field of investigation.

The four questions above make the limitations of a single focus approach obvious. Effective poverty reduction measures emerge from a triangulation of the three focal approaches to livelihood.

6.6.3 Focus II – the livelihood assets

Focus II deals with assets (*Figure 6.5*). Assets – things that a household possesses that secure its existence – constitute a crucial element of livelihood. Establishing an overview of the asset portfolio of a livelihood system generates important information regarding the poverty status of a household. Focus II deals with the 6 assets shown in Figure 6.6.

Human capital

Human capital represents the skills, knowledge, capacity to work and good health that together enable people to pursue different livelihood strategies and achieve their livelihood outcomes. (Human capital is important in its own right; health, knowledge and skills help create sustainable livelihoods. Human capital is also necessary to be able to make use of the other five types of assets.)

Social capital

Social capital is defined as the social resources upon which people draw in pursuit of their livelihood objectives. These social resources are developed through (1) interactions that increase people's ability to work together, (2) membership in more formalised groups governed by accepted rules and norms, (3) relationships of trust that facilitate cooperation, reduce transaction costs, and can provide informal safety nets.

Natural capital

Natural capital is the term used for the natural resource stocks (e.g., land, water, forests, clean air, and coastal resources) upon which people rely. The benefits of these stocks can be direct and and/or indirect, and they are tightly linked with property and user regimes.

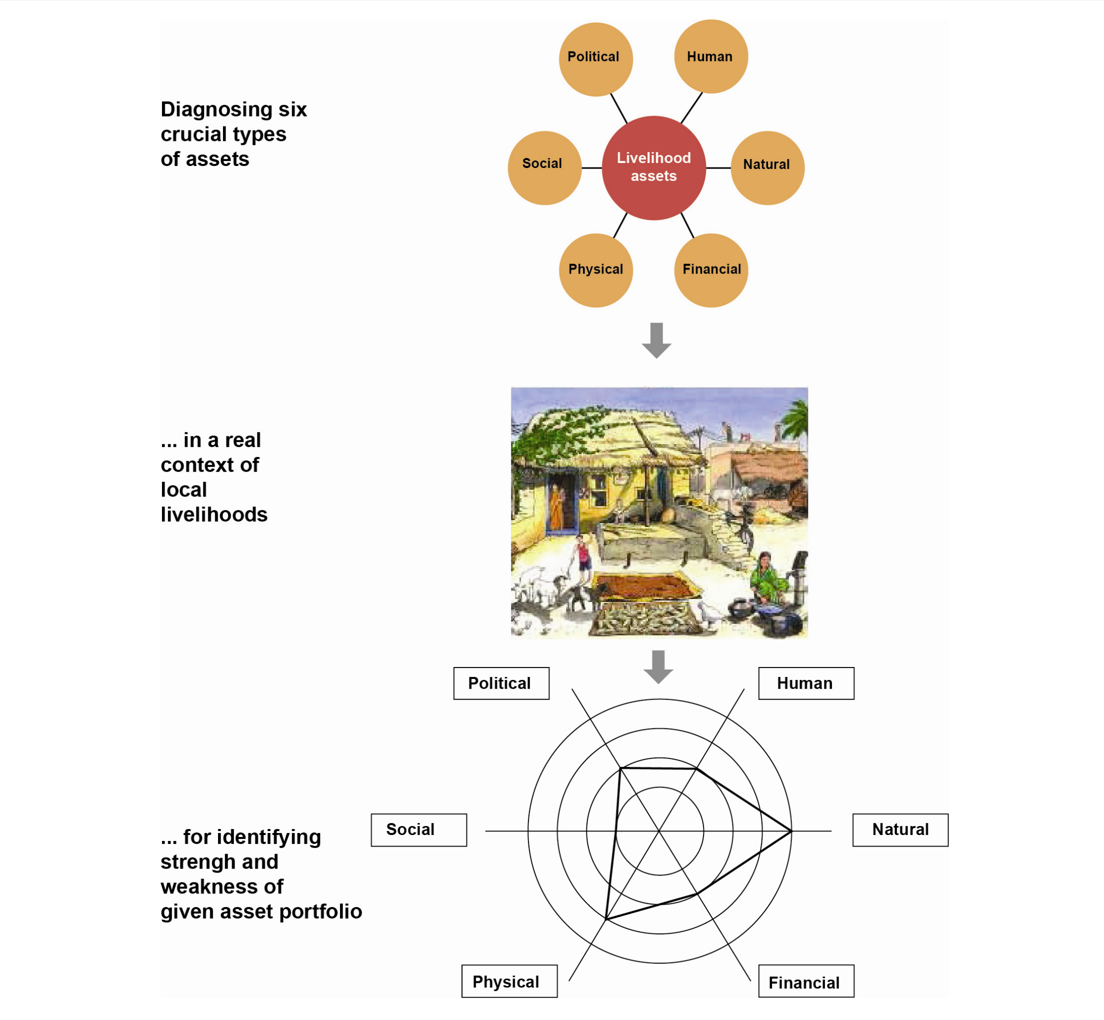

Figure 6.6 *Focus II: Analysing the assets of a livelihood system (NADEL, ETH Zurich and SDC, Bern 2007)*

Physical capital

Physical capital comprises the basic infrastructure and physical goods that support livelihoods. Infrastructure consists of changes made to the physical environment that help people to meet their basic needs and to be more productive.

Financial capital

Financial capital is defined as the financial resources that people use to achieve their livelihood outcomes. These are resources in the form of available stocks and regular inflows of money (for example, livestock and the related flow of income).

Political capital

Political capital is the power and capacity to influence political decision-making through formal and informal participation and/or access to political processes. It therefore includes the ability to represent oneself or others, and the freedom and capacity to become collectively organised to claim rights and to negotiate access to resources and services. It also extends to the right to hold government and service providers accountable for quality and access.

6.6.4 Focus III – livelihood strategies, outcomes, and meaning

Focus III deals with decision-making, livelihood strategies, and outcomes (*Figure 6.7*). Livelihood strategies reflect the **range and combinations** of activities and **choices** that people make in order to achieve livelihood outcomes and goals. Livelihood strategies evolve from implicit and/or explicit **decision-making**, which is informed by the inner and outer realities of livelihood. Livelihood strategies are **diverse** and in a constant process of change and adaptation.

The offers a framework for structuring the exploration of decision-making in a livelihood system and for tracing material and non-material livelihood outcomes towards which people aim. Understanding people's livelihood strategies means exploring the role of factors and forces that determine the use of their resources – for example, the role of gender relations, of collective or family based value-orientations, and of individual ambitions.

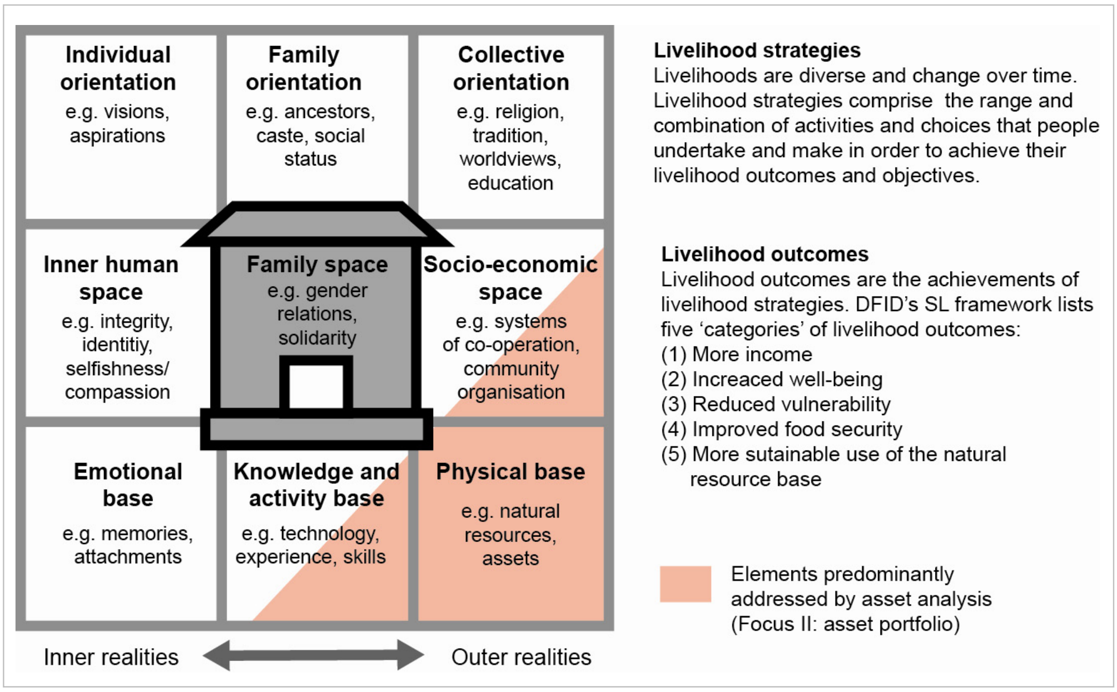

Figure 6.7 RLS Mandala (NADEL, ETH Zurich and SDC, Bern 2007 / adapted to this report)

Livelihood strategies

Livelihoods are diverse and change over time. Livelihood strategies comprise the range and combination of activities and choices that people undertake and make in order to achieve their livelihood outcomes and objectives.

Livelihood outcomes

Livelihood outcomes are the achievements of livelihood strategies. DFID's SL framework lists five 'categories' of livelihood outcomes: (1) more income, (2) increased well-being, (3) reduced vulnerability, (4) improved food security, (5) more sustainable use of the natural resource base.

It is important to note that a livelihood strategy is not an end in itself, but a means to ensure that the "house goes on", and, above all, to **give meaning to one's life**, both as an individual and as a member of the social units to which every individual belongs. Livelihood ceases to be sustainable when it loses meaning. Meaning has its vital roots in the inner realities of human life, in personal experience and orientations, in emotions, and in people's perceptions of themselves. These elements of inner reality manifest themselves in the development of livelihood strategies and the outcomes desired.

6.7 The livelihood framework as a platform for development options and interventions

Development measures are always focused, for example on specific sectors (water development) or a range of sectors (watershed management, poverty alleviation, etc). No project, programme, or intervention can be holistic and cover all aspects that influence a livelihood. The key question is therefore: how can we use holistic livelihood frameworks to implement focused intervention?

The answer is that the frameworks provide us with a number of entry points for such interventions. *Figure 6.8* shows us, for example, five alternative entry points, or options for intervention, in this case for poverty reduction measures:

1. Promoting and implementing **poverty-oriented policies** (pro-poor growth, favourable labour markets, etc.).
2. Initiating **pro-poor institutional change** (e.g., increased organisational efficiency and effectiveness of public and private service providers, political participation, etc.).
3. Improving **coping capacities** of poor people, enhancing their **capabilities** for pursuing more sustainable livelihood strategies (e.g., negotiations skills, education, crop insurance, etc.).
4. Facilitating **access to existing opportunities** for people constrained in their access to such opportunities (e.g., access to credit systems, markets, new technologies, etc).

5. Reducing **exposure to risks** by tackling them directly and thus reducing poor people's vulnerabilities (e.g., vulnerabilities resulting from natural hazards such as floods, or caused by seasonal price fluctuations).

In development practice, an engagement in one of the five options may call for **complementary support** in one or several fields of the other four options. For example, access to micro-credit (option 4) might first require establishing adequate lending rules on the part of the banks (2), supplemented by empowering small farmers to handle credits (3) and, on top of that, changing the re-financing policies of the country's national bank (1).

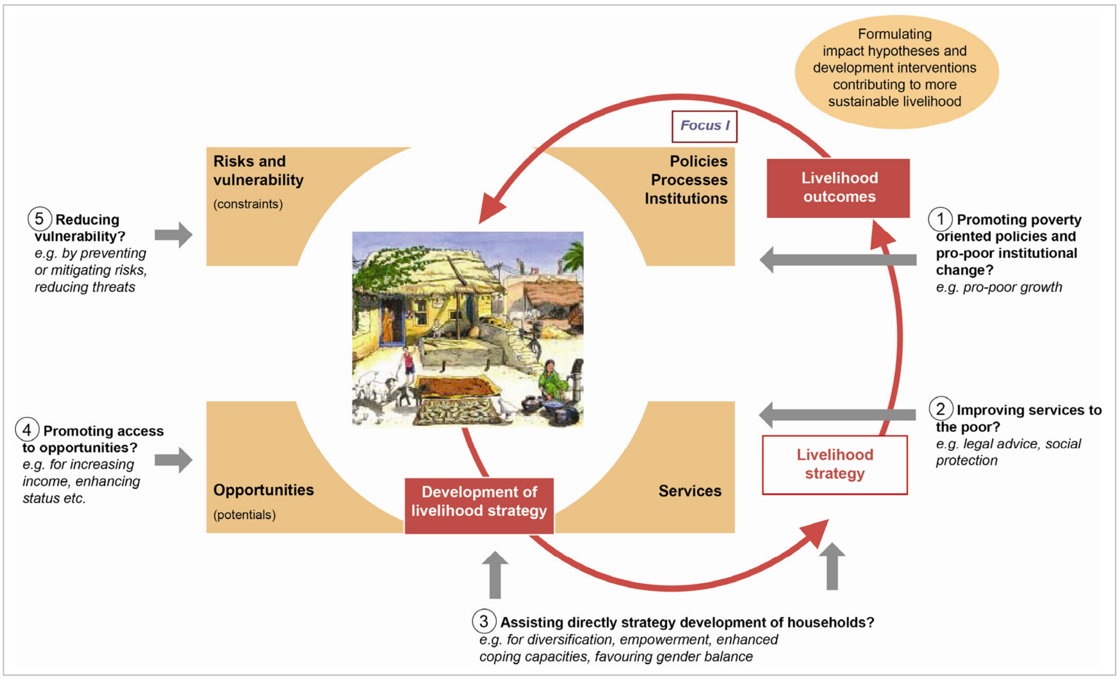

Figure 6.8 Entry points of interventions: Choosing among five basic options for effective poverty reduction measures (NADEL, ETH Zurich and SDC, Bern 2007)

6.8 Livelihoods and poverty

6.8.1 Concepts of poverty

Approaches to reducing poverty are informed by and based on perceptions of poverty; tackling poverty requires poverty concepts that lead to meaningful development hypotheses which can guide practical action. Poverty is closely linked to livelihoods, and an analysis of livelihoods can help explain why people are poor, and can help design meaningful action for reducing poverty. Therefore, the poverty concept developed by the Development Assistance Committee (DAC) of the OECD in its guidelines on poverty reduction represents a generally accepted approach that also shows the need to apply a livelihood focus, especially when dealing with a poverty concept based on human capability (http://www.oecd.org/dataoecd/47/14/2672735.pdf[13]).

6.8.2 Defining poverty

In the DAC guidelines, poverty is defined as a deprivation of capabilities in the following 5 core dimensions:

- **Lack of economic capabilities**; which means the ability to earn an income, to consume and to have assets, all of which are a key to food security, material well-being and social status. These aspects are often raised by poor people, along with secure access to productive financial and physical resources: land, implements and animals, forests and fishing waters, credit, and decent employment.
- **Lack of human capabilities** i.e. lack of health, education, nutrition, clean water and shelter. These are core elements of well-being as well as crucial means to improving livelihoods. Disease and illiteracy are barriers to productive work, and thus to economic and other means of poverty reduction. Reading and writing facilitate communication with others, which is crucial in social and political participation. Education, especially for girls, is considered the single most effective means for alleviating poverty and some of its major causal factors, for example illness – in particular AIDS – and excessive fertility.
- **Lack of political capabilities** i.e. human rights, a voice and some influence over public policies and political priorities. Deprivation of basic political freedoms or human rights is a major aspect of poverty. This includes arbitrary, unjust and even violent action by the police or other public authorities that is a serious concern of poor people. Powerlessness aggravates other dimensions of poverty. The politically weak have neither the voice in policy reforms nor secure access to resources required to rise out of poverty.
- **Lack of socio-cultural capabilities,** which concerns the ability to participate as a valued member of a community. These refer to social status, dignity and other cultural conditions that are part of belonging to a society and which are highly valued by the poor themselves. Participatory poverty assessments indicate that geographic and social isolation is the main meaning of poverty for people in many local societies; other dimensions are seen as contributing factors.
- **Lack of protective capabilities,** which would enable people to withstand economic and external shocks. These are important for preventing poverty. Insecurity and vulnerability are crucial dimensions of poverty with strong links to all other dimensions. Poor people indicate that hunger and food insecurity are core concerns along with other risks such as illness, crime, war and destitution. To a large extent, poverty is experienced intermittently in response to seasonal variations and external shocks – natural disasters, economic crises and violent conflicts. Dynamic concepts are needed because people move in and out of poverty. Today's poor are only partly the same people as yesterday's or tomorrow's. Some are chronically poor or inherit their poverty; others are in temporary or transient poverty.

6.8.3 Poverty and well-being

Poverty as understood today is thus a broad concept, and embraces all major aspects of life: "An adequate **concept of poverty** should include all the most important areas in which people of either gender are deprived and perceived as incapacitated in different societies and local contexts. It should encompass the **causal links** between the **core dimensions** of poverty and the central importance of **gender** and environmentally **sustainable development**" (OECD, 2001, p. 38)[14].

The UN Millennium Declaration and the Millennium Development Goals reaffirm the basic right of all human beings to participate in the economic, social, and political processes of society. This means their right to freely, actively, and effectively participate in shaping society, take part in decision-making processes, and share in the fruits that development brings. These factors are the ingredients of well-being within a society or community (*Figure 6.9*).

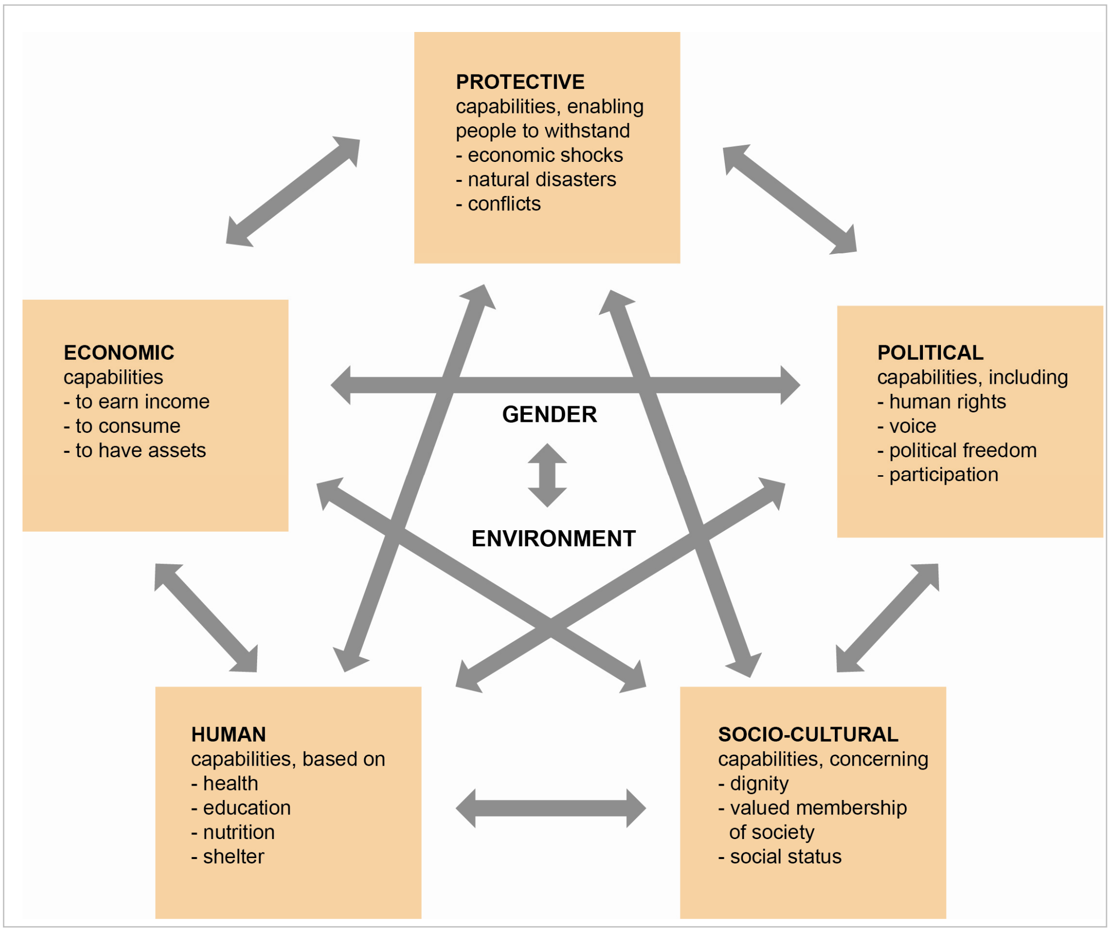

Figure 6.9 Definition and interactive core dimensions of poverty and well-being (Adapted from OECD (2001), The DAC Guidelines: Poverty Reduction, pp. 38-40)

6.8.4 Poverty, risk, and livelihoods

Poverty reflects lack or loss of sustainable livelihood. The generally accepted definition of sustainable livelihood as presented at the outset of Chapter 6 precisely reflects this understanding: A livelihood system is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both in present and future, without undermining the natural resource base. The definition also refers to the fact that livelihood as such becomes vulnerable when unsuitable strategies undermine the natural resource base.

Effective livelihood approaches must, therefore, prove their capacity to analyse the nature and extent of vulnerability in order to conceive effective poverty reduction measures. This task encompasses the analysis of risks (frequency, magnitude, probability) in the context of livelihoods **and** the exploration of crucial dimensions of coping capacities at the core of livelihoods. As far as vulnerability and risks are concerned, livelihood approaches should provide answers to questions such as: Should poverty reduction focus on preventing or mitigating the risks to which a livelihood is exposed? Is it more effective to increase the coping capacity of the livelihood concerned? Or, in the end, is a combination of all required?

Risks can be categorised in four main dimensions:

1. ***Harmful trends,*** such as increasing soil erosion, frequent droughts, increasing incidence of HIV/AIDS, unfavourable development of commodity or input prices, etc.
2. ***Shocks,*** such as earthquakes, floods, disease, loss of jobs, violent conflicts, destruction of physical infrastructure (such as roads, bridges), etc.
3. ***Harmful seasonal fluctuations***, such as price fluctuations in crop and livestock markets, fluctuations in food availability due to seasonal climatic changes, etc.
4. ***Unfavourable socio-political environments*** characterised by absence of rule of law, deprivation of rights, gender-related discrimination, etc.

An adequate assessment of the response capacities of livelihood systems to risks requires more than just taking stock of assets. People's reactions to risks are guided by their worldviews and experience and are informed by gender-related decision-making as well as modes of cooperation in a given social system (*Table 6.2*). When conceiving poverty reduction measures, it might also be appropriate to distinguish between interventions that favour coping or promote adaptation. Coping strategies are generally understood as shorter-term and direct reactions to a specific shock such as drought or flood. On the other hand, adaptive strategies entail a longer-term change in behaviour patterns as a response to a shock or stress.

Table 6.2 More effective poverty reduction means focusing on livelihoods

1) Access to people's visions of "development and well-being"
People's visions of "development" are reflected in their livelihood strategies and in the livelihood outcomes they strive for. Thus "development" does not happen unless people participate in conceiving and realising "development". Each form of development cooperation therefore requires an adequate level of insight into and understanding of both the livelihoods addressed and the context with which they interact.

2) Poverty reduction goes beyond material well-being
SDC's engagements in poverty reduction should enhance "the prospects of living a life in dignity". SDC's engagement is thus value-based. Living up to such a commitment requires a livelihood approach that can capture livelihood diversity in partner countries and provide operational guidance for conceiving and implementing poverty-oriented development support that takes livelihood diversity into account.
3) Promoting coherence between poverty reduction concepts & definitions of poverty
SDC subscribes to the DAC definition and understanding of poverty, which are based on a capability approach. Empowerment, understood as sustainable improvement of capabilities of the poor, thus becomes a key element of poverty reduction. Basically, capabilities are not given but acquired by human beings. Capabilities are embedded in livelihood systems. They become functional in pursuing livelihood strategies.
4) Building on strengths and potentials -acknowledging contextual factors & forces
A livelihood focus in poverty reduction means building systematically on the strengths and potentials of the poor. A livelihood focus also acknowledges the role and impacts of contextual factors and forces resulting from policymaking, institutional change, external shocks and trends, etc. It therefore invites assessment of the extent to which the socioeconomic, political and cultural context is conducive to alleviating poverty
5) Understanding multifaceted rationalities in people's decision-making
Diversity of livelihood strategies is also a reflection of a diversity of rationalities guiding decision-making. Approaching poverty with a livelihood focus thus means examining explicit and implicit rationalities that shape livelihood strategies pursued by the stakeholders (Syöstrand 1992[15], Simon 1984[16]).
6) Perceptions of sustainability and sustainable livelihood are context-bound
Poverty reduction aims at more sustainable livelihood. The generally accepted definition of sustainable livelihood reads: *"A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, without undermining the natural resource base (Carney et al 1999, p.8*[17]*)*. To become an operational guideline in development collaboration, this definition also requires a context-related interpretation of sustainability that acknowledges the role of time, space, and culture.
7) Culture and spirituality as constitutive elements of development
Livelihood approaches help to integrate culture into development thinking and practice as an essential dimension. The holistic approach of a livelihood focus provides insights into "how culture matters" without promoting cultural determinism of development. Spirituality, reaching beyond religious reference frames, forms part of the inner development of livelihood. Worldviews, attitudes and goal setting, or livelihood strategies in general, are also informed by spiritual dimensions (Baumgartner & Högger 2004. Compare also Holenstein 2005[18]). People-oriented development thus calls for approaches that further our understanding of the roles of these aspects of sustainable livelihood.

Source: SDC 2007

6.9 Initiatives and approaches in poverty alleviation

6.9.1 Millennium Development Goals – poverty reduction based on understanding livelihoods

The Millennium Declaration (MD) is expected to enhance global resource allocation for fighting poverty. The Millennium Development Goals (MDGs) provide a generally accepted framework for global development efforts in eight selected goal areas. The MDGs are thus clearly goal-oriented and are – since they emanate from a top-down process – exposed to the risk of generating predominantly goal-driven development without proper grounding in the realities of people's livelihoods, even though these are seen as important (*Figure 6.10*).

The MDGs face their biggest challenge on the African continent, especially in the countries of Sub-Saharan Africa. An uncritical orientation towards the MDGs when formulating PRSPs for countries of Sub-Saharan Africa may increase the risk of unrealistic goal setting exercises and overtaxing of the absorptive capacity for increased aid flows, instead of developing context-related strategies in favour of more sustainable livelihoods.

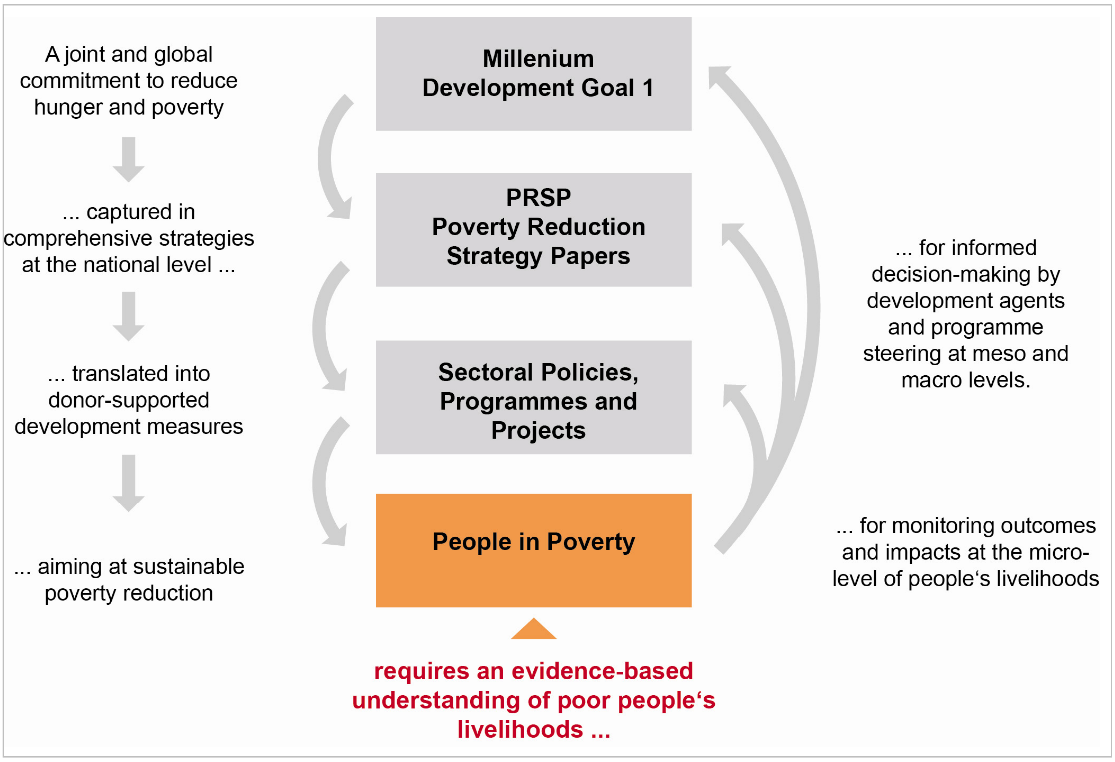

Figure 6.10 Livelihoods as a key element for understanding poverty and achieving the MDGs (NADEL, ETH Zurich and SDC, Bern 2007)

There are valid reasons to assume that livelihood approaches must play an important role in assessing the specific nature of poverty and the absorption capacity of the poor. A pro-poor orientation also means acknowledging the visions and criteria of well-being expressed by the poor. In this way livelihood approaches provide a much needed complementary micro perspective for conceiving, implementing and monitoring pro-poor development, be it institutional change, new policy frameworks or programmes and projects.

6.9.2 Pro-poor growth at the interface between macro and micro perceptions

It is now recognised that pro-poor growth is an essential element for achieving sustainable poverty reduction (see Klasen, 2003)[19]. PRSPs are considered to provide useful platforms for conceiving strategies for economic growth that benefits the poor and poorest sections of the population over-proportionally, for instance by creating access to gainful employment. Yet among the many hurdles at least two are generally acknowledged: Poverty is very often associated with a much skewed distribution of political power, which in turn allocates the gains of any economic growth once again to the rich and powerful members of a given society. Interventions in favour of good governance deal generally with this hurdle.

The second hurdle is also linked to distributional effects. In this case, however, the hurdle is part of precisely those livelihoods that should be favoured by pro-poor growth: Under conditions where actual allocation of resources to family welfare differs widely between husband and wife, a prevailing gender imbalance in decision-making within households can nullify or even reverse actual gains from pro-poor growth. An understanding of livelihood realities - and gender-related decision-making in poor households is part of livelihood realities - can provide essential insight and awareness for conceiving development interventions at the micro level, which are complementary to economic strategy formulation at the macro level.

6.9.3 Good governance and decentralisation between constitutional and local reality

Many development initiatives today support decentralisation as an effective measure of good governance. Devolution of political decision-making to local levels, e.g., to communities, should promote effective political participation of citizens, both women and men, in favour of local development - and thus also in favour of effective poverty reduction. It should lead to responsive and accountable local governance and give minorities a voice. Gender discrimination in political decision-making is expected to decrease. It may even be tackled directly by quota systems.

A prominent example in this respect is the amendment of the Indian constitution that makes the membership of women in local governance a condition. Constitutional amendments are just one side of the coin, leaving unfinished business. Local livelihood systems are conditioned by traditions of local governance, embedded in worldviews and power relations that can only be understood when we also turn attention to the microcosmos of villages or communities where decentralisation should become reality, be it in India, Africa or the Andes. External support of local governance, therefore, requires a livelihood perspective providing access to local forces and factors that may favour or hinder successful decentralisation processes.

6.9.4 Rights-based approach: Empowering rights-holders and strengthening duty-bearers

A livelihood focus can contribute to a more meaningful analysis of context and actors for rights-based approaches in development cooperation. A rights-based approach to development basically means addressing simultaneously two separate, yet interacting, parties – the right-holders and the duty bearers. Yet moving from rhetoric to action may require a closer look into the livelihood conditions of both parties. A rights-based approach would appear appropriate, for instance, in the case of a forest officer, as an official duty bearer, denying a tribal farmer, as a right-holder, entitled access to forest products. Yet this kind of interaction between right-holder and duty bearer takes place not only at the interface of two different institutional setups, but is conditioned at the same time by the specific livelihood strategies of right-holders and duty bearers. There is no lack of empirical evidence showing that policy changes at the macro level, informed by purely institutional focus, often remain ineffective (Geiser & Steimann, 2004[20]). Giving proper attention to livelihood strategies of the stakeholders may help us to understand why, for instance, "not claiming rights" and "not delivering duties" may be rational behaviour. It follows that a crucial challenge in a rights-based approach is to promote empowerment of the right-holders while simultaneously doing justice to the duty bearers by also focusing on forces and factors that condition their livelihoods.

6.10 Questions and issues for debate

- For which purpose was the Sustainable Livelihood Approach (SLA) of DFID originally developed? Why is it called holistic?
- Apply the livelihood framework, as it is shown in Figures 6.6 and 6.7 to sustainable land management. Proceed in the way suggested in Chapters 6.8.2 – 6.8.4, Focus I to III).

  Focus I: What are the risks, vulnerabilities, and constraints for sustainable land management in Eritrea? What are opportunities? What policies and services can make land management more sustainable, or less sustainable?

  Focus II: What assets do farmers need to sustainably manage their land?

  Focus III: What are the strategies that they use to "keep the house going"?

- Discuss (in groups, or in writing), which interventions could be envisaged to support farmers in making land management more sustainable, if necessary. Which entry points for interventions do you think are promising? Why?
- How are poverty and livelihood linked?

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Chapter 7

Bio-physical Aspects of Sustainable Land Management

7.1 Indigenous SWC measures

One of Africa's major untapped resources is the creativity of its farmers (Rej, C. et T. Thiombiano 2003[1], Reij and Waters Bayer 2001[2]). The situation in Eritrea is also similar to that of the rest of the continent, where farmers have developed indigenous Soil and Water Conservation (SWC) practices. The various ethnic groups have developed and adapted, over the years, different conservation methods to combat soil erosion and to maintain soil fertility in their fields. The main objectives of the SWC measures and techniques are twofold: controlling soil erosion and maintenance of soil fertility in their agricultural fields. The aim of this chapter is to identify the indigenous SWC measures used and to evaluate the effectiveness of these measures vis à vis other techniques and approaches used elsewhere. At the end of the course, students should be able to make their own judgements as to the effectiveness of these conservation measures.

7.1.1 Traditional soil erosion control measures

Some of the most important SWC methods and practices in use by farmers are stone and earth bunds, stone wall diversion structures across slopes, ridging along the contour, and leaving trees standing in agricultural fields (Kebreab[3], 1996, Ogbazghi and ul Haq, 1999[4],

Table 7.1 Traditional SWC techniques used in Eritrea to combat soil erosion on agricultural and non-agricultural lands. The ++++=100%, +++ = 75%, ++= 50%, + = 25%, - = do not use at all. na= data not available

Methods used	Ethnic group								
	Tigrigna	Tigre	Bilen	Saho	Afar	Kunama	Rasheida	Nara	Hidareb
Stone-walled terraces	++++	+++	++++	+++	na	na	na	+	-
Earth bunds	++++	+++	+++	++	na	na	na	+	+
Stone-wall diversions	++++	++	++++	++	na	na	na	-	-
Structures across slopes	++++	+	+++	++	na	na	na	++	-
Ridging along the contour	++++	+	++	+	na	na	na	-	-
Leaving trees	++++	++	+++	+	na	+	na	++	-
Barriers of bush to accumulate debris	+	+	+++	++	na	+	na	+	+

Source: Ogbazghi 1999

Ogbazghi 1999[5]). Table 7.1 outlines the various SWC techniques employed to combat soil erosion across the nine ethnic groups (socioeconomic groups) in Eritrea. Empirical data are needed to make elaborate analyses of the genesis and development of these soil erosion control techniques over time. Moreover, it is also important to find the most important techniques used by the local communities vis à is their social acceptability, economic feasibility, and ecological significance over time. It is not yet known if these traditional measures could be adapted for use as entry points for sustainable land management in selected agroecological zones.

The values indicated in Table 7.1 are relative and need further testing at field level.

7.1.2 Traditional soil fertility maintenance measures

Besides the soil erosion control techniques used, farmers have developed various methods to tackle the decline in soil fertility. Table 7.2 shows that none of the ethnic groups apply forest fallow. This is mainly because of human population pressure that results in a shortening of the fallowing period. Owing to lack of funds and the scarcity of industrial fertilisers, the majority of the population use little or no commercial fertilizers. Fertiliser use is limited to irrigated vegetable crop production and commercial farms.

Table 7.2 Traditional methods used to combat soil fertility decline by the nine ethnic groups of Eritrea. The ++++=100%, +++ = 75%, ++= 50%, + = 25%, - not used at all

Methods used	Ethnic group								
	Tigrigna	Tigre	Bilen	Saho	Afar	Kunama	Rasheida	Nara	Hidaerb
Forest fallow	-	-	-	-				-	-
Bush fallow	-	-	-	-				++++	++++
Short fallow	+	++	+	++				++	++
Manure application	++++	++	+++	++				++	+
Commercial fertilizers	-	-	-	-				-	-
Crop rotation	++++	++	+++	++				-	-
Intercropping /mixed cropping	++++	+	+++	+				-	-
Vegetation burning	+	+	++	+				++	+

Source: Ogbazghi 1999

In the highlands, where the *Dessa* land tenure system is common, most people live from subsistence agriculture. Under this arrangement, arable and grazing lands remain village property and rotation is practiced at village level. To ensure that annual subsistence needs are met, every family must invest its labour in terracing, ridging and applying manure to the fields. At village level, farmers are entitled to get land from three major traditional land classes. Every village land is divided into fertile, medium and poor land based on the visual characteristics of soil types. Long fallows have almost ceased to exist due to population pressure.

7.2 Constraints on SWC practices

Table 7.3 describes the major constraints on SWC.

Table 7.3 Major constraints on SWC practices

Constraints	Explanation
Disintegration of Rural Indigenous SWC Management Institutions	Rural institutions influence the choices by influencing the availability of information and resources, shaping incentives, and establishing rules and social transactions. All of the customary laws of Eritrea covered land tenure, land management, civil laws, family laws and penal laws. These laws, being gradually replaced by new ones, are created in response to severe competition for land among users. The main functions of these laws are to regulate access to land among users, provide arbitration and conciliation, and ensure forceful sanctions such as group morality and public opinion (Nadel, 19466). With the disintegration of these customary laws, and lack of effective and applicable land laws, a gap has been created that aggravates land degradation and unregulated use of land. Gaps in soil and water conservation responsibilities (who does what?)
Lack of Land and Tree Tenure	The code of customary laws contains a wealth of information regarding the traditional resource management systems in a country with a mosaic of tradition and culture, originating in varied socioeconomic backgrounds. In view of the varied ecological and socioeconomic setting of the country, it is difficult to make generalized statements about land tenure and land management practices. The Dessa land tenure system has been questioned (Gaim, 1996), as it does not provide incentives for farmers or investments on the land, and overuse and underinvestment occur because of the possibility of transfer to other land users. The new land law promulgated in 1994 has not been fully implemented and it is not yet known whether this new law provides adequate incentives to land users to invest in land (GoE 19947).
Lack of replicability of soil & water conservation research outputs	The Afdeyu research station has generated a number of research outputs over the last three decades. A number of M.Sc and B.Sc – level research results have been produced on runoff and erosion. Despite these studies, however, much remains to be done to replicate the experiment and studies in other agroecological zones of the country. More important, however, is the translation of these facts and figures into concrete action-oriented development programmes.
Lack of Soil and Water Conservation Legislation	Technical support and extension works have to be strengthened through legal frameworks. There is a lack of soil and water conservation legislation. There are no legal instruments to control abuse of land. The land tenure system should clearly stipulate detailed legal frameworks to encourage people to invest enough in permanent structures and discourage those who are not doing so.

Source: Ogbazghi 1999

7.3 Soil and water conservation measures

Soil conservation in sub-humid areas

The humid escarpment agro-ecological zone (AEZ) is located on the eastern slopes of the highlands. The altitude range is 600-2,600 m with average annual rainfall of 700-1,100 mm. The length of the growing period is 120-210 days. Owing to the steep slope and rugged topography, mechanical soil and water conservation measures were specially designed for the area. Farmers plant coffee and maize on well-established terraces. Bench terraces, cisterns and fog harvest are the major soil and water conservation activities in the area, along with stone check dams and planting of trees across the contour.

Soil conservation in arid and semi-arid areas

The arid and semi-arid areas occupy the vast majority of the country surface area.

7.3.1 Conservation of uncultivated hillsides

Physical soil conservation measures usually consist of mechanical works involving construction of earthworks such as terraces, check dams, and water diversions. Afforestation must be combined with physical measures to reduce the effects of slope length and angle (Negassi et al. 2002[8]). The earth-work construction intercepts and slows down runoff water, which prevents sheet, rill and gulley erosion. The intercepted water gradually percolates into the soil and may make useful additions to the recharge of ground water. The main objective of all such measures is improved SWC, provision of wood and non-timber forest products, and biodiversity conservation.

Enclosures (hillside enclosures managed by the local communities or government)

- Afforestation (tree planting, enrichment planting)
- Hillside terraces (forest terraces)
- Micro-basins (hillsides)
- Check dams (for gulley reclamation)

7.3.2 Conservation of cropland

Many cultivated areas, particularly in the highlands, are severely degraded due to over cultivation, overgrazing, and other poor land management practices. To prevent soil erosion, and to rehabilitate the degraded lands, agronomic and vegetative measures including agroforestry, as well as physical measures, are required. This chapter focuses on agronomic and vegetative measures.

Agronomic measures are those measures or biological practices for the management of annual and perennial crops that aim to promote soil conservation. Such agronomic measures include use of organic manure, inorganic fertilisers, use of cover crops, crop rotation, intercropping, application of crop residues and organic matter management, tillage practices, use of trash lines on contour and contour strip cropping.

The vegetation cover can be improved in different ways. A cheap and effective measure for achieving better vegetation cover is the establishment of area enclosures to enhance natural regeneration of the vegetation. Human activities are restricted for shorter or longer periods, or even permanently. A costlier option is to actively plant trees to form new forests or woodlands (Negassi et al 2002).

Application of fertilisers

In most cultivated soils, fertility has been depleted because nutrients are being lost through soil erosion and crop removal without replenishment by addition of natural or chemical fertilizers. Farmers rarely use chemical fertilisers, animal dung and crop residues. Due to shortage of firewood, crop residues are nowadays used as firewood. It is estimated that animal dung contains nitrogen in the amount of approximately 2.77 kg/ton, and phosphorus in the amount of nearly 2.57 kg/ton (MoA, 2002[9], Fekadu, 2007[10]).

Adding manure and inorganic fertilisers to soil increases plant growth and enhances soil cover, which in turn reduces soil erosion. Most farmers apply inorganic fertilisers. The amount and kinds of fertilizers applied depends on the financial resources available for inputs, types of crops and rainfall. Some farmers prefer to apply organic fertilisers to soils such as vertisols, which have good water holding capacity. Crops grown in such soil types respond better due to the availability of soil moisture. The most common types of fertilisers used in Eritrea are DAP (di ammonium phosphate) and urea. DAP contains 18% N 48% P_2O_5, while urea contains 46% N. Recommendations for Eritrea are as follows: Cereals (barley, wheat maize and sorghum, pearl millet): 100 kg DAP plus 50 kg of urea per ha. For vegetables (potato) 200 kg of DAP and 100 kg of urea per ha.

Many cultivated areas, particularly in the highlands, are severely degraded because of continuous cultivation combined with overgrazing and other land mismanagement practices. In this sense, the land tenure system described earlier also contributes to land degradation. To prevent soil erosion, and for rehabilitation of degraded lands, agronomic and vegetative measures including agro-forestry as well as physical conservation measures are required.

Use of cover crops

The type and density of crops play an important role in determining the level of soil erosion. Bare soils have the highest erosion rate. Thus, the denser the crop, the better it protects the soil, and in addition, a large amount of useful crop residues will be produced. Close and short stature crops are very effective in the interception of rainfall, i.e. reducing its energy, and in limiting soil losses, while tall crops generally have a lower density and are less effective in reducing soil losses. Besides, the crop types also influence the amount of organic matter available to the plant and the amount returned to the soil (Tivy 1997[11]).

Box 7.1 Characteristics of cover crop

- Fast-growing to accumulate biomass over a short period of time;
- Suitable for areas where the growing period is short;
- Able to fix atmospheric nitrogen;
- Deep rooted to improve soil structure and enhance nutrient cycling;
- Produces many leaves that decompose easily;
- Little competition for moisture and plant nutrients; and
- Has multiple uses: animal feed and food

Various leguminous crops such as peas and beans and microorganisms (e.g. blue green algae) are important to replenish soil fertility by fixing atmospheric nitrogen. The maximum benefit of a leguminous crop is obtained if it is ploughed into the soil as green manure. While the above-mentioned characteristics are ideal features, farmers in Eritrea have other preferences when choosing a particular cover crop. Barley is grown in the cooler highlands as insurance against drought, as it is early maturing. Sorghum and pearl millet are grown in the lowlands mainly because of their tolerance to drought. Maize is, however, a much more demanding crop in terms of moisture and soil nutrients and is grown in fertile soils locally called *gedena* fields near their homestead.

Crop rotation

Crop rotation is the practice of growing a series of dissimilar types of crops in the same space in sequential seasons. This avoids the build-up of pathogens and pests that often occur when one species is continuously cropped. Crop rotation balances the fertility demands of various crops to avoid excessive depletion of soil nutrients. Crop rotation can also improve soil structure and fertility by alternating deep-rooted and shallow-rooted plants. A typical crop rotation practice in the highlands is shown in Table 7:4:

Table 7.4 Crop rotation sequences in the highlands of Eritrea

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Sorghum	Barley	Barley	Barley	Pulses	Fallow
Chick Pea	Barley	Sorghum	Taff	Fallow	-
Horse bean	Barley	Barley	Sorghum	Taff	No fallow
Maize/ Sorghum	Barley	Taff	No fallow	-	-
Barley	Pulses or flux	Potato	Fallow	-	-
Barley	Wheat	Sorghum/maize	Pulses	No fallow	-
Barley	Wheat	Flax	Fallow	-	-
Taff	Barley	Taff	Fallow	-	-

In the lowlands, cereals are continuously grown without rotation. In such cases, the protection of the soil by crops is less effective than if there were rotational cropping, mainly due to decline in the crop's performance. In addition, plant pests and disease thrive better in mono-cropping systems. Crop rotation with cereals and legumes is recommended. Alternating a cereal crop legume (pulses, lentil or beans) provides extra nitrogen to the soil through the nitrogen fixing ability of the leguminous crops. The crops generally perform better and the legume also provides ground cover during certain periods, all of which reduces the risk of soil erosion.

Owing to increase in population pressure coupled with acute shortage of land in the highlands, the use of fallow is not as frequent as it ought to be. In the lowlands, where sorghum, maize and pearl millet are common, farmers are not familiar with the practice of crop rotation. The same crops are grown continuously and, as a result, there is a depletion of soil fertility and hence a decline in agricultural productivity. Therefore, crop rotation with cereals and legumes should be promoted in these areas to maintain and enhance soil fertility.

Intercropping/ mixed cropping

Intercropping is an agronomic practice of growing two or more crops simultaneously on the same field in rows or mixed with other crops. Combinations of legumes and cereals, e.g. beans or peas with sorghum or maize, help to protect the soil against runoff. The leguminous crops can also fix atmospheric nitrogen, which generally increases production, and tall cereal crops can provide legumes with support and in this sense, both crops benefit mutually. Legume crops such as beans and cow pea that provide good soil cover can be intercropped with maize or sorghum to protect the soil from the impacts of raindrops. Intercropping should be done carefully, so that the inter-planted crop does not cause undesirable yield reduction of the main crop. It is the combined output of the different crops that must be assessed and compared with the output of a single crop. Hence, some yield reduction of the main crop may be tolerated, provided it is compensated by the production of the additional crop. The major advantages of intercropping are:

- More efficient use of light (different layers and leaf sizes)
- Better soil fertility (can be achieved with leguminous crops)
- More efficient uses of water and nutrients (different rooting depths)
- Opportunity from compensatory growth (if one component fails due to pest problems, climate others components may compensate the shortfall),
- Breaking the cycle of increased diseases, insects and weeds.

Farmers in the highlands of Eritrea mix wheat and barley, locally called *hanfets* (Woldeamlak, 2001[12]). The advantage of such a practice is that the incidence of pests is reduced and the combined yield is higher than from the single crop.

Management of crop residue and of organic matter

Dry grass, straw, maize and sorghum stalks, dry leaves and other crop residues can be spread on the bare soil surface or placed around the stems of plants to control soil erosion and conservation of moisture (Isaak 2008[13]). This mulch layer abstracts run-off often and reduces the velocity and the capacity to transport soil. Even if the soil is completely covered by growing plants, mulch can still have important effects in reducing soil losses. However, mulch is not recommended on heavy clay soil with water logging problems as it impedes the effectiveness of the shallow drainage ditches. Crop residues are used for mulching not only to protect the soil against runoff but also as a good source of organic matter when decomposed. Another important source of organic matter is animal manure.

The use of animal manure as fuel is detrimental to the recycling of organic matter and nutrients. If collected animal manure is exposed to rain and sun, its nitrogen content can be leached or evaporated easily and the nutrient value of the manure decreases. To prevent this, manure must be kept in a covered pit before it is applied on the field and then covered with soil soon after its application. In Eritrea, mulching is not widely used because of shortage of grazing land and lack of awareness of its benefits. Crop residues are used as livestock feed during the dry season or as a source of fuel. Manure and compost are, however, used in limited areas such as homestead farms and in intensively managed *ghedena* fields.

Tillage practices

Tillage and planting along the contour, i.e. across the slope instead of up and down the slope, is an effective method of reducing soil erosion. Each planted row of crops acts as a barrier to run-off water flow. Contour tillage and planting along the slope can be effective on gentle slopes up to 8% (Negassi 2002). On steeper slopes, other supporting measures such as grass strips or terraces must be used.

Contour strip cropping

Contour strip cropping is a practice of growing alternate strips of different crops in the same field. Strip cropping is used to reduce water and wind erosion. In order to control water erosion, the strips are always on the contour, but in areas prone to wind erosion, the strips should be placed across the direction of the prevailing wind (Young 1997[14]). To achieve good crop rotation, the crops should alternate between the strips, and for strip cropping to function well, both the uninterrupted length of the sloping field and the width of the strips should not exceed certain limits. Those limits depend on the gradient (Wijntje 1983[15]). The reduction in soil loss has been calculated based on comparison between up- and downhill cultivation.

Strip cropping, as a method of soil conservation, is based on the principle that the risk of soil erosion is different for different crops. The risk is generally high with tall and widely spaced crops; whereas crops that provide good cover near the soil surface result in a lower erosion risk. In general, densely growing crops such as barley should be alternated

Table 7.5 Maximum strip width and reduction in soil loss from strip cropping

Slope Gradient (%)	Maximum strip width (m)	Maximum length of field (m)	Reduction in Soil loss (%)
1–2	40	240	50–70
3–5	30	180	60–75
6–8	30	120	60–75
9–12	25	72	50–70
13–16	25	48	40–65

Source: Wijntje 1983

with strips of more widely spaced crops such as maize. The main function of the densely planted crop is to slow the velocity of runoff and to intercept soil that is transported in the strip with wider spacing. Since the runoff stays longer in the strip with densely spaced crops, the degree of water infiltration into the soil also increases.

Soil loss under strip cropping can be reduced by 40–70% of what it would be if only tall, widely spaced crops were grown and the land was cultivated up-and downhill. Strip cropping is an effective conservation measure provided that slopes are not too steep or too long (Table 7.5). Strips of closely grown crops can also improve the soil structure, if organic matter is ploughed back into the soil. This is easier for dense and low crops such as wheat and barley than for maize and sorghum. For purposes of erosion control, the rotational period of contour strip cropping should not be more than two years. The common densely grown crops used for contour strip cropping are barley, taff, wheat and forage legumes, while the common wider spaced crops are maize, sorghum and pearl millet.

The usage contour cropping is not well documented. What are the reasons why farmers do not use strip cropping?

Figure 7.1 Construction of earth bunds to conserve moisture in Kenya (Photo by Boniface Kiteme)

Grass strip along contour (locally called *Deret*)

Unplugged grass strips along the contour are common in the highlands of Eritrea. These strips serve as barriers, which capture soil particles that have been detached and are transported with runoff from cultivat ed land. The strip should be about 0.5-1.00 m wide and spaced at normal terrace spacing with a maximum vertical interval of 1.8 m. Grass strips are effective soil conservation measures on soils with good infiltration and slopes up to 3% (Thomas, 1997[16]).

Grass strips should have very dense growth near the soil surface to effectively slow down run-off and retain eroded soil. Preferably, grass strips should be permanent and allowed to develop terraces. Some farmers may, however, prefer rotational grass strips. The natural vegetation is usually used as grass strips, but grasses may also be deliberately planted in strips. For instance, Vetiver grass, which is relatively unpalatable to animals, can be recommended in areas where grazing takes place during dry season.

Agroforestry

Agroforestry is defined in a variety of ways by different authors, but there is general agreement that it is a collective name for land use systems involving trees associated with crops and/or animals on farm or landscape:

> Young (1997) defined agroforestry as a “collective name for land use systems in which woody perennials (trees, shrubs, etc.) are grown in association with herbaceous plants (crops, pasture,) and/or livestock in spatial arrangements, rotational or both, in which there is both biological, and economic interaction between the tree and non-tree components of the systems.

Figure 7.2 Agroforestry in semi-arid climate, Kenya (Photo by Anna Büchi)

ICRAF (2000[17]) describes agroforestry as a dynamic, ecologically-based natural resources management system that, through the integration of trees in farms and in the landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. In this case, agroforestry, as one type of land use system, fulfils production and service functions. Its production functions include fuel-wood, fodder, fruits and a range of other functions such as the production of non-wood forest products (e.g. gums and resins, medicinal products and thatching material), while the service functions include environmental components such as the provision of shade, fencing, and a means of soil and water conservation. The major advantages of agroforestry are the following.

- It allows trees to grow in crop and livestock areas (biodiversity conservation);
- It is extremely important to maintain the proper functioning of ecosystems;
- The majority of our medicines and agricultural crops come from the environment;
- It is important for providing ecosystem services such as pollination and pest control.

Parkland agroforestry

Parklands are landscapes in which mature trees occur scattered in cultivated or recently fallowed fields (Raison, 1988[18], Pullan, 1974[19]; Sautter, 1968[20]). In the ICRAF Agroforestry Systems Inventory, agroforestry parklands are included in the very general category of 'multipurpose trees on farmlands' (Nair, 1985[21]). Livestock production may be a significant or secondary component in these systems.

The best-developed indigenous agroforestry system, at present, is the 'transitional parkland'. In this system, widely spaced pollarded trees grow in cropland of sorghum, (*Sorghum bicolour*) pearl millet (*Pennisetum glaucum*) and taff (*Eragrositis teff*). Livestock rearing is also part of the farming system. In this system, *Faidherbia albida*, *Balanites aegyptiaca* and *Acacia tortilis* are habitually managed for their favourable effects. These species allow for both crops and pasture grasses to grow underneath, and for the provision of firewood, fodder for livestock, edible fruits, shade and shelter (Bein, 1997[22]). The parkland agroforestry in selected areas of Eritrea is shown in Table 7.6.

Negassi (2002) indicated that in the parkland, there were 10-20 trees ha^{-1} which is far less than the expected tree density of 40-60 trees ha^{-1} for improvement of the productivity of the systems. Farmers pollard the tree branches too much for fencing and fuel-wood and occasionally cut them down for construction. This practice, if not combined with new tree planting or tending of natural re-growth, eventually results in the decline of tree population density. In order to increase the tree population at the farm level it is important to:

- Discuss the benefits of agroforestry with the local communities;
- Train farmers in the techniques of pollarding, natural re-growth and the protection and management of saplings and seedlings;

- Supply farmers with multipurpose perennial plant species to enrich their parklands; and
- Establish windbreaks and shelterbelts on farms and homesteads as demonstrations.

Table 7.6 Parkland agroforestry in selected areas of Eritrea

Administrative zone	Administrative sub-region (Sub-Zoba)	Villages	Combination of woody perennials and field crops
Anseba	Hagaz	Begu	Balanites aegyptiaca with pearl millet
Gash-Barka	Laelay - Gash	Adi -Berbere	Balanites aegyptiaca with sorghum
Debub	Mai - Aini	Hadas Agulae'	Cordia africana with maize, Sorghum, taff
	Tsorona	Hazemo	Balanites aegyptiaca, Acacia tortilis with taff with sorghum
	Adi - Quala	Aila Gundet	Balanites aegyptiaca, Faiderbia albida with taff, finger millet
	Emni Haili	Meraguz	Faiderbia albida with taff, sorghum,
Semenawi Keih Bahri	Ghindae	Dongolo Laelay	Balanites aegyptiaca with maize
	Nakfa	Rora Habab	Olea africana with barley

Source: Bein 1997

Trees shrubs and grasses in soil conservation structures

In the central highlands of Eritrea, soil bunds and bench terraces are constructed to conserve soil and water in croplands. Trees and shrubs are not the primary means of checking run-off and erosion-control structures. If trees and shrubs are trimmed to hedgerow, branches can be placed above and between the trees as a trash line. Planting of trees, shrubs and grasses on soil, and water conservation structures on croplands are not yet well developed in Eritrea. However, *Acacia polyacantha* has been planted on soil bunds in some parts of Zoba Debub. Studies carried out elsewhere show that there are a number of benefits that can be gained from such practices (Rocheleau et al. 1988[23]). These are:

- Farmers derive a number of benefits from combining trees, shrubs and annual crops with soil conservation;
- Trees and shrubs complement the improvement derived from terrace structures;
- Stabilizing slopes, conserving topsoil, and improving the water availability below the soil surface;
- Trees and shrubs planted on terraces affect soil temperature, wind, and soil moisture availability in ways that are beneficial to crops, and all these effects result in increased stability and increased yield.

Live fencing

A live fence is established to control the movement of domestic animals, as ornamental planting, for microclimate improvement, land demarcation, soil and water conservation, provision of security or privacy, and to provide shelter for backyard poultry. In the central highlands, live fences are found around many homesteads, schools, place of worship compounds. *Euphorbia tirucalli* is grown around residential houses, while *Euphorbia abyssinica* is grown in rows around farmlands homesteads in the highlands of Eritrea (Haile et al 1998[24]).

a. Euphorbia abyssinica around homestead and farm fence

b. Agave sisalana live fence

Figure 7.3 Live fence in the highlands of Logo Anseba (Photo by Woldeselassie Ogbazghi)

7.4 Land management and land use changes

Land management is the process of managing the use and development, in both urban and suburban settings, of land resources in a sustainable way. Land is a broad term and is variously defined to cover all the physical and biological components of the environment. Land resources are commonly understood as soils, water, and biological resources (vegetation and wildlife). Land resources are not renewable unless continuously and carefully managed and nurtured.

Land management for agriculture requires a more holistic integrated land management approach increasingly referred to as better ‘land husbandry’. This is based on the premise that with improved crop management (e.g. higher yields, good vegetative cover, and reduced raindrop impact), improved soil management (better organic matter management, integrated plant nutrition, improved soil structure) and improved rainwater management (reduced runoff, increased infiltration,) it is possible to reduce erosion, improve fertility, increase food security, and enhance livelihoods. The socioeconomic circumstances of the land users and/or the social, cultural economic and policy environment, in which they operate, must also be taken into consideration to propose suitable improved land management practices which will be acceptable to and sustained by the farmers.

7.4.1 Land tenure

Land tenure is the ownership or leasing system of land or the right to use it. Historically, Eritrea had a number of different land tenure systems. The extended-family system and village systems of land ownership were dominant in the Central Highlands Zone, whereas tribal systems and government ownership are dominant in the Eastern and Western Lowlands. In the past, three major land tenure systems coexisted for many years. These are the *Rsti* (family ownership), *Dessa* (village or collective ownership), and *Demaniale* (state ownership (Nadel 1946, Zekarias 1966[25]). The land tenure system varies from place to place. A new land law issued in 1994 has officially replaced all three traditional land tenure systems, but in practice the situation has not changed (GoE, 1994). If these land tenure systems are being gradually replaced by state ownership of land, one might naturally ask why it is then important to revise the traditional land tenure systems that existed in the past. We assume here that analysing land tenure from a historical perspective becomes crucial to underscore the current state of the land and to design an appropriate land tenure system to guarantee sustainable land management practices.

The individual family ownership of land refers to a system in which land could be acquired by settlement in a vacant area, purchase, or grant of land by rulers (Zekarias 1966). An individual holder of *Rsti* land can cultivate or lease it or arrange sharecropping, but cannot sell or give it away to an outsider without the consent of family members. Thus, individual *Rsti* holders do not have absolute rights over their lands. Haile et al. (1998) mentioned that, although individual families have legitimate rights over their agricultural lands, grazing areas and fallow lands are communally used. In villages with *Rsti* land tenure system, streams, wells, and land around settlements were owned and managed communally and managed by a village council elected by villagers (Zekarias 1966).

How the Dessa system of village-wide communal ownership came into being in Eritrea is not clearly known. Some sources (e.g. Nadel 1946, Trevaskis 1975[26], Jordan 1989[27]) report that the Italians introduced it as a means of settling land disputes in the *Rsti* systems. In this system, the village elders form three committees (locally known as *Aquaro, Gelafo and Metaro*). These committees establish criteria for eligibility to a full share or a half share of a crop field. The *Aquaro* keep records of the land qualitatively and quantitatively, the *Gelafo* set allocation criteria and screen eligible individuals for land, and the *Metaro* actually allocate land by measuring land from three categories (poor, medium and fertile) of land.

The *Dessa* system involves land re-distribution every five to seven years by which each eligible household receives often scattered fields of different fertility classes. This situation discourages the landholders from making long-term investment such as planting trees, constructing soil and water conservation structures and other permanent structures. After land redistribution, as farmers are obliged to leave their holdings, they often have to build new houses, and this puts extra pressure on the remaining forest resources.

Demaniale mainly refers to state land. This system emerged during the Italian colonial period (1989-1940) and later continued during the British administration (1941-1952), where traditional individual lands were confiscated in favour of Italian commercial agriculture (Longridge 1974,[28] Trevaskis 1975, Mesghena 1988[29]). In the highlands, *Demaniale* lands were limited to the fertile lands used for irrigated agriculture and dairy farms. In the lowlands, however, all areas below 850 m were declared state lands. The *Demaniale* allowed open access to lands resulting in massive clearing of land and extensive unsustainable land use.

Woldeselassie Ogbazghi Both *Dessa* and *Demaniale* land tenure systems coupled with rapid population growth are believed to have led to land degradation and unscrupulous cutting of the natural vegetation similar to what Hardin (1968[30]) described it as "the tragedy of commons."

7.4.2 The new land law

The management of grazing and arable land and the maintenance of its productive potentials are essential for sustainable development. However, due to the traditional land tenure systems that prevailed in Eritrea, soil erosion and deforestation have progressed far, in that the land has become increasingly degraded. The tenure system in practice has not encouraged innovation, nor has it permitted new sustainable land management practices and modern ways of exploiting land to improve production. Traditional land tenure did not enhance protection or proper use of the environment, nor did it guarantee tenure over land. On the contrary, the system invited time-consuming litigation leading to loss of labour productivity and poor management of land. This required formulating a new land law that would create incentives for better management of natural resources (GoE 1994).

In order to improve land use and management of natural resources, Land Law No. 58/1994 guaranteed all Eritreans above age 18 the right to land based on the usufruct principle. As the government owns land in Eritrea, it allocates land fairly and equitably without discrimination based on race, religion, gender or national origin. This new system of land allocation is expected to confirm and reinforce security of tenure, thus increasing the impetus for environmental improvement.

7.4.3 Land use

Land use is human modification of the natural environment to create a modified environment such as crop fields, pastures, and human settlements. The major effect of land use on land since the advent of Italian colonialism has been land clearing (deforestation) for various purposes. More recent significant effects of land use include urban spread, construction of roads and highways that result in accelerated soil erosion, soil degradation, salinization, and widespread desertification.

Land use changes, together with use of fossil fuels, are the major anthropogenic sources of carbon dioxide, a dominant greenhouse gas. Land use has also been defined as "the total of arrangements, activities, and inputs that people undertake in a certain land cover type" (FAO, 1997; FAO/UNEP, 1999). Retrieved from "http://en.wikipedia.org/wiki/Land_use" on 22 of May 2008[31].

To date, there is no precise estimate of the land use categories in Eritrea. Less than 2.1

million hectares (17%) has been provisionally assessed as having potential for rainfed and irrigated crop production (FAO, 1994[32]). In 1994, it was estimated that about 472,000 ha had been opened up for rainfed agriculture and that a further 22,000 ha were under irrigation. Of the 472,000 ha, 371,400 ha were used and the remainder was left fallow. In spite of large area of land suitable for crop production, just over 1.6 million hectares is currently cultivated due to a number of potential problems associated with its use (Bojo 1996[33]). Figure 7.4 present an overview of land use and land cover in the country.

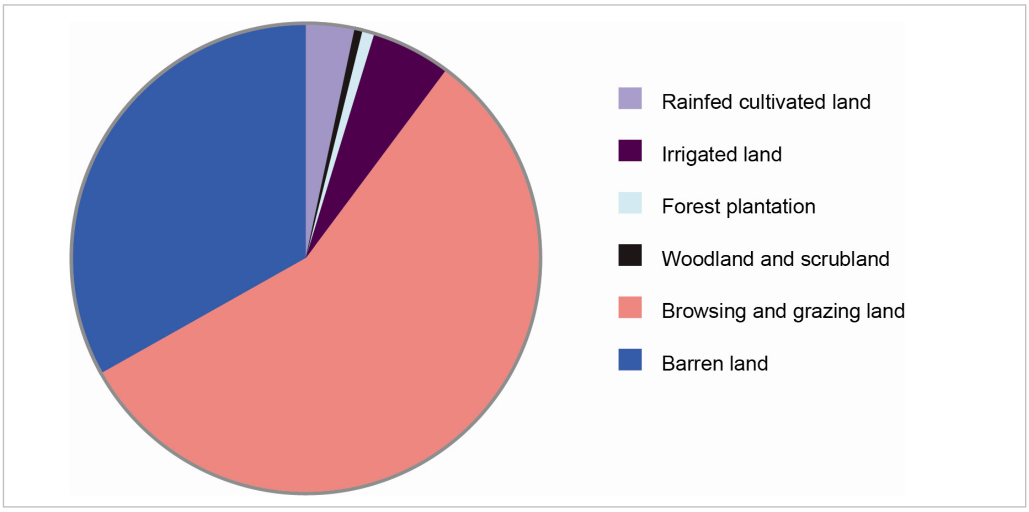

Figure 7.4 Different land use types and area coverage in Eritrea

7.5 Protection of non-agricultural land

Protection of non-agricultural area refers to all lands which are currently not cultivated for various reasons, i.e. lack of rainfall, rugged topography and problems related to land degradation. More than 60% of the total land area of Eritrea is arid and semiarid, unsuitable without irrigation. Non-agricultural lands are subject to open access to the exploitation of land resources. The Forestry and Wildlife Law protects all natural habitats including non-agricultural land against abuses such as cutting trees and hunting of wild animals. About 220,000 ha of land are set aside as enclosed areas to prevent livestock grazing and cutting of trees. Despite this, however, there are no legal instruments aimed at protecting non-agricultural areas especially with respect to erosion and land degradation.

7.6 Land use pressure, agricultural intensification and SLM

The land reform proclamation (No. 58/1994) has established the basis for a new and systematic type of land use planning. A land-use planning unit in the MoLWE Department of Land is in its infancy stage and focuses mainly on urban and peri-urban areas owing to the high demand for land for urban expansion and the need to protect agricultural land loss in these areas. Since mid 1997, land classification and partial land-use planning have been accomplished for 117 villages and towns. Additionally, land use has been approved for 42 areas of investment and social services. Beyond this, *Dessa* (land traditionally given by a Village to its inhabitants for residential purposes) has been given out (e.g. in 240 Villages in southern Eritrea) (MoA 2002).

However, land-use planning is also needed in rural areas, where there is an urgent need for wise use of scarce land resources. The wise use of land through land-use planning will help to control land degradation. Since land-use planning takes ecosystem carrying capacity into consideration, it can help communities to achieve sustainable use of their resources. Careful planning can deal with infrastructure expansion with due environmental consideration. Hence, in view of existing limited capacity, land-use planning needs to be introduced in prioritized areas of environmental and economic significance. The following recommendations are important with respect to land use issues *vis-à-vis* desertification:

- An integrated national land-use policy is required which integrates the various sectoral policies, based upon the principles of efficiency, equity, and environmental soundness.
- A systematic and user-oriented assessment of the land resources of Eritrea should be a priority.
- Guidelines, directives, and standards for implementing the new land-tenure system and the introduction of land-use planning are required.
- The institutional and professional capacities of land use need to be strengthened.
- Land-use planning should precede every development activity on land

Land use pressure

The main factors that cause pressure on land are human and livestock population increase, over-cultivation, and soil and air pollution. Population pressure has a direct bearing on deforestation for cultivation, firewood collection and construction of houses. Globally, human population has quadrupled during the past century. The consequence of the increase in human population has been the opening up of new agricultural areas in marginal locations on steep slopes, resulting in accelerated soil erosion and widespread land degradation. In the mixed farming system, the livestock population has also increased along with the human population. In such a situation, there are two options to choose from: either open new agricultural land or intensify agricultural production. Intensification means increased levels of agricultural inputs, which could be fertilisers, herbicides, or pesticides. Agricultural intensification has so far been carried out without due concern about the environment. The main environmental issues in focus are soil contamination, climate change, and degradation of land resources.

In response to population pressure, agricultural scientists have developed a concept of agricultural intensification, where multiple crops are grown on the same piece of land using improved technologies. Intensification also includes improvement and expansion of agricultural research, extension services, and training covering all agricultural subsectors: crop and horticultural production, rainfed and irrigation farming, livestock husbandry and animal health, land resources, soils, soil- and water-conservation practices, and forestry. In Eritrea, intensification could also mean setting up a programme of importing and testing improved crop varieties with potential for use under different agro-ecological conditions, together with an extensive fertilizer trial and demonstration programme. Adoption of improved varieties from neighbouring countries may be especially useful. Moreover, intensification could mean expansion of mechanised farming in areas of high potential, especially in the lowlands, that can be irrigated or rain-fed with supplementary water, with the use of appropriate soil and water-conservation measures.

As one step towards agricultural intensification, integrated farming was introduced in 1998 in Eritrea. In that initial operation, tractors were used to cultivate 42,504 ha of farmland mainly in the highlands with a total yield of about 70,000 tons. Despite the claim that yields obtained from integrated farming were double those from traditional farming (MoA 2002), the productivity was far less than the national average of 0.74 tons per ha (World Bank 1994[34]). In the long run, problems associated with mechanized farming include the deterioration of soil structure owing to excessive cultivation, and soil compaction will be evident. Such undesirable effects can be minimized or avoided using appropriate tillage practises (e.g. minimum-tillage, no till) because with fewer cultivation operations, the soil is less disturbed, less compacted, and less vulnerable to erosion. In this regard, detailed studies and surveys should be made in conjunction with introducing mechanized agriculture, research should be carried out with a focus on the soil type, soil depth, slope of the land, soil-moisture content, vegetation cover, vulnerability to soil erosion, and types of machinery to be used (MoA, 2002).

Food production in sub-Saharan Africa and data from 37 countries in SSA confirms a significant relationship between population pressure, reduced fallow periods and soil nutrient depletion, indicating unsustainable dynamism between population, agriculture and the environment. It is estimated that nutrient depletion accounts for about 7% of the agricultural share in the average Gross Domestic Product of the countries, with national values ranging up to 25%, indicating soil nutrient mining as a significant basis of current economic (mal) performance. With respect to increasing population densities, it is argued that more than proper soil management will be required to sustain food security. While soil scientists and farmers can reduce the speed of the dynamism only, policy-makers are will be required to address the demographic and economic root causes of soil degradation as well.

Table 7.7 Projected population growth and arable land per capita for Eritrea (1900-2015)

Year	Population size	Arable land (per capita)	Reference:
1900	330,000	1.33	Longridge 1945
1928	510,000	0.86	Longridge 1945
1941	760,000	0.58	Longridge 1945
1952	1,031,000	0.43	Trevaskis 1975
1964	1,500,000	0.29	Aradom 1964
1994	3,602,000	0.12	UNICEF 1994
2002	4,038,000	0.11	MoA 2002 (Nat. Action Plan to combat desertification)
2010	5,075,000	0.09	MoA 2002 (Nat. Action Plan to combat desertification)
2015	5,855,000	0.07	MoA 2002 (Nat. Action Plan to combat desertification)

The data in Table 7.7 are taken from various sources to document the population change in relation to land in Eritrea. The calculation is based on a population growth rate of 2.9% per year from 1997 onwards; and on a constant area of arable land of 439,000 ha. The Table shows that as the population increases, the per capita arable land decreases. Although the data are based on a number of simple assumptions, they do provide valuable insight into issues in the making and the strategies to be used in relation to land management.

7.7 Question for discussion and debate

1. Identify and describe the major indigenous soil and water conservation practices among the various socioeconomic groups of Eritrea
2. Why is land use planning necessary for sustainable land management? Is there a mismatch between the present and traditional land use systems in the villages?
3. Nowadays, many farmlands are being taken up by buildings. What would your grandfather say about these practices?

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Chapter 8

Economic Aspects of Sustainable Land Management

8.1 Introduction to sustainable agro-economy

The concept of sustainability evolved from the "Limits to Growth" debate of the early 1970s, which centred on whether or not economic development would lead to environmental degradation and the collapse of societies (Pezzey, 1992[1], Harris, 2000[2]). Since then the concept of sustainable development has been refined and has become central to the way we think about environment and development, as reflected in the Earth Summit held 1992 in Rio de Janeiro, when the Brundtland Commission definition was the most prominent approach to explaining sustainable development.

"Sustainable development" as defined by the Brundtland Commission in 1987:

Sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their needs.

The definition by the Brundtland Commission (WCED[3]) was too vague for operational purposes at project level. Economists subsequently criticised the Brundtland definition for its failure to (Bartelmus 1997a[4]):

1. Specify what human needs are
2. Clarify the timeframe for analysis of future generations
3. Mention the environment as a key concern in sustainability

Bartelmus further refined the definition and included standards, targets and norms, leaving them open to societal negotiation. His definition reads as follows: "... 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..."

In the late 1990s sustainable development was broken down into its three key components, which are described separately, e.g. by Harris, J.M. 2000[5]:

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 debt, and to avoid sectoral imbalances that 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.

The concept of the three pillars (or components) of sustainability is still valid even if there is ample evidence that current production and consumption patterns do not meet the criteria set in the above definition.

It is evident that the definition of sustainability is not free of conflict, as the goals expressed are often multidimensional and therefore raise the issue of how to balance 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 that is capable of linking the phenomena with each other, as well as with the costs and benefits of related economic activities (Bartelmus 1997a). 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 (Dasgupta, 1996[6]).

Economic aspects of sustainable land management

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" (*Tisdell, 1993"[7]).

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 (Perich, 1993[8]). 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. This way of looking at the environment as a mere production factor is 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 (Dinwiddy and Teal 1996[9]).

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 (values for indirect use, 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 a supplier of raw materials, which are 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 at 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 (Endres and Querner, 2000[10]).

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 (*Figure 8.1*). 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 industrialized countries attribute to the snow leopard and its preservation is much higher than the value attributed to the animal by Afghan highland farmers, who suffer livestock losses.

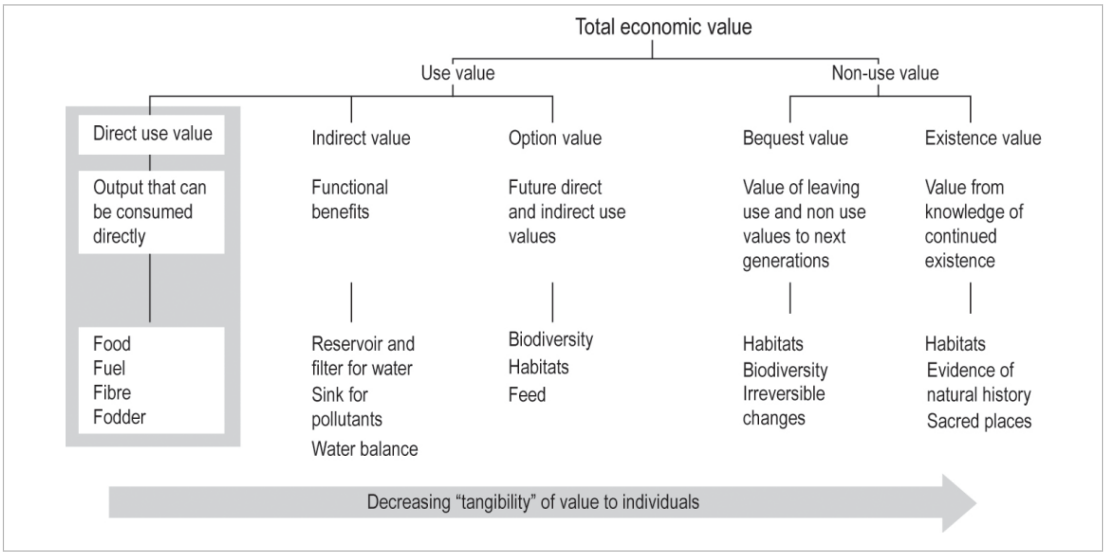

Figure 8.1 *Economic values attributed to environmental assets with reference to soil (Munasinghe, 1993[11], 1992, 22; Grohs, 1994[12], 15 and Ludi E. 2002[13], 51)*

8.2 Economic aspects of sustainable land management

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 the 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 internalizing external costs, and therefore do not reflect true scarcity and do not allow for efficient allocation. Without a market to determine prices, two important aspects cannot be clarified: (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 (Perich, 1993[14]) or if they intervene, their 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 (Sanders et. al. 1995[15]), and 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 the costs that arise from the production or consumption of a good for which the producer 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, environmentally friendly goods and services are marginalized. The solution would be to internalize external costs, to correct prices to truly reflect the total economic value of an environmental good, and to let the producer 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 (OECD, 1997[16]).

Open access resources 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 those 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 (Perich, 1993[17])

With respect to sustainable use of agricultural soils, economic analysis should provide:

- 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 inter - temporal 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 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 damage 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 the 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 can environmentally friendly management practices become more attractive.

8.3 Costs and benefits of sustainable land management

Cost-benefit analysis (CBA) 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 (Arrow K.J., et. al. 1997[18]). CBA is not limited to evaluating 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 (impacts) on the welfare of a community (de Graaff J. 1996[19]). In contrast to multi-criteria analysis (MCA), CBA concentrates on costs and benefits and centres on 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, the effects of an activity are expressed in monetary terms, whereas in an MCA, different criteria are weighed and compared without monetary values being assigned (de Graaff J. 1996). Thus, non-market goods and intangible side effects of an activity can also be included in the valuation without having to be assigned a price. In the agricultural sector, and especially for subsistence farmers, it is usually not the maximisation of one goal that is in the foreground, but rather the optimization and meeting of several objectives. 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 to different criteria (Drechsel and Gyiele, 1999[20])

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 (Enters T. 1998a[21]). 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, the 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 end in themselves, 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 (*Figure 8.2*). With respect to soil conservation, a CBA would be sufficient only if farmers operated under perfect markets with the single objective of maximising profits (Pagiola S. 1994 [22]). 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)[23] 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 (Hanley and Spash, 1993[24]). 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 (Abelson, 1996[25]).

The simple model presented in Figure 8.2 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 greater the consumer surpluses are obviously 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.

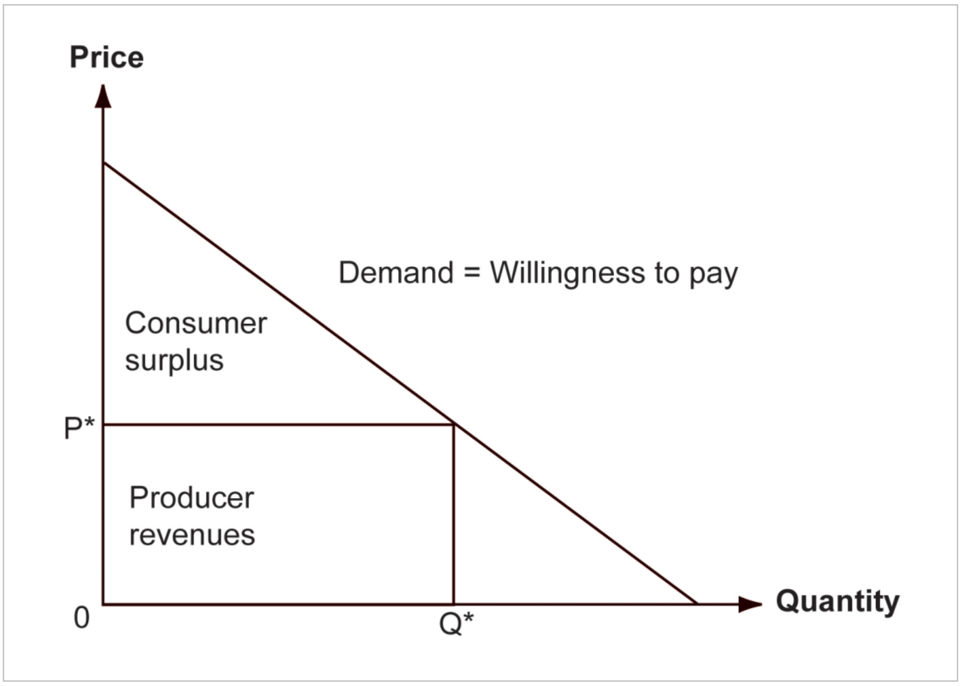

Figure 8.2 *Willingness to pay consumer surplus and producer revenues (Abelson, 1996; Ludi, 2003)*

As mentioned in section 8.2, 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 (Goodland, 2002, 1)[26]. Problematic is the fact that many environmental assets do not have a market. Thus, they are considered to have a price of zero and are provided for free (Chichilnisky, 1997[27]). Since environmental goods are available to consumers at 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 (Bann, 1997 [28])

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:

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 requires that the willingness of consumers to pay, which equals the demand curve (D–D1), can be established as a measure to capture the total value of the good or service (Figure 8.3).

One basic assumption in economics is that society's objective is to maximise the total welfare derived from goods and services that people consume. 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 (Poe G.L. 1999[29]). 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 8.2.

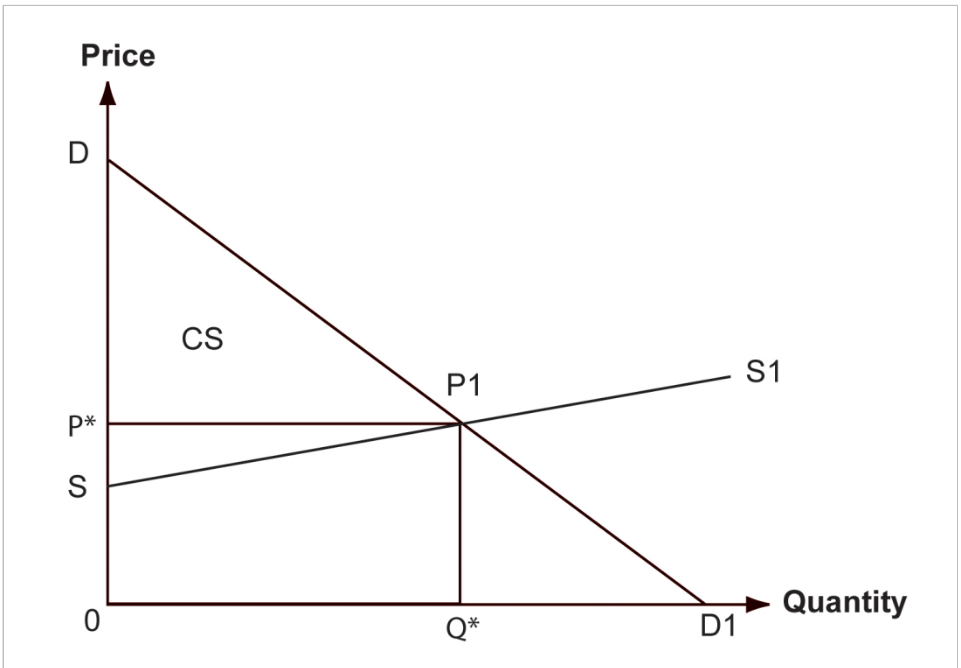

Figure 8.3 *Supply (S–S1), demand (D–D1), price, consumer surplus (CS) and the value of an environmental good or service (Bann, 1997; Ludi, 2003)*

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 (Enters, 1998a[30]). 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 onsite 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* (Dixon and Hufschmidt, quoted in: Barbier E.B. 1998a"[31])

A number of problems are encountered in extending cost-benefit analysis with environmental project impacts (Barbier, 1998b[32]) 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 value 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, inter- temporal choices are difficult to resolve.

CBA and its implications for the environment are subject to controversial debate. Three main aspects evolve:

1. It is difficult to assign monetary value to intangible environmental resources.
2. It is difficult to assign monetary value to environmental impacts.
3. There is controversy concerning the discounting of identified costs and benefits (Lumley, 1996[33]).

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 (Barbier, 1997[34]). 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 (Arrow, et. al. 1997[35]). 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 diffuse nature of the problem, regulations are extremely difficult and costly to enforce (Davies R. 1997[36]) and therefore more expensive than technical solutions.

8.4 A case study on economic profitability of adapted and introduced measures

Figure 8.4 shows as an example the results of an economic assessment of costs and benefits of introduced and of adapted / traditional soil and water conservation structures for different slopes and different soil depths. The analysis was carried out on the basis of a long-term monitoring of soil and water conservation measures. The graphs in Figure 8.4 are based on 18 years of data collection. Soils are already rather shallow in the catchment area and soil erosion rates are high. The altitude (3000 to 3500 m) limits crop growing at least in the upper part of the catchment and soil formation rates are also limited by temperature. In the upper part of the 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 4th 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. 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 rainfall is not very variable in the study area, fertiliser application is not a big risk. 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.

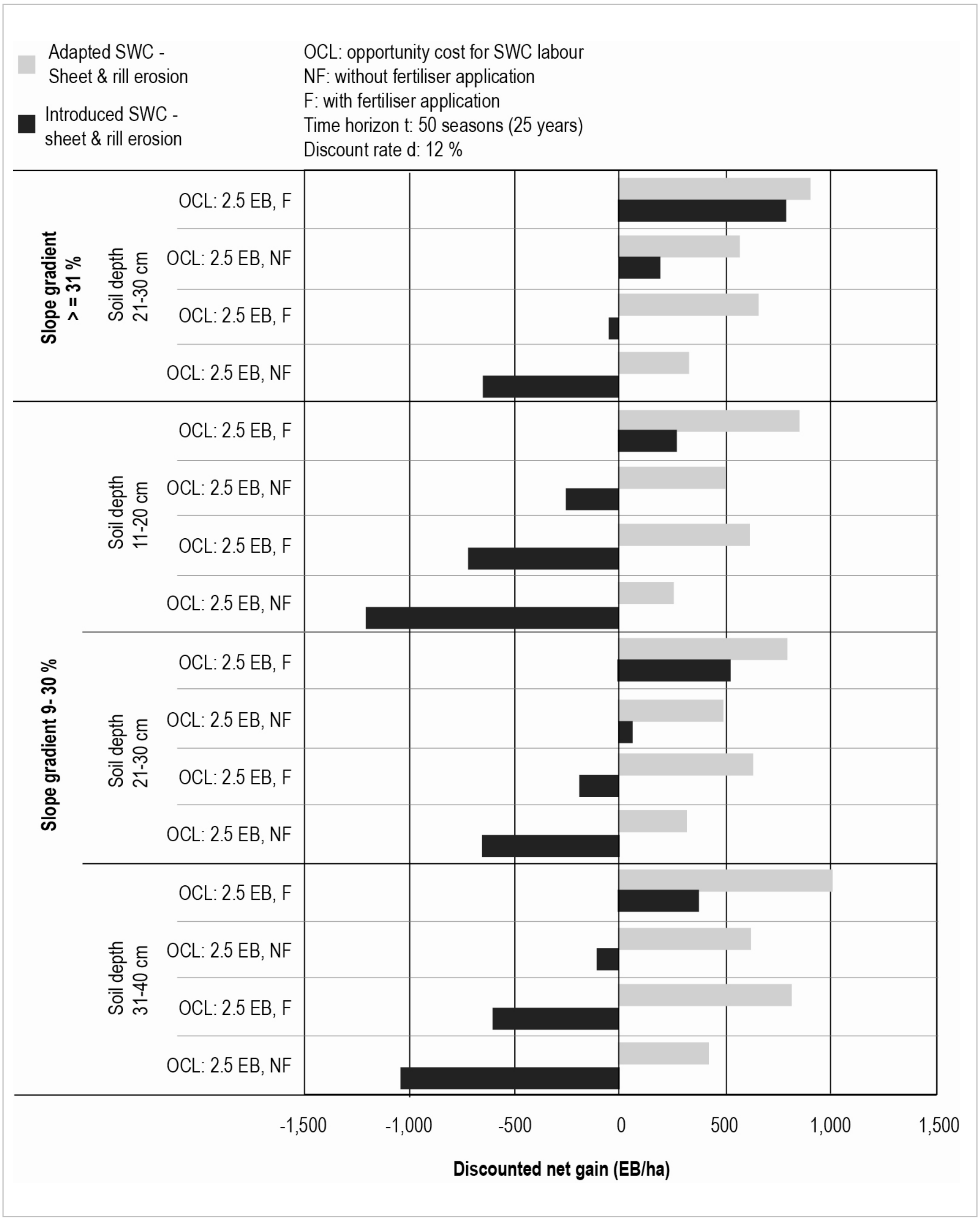

Figure 8.4 *Discounted net gain of introduced and adapted SWC structures compared to sheet and rill erosion in a highland study area (see text) (Ludi, 2002, 363[37])*

8.5 Questions and issues for debate

1. Comparing the two economic concepts, the neoclassical one on the one hand and the environmentally sound economic concept on the other, analyse and discuss, by taking a concrete local or regional example, the conflicts that these concepts may create between actors.

2. What are the external costs of land use systems that are dominated by monoculture, high-yielding crop varieties, chemical fertilizer, pesticide inputs and heavy agricultural machinery input? Try to compare these costs, and the cost structure, with land use systems presently found in Eritrea, for example highland small scale farming.

3. What are the most important points to be considered, when introducing and adapting SWC measures within an existing land use system (put the focus on the land user)? Can CBA in a real setting be helpful for the introduction of such measures?

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Chapter 9

Social Aspects of Sustainable Land Management

9.1 Introduction

Many developing countries, particularly in Africa, are showing declines in agricultural production per capita, with people migrating away from degraded dryland areas. With this in mind, the social aspects of SLIM attempt to address the overall problem of land degradation and provide ways in which land productivity and viability can be maintained or increased and managed for future years. This section is based on selected case studies and field research projects carried out in Eritrea. It encourages greater involvement of the local population in developing methods of managing their own natural resources. It aims to demonstrate that land management must develop around the priorities, needs and objectives of the people concerned and emphasizes the need to involve local people in solving the problems of resource degradation, so that future research and modern technologies can be developed with their participation. It acknowledges the value of indigenous knowledge in SLM, so that such knowledge systems can become the entry points from which to plan management strategies and new technological adaptations.

The current pressure on land resources necessitates the development of SLM systems. The process of developing such systems requires that methods are available to assess sustainability easily. Indicators of SLM need to include indicators of soil quality and land quality. In addition, they must take account of the environmental setting and include the human aspects of land management: social aspects (socially acceptable methods), economic dimensions (feasibility) and political aspects, alongside ecological sustainability.

Many studies have been done to assess the sustainability of different land management systems practised by farmers on sloping lands. In Indonesia, Thailand and Vietnam, for example, using the framework for evaluating sustainable land management (FESLM), detailed socio-economic and biophysical surveys were undertaken on 53 farms (Cornforth, 1999[1]). The survey aimed to characterise the land management systems and outline their constraints and potentials; it focused on identifying indicators and thresholds of sustainability in line with the five pillars of sustainability: productivity, security, protection, viability, and acceptability. The data were used to develop a suite of SLM indicators, with associated thresholds. These indicators have been included in a prototype decision support system. Feedback on the indicators was obtained from the farmers after the decision support system was used to evaluate their farming systems.

While the importance of the concept of the sustainability of land management practices is now widely accepted, there is still considerable debate on methods of identifying sustainability. Series of criteria exist that can be used to select indicators for assessing the sustainability of land management systems. Sustainable land management is defined using the five objectives of productivity, security, protection, viability and acceptability (Cornforth, 1999).

According to Cornforth (1999), indicators must be able to identify critical values beyond which a particular system of land management is no longer sustainable. Critical values may vary, depending on the characteristics of the system. Indicators will be independent of management, although management will influence the rate at which an indicator approaches its critical value. The criteria used to select biophysical indicators can also be used for selecting indicators of the economic, social and commercial aspects of sustainability.

9.2 Indigenous knowledge: the entry point to participatory development

Indigenous Knowledge (IK) or Local Knowledge (LK) is knowledge that is unique to a given culture or society. IK contrasts with the conventional (international) knowledge system generated by universities, research institutions and private firms. It is the basis for local-level decision making in agriculture, health care, food preparation, education, natural-resource management, and many other activities in rural communities (Warren 1991[2]). IK is the information base for a society and facilitates communication and decision-making processes at all levels. Indigenous information systems are dynamic, and are continually influenced by internal creativity and experimentation as well as by contact with external systems (Flavier, 1995[3], World Bank 2001[4]).

There is no single definition of IK This is in part owing to the differences in background and perspectives of the authors, ranging from social anthropology to agricultural sciences. However, indigenous technologies, practices, and knowledge systems have been studied extensively. Most of these studies concentrate primarily on the social or ethnological aspects of knowledge rather than on the technical ones.

The literature contains limited information regarding the systematic transfer of local knowledge across communities and cultures. The following highlights the special features of indigenous knowledge, which distinguishes it broadly from other knowledge. It refers to a set of experiences generated by people living in communities. Separating the technical from the non-technical and the rational from the non-rational can be problematic. Therefore, when transferred to other places, there is a potential risk that Indigenous Knowledge will be dislocated. It is tacit knowledge and, therefore, not easily modifiable and transmitted orally or through imitation and demonstration.

Experience and trial and error, tested in the rigorous laboratory of survival of local communities, constantly reinforce IK. Repetition helps in the retention and reinforcement of IK. Constantly changing, being produced as well as reproduced, and discovered as well as lost, IK is wrongly perceived by many external observers as being somewhat static (Ellen and Harris 1996[5])

9.3 Indigenous knowledge in Eritrea

9.3.1 Examples from the Bilen community

Stone-walled terracing: The Bilen are one of the many ethnic groups of Eritrea. They inhabit the Arid Anseba region of Eritrea, located about 100 km north of Asmara in the vicinity of the regional town of Keren. The mean annual rainfall in this area is in the range of 350-450 mm with great variability in space and time. The average landholding is less than one hectare and the average family size per household is 5 people (FEWS, 2005[6]). The main indigenous soil and water conservation practiced in the Bilen area is stone (back-slope) terraces. People use ox-driven ploughs and the space between the terraces varies depending on the slope. The steeper the slope, the narrower the width between the terraces. Back-slope terracing has been applied for many generations. In this mountainous region with considerable population pressure, terrace construction is a prerequisite for bringing more land into cultivation and also for conserving moisture for rainfed agriculture. The stone-walled terraces need periodic maintenance and this is possible thanks to the availability of family labour and private ownership of land. The stone-walled terraces are strengthened by using standing trees along the contour in the form of parkland agroforestry (*see Chapter 8*).

Mixed cropping involves growing different types of crops simultaneously. Pearl millet or sorghum is mixed with beans or ground nuts as a component of land use intensification with no apparent spatial arrangement. The seeding rate depends on the level of soil moisture, which is assessed by the farmers. If moisture is sufficient, less seeds are planted than under dryer conditions (Haile et al., 1998). Farmers cultivate their fields to thin their crops as well as to enhance the soil moisture retention and aeration of the soil. Parkland agro-forestry using various indigenous acacia species is practiced. These trees provide fodder, firewood and shade.

9.3.2 Examples from the Tigre and Tigrigna communities

Dam construction for trapping silt and storing water: The practice of trapping silt and harvesting water in narrow valley bottoms is widespread in the highlands of Eritrea. Similar practices have also been reported in the Irob area bordering Ethiopia (Mengistu, (2002)[7]. The following description is based on studies carried out on the rehabilitation of degraded lands from 1996-1998 (Haile et al. 1998) and on preliminary field observation of the authors in the Logo Anseba and Debresina areas in Zoba Anseba.

The landscape of Logo Anseba and Elabered is mountainous, dominated by rugged and stony terrain. The area has very steep slopes and deep narrow valleys carved out of the plateau by flash floods, which makes the land less suitable for cultivating crops. The altitude ranges from 1300 up to 2200 m above sea level. Owing to the wide altitudinal range, the area experiences abrupt climatic changes between dry and cold weather. Like the rest of the country, the area is hard hit by recurrent droughts. It is inhabited by the Tigrigna and Tigre ethnic groups. Traditionally, these are agro- pastoralists practicing mixed cropping with seasonal migration of livestock. In Logo Anseba, inhabitants move their livestock seasonally from the highlands to the western lowlands. On the other hand, farmers in the Debresina area move their animals to the eastern escarpment and the lowland areas, locally called Bahri.

In response to the ruggedness of the terrain and the need for reclaiming additional land for crop cultivation, the inhabitants have developed well elaborated site-appropriate methods of land management. Farmers break rocks and build terraces and check dams to trap the silt load and also capture moisture for crop production. Lands reclaimed in this way are excellent for making use of the small rains locally known as *akeaza*, during which farmers are able to plant long-duration high-yielding maize and sorghum varieties.

The aim of such physical structures, or *deledel*, is to capture soil and water and increase household farm size. They build a series of check dams in the seasonal watercourses and raise and lengthen the walls every year. Through this process of building, they have created step-like terraces that are about 8 m wide and up to 10 m high, with about 20 m between dams. This innovation is locally known as *daldal* and it requires year-round effort over many years or even decades to establish (Hagos and Asfeha, 1997).

In this terrain, the innovative *daldal* technique is a best practice because it is an indigenous land management practice that has been recognized by the local people. This type of land management system has also been recognized elsewhere as being one of the most effective soil and water conservation practices to mitigate the adverse effects of drought and also create land to produce food and obtain a supply of clean water (Asfaha and Waters-Bayer, 2001[8]). Waters-Bayer and Mengistu, (2002[9]) believe that the practice is sustainable in environmental terms, as it reduces soil erosion and makes use of soil and water that would otherwise flow into barren depressions and be wasted. In Eritrea, family members maintain their *daldal* independently, but when the *daldal* becomes bigger, then larger community groups *(Wofera)* take over the task of maintaining what has now become a common resource.

9.4 Role of women in SLM

Globally, women play a crucial role in the overall socio-economic life of their communities. Women play a vital role in sustainable land management: in food production, utilization and distribution. Women in Africa constitute the majority of the agricultural labour force (Quisumbing et al 2004[10]). Nonetheless, in many societies the contribution of women is overlooked and at times completely neglected.

Women have a key role in transfer and adaptation of traditional knowledge. Women know the importance of seed selection in field crops and vegetative propagation in home gardens. They possess vital knowledge and skill and know-how about plants and animal growth and development. In many countries, including Eritrea, due to traditional and cultural inhibitions, their contribution to food production and involvement in agriculture is not often recognised as a positive contribution to insuring food security.

In Eritrea, women participate in all activities related to food security at household and national levels (Ghebru and Ogbazghi 2007[11]). They are food producers, distributors and users of processed food products, either as partners with their husbands or as household heads. Estimates of female-headed households range from 30% (GoE, 2004)[12] to 47% (NSEO and ORC, 2003)[13], which suggests that the involvement of women in ensuring food security at household level and thereby also at national level is significant. Women thus comprise a large percentage of the subsistence farmers.

Moreover, a total of 18% of all rural households are headed by widows - the legacy of long years of the war for independence. Households headed by women are poorer than average, because the majority of the women in the rural areas are engaged in low-paying manual labour in construction and agriculture and also because, on average, female employees earn less than half of what males earn. Furthermore, female-headed households have fewer household assets, including livestock (GoE 2004[14]).

9.5 Ethnobiology, ethno-ecology and ethno-pedology

Ethnobiology is the scientific study of dynamic relationships between peoples, biota, and environments, from the distant past to the immediate present. "People-biota-environment" interactions around the world are documented and studied through time, across cultures, and across disciplines in a search of valid, reliable answers to defining questions (Berlin, 1992)[15] such as the ways in which human societies use nature. The main subdivisions of ethnobiology are ethnobotany, ethno-zoology and ethno-ecology.

At the beginning naturalists were interested in local biological knowledge (Sillitoe, 2006[16]). "At its earliest, this comprised a listing of the names and uses of plants and animals in traditional populations in the context of ethno-biology as descriptive biological knowledge of 'primitive' peoples (Ellen, 2006[17]). The 'second' phase was in Northern America, "The relation of Hanunóo culture to the plant world" (Conklin, 1954)[18]. In the mid 1970s in France, linguistic studies on botanical nomenclature by André-Georges Haudricourt legitimised the "folk biological classification" as a worthy cross-cultural research endeavour (Haudricourt, 1973[19]). This was followed by the works of Porteres and others on economic biology (Porteres, 1977[20]).

By the end of the 20th Century, ethno-biological practices, research, and findings had a significant impact and influence across a number of fields in biological and other disciplines. For instance, ethnobiology influenced ecology (Balée 1998[21]; Plotkin 1995[22]; Schultes & von Reis 1995[23]); conservation biology (Johannes, 1989[24], Cunningham, 2001[25]; Laird, 2002[26]); Tuxill & Nabhan 2001[27]); development studies (Warren, Slikkerveer & Brokensha 1995)[28]; and political ecology (Zerner, 2003[29]). This suggests that ethnobiology developed into a rapidly growing field of research, with tremendous significance for sustainable land management. The discipline is now taught within many tertiary institutions and educational programmes around the world (Ellen, 2006), with its own methods manuals. Examples of ethnobiology methods manuals can be found in: Alexiades, 1996[30], Martin[31], 1995, 2004)[32], and many other sources.

Ethnobiology attempts to record the words used in particular cultures for living things, from the most specific terms (analogous to species names, in Linnaean biology), to more general terms such as 'tree' and even more generally 'plant' system (Ellen, Roy (1993)[33]. In order to live effectively in a given place, people need to understand the details of their environment, and many traditional societies have complex and subtle understandings of the places in which they live. Hence, ethnobotany investigates the relationship between human societies and plants. It investigates how humans use plants – as food, technology, medicine, and in ritual contexts. It also studies and attempts to understand how local people view and understand plants, and their symbolic and spiritual role in their own culture.

Ethnobotanists and local people face a challenging task of not only recording knowledge about the plant world but also applying the results of their studies to biodiversity conservation and community development (Martin 1995, 2004). As the study of the classification, use and management of plants by people, ethnobotany draws on a range of disciplines including the natural and social sciences. It attempts to show how local knowledge about plants could be used for conservation and sustainable use of plant resources. Ethnobotany is also critical to the growing importance of developing new crops (domestication of wild plants) and the production of medicinal drugs from plants used traditionally.

Ethnozoology focuses on the relationship between animals and humans throughout human history. It studies human practices such as hunting, fishing and animal husbandry in space and time. It also investigates human perspectives on animals, such as the role of animals in the moral and spiritual realms. This lays the foundation for the conservation of wild animals outside the homestead.

At the ecosystem level, **ethnoecology** studies the way different groups of people in different locations understand ecosystems around them – the environments in which they live. It depicts the relationship of people to the various components of the ecosystems. It also seeks valid and reliable understanding about how humans interact with their environment and how these intricate relationships have been sustained over time. The “ethno” prefix in ethnoecology indicates a localized study of people, and in conjunction with ecology, signifies people’s understanding and experience of ecologies around them. Knowledge of an environment is thus situated in a specific spatial context. Depending on this context, it calls for different knowledge to be present or absent. Hence, ethnoecology not only studies what local knowledge is but also investigates how knowledge systems affect a particular action and lead to certain behaviour ("What is Ethnobiology" webpage accessed 12 April 2008[34]).

The information on **ethno-pedology** is derived from studies carried out in Latin America. According to Winkler, et al. (2004[35]), ethno-pedology is the study of local knowledge of soil and land management in an ecological perspective. Like other ethno sciences, various data sources and information are gathered and analysed while studying ethno-pedology. Ethnographical, ethnohistorical, archaeological, geographical, agronomic, ethnoecological, and development studies contribute substantially to understanding the practices related to local knowledge about soil management. Further in-depth investigation also calls for information inputs from the following:

- Ethno-historical and archaeological evidence of ethno-pedology;
- Local soil and land classification systems;

- Local land management systems;
- Local perceptions and beliefs about soil and land resources; and
- Local soil fertility management practices.

After analysis of past and present research trends in the above-listed areas, concrete recommendations should be given on how these ethno-pedological studies could help to enhance sustainable land use and management (Winkler, et al. 2004)[36].

9.6 Questions and issues for debate

1. How and in what ways do human societies use nature in general and land resources in particular"
2. How and in what ways do Eritrean societies view nature and how do they use their local knowledge for sustainable land management"
3. How can ethno-ecological and ethno-pedological knowledge be used for sustainable land management"

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Chapter 10

Institutional Aspects of Sustainable Land Management

10.1 The importance of social institutions in SLM

Contemporary sociologists use the term, *"social institution"* to refer to complex social forms that reproduce themselves such as governments, the family, human languages, universities, hospitals, business corporations, and legal systems. Social institutions can be defined as "a complex of positions, roles, norms and values lodged in particular types of social structures and organising relatively stable patterns of human activity with respect to fundamental problems in producing life-sustaining resources, in reproducing individuals, and in sustaining viable societal structures within a given environment" (Turner, 1997)[1]. Often, we speak of institutions, leaving away the term "social".

Institutions are the more enduring features of social life. According to Giddens (1984[2]) institutions include institutional orders, modes of discourse, political institutions, economic institutions and legal institutions. The contemporary philosopher of social science, Rom Harre, follows the theoretical sociologists in offering this definition: "An institution was defined as an interlocking double-structure of persons-as-role-holders or office-bearers and the like, and of social practices involving both expressive and practical aims and outcomes." (Harre (1979[3]) gives as examples schools, shops, post offices, and police forces etc. – institutions which are thus found in most of today's societies.

10.2 National institutions

In Eritrea, specific environmental issues are managed and monitored by various government institutions. These institutions are housed under different line ministries. At the national level, the Department of Environment (DoE) of the Ministry of Land Water and Environment (MoLWE) is responsible for all issues related to the environment. Presently, the DoE is focusing on soil erosion (land degradation), depletion of water resources, climate change, desertification, and loss of biodiversity. These challenges should be analysed in the context of marginalised livelihoods, and a knowledge management system should be created to efficiently synthesise and use information on the environment.

Globally speaking, climate change, soil erosion, deforestation, and depletion of water resources, ecosystem degradation and loss of biodiversity are very important issues. Sustainable development can only be achieved if proper measures are taken to protect the environment. Hence, proper land use planning is necessary to protect and conserve terrestrial, marine and agro-biodiversity ecosystems at species and ecosystem levels. While the DoE is the focal point for biodiversity and climate change, the MoA is the focal point for the UNCCD (UN Convention to Combat Desertification) on land degradation. The proper conservation and utilization of environmental resources cannot be achieved by the activities of a single government institution alone, as these issues touch on complex and vast problems and require multi-sectoral collaboration and cooperation. In fact, various ministries directly or indirectly address environmental management issues within their portfolios. For instance, the MoA addresses environmental management issues related to agricultural activities, and the Ministry of Fisheries (MoF) tackles matters related to fisheries and coastal area management.

The role of the DoE is to ensure that efforts are coordinated among various government and non-governmental organizations directly or indirectly involved with environmental issues. It is involved in developing environmental regulatory frameworks, gathering and analysing environmental data and making them available to end-users.

10.2.1 Environmental policy

The main principle of Eritrea's environmental policy is to harmonise sustainable economic growth and development in the country with proper environmental protection and management. Environmental policy includes the following key elements:

1. It aims to increase agricultural production without compromising land degradation and biodiversity loss;
2. As water (both marine and fresh) is a strategic resource, efforts are made to protect this vital resource from pollution;
3. Efforts are underway to preserve the coastal and marine environments;
4. Measures will be taken to ensure the co-operation of various institutions to prevent pollution and contamination of land arising from poor solid and liquid waste disposals;
5. Although air pollution is not currently a major problem, efforts will be made to monitor the build-up of anthropogenic greenhouse gas emissions.

The main objective of the environmental policy of Eritrea is thus to ensure proper protection and judicious use of the environment through effective harmonisation of policies, objectives, strategies and activities aimed at achieving sustainable socio-economic development in the country.

10.2.2 Strategies for implementation

In order to implement environmental policy, the following strategic approaches are pursued at the national level:

- Promotion of active participation by government institutions, civil society and the general public in the proper conservation and wise use of the environment;
- Introduction of environmental education in the national educational system;
- Cooperation with appropriate regional and international organizations;
- Introduction of appropriate environmental enforcement laws at national and sectoral levels to ensure the conservation and sustainable use of the environment.

10.2.3 Institutional and regulatory Instruments

In 1993, the government established an inter-ministerial committee whose main task was to prepare an environmental management plan for Eritrea. After intensive consultative processes among the Eritrean population, this plan (NEMP-E) was finally prepared in 1995 (NEMP-E, 1995)[4]. In collaboration with other relevant government agencies, the DoE is thus responsible for overseeing the implementation process for environmental policies. With respect to establishing regulatory instruments, the DoE envisages that there should be environmental management laws and regulations at two levels:

1. The level of specific laws and sector-specific issues such as forestry, wildlife, mining, energy, fishing, transport, etc.; and
2. The more general level of broad laws addressing cross-cutting environmental issues.

Box 10.1 Examples of regulatory measures taken in Eritrea:

- A proclamation to promote the development of mineral resources no. 68/1995[5], in association with the regulation of mining operations (legal notice 19/1995[6]), makes several provisions for environmental protection and sustainable use, including biodiversity conservation and sustainable use, and the protection of the environmental and archaeological sites which may be affected in the course of mining operations.
- The regulations on petroleum operations: legal notice no. 24/1995[7] makes provisions for environmental damage that may arise during the development of the petroleum industry in Eritrea. This legal notice pays special attention to the requirements for environmental impact studies in order to ensure environmental protection, pollution control and safety measures.
- In November 2006, the MoA issued new regulations (legal notice no. /2006[8]) dealing with forestry and wildlife, and quarantine regulations dealing with the import and export of living organisms and materials. These regulations are expected to halt all sorts of abuses of flora and fauna in general and abate the overall land degradation process in Eritrea.

10.2.4 Human and institutional capacity

Shortage of qualified manpower has been a limiting factor in the implementation process of various activities related to environmental management issues in Eritrea. Since institutional set-up and human technical capacity are closely linked, shortage of skilled personnel means that the current institutions responsible for the environment are not strong enough to introduce national environmental management plans and regulations to the required standards. Likewise, establishing, maintaining, administering, and updating a national environment database and environment management/administration services has been very difficult.

10.2.5 Relationship between government and donors

As the main role of the DoE is to provide co-ordination and guidance for proper environmental management, the creation of strong working relationships with government agencies, national, international non-government agencies, and the public in general, is critical to achieving the DoE's objectives. In order to harmonise the implementation process of environmental projects, national steering committees are established to promote discussion and consultation among concerned partners. The efficiency of such ad-hoc committees has, however, been questionable. For example, the lack of well-defined roles and responsibilities among the various government sectors in relation to the roles and responsibilities of the DoE for managing environmental issues is a source of misunderstanding; this may be overcome by the National Environment Law, which is in the drafting process. The establishment of institutional linkages among the various stakeholders enhances synergies for efficient and effective collaboration and cooperation between the DoE and the relevant government and non-government agencies.

As environmental issues know no boundaries, it is natural for the DoE to have relationships with the relevant regional or international organizations that deal with environmental issues. Following the GoE's accession to UNCBD and UNFCCC, the DoE is serving as the National Focal Point for these conventions. The MoA is the focal point for UNCCD. The Global Environment Facility (GEF) has supported two projects in Eritrea:

- A project to prepare and implement a National Biodiversity Strategy and Action Plan under the CBD;
- A climate change project, under the UNFCCC

To facilitate linkage, efforts have been made to participate in regional environmental collaborative efforts of the African Ministerial Council on the Environment (AMCEN), of which UNEP is the main organiser. On a regional level, the DoE has made contact with the Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden, with a view to exploring the possibility of future collaboration with this organisation.

10.3 Protected areas as an institutional arrangement

10.3.1 Protected areas and biodiversity conservation

According to the Convention on Biological Diversity, Protected areas are an important tool, or institutional arrangement for safeguarding biodiversity. Article 8 (a-c)) (CBD 2001[9]) defines the roles of each Contracting Party of the Convention. Each party shall, as far as possible and as appropriate:

- – Establish a system of protected areas or areas where special measures need to be taken to conserve biological diversity;
- – Develop, where necessary, guidelines for the selection, establishment and management of protected areas or areas where special measures need to be taken to conserve biological diversity;

- – Regulate or manage biological resources important for the conservation of biological diversity, whether within or outside protected areas, with a view to ensuring their conservation and sustainable use.

The establishment of the protected areas should be based on the ecosystem approach as defined by the CBD (2001).

10.3.2 The ecosystem approach

1. The ecosystem approach is a strategy for the integrated management of land, water and living resources. Thus, the application of this approach will help reach a balance of the three objectives of the Convention on Biological Diversity which are: conservation, sustainable use, and fair and equitable sharing of the benefits derived from the utilisation of genetic resources.
2. An ecosystem approach is based on the application of appropriate scientific methodologies focused on levels of biological organisation, which encompass the essential structure, processes, functions and interactions among organisms and their environment. It recognises that humans, with their cultural diversity, are an integral component of many ecosystems.
3. This focus on structure, processes, functions and interactions is consistent with the definition of 'ecosystem' provided in Article 2 of the Convention on Biological Diversity: '"*Ecosystem*" means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.' (CBD 2001). This definition does not specify any particular spatial unit or scale, in contrast to the Convention definition of 'habitat'. Thus, the term 'ecosystem' does not, necessarily, correspond to the terms 'biome' or 'ecological zone', but can refer to any functioning unit at any scale. Indeed, the scale of analysis and action should be determined by the problem being addressed. It could, for example, be a grain of soil, a pond, a forest, a biome or the entire biosphere.
4. The ecosystem approach requires adaptive management to deal with the complex and dynamic nature of ecosystems and the absence of complete knowledge or understanding of their functioning. Ecosystem processes are often non-linear, and the outcome of such processes often shows time lags. The result is discontinuity, leading to surprise and uncertainty. Management must be adaptive in order to be able to respond to such uncertainties and contain elements of 'learning-by-doing' or research feedback. Measures may need to be taken even when some cause-and-effect relationships are not yet fully established scientifically.
5. The ecosystem approach does not preclude other management and conservation approaches, such as biosphere reserves, protected areas, and single-species conservation programmes, as well as other approaches carried out under existing national policy and legislative frameworks, but could, rather, integrate all these approaches and other methodologies to deal with complex situations. There is no single way to implement the ecosystem approach, as it depends on local, provincial, national, regional or global conditions. Indeed, there are many ways in which ecosystem approaches may be used as the framework for delivering the objectives of the Convention in practice

As stated before, a major task in line with the Convention is the establishment of protected areas. These could be any habitat including the coastal, marine and terrestrial ecosystems. In this process, it is important to consider the World Conservation Union's (IUCN's 1986[10] and 1987[11]) categorisation of protected areas (*Table 10.1*).

Table 10.1 IUCN categorization of protected areas

Category of protected area	Objective of protected area	IUCN Protected area system classification
Strict Nature Reserve (SNR)	SNR protected areas are managed for strict protection of natural area and for scientific research.	Highest level of protection (Category I)
National Parks (NP)	NPs are protected areas that are managed for ecosystem conservation and tourism. In this case, communities living in the vicinity and forest reserves undertake community-based economic activates.	Second category of protected area (category II)
Biodiversity Conservation Area (BCA)	BCA provides conservation of biodiversity by ensuring that the human use of the natural resources, including water, timber wildlife including fish, pasture or marine products is carried out in a sustainable manner.	BCA could correspond to several levels of protection categories (V – VII) of the IUCN protected area classification, depending on the exact management area

Source: IUCN 1986 and 1987

It is also important to define the roles and responsibilities of the various government agencies and develop framework plans for managing and administering protected areas. The establishment of marine and coastal protected areas through Article 13 of Proclamation No. 104/1998[12] is a measure pointing in the right direction.

10.4 Solid waste management

It is essential to regulate pollution in all its forms: solid or liquid waste, air and noise pollution. Some of the major risks related to solid waste involve the use of landfill materials as a source of fertiliser (Ogbazghi et al. 2005)[13]. In many countries, significant proportions of the urban populations are involved in recycling their waste (Gonzenbach and Coad, 2007[14]) using various methods and approaches. These include:

1. Collecting discarded items directly from houses and businesses that can be sold for reuse or processing;
2. Sorting mixed wastes and taking out materials and items that can be sold;
3. Washing and sorting these salvaged recyclables; and
4. Processing them into raw materials that can be used by others, e.g. for manufacturing new products etc.

10.4.1 Solid waste management in Maekel Region, Eritrea

Field research on the benefits and risks of organic matter gained from landfills and used for agricultural purposes was carried out in the Maekel region of Eritrea (Ogbazghi 2005). The study had two focal points: the nutrient content and the heavy metal contamination of the organic matter gained from landfills were assessed according to the age of the material. Additionally, options for mitigating existing risks were assessed and the potential market for compost or organic matter, as well as the farmer's perceptions of the material and the willingness to pay for improved quality material, were assessed (*Table 10.2*).

Figure 10.1 Female street cleaner collecting compostable waste in Asmara (Photo by Silke Rothenberger)

Table 10.2 Summary of the objectives, results and recommendations of the landfill studies carried out in Maekel Region, Eritrea

General aim of the study	Provision of information about the benefits and risks of the use of organic matter gained from decomposed solid wastes from landfills and provision of measures for mitigating risk
Specific objectives	• Understand the relation between contents and age of the landfill site and their influence on the quality of organic matter; • Gain knowledge about the market demand for organic matter or compost from landfills, considering the perceptions and concerns of the farmers using the organic matter as fertilisers; • Get information about costs and benefits of current activities that support further decision-making regarding the use of organic matter from landfills; and • Suggest recommendations for improvement of the quality of the landfill material, if necessary.
Results	1. Approximately 60% of landfill material is classified as impure, comprising metal scrap, stones, plastic, bones and glass pieces. 2. At the landfill site the landfill material shows significantly higher Nitrogen, Phosphorus and Potassium level (NPK) values and contains a higher amount of organic matter than soils from agricultural land. Hence, landfill material contributes to fertilising the soils and improving soil structure. 3. Landfill material compared to compost produced from organic waste contains less plant nutrients, organic matter and moisture. Hence compost derived from fresh organic waste, which was not incorporated into the landfill site, seems to be a promising alternative for landfill material. 4. Landfill material contains high concentration of heavy metals, particularly Cu, Pb, Cr, and Zn, which exceed the permissible limits set by international standards. Especially Pb and Cr have no positive effect on plant growth and the high Cu concentration may also inhibit plant growth. The landfill contains several “hot spots” with very high pollution. 5. Preliminary studies show that soils on which landfill materials were applied have better physical and chemical fertility than soils with no landfill material. The landfill material has enriched the soils with plant nutrients such as N, P, K, and $Ca2+$ and organic matter. Due to the current low rate of application, the heavy metal concentration on the farms was still found to be low. 6. Poor soils could benefit from the input of organic matter and plant nutrients, which may eventually lead to increased agricultural production. However, this will only be achieved and become sustainable when the application of landfill materials to agricultural land improves the soil conditions for crop growth while ensuring the protection of environmental quality and the health of living organisms in the ecosystem.

Results	7. Regardless of the type of crop grown and the distance from the landfill site, farmers perceive that landfill material increases their crop output provided there is ample moisture in the soil or water available for irrigation. 8. Landfill material is applied both by small and large-scale farmers to rainfed and irrigated agriculture. There are two seasonal peaks in demand for the landfill material, namely in March and June. While the first refers to the use of landfill for irrigated horticultural crops, the later corresponds to the use of landfill material for rainfed cereal production. 9. Farmers still prefer manure to landfill material but they are obliged to use landfill material, as the other sources of organic matter are scarce, unavailable or expensive. Landfill material is applied either to supplement or replace other types of organic fertilisers.
Recommendations	1. The organic matter and nutrient content of the landfill material can contribute to soil fertility and higher crop yields. 2. Other options such as composting should be considered and tested. Farmers should have the chance to compare the quality of landfill material with that of compost from organic waste. 3. Monitoring and evaluation of incoming organic waste in comparison to the landfill material should be part of the whole landfill material management intervention. With regard to organic matter and nutrient content, the landfill material can contribute to soil fertility and increased crop yields. However, compost retrieved from fresh organic waste would be even more beneficial to the soils, given higher nutrient values and lower heavy metal loads. 4. Improving the existing landfill material would involve sorting and sieving out visible pollutants before use in agriculture. The visible pollutants pose a threat to people, animals and the environment and cause avoidable costs to farms.

Source: Ogbazghi et al. 2005

10.5 Public participation and awareness

Besides introducing rules and regulations, increased environmental awareness among the wider public is critical for SLM in particular and the environment at large. Environmental training programs have been going on since 1997 at sub-zoba level, targeting people working with public institutions. Future training programs should aim at subsistence farmers while at the same time organising trainers of training programs.

Collaboration and linkages with civil societies should be established with NGOs such as the National Union of Eritrean Women (NUEW), the National Union of Eritrean Youth (NUEY), the National Confederation of Eritrean Workers (NCEW), and the Eritrean Business Community. The role and responsibilities of these grassroots organisations should be identified and defined.

Use of the mass media for dissemination of environmental information should be designed and well targeted. Seminars and workshops should be frequently organised to identify priority environmental issues. Such seminars should be organised at the regional and district levels to have direct impacts on the local communities.

10.5.1 Impact of religious community institutions on SLM

Nowadays most of the relic vegetation, especially trees, is confined to inaccessible terrain in narrow grooves, steep slopes, monasteries and holy spots, locally known as *maichelot*, referring to holy baths. This indicates that religious institutions play a significant role in preserving plants and animal species in their vicinity. Invariably, all religious institutions advocate the preservation of plants in particular and sustainable use of land resources.

Can these community institutions be strengthened to enhance SLM? Preserving trees means protecting wild animals, and preserving the local vegetation automatically implies conservation of the soil and water and hence reduction in runoff and erosion. This should be taken as part of the indigenous knowledge management system. The role of social institutions should be well documented to derive the most important lessons and relevant information for SLM. As community members have deep-rooted beliefs in such spots and listen to the preaching of religious leaders, SLM strategy should incorporate the role of religious leaders in SLM.

10.6 How to address SLM in general terms

Despite the absence of a specific legal notice to address sustainable land management in general terms, some aspects of SLM are addressed and included in the different sectors of the economy. The legal framework should encompass generic and specific legal instruments that address the various aspects of SLM. The MoA and MoLWE as well as the MoF have issued various legal notices referring to land, forestry and wildlife, climate change, and biodiversity.

Table 10.3 Eritrea's Land Reform Proclamation as a tool to promote SLM

Legal notice no.	Main elements of the legal notices
58/1994	Promulgation of the Land Reform Proclamation is one step forward in the fight against land degradation and towards the introduction of wise land husbandry in Eritrea. This Proclamation is intended to change existing land tenure systems and introduce a new and uniform system throughout the country. The Land Reform Proclamation guarantees all Eritreans above 18 years of age the right to land based on the usufruct principle. The government owns all land in Eritrea, and will allocate land fairly and equitably without discrimination on the basis of race, religion, gender, or national origin. The new system of land allocation and tenure is expected to confirm and reinforce the security of tenure and thus improve incentives for better husbandry of land resources. However, the land reform proclamation gives only a general framework, and detailed work is needed in drawing up the necessary policies, rules, regulations, and guidelines for implementation.

Source: Eritrean Land Proclamation 1994. www.http://faolex.fao.org

Table 10.3 suggests that a comprehensive land-use policy is needed to balance the competing demands for land amongst different sectors of economy - food production, export crops, tourism, wildlife conservation, housing, public amenities, and other infrastructure. Article 46 (sub-articles 1 and 2) of the Land Reform Proclamation (No. 58/1994) states, that the Government shall have supreme authority in formulating the country's land-use policy. Responsibility lies mainly with the MoLWE Department of Land. The establishment of functional land administration bodies at lower levels (regional, local) is another ongoing task. Further, the role of the land users at the community level and individual holdings will have to be specified.

10.7 Questions and issues for debate

1. Describe and discuss the current institutional set up dealing with sustainable land management in Eritrea. Do you think this set up and its arrangements are sufficient to guarantee the conservation and sustainable use of natural resources?
2. If you think that the current institutional set up is inadequate or ineffective to deal with current environmental conditions, organise small groups and brainstorm proposals for feasible and efficient institutional arrangement that can be adapted at the local level!
3. What are the advantages of having national parks, nature reserves, and biodiversity conservation areas? Which of these protected areas do you think are feasible in the Eritrean context and why?

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Chapter 11

Assessment and Adaptation of SLM

11.1 Criteria for assessing the sustainability of SLM

Several proposals have been made in literature to design more or less simple and practical ways to assess and come close to "sustainability" and sustainable land management. Any land use system is unsustainable if it leads to irreversible biophysical changes in the ability of the land to produce equally well in a future cycle of similar land use, or if the costs of reversing the negative changes are prohibitive. As already discussed, the most common categorisation is describing sustainability as a function of three dimensions: ecological, economic and social, with the social dimension including policy, institutional and cultural aspects. Thus, unsustainability may either be found in the biophysical, social, or economic dimension, or in a combination of these dimensions.

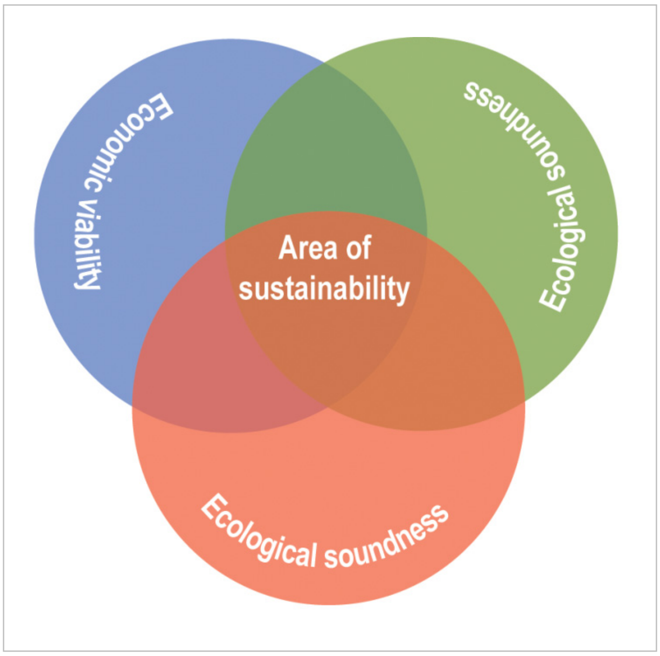

Figure 11.1 The three dimensions of sustainability

The terms used in the above figure have been practically and theoretically defined differently, depending on the research institution, the project context and the goals focused on. Therefore an open list of relevant questions is given below which could be used to check whether a project or a specific form of land management is sustainable. This list may be more useful than a theoretical definition. It should be taken as an inspiration to which other questions can be added!

Economic viability

- Does the project lead to higher income in terms of finances and/or goods?
- Can a farmer / community / region afford a certain measure?
- Is maintenance of implemented (infra)structure affordable for the project beneficiaries (both in terms of costs and work)?
- Is the project contributing to the minimisation of storage losses?
- Does the project contribute to poverty eradication as formulated in the Millennium Development Goals (MDG)?
- Is reliable market information and access to markets available?
- What is the time span of return on investments? Is this time span feasible for the project beneficiaries?
- Are cost and benefit balanced?
- Can the additional workload be integrated in the work schedule of the concerned persons?
- Does the project develop new economic opportunities for the local population?
- Does the project offer alternative (non-agricultural) income generation possibilities?
- Is a component for the formation of working capacity (by savings) foreseen?
- Does the project promote local economic development?
- If technical novelties are introduced, is there an appropriate service and extension system to support the local population (e.g. with knowledge, with spare parts)?
- Are subsidies helpful to lower the high demands on natural resources?

Social / cultural / political acceptance

- Do the persons responsible for the project interact with the project beneficiaries?
- Is the project addressing the “right” people (e.g. in the sense of gender, local honoraries, disadvantaged people)?
- Does the project account for local customs?
- Is institutional and public participation guaranteed?
- Are existing decision-making processes taken into consideration?
- Are minorities (e.g. disabled persons, female headed households) included in participatory decision-making processes?
- Is the area under planning free from cultural or social bans (traditional meeting places, holy places, graveyards)?
- Do local institutional settings allow for planned interventions?
- Do the focused project goals meet the national, regional and local policy goals?

- Can project innovations be integrated into the actual socio-political system?
- Does the project strengthen local capacities (e.g. for conflict management, infrastructure management, maintenance activities, surveys)
- Is project ownership clear; are the responsibilities of the parties clear?
- Does the law of inheritance allow long-term planning?
- Is access of all concerned people to natural resources guaranteed?
- Is the land tenure system not in conflict with the proposed project activities?
- Is local / regional knowledge and tradition included into project development?
- Are the project planners aware that hungry people have very few options and do not care first about sustainability but rather about tomorrow's needs?

Ecological soundness

- Will the SWC measures planned reduce soil erosion and run-off to tolerable levels, given local rates of soil formation?
- Is it necessary to introduce new SWC measures? What is the effect of traditional SWC measures that might already be in place in reducing soil loss to tolerable levels?
- Which measures are appropriate for which soils in a catchment area, so as to reduce soil loss to tolerable levels, without causing water logging?
- Which measures are appropriate for which slope gradient to reduce soil loss to tolerable levels?
- To what extent do vegetative measures reduce soil erosion, and what is the minimal amount of rainfall that is needed to propagate such measures?

A Logical Framework (or logframe) as a planning tool can help to define the relevant issues to be addressed, the activities for tackling them, and the results expected from these activities. The logframe is a tool that has the power to communicate the essential elements of a complex project clearly and succinctly throughout the project cycle. It is used to develop the overall design of a project, to improve project implementation and monitoring and to strengthen periodic project evaluation. In essence, the Logframe is a "cause & effect" model of project interventions to create desired impacts for the beneficiaries. For example, the logframe as a tool has been in use since 1997 by the World Bank and is one of the Bank's core project documents. Developing a logframe is a collaborative process among all stakeholders and it supports participation as well as conflict resolution discussions. The World Bank offers an excellent step-by-step handbook on the development and the use of a logframe:

http://gametlibrary.worldbank.org/FILES/440_Logical%20Framework%20Handbook%20-%20World%20Bank.pdf[1]

11.2 The issue of personal perception

The selection of appropriate and sustainable land management approaches depends not only on rational factors but also on personal perceptions: often traditional SWC measures are accepted by farmers while experts are convinced that introduced ("modern") measures are more effective. At the same time, introduced measures often demand a high input of knowledge, money and labour and are frequently not feasible for farmers. The success of project development and implementation therefore always depends on all three dimensions of sustainability.

For many years, soil and water conservation has been considered a more or less technical issue, based on years of dominantly biophysical, problem-oriented research on factors such as climate, soils, topography, vegetation, etc. Consequently, many SWC guidelines were published with a predominantly technical character (for example: Hudson 1995[2]; Woldu 1995[3]; Schwab et al. 1993[4]; Landon, 1991[5]; Singh 1991[6]; FAO, 1989[7]; Wenner 1989[8]; Hurni, 1986[9]; Wenner and Kebede[10], 1984; Wijntje, 1983[11]; FAO, 1976[12]; USDA, 1975)[13]. Much less information is available about solution-oriented research that addresses, among other things, the compatibility of technical solutions with prevailing socio-cultural and economic settings of a specific area, and about the process of adapting SWC to such settings (Liniger and Schwilch, 2002)[14].

In the 1980s and 1990s, SWC in Eritrea focused on preventing further decline of the remaining soil resources and on rehabilitating already degraded soils. It was unfortunate that the issue of resource management was split into different tasks addressed by different departments without appropriate coordination. In the course of the political changes in 1991, Eritrean farmers began on a large scale to remove and modify SWC schemes that were previously established by the Ethiopian administration under food for work programs. These reactions were an eye-opener for many SWC experts who were forced to realise that SWC could only be made effective if economic viability and social acceptability are given the same attention as ecological soundness and technical feasibility.

Particularly under subsistence farming, successful SWC interventions faced a common challenge: if the measures were viable for the farmer, they often insufficiently controlled erosion; if they controlled erosion effectively, they were often too costly and no longer viable, let alone acceptable, to the farmer. It seems difficult if not impossible to develop standard solutions that fulfil all the requirements simultaneously (soundness, feasibility, viability, acceptability). In this context, it should not be forgotten that "assessment" means personal judgment, that farmers and experts have different aims and perceptions, and that they do not always agree on the same assessment criteria! Instead, SWC seems always to be a compromise under the given local conditions.

The following examples are intended to shed light on how SWC measures can be assessed. They also contain lessons to be learned about the consequences of assessments. Although planned with good intentions, innovative SWC will always produce negative side effects as well. Improving a technology therefore means admitting mistakes and drawing the right conclusions. Ignoring side effects means that land users will bear the consequences later on (Fikru et al., 2005)[15].

11.3 SWC measures and farmers' perceptions

11.3.1 Why the best is not accepted: SWC and land scarcity

This example considers soil loss and runoff, two ecological criteria, for assessing different SWC technologies in the semi-arid environment of the Afdeyu research site in the central highlands of Eritrea. A double mass curve was chosen as a graphic representation, with cumulative soil loss on the Y-axis and cumulative runoff on the X-axis *(Figure 11.2)*. Each dot represents the increase in soil loss/runoff for one rainstorm period. Each graph contains the data for all four experimental plots for one year. The scales differ for each year (Stillhardt et al., 2002)[16] because, if uniform scales are taken, the total amount of runoff and soil loss in relatively dry years is too small to produce a visible picture. This is important to keep in mind when using the graphs to compare different years!

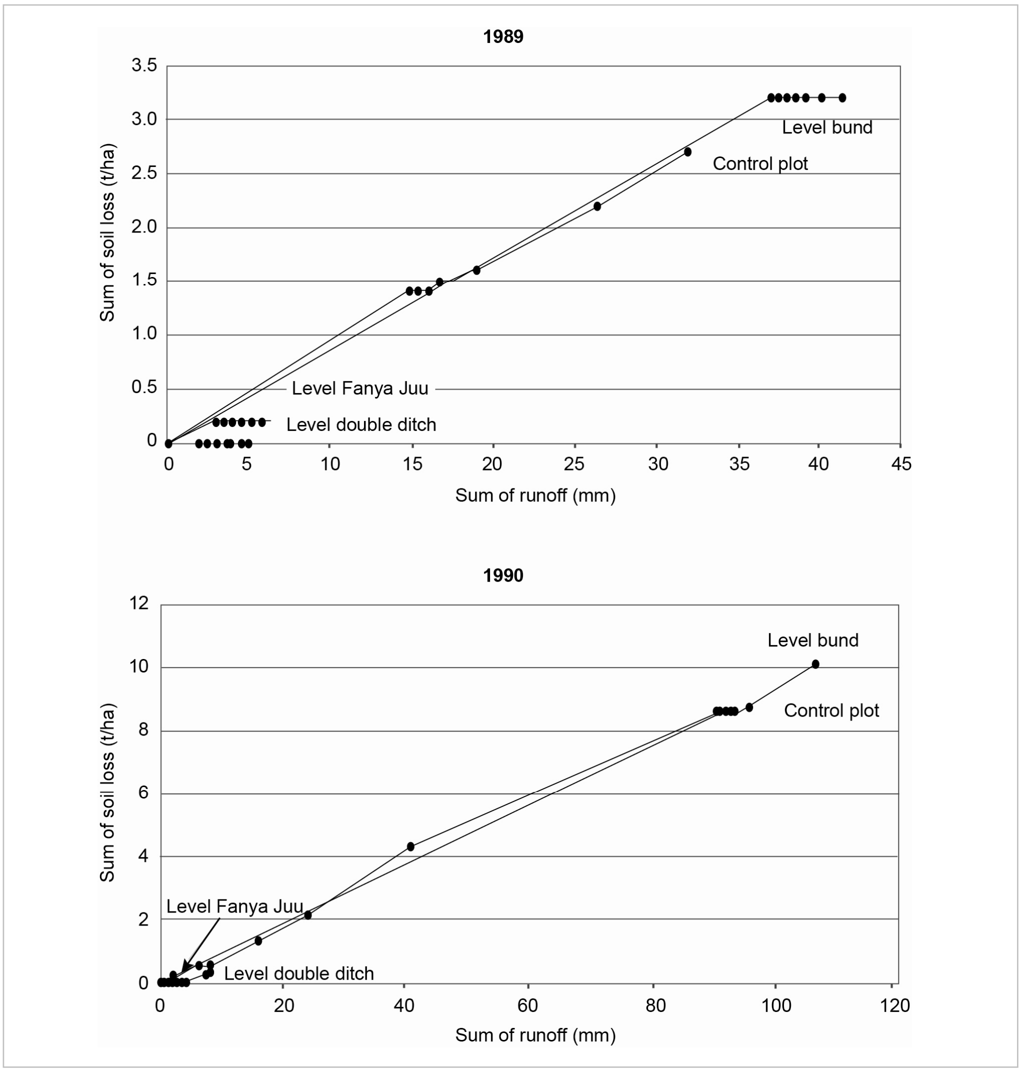

Figure 11.2 Soil loss / runoff for different SWC plots and years in Afdeyu. Generally, the control plot (traditional management without specific SWC measures) always shows the highest runoff and soil loss values, with the exception of 1989 and 1990, which were very dry years.

Table 11.1 Ranking of different SWC measures. Ranking of each plot compared to the other plots from 1 (highest soil loss or runoff = weakest erosion control) to 4 (lowest soil loss or runoff = strongest erosion control)

	Control plot		Level bund		Level Fanya Juu		Level double ditch	
Year	Soil loss	Runoff	Soil loss	Runoff	Soil loss	Runoff	Soil loss	Runoff
1989	2	2	1	1	3	3	4	4
1990	2	2	1	1	4	4	3	3
1994	1	1	4	2	4	3	4	4
1995	1	1	2	2	4	4	3	3
1996	1	1	2	2	4	4	3	3
1997	1	1	2	2	3	4	4	4
1998	1	1	2	2	3	3	4	4
Total	9	9	14	12	25	25	25	25
Rank	1	1	2	2	4	4	4	4

Source: Database Afdeyu

In Table 11.1, soil loss and runoff are ranked plot-wise for each year. The lowest soil loss and runoff indicates the strongest erosion control and corresponds to the highest rank (4). The results show that in the environment of Afdeyu, all SWC measures are able to reduce runoff and soil loss considerably. “Level *Fanya Juu*” and “level double ditch” show very similar effects and are more effective than “level bund”. Considering only these two ecological criteria, *Fanya Juu* and double ditch would be recommended.

However, farmers’ choices might look completely different. According to Awet and Bereket (1999)[17], about 98% of the cultivated land in Afdeyu is conserved with structural SWC, and each structure occupies a certain area that temporarily does not produce crops. About 75% of the farmers stated that “level bund” would be their favourite SWC measure. The main reason for their preference is that the loss of productive area (14%) of level bunds (Semere, 1998)[18] is smaller than that caused by *Fanya Juu* (17%) or double ditches (24%). Additional costs and lack of experience with *Fanya Juu* and double ditch are other reasons why farmers prefer bunds.

- Qualitative observations and statements of farmers in general show that farmers often complain about implanted (top-down) SWC measures (Ludi, 1997[19]; Belay 1992)[20]. Generally, their main arguments are that:
- SWC structures occupy scarce and hence precious cropping area;
- The area occupied by SWC structures is not ploughed, which means that weeds and rodent habitats are no longer destroyed and cultivated fields are infested;
- Despite a drainage gradient of 2% or higher, water-logging is frequently observed above SWC structures, which reduces yields;
- Maintenance work requires unacceptably high labour input;
- Farmers have problems carrying out their traditional farming operations. Narrow terrace spacing makes it difficult or impossible to plough the slope in diagonal lines

and turn the ox-drawn plough. This is true especially in steeper terrain (narrow terracing).

11.3.2 On- and off-site effects of tied ridges

In 1997, stone bunds with tied ridges were introduced at Afdeyu. Tied ridges are long, semi-permanent ditches on the upper side of contour bunds, divided by small ridges into a series of about 10 m-long micro basins. They are always constructed in combination with earth bunds or stone bunds. The main purpose of the structure is water harvesting, but at the same time washed out topsoil is trapped in the micro-basins and can be redistributed on farmers' fields.

Figure 11.3 Tied ridges (Photo by Mats Gurtner)

Tied ridging was implemented through campaigns. After implementation of the tied ridges, the runoff coefficient at the catchment decreased from 12% to about 6%, indicating that 50% of the former discharge was additionally stored within the catchment, i.e. within the soil. Also the sediment yield was lowered considerably. At the same time, a small irrigation dam was planned downstream. The impacts of the tied ridges on the dam appeared to be conflicting. On the one hand, on-site tied ridges reduce soil loss, which prevents the dam from being silted up too quickly. On the other hand, on-site SWC also reduces river discharge by about 50%, thus lowering the expected run-off and hence water supply to the dam *(Table 11.2)*.

Table 11.2 Hydrological data for reservoir planning in Afdeyu

Year	Cumulative Discharge River Gauge (m3)	Expected Storage Planned Dam (m3)	Modelled Level of Lake Surface (m)	Cumulative Precipitation (mm)	Runoff Coefficient (%) River Gauge
1986	81668	110494	16.4	488	9.4
1987	79672	110952	16.5	397	11.3
1988	138750	206609	19.4	606	12.9
1996	122794	178053	18.8	552	12.6
1999	69748	98369	15.9	598	6.6
2000	49953	69352	14.5	527	5.4

Source: Burtscher 2002[21]

Depending on the interests of stakeholders, tied ridges may be assessed differently. Farmers in the upper part of the catchment might make a positive assessment because the (on-site) effect of tied ridges increases the amount of available water and production on their cropland. Farmers who irrigate land below the dam would probably make a negative assessment because the (off-site) effect of SWC reduces the amount of irrigation water available from the dam. The dam was never built and a study revealed that even though the water-conserving potential of tied ridges was proven, farmers did not accept them because of the high loss of productive area.

A Study in 2005 (Mats Gurtner et al, 2006[22]) revealed that four years after implementation, the tied ridges had almost completely disappeared from the fields with only very few remnants left mainly on uncultivated land or areas of poor fertility that had not been ploughed during the past years. Farmers had in fact actively got rid of the ridges. Their main reasons for doing this were:

- Topsoil was accumulating in the basins and was therefore lost for production
- Maintenance could not be included in the normal agricultural activity schedule
- Maintenance of tied ridges was considered too labour-intensive
- Loss of productive area was considered too high
- In some places (soils with a high content of fine fractions) water logging occurred.
- After harvest animals grazed on the cropland and destroyed the structures

Gurtner et al, in their 2006[23] study at Afdeyu, also assessed traditional / indigenous SWC structures and introduced (modern) conservation measures in terms of their bio-physical effects and their acceptance by farmers. They found that large areas of the catchment area were conserved mainly by stone and earth bunds and terraces, including different mixed (traditional and modern) forms. Asked for limiting factors regarding SWC activities, farmers listed their reasons in order of importance, which are summarised in Table 11.3. In the column “Farmers’ perceptions” the outcome of many hours of group- and single interviews with farmers in Afdeyu are shown. At the same time the study team, with seven experts, made the same ranking, which is shown in the column “external perception”.

Some aspects show clearly the difference in perception between the land users and the expert team.

Table 11.3 Limitations to the implementation of SWC measures as perceived by farmers at Afdeyu, Eritrea (local view), and researchers (external view).

Aspect	Farmers' perception	External perception	Measures/activities affected
Importance of off-farm income	XXX	XXX	Agricultural activities in general, including SWC measures
Lack of incentives	XXX	XX	Structural measures (e.g. terraces, stone and earth bunds, tied ridges, check dams)
Lack of manpower	XXX	XXX	Structural measures (e.g. traditional stone terraces, check dams, stone and earth bunds); application of compost / manure (if requiring transport)
Attitude	XXX	XX	All SWC measures; particularly introduced measures
Insecure land use rights	XXX	XX	Measures with medium- or long-term benefits (e.g. new contour bunds, tree planting) and/or measures requiring high initial inputs (labour, other; e.g. stone terraces, gully reclamation); generally measures applied on communal land (e.g. afforestation area)
Loss of productive area (land shortage)	X(X)	XX(X)	Tied ridges; enclosure for afforestation (permanent loss of arable land); fallowing (temporary enclosure); fanya juu / double ditch; traditional stone terrace (high risers)
Lack of collaboration	X(X)	XX	Structural measures that require high labour input (terraces)
Lack of knowledge / awareness	XX	XX	Grass strips, tied ridges; introduced measures in general
High costs / low availability of inputs	X(X)	XX	Application of fertiliser / compost (shortage of manure); local ploughing system (lack of ploughing tools, need to rent oxen); seedlings and seeds for grass strips and tree plantation (partly available free of charge from MoA plant nurseries); levelling instruments for measures laid out along the contour (e.g. stone / earth bunds; tools are provided during campaigns)
Low effectiveness of SWC measures	X(X)	X	Soil bunds (low durability, not resistant to high runoff); tree planting on cropland; tied ridges; stone mulching; grass strips (on bunds); micro-basins (for tree plantation); live barriers / fences (sisal); stone bunds not combined with soil (low potential to conserve water); vegetative measures (low durability, affected by drought and over-grazing)
Ecological disadvantages	X	X	Tied ridges / soil bunds in flat areas (waterlogging), trees / shrubs on cropland (competition with crops for water / nutrients / light; habitat for birds that eat seeds and rodents that induce pipe erosion); stone mulching (limits

			growth of certain crops such as onions, potatoes)
Lack of legislation	X	XX	Structural measures in general (with regard to maintenance)
Grazing practices	X	XX(X)	Grass strips; structural measures on cropland (stone and earth bunds); manure application
Cultural aspects	X	XX(X)	Mainly introduced measures (not integrated in farming system); measures requiring a high labour input (restricted working time due to religious holidays); water drainage (conflicts); vegetative measures ("trees are bad")
Low productivity of a site / expected yields	X	XXX	Structural measures (such as contour bunds, terraces) that require annual maintenance; site-specific application of manure and fertiliser
Poor accessibility of a site	–	XX	SWC activities in general; steep, marginal land situated far from the village is often in a poor condition (whereas the steep slopes close to the settlements are nicely conserved). This problem is linked to productivity.
Lack of land users' involvement	–	XXX	Generally new (introduced) measures

XXX = high impact on acceptance of SWC measures

XX = moderate impact on acceptance of SWC measures

X = low (but still significant) impact on acceptance of SWC measures

Source: Gurtner et al, 2006

In short, SWC in Eritrea as promoted by the authorities has been based on three assumptions: (1) without SWC, erosion would decrease production in the long run; (2) with SWC, production would stabilise or increase; (3) the expected stabilisation or increase in production would be an incentive in itself for farmers to maintain SWC structures. However, a different development was observed following political changes in 1991, when government control over the rural population diminished (Herweg, 1992a and b)[24]. As long as there was an incentive (e.g. food for work), this additional source of income helped secure the livelihood of the local communities (Kebede, 1992)[25]. Consequently, many farmers tolerated imposed SWC structures on their land. Moreover, in many semi-arid areas, maintenance of SWC structures implied short-term benefits for farmers because moisture conservation directly enhanced crop production. In some areas of the highlands, a partial modification of SWC structures and integration into the complex indigenous land management system was observed, while in other parts a considerable number of SWC structures were removed in the early 1990s.

Some of the factors influencing the social acceptability of introduced SWC measures are, for example, legislation, national, regional and local policy, land ownership, availability and quality of extension services, financial support, access to markets and information, conformity with traditional land management systems, availability of labour force, planning horizon, traditional norms and values, religious or social taboos, local power structures, leadership, local interrelations and group work, availability of alternatives, technical skills, health status, etc. Some of these factors might influence all farmers in a certain area in a similar way, but normally different households have several and perhaps competing interests, according to their assets or preferences. Such complex situations are not easy to understand and difficult to manage. Prediction of what might happen to introduced SWC structures is almost impossible but can be monitored during or after implementation.

SWC structures can thus have entirely different effects depending on local conditions and feelings (Herweg 1995)[26]. An SWC measure that most efficiently controls erosion in one place may not be worth the effort of implementation elsewhere if local farmers cannot accept it. The social dimension of sustainability can only be assessed through interviews and discussions with local stakeholders. From outside, social acceptability often seems to lack rationality. But the problem is rather that the logic of an external scientist or engineer might differ remarkably from the logic of a local farmer, as do their livelihoods. Especially when uniform top-down approaches are used for implementation of SWC, local knowledge is not sufficiently included in the planning process and there is not much effort to explain introduced measures.

11.3.3 Preliminary conclusion on good practices

Taking the above described results on effects and perceptions of SWC measures into consideration, a blueprint recommendation of one "best" SWC technology is clearly inappropriate. Instead, the pros and cons of each measure have to be carefully weighed against each other, and the final decision about which of the advantages and disadvantages of each measure are acceptable should be left to the land user, who has to bear the consequences of what is implemented on his or her land.

In general, the reduction of soil loss was considerable under most SWC measures, although absolute erosion rates were still high in some cases. Runoff control, by contrast, requires greater emphasis during the design of SWC structures:

- In semi-arid areas, level SWC structures performed well in conserving moisture. However, in Lesotho, Wenner (1989)[27] found that many large rills and gullies developed because of level terracing. He therefore refrains from advocating level earth terraces in general. Instead, such terraces could be improved as described for sub-humid areas.
- Sub-humid areas with insecure rainfall are principally subject to both extremes: excess and shortage of water can follow each other closely. In this case, SWC aims to achieve a compromise. Since there is always a probability of excess rainfall, SWC structures need a gradient and waterways, or they must be breakable during high rainfall events. To ensure water retention during dry spells, supplementary structures such as tied ridges can be useful. Wenner (1989) suggests adding small ditches in the middle of the production area parallel to the SWC structures to increase infiltration and to decrease overtopping of the structures.
- Sub-humid areas with secure high rainfall structures must have a gradient and waterways to safely drain excess water. In particular, the waterways need to be grass-covered or protected in another way from incision and gully erosion.

Recommendations such as those mentioned above would give the extension service clues about which directions to take when seeking suitable SWC technologies. For the farmer, however, what counts is production, and for the subsistence farmer it is mainly the production of the current season that guarantees the mere survival of the family. As pointed out by Hurni (1988b)[28], SWC is a reproductive process, which unfortunately involves short-term costs while benefits can only be expected in the long run. SWC has rarely been in the short-term interest of land users because it often shows a negative net present value (Kappel, 1996)[29]. This is due to the unfavourable time gap between paying the costs and reaping the benefits.

The need to keep conservation costs low and to increase production calls for intensified production, supported, for example, by agronomic and vegetative SWC. Generally, soil cover is considered a highly efficient means of controlling erosion, at least as effective as the runoff barrier approach, but less costly (Young, 1989)[30]. However, one should not draw the conclusion that vegetative SWC can entirely replace structural SWC. Research has shown that during extreme rainfall periods in the beginning of the rainy season plant cover may not provide sufficient protection and large amounts of erosion might be the effect of one or two rainfalls. Similarly, run-on from upslope areas often causes rill and gully erosion that may not be controlled by vegetative measures alone. Therefore, structural SWC is still an indispensable component of farm management, in particular to control drainage and erosion, both during times of low and high vegetation cover.

Successful SWC is frequently connected with the following attributes: technical feasibility and adaptability, ecological soundness, economic viability, and social acceptance (Hagmann et al., 2002)[31]. The preparation of any SWC research experiments should take these attributes into consideration: negotiations with farmers must help reveal which measures to test. Ideally, farmers and researchers select the most promising indigenous – i.e. already accepted and integrated – technologies together, and improvements are negotiated on this basis. SWC measures need to be designed, monitored and assessed jointly so that they can be incrementally improved.

Many of the above conclusions for making SWC more effective by increasing production and popular participation are not at all new. Hagmann (1996)[32] provides an example from Zimbabwe indicating similar acceptance problems of SWC due to technical difficulties. Already in the 1980s, recommendations were made to address land tenure issues, to develop a multi-sectoral strategy, or provide better infrastructure. Hurni (1993)[33] developed several possible scenarios and options for the management of the land resource, stating that sustainable land management is more than technological development only. There is a great demand for improvement of the socio-economic and political framework so that it enables farmers to use their land in a sustainable manner. Although these proposals are not new, improved socio-economic conditions are far from being achieved. Consequently, frequent failure of dominantly technical approaches can also be expected in the future (Nyssen et al., 2004b)[34].

Assuming that all technologies listed above were already successfully implemented somewhere in the world, this does not automatically imply that they will also be useful when they are exported to other areas. Each implementation is accompanied by site-and-user-specific limitations, which must be overcome to achieve efficient soil protection and sustainable land management. From a farmer's point of view, the decision about how to use the land and which crops to grow is not necessarily a deliberately haphazard act!

Farmers' decisions depend greatly on such factors as farm size, household income, assets, consumption patterns, family structure (producers and consumers), experience and knowledge, and many other things. For an erosion and conservation expert, however, SWC is a mandate and hence a service to be delivered. For a farmer, by contrast, conservation is one task among many others, and often not the most urgent one. The central question from the farmer's point of view is how to meet the daily needs of the household in terms of food, energy and water, and whether SWC can be accommodated within the work that is associated with these needs. This is especially important in areas where poverty prevents farmers from making long-term investments in their land. In other words, farmers need to decide whether it is worthwhile to invest time, labour and other resources in SWC, or whether other activities deserve more attention.

In order to make it more attractive particularly to small-scale farmers, SWC comes with incentives and subsidies (food for work, cash for work). One cannot say that this approach has generally failed, because many impulses given through technical innovations would not have been possible without incentives. But the food for work approach cannot be called a success either. Its most important shortcomings are listed below (Fitsum and Holden, 2003[35]; Bekelle and Holden 1996[36]; Nyssen et al. 2004a, Gurtner et al 2006):

- The top-down approach, i.e. decisions on which technology to choose, where, when and how to implement it, were usually made without consulting local stakeholders. Consequently, local knowledge that prevails in the community was altogether ignored or shallowly referred to.
- Lack of technical assistance and information about the purpose and functioning of introduced measures. New approaches and their effects are not understandable to farmers.
- Uniform technologies and implementation modalities ignored biophysical, socio-cultural and economic diversity.
- Traditionally, SWC was integrated into the farming system and benefited from synergies between different farming activities. After services and activities for undertaking SWC were paid separately (through Food for Work schemes), SWC became an isolated activity possibly performed for the sake of the one who pays, thus introducing the dependency syndrome prevalent in many communities.
- The focus was on initial construction of structural SWC, while subsequent maintenance activities were considered the responsibility of the land users without giving due consideration to whether this was feasible at all and within the capacity of the farmers.
- Technologies chosen in such a top-down manner and approach resulted in several technical shortcomings once they were implemented. Since the aim of such campaigns was "adoption" (acceptance of technologies one-to-one, as they were introduced), the potential of "adaptation" of the measures to the local situation was rarely taken into consideration. This again reinforced abandonment and neglect of as well as loss of confidence in the farmers' part in the introduction of further SWC.

11.4 Water harvesting systems under semi-arid conditions

Eritrea is not a "physically" water-scarce country, but its current technological capabilities do not allow the extraction of water sufficient to produce food production for its population. The annual water withdrawal rate is estimated at 4% of the renewable water resource. One way of increasing this rate is by introducing feasible irrigation technologies that extract and distribute water efficiently (Mehari 2003)[37].

11.4.1 Runoff irrigation systems

Runoff irrigation is the oldest form of irrigation and has been practiced in semi-arid and arid areas for thousands of years ((UNDP/ FAO, 1987[38], Evenari et al, 1971)[39]. Runoff irrigation systems have two main parts: the catchment area, where runoff is generated, and the field area, where runoff water is concentrated to grow annual or perennial crops.

Principles and practices of runoff irrigation

Runoff irrigation is a method of irrigation that directs large quantities of surface runoff from rainfall in upland areas (nearby hills and mountains or distant watersheds), which is emitted through normally ephemeral streams or wadis, to irrigate fields in the lowlands or adjacent foothills. The runoff water is diverted to the fields by means of simple earthen structures, brushwood, gabion or concrete structures.

Two basic requirements must be met to establish a runoff irrigation system (Tauer and Humborg, 1992[40]). First, the area should have a mountainous or hilly topography to generate run-off, with adjacent low-lying fields on the same plain or at the foot of the slope to which the runoff water can be directed. Secondly, the fields should have deep soils that are capable of storing ample moisture to supply the crops during periods of no precipitation. This is because in runoff irrigation systems, plants receive their supply of water during a dry period following a rainfall event exclusively from the moisture thus stored in the soils.

Two different types of runoff irrigation systems are employed, depending on the slope of the terrain. One is for locations where the catchment area and the fields lie adjacent to each other on the same plain; this type is called a micro-catchment system. The second type is for catchment areas located on a slope with the usually terraced fields at the foot of the slope, called a macro-catchment system. The ratio of the catchment area to the field area in a micro-catchment runoff system varies from 1:1 to 10:1 and in macro-catchment systems from 10:1 to 100:1 (Mehari and Tesfai 2003)[41]. In a macro-catchment, there is no loss of potential arable land caused by the presence of the catchments, because the catchment areas are sloped and thus unsuitable for agriculture. Whereas in a micro-catchment system, there is a loss of arable land because the catchment basin and the fields lie on the same plain adjacent to each other.

The micro- and the macro-catchment runoff irrigation systems are both applied in Eritrea. Most of the runoff irrigation systems used in the western lowlands of Eritrea are of a micro-catchment type. The spate irrigation system, believed to have been used in the Eastern Lowlands of Eritrea for over 100 years (Tesfai, 2001)[42], is an example of macro-catchment runoff irrigation.

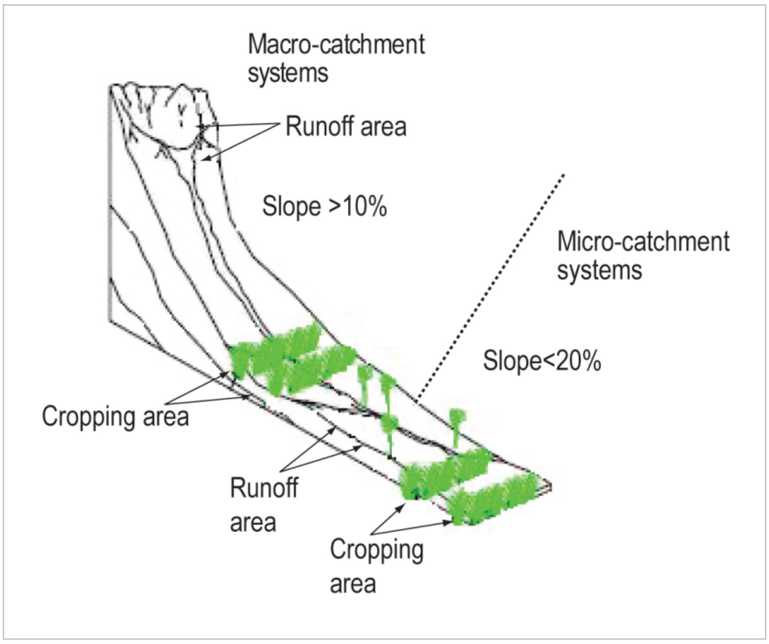

Figure 11.4 The runoff irrigation systems in Eritrea (Mehari and Tesfai M, 2003)

11.4.2 Spate irrigation

Spate irrigation is a pre-planting system of irrigation where use is made of seasonal rivers (Wadis) producing flash floods (of very short duration) from highlands and mountainous areas (Tesfai, 2001). Spate irrigation is traditionally practised in arid and semi-arid areas of the world, where rainfall is too low for rainfed agriculture. It is practised in the Middle East, Yemen, North Africa, Sudan, Somalia and Eritrea. At present spate irrigation covers about 50% of the total irrigated area in Eritrea (Tesfai, 2001). Most of the spate irrigation areas are located in the coastal areas of the country. Introduced to the Sheeb area by the Besissian people of Yemen from the Zula area, the spate irrigation system is now widely practised in the piedmont of the Eastern escarpment (Haile et al. 2003[43]). The first spate irrigation system was established at Wadi Laba (Halcrow 1997[44], Haile et al. 2003).

Spate irrigation (Wadi agriculture), also known as *Arroyo* agriculture in America (Barrow, 1987)[45] is a term for floodwater farming. In the context of Eritrea, it can be defined as a pre-planting system that uses short duration floods from the highland catchment areas to irrigate low-lying land where rainfall is insufficient for crop cultivation. The term spate irrigation is applied to systems of earthen or stone bunds designed to spread water over the ground to moisten the soil and/or to trap wet silt that can then be planted with crops (Barrow, 1987). In spate irrigation, floodwater is diverted into canals by constructing water diversion structures using brushwood, riverbed materials, stones or combinations of these. Fields are bordered by earthen bunds, thus allowing inundated water to infiltrate into the soil (UNDP/FAO, 1987). Water is conveyed from higher to lower fields by intentional breaking of the earthen bunds or, as in some areas, water is conveyed with a permanent distribution structure to attain the desired level of irrigation water.

Depending on the water-holding capacity of the soil, one or two deep applications are enough for crop cultivation and the crop grows using the retained moisture of the soil profile. In spate systems, irrigation is performed before planting to avoid water logging of the developing crops due to flooding. Due to deep spate soils, most farmers flood their fields only once or twice and are able to grow two or even three crops (ratoons) in sequence from the residual moisture of the soil. Spate irrigation nowadays is widely practice in Bada, Ghedeged, Afta Zula, Labka, Wokiro, Wadilo and Metkel Abet areas (Haile et al 2003). Spate diversion systems can vary greatly in their hydrology and water management practices. However, in Eritrea, the system can be classified in two main parts (traditional uncontrolled) and improved (controlled) spate systems, based on the method of management of the diversion systems. Currently, a controlled diversion system is used on only 4,530 ha of land (2880 ha in Laba, 850 ha in Mai Ule and 800 ha in Afta Zula).

11.4.3 Principles of spate irrigation in Eritrea (Sheeb area)

Principles

In traditional spate irrigation, diversion structures (called *Agim* in Eritrea) are temporarily made of local materials such as soil, stone, riverbed sand and gravel, tree trunks and brushwood. They are normally constructed across a riverbed to divert river flow into farm areas to irrigate fields. The riverbed topography changes after almost every medium to heavy flood because of degradation and deposition. Therefore, during heavy floods, these structures are partially damaged or washed away completely. In Eritrea, water is diverted before the planting season as a collective community action. Arable lands surrounded by bunds are flooded using several spates. The water soaks deep into the soil profiles and provides residual moisture for crops to grow. Several floods and soakings are necessary before a cumulative amount of 1000 mm of water has infiltrated into the soil. The fields are flooded to saturation and all the macro and micro pores in the soil become completely filled with water. Crop growth is entirely dependent on the residual soil moisture stored in the soil profile. If the basin fields are flooded adequately, the resulting residual soil moisture is sufficient for two or sometimes three crop harvests (Tesfai, 2001).

Figure 11.5 *Evolution of spate irrigation system in Eritrea:* ***A*** *dry riverbed (Wadi),* ***B*** *traditional Agim using branches and twigs,* ***C*** *Permanent diversion structures,* ***D*** *major diversion structure (Photo taken from downstream, Woldeselassie Ogbazghi).*

The spate irrigation system builds up land by depositing rich sediment on the fields; therefore, the elevation of the irrigated lands rises every year. Moreover, the system requires substantial woody material annually for constructing diversion structures, which are often washed away by heavy floods. In general, the overall irrigation efficiency of spate schemes is only about 20% because of the difficulty of controlling floods and because water is lost by percolation, seepage and evaporation (Tesfai et al. 2007). Suggestions have been made to improve the system and make it more sustainable: permanent flood diversion and distribution structures have been built to effectively divert the floods and to reduce water loss through percolation and seepage. Moreover, basin fields should be properly levelled to distribute the floodwater uniformly over the entire field.

The spate irrigation system has four major components, namely *Agem, Misgha, Kifaf* and *Tewali.* Their roles and functions are explained in Table 11.5.

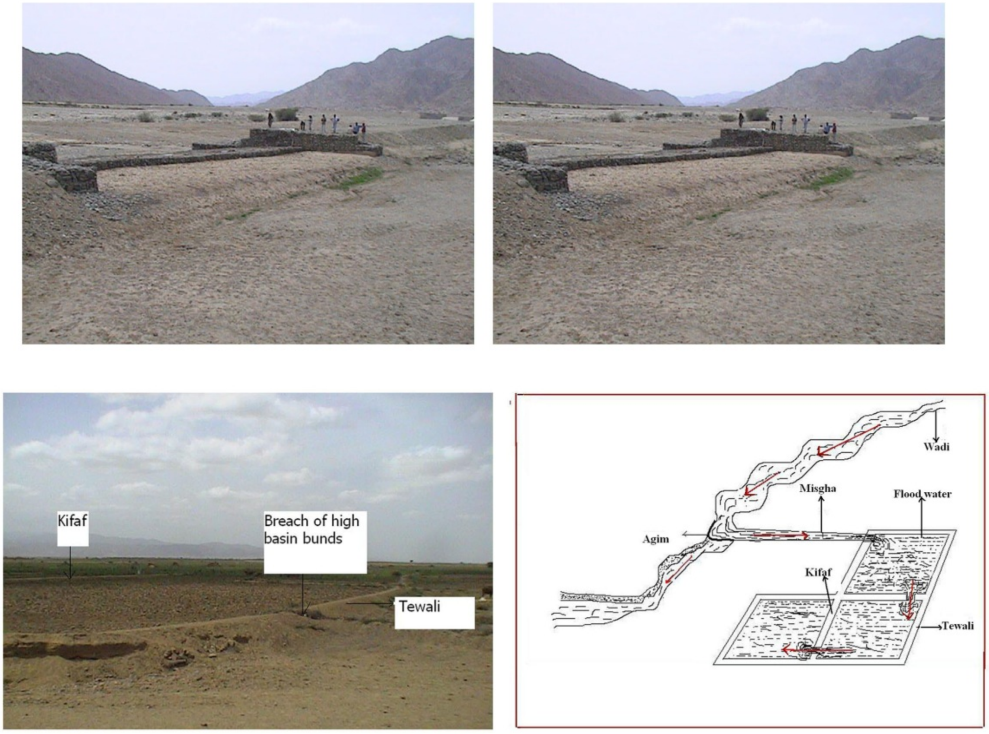

Figure 11.6 Photo and figure representation of the spate irrigation system at Sheeb. (Tefsai 2001)

Table 11.4 Major components of a typical spate irrigation system such as that in place in Sheeb

Component of spate system	Height (m)	Base width (m)	Function
Agim	3 – m m	5 – 10	This is a temporary structure erected at a low flow side of the wadi. It is made up of brush, woods, trees, stones and boulders. The aim of the Agim is to divert a large part of the spate flow (flooding) to adjacent agricultural fields.
Misgha	na	3-5	Msgha is an earth embankment built at the end of the Agim to distribute the flow into two or more smaller canals as it reaches the irrigation area and has a large capacity in relation to the irrigated area because of the short duration of the spate flow.
Kifaf	1m	na	Kfaf is interior earthen bunds, often steering the flood flow (zigzag). In one field, a farmer will construct two or more Kifafs to irrigate his fields plot by plot
Tewali	1.5	na	This is an exterior earthen bund constructed around the edges of individual spate fields. It controls the flow of water to adjacent fields. The size of the field varies from 0.5 up to 1 ha and is often rectangular.

Source: Tefsai 2001

Table 11.4 shows that the irrigated fields are designed so that water flows into individual fields by gravity. The bunds around each field are constructed in such a way that the side of the field is higher than the other side, to impound the flood water. The floodwater enters the field on the lower side and flows towards the higher bund. By the time the flood reaches the higher side of the bund, the whole field will be adequately flooded to a depth of about 0.5 m to 1 m, allowing the wetting depth of about 2.0 to 2.4 m in the soil profile. At this point in time, farmers breach the high basin bund and the water flows into the lower bund side of the next field downstream. The whole process continues in this manner from one field to the other field until the total command area receives water.

Construction and maintenance

In the spate system, farmers use oxen-drawn implements locally known as *mehar* to scoop out soil to construct the field embankment. Several indigenous techniques have been developed to divert seasonal spate floods and irrigate farm areas. If the flood is very high and beyond the capacity of the main diversion (*agim*), normally the structure immediately breaches. This saves the farmers from destruction of the main canals, locally called *mushga* or *bajur*, and field embankments, locally called *kifafs*. The farmers also have traditional diversion structures, which have considerable advantages. The advantages and disadvantages of spate irrigation in general are described in Table 11.5.

Table 11.5 Advantages and disadvantages of spate irrigation systems

Advantages	Disadvantages
• Provides irrigation water to grow multiple crops • About 10% of the population earns its livelihood from spate irrigation systems • The traditional structures are constructed and maintained by the local communities • Simple diversion structures are sufficient to divert small to medium-sized floods, and • Spate irrigation systems build up the soil as the result of the seasonal silt deposited with the floods • The salts are leached deep into the soil profile and the development of saline alkaline soils is reduced • The system requires minimum input as water flows by gravity.	• During large floods, as there is no provision for emergency spillways, the diversion structure is breached deliberately or then overtopped as the flood rises and the flood water cannot be diverted until the structure has been repaired • Towards the end of the flooding season, when farmers do not expect any more floods, a type of soil tillage called Mekemet is carried out in the flooded area. The field is ploughed about 15 cm deep to create soil tilth • The purpose of the Mekemet , also called “conservation tillage” is to create a water vapour barrier to conserve the stored moisture in the soil profile by reducing the evaporation losses from the soil surface until sowing time.

Source: Tefsai 2001

11.5 Innovations at farm level

11.5.1 Combating desertification and conservation of water: The *Zia* system of water harvesting in Mali and Burkina Faso

The *Zia* system is practiced in Mali, Burkina Faso and Niger (in the latter country it is called *tassa*). It is a traditional technique for conserving water and rehabilitating degraded land. To combat desertification and to practice water conservation in a stressed water environment, farmers in Mali employ this traditional system of water harvesting. It is highly effective in mitigating the effects of desertification and it meets the criteria for three types of conservation practices - soil conservation, water conservation, and erosion protection.

The *Zia* system is a series of man-made pits or holes. *Zia* pits are dug approximately 80 cm apart to a depth of 5 to 15 cm and with a diameter of 15 to 50 cm, on abandoned or unused land. The pits are then planted with annual crops such as pearl millet or sorghum. The pits extend the favourable conditions for soil infiltration after runoff events, and they are beneficial during storms, when there is too much water. The compost and organic matter in the pits absorb excess water and store it for the planted crops. Maintenance of the pits requires the farmer to invest additional time in watching over, deepening and refilling the pits. However, the economic return on the farmers' investment is 100% because the land brought under production is abandoned or unused land.

The success of *Zia* planting pits has been recognized in some Sahelian regions. In 1989-1990, a project implemented by the Djenné Agricultural Systems Project (SAD) showed that agricultural yields increased by over 1000 kg/ha as compared to traditionally ploughed control plots. Approximately 1600 farmers from 17 villages participated in this project. The *Zia* system is often practiced in combination with contour stone bunds and the planting of trees.

11.5.2 The *Zia* System in Burkina Faso

In the 1970s the densely populated northern part of the Central Plateau of Burkina Faso faced recurrent drought leading to out-migration to less densely populated regions with better soils and higher rainfall. Vegetation was destroyed for firewood to expand cultivated land. The surface area of completely barren land increased dramatically (Kaboré and Reij, 2004[46]). The population increase was accompanied by a strong reduction of fallow, a decrease in soil fertility, increasing erosion, a drop in agricultural production and a strong expansion of cultivated lands on marginal agricultural soils. The area of cultivated land increased much faster than the population, which is an indicator of extensification. About 70-85% of the village territories were cultivated and about 40% of this cultivated land was marginal to agriculture.

Until 1980, the extension system had not been able to offer effective resource-enhancing technologies acceptable to resource-poor farmers. In the early 1960s a large--scale mechanized SWC project was stopped prematurely, because farmers did not maintain and sometimes deliberately destroyed conservation works. Marchal (1979)[47] remarked that the objective of this project was to treat soils and not land cultivated and used by rural societies. Again maintenance was poor and many earth bunds were deliberately destroyed or breached by farmers, because they prevented runoff from non-cultivated fields from entering the cultivated fields or their maintenance requirements were considered too high (Reij 1983[48], Reij and Waters-Bayer 2001[49]). In this difficult context, both farmers and NGO technicians began to experiment with SWC techniques in which the farmers concentrated on improving traditional planting pits (*Zia)* and NGO technicians concentrated on contour stone bunds (Ouedraogo and Sawadago 2001).[50]

Development and dissemination of the *Zia* technology

Around 1980, farmers in the village of Gourga, which is situated close to the regional capital Ouahigouya, started to experiment with traditional planting pits or Z*ia*. Traditionally, planting pits were used on a small-scale to rehabilitate rock hard, barren land, in which rainfall could no longer infiltrate. These patches of barren land are not necessarily formerly cultivated fields, which degraded because of over-cultivation. Most of the degraded land was created by the destruction of its vegetative cover. The improved planting pits concentrated water and nutrients in one spot.

The role of individual farmers in the spread of the *Zia* system

One farmer, Yacouba Sawadogo, stands out as a key innovator in Z*ia.* Though he may or may not have been the very first farmer to experiment with *Zia,* he has played a decisive role in experimenting with traditional planting pits. While many families had already left the region to settle in better parts of Burkina Faso or in Ivory Coast, this farmer preferred to stay on the land of his ancestors. The millet and sorghum yields obtained by Yacouba on land which used to produce nothing were remarkable and quickly perceived by other farmers in the village who started copying him. With some delay *Zia* started spreading to other parts of the Central Plateau. Two farmers have played a key role in the dissemination of the technology and formed an Association for the Promotion of *Zia.* Yacouba Sawadogo trained farmers in many villages in the use of this technique. The contour stone bunds are the outcome of a process of on-farm experimentation during 1979 and 1981. In 1982 this project designed an extension strategy for contour stone bunds (Wright 1985[51], Reij 1983). Contour stone bunds and *Zia* have become the most successful SWC techniques on the Central Plateau and are now widespread.

Zia School Model

This led to the creation of the so-called *zia* school, which is a group of farmers jointly learning to rehabilitate a plot of degraded land. The district association of *Zia schools* now has about 1000 members (Sawadogo, et al. 2001[52]). SWC projects have played a key role in the spread of *Zia* outside the original area. Farmers rehabilitate degraded land with *Zia* without any external support. A visit was organised to the Yatenga SWC project in Illela district (Niger) for 13 farmers, which has produced an impressive spreading of Zia, called *haussa (tassa*) in this region. Already in 1992, farmers in Illela District were actively buying and selling heavily degraded land to rehabilitate it with *tassa*.

Area treatment under the *Zia* System

Farmers treat their individual fields and often their bush fields, which are spread over the village territory. Digging the *Zia* demands considerable quantities of labour, about 300 person-hours per hectare and for that reason farmers treat their fields progressively. Each dry season, farmers rehabilitate some land, but how much they do depends on available labour and on motivation. Farmers dig *Zia* in year 1 and after 2 to 5 years; they dig new ones in between the existing pits. The larger the sand fraction of the land, the quicker the process of conversion to normal land. Farmers rehabilitating gravelly and shallow lateritic soils maintain *Zia* on a quasi-permanent basis.

A survey undertaken in 1998 in provinces covering the northern part of the Central Plateau showed that 123 households that had undertaken SWC had reclaimed on average 1.33 ha per household using *Zia* and contour stone bunds (Société Africaine d' Etudes et Conseils, 2000[53]). This means that in most cases pits disappear over time, but as most pitted land is also treated with contour stone bunds, this does not lead to increased erosion. The advantages and disadvantages of the *Zia* system are shown in Table 11.6.

Table 11.6 Summary of the advantages and disadvantages of the Zia system

Advantages	• Zia rehabilitates heavily degraded land. Farmers also expand the size of their farms on fields where before nothing would grow. Without Zia, yields are 0 kg/ha and with Zia from 300 to 400 kg of sorghum in a year of low rainfall to easily 1500 kg/ha in a year of good rainfall. Investments in SWC produce benefits in the medium or long-term. However, water-harvesting techniques such as Zia produce a yield from the first year. • Zia is labour-intensive, but the pits are dug progressively during the dry season and vary depending on available family labour and on the possibility of hiring labour. • Water infiltrates in the pits and the water retention capacity of the soils increases; crops suffer less from drought spells at the onset of the rainy season as well as during the rainy season. • Manure is concentrated in the pits, and therefore used more economically, which is particularly attractive to farmers with few livestock. It captures windblown soil and litter (Ouedraogo and Kaboré 1996)[54]. In the first few years, fields reclaimed with Zia are little infested by Striga and other weeds, hence labour requirements for weeding are lower than on other fields. • Land is prepared during the dry season, and farmers can immediately sow their fields with Zia when the rains arrive. Some farmers gain even more days early in the season, because they practice dry seeding in April. In Niger's Illela district, the introduction of improved traditional planting pits appears to have contributed to a revival of traditional work parties as well as to the emergence of a labour market (Hassane, et al., 2000)[55]. • Because more water is harvested and conserved and organic matter is used in the pits, conditions are improved for using some mineral fertilizers to increase yields and biomass production. Manure applied to the pits contains seeds of trees or bushes that have passed through the intestines of livestock, which facilitates their germination. The young seedlings also benefit from the concentration of water and manure (Roose et al. 1999)[56]

Disadvantages	
	• The labour requirements for digging of Zia are high (about 300 man-hours/ha). How high depends on the type of soils in which they are dug. The labour requirements for their maintenance depend on soil type. Pits dug in soils with a high proportion of clay or with a lot of gravel require less maintenance than pits dug in sandier soils. • Mechanization is impossible. Pits are dug by hand and maintained by hand. By digging the pits at the cross-sections, labour requirements are halved (Roose et al. 1992[57]).

Ngolo pits in moist areas (Zambia, Tanzania)

In parts of Zambia and Tanzania, pits (called *Ngolo*) are dug not to rehabilitate degraded land, but on cultivated fields. These pits are filled with manure and planted with, for instance, maize (Malley, et al. 2001)[58]. The *Ngolo* are thus used in areas with higher rainfall and on agricultural fields.

11.5.3 Impact of the *Zia* system on farm household and farmland

The impacts of the *zia* system on farm household, farm economy, and related aspects such as livestock management, soil fertility and so on are summarised in Table 11.7. The table shows that these impacts are largely positive

Table 11.7 Impact of Zia system on land management household economy

Impact of Zia on	Impact on land management
Crop yields and household food security *Continue next page ->*	Although improved traditional planting pits have been used increasingly since 1980, reliable yield data are not available. Maatman (1999)[59] estimates that digging Zia on 1 ha requires 450 to 650 hours depending on soil conditions. The number of pits varies, largely depending on the region, from 8,000 to 18,000/ha (Hien and Ouedraogo, 2001)[60] in one region, to 23,000-31,000 in another (Kaboré, 1994[61]), and to 46,000 51,000/ha in yet another region (Slingerland and Stork, 2000[62]). The number of Zia per hectare and their dimensions determine how much water they harvest. Also the quantity and quality of organic matter used influences yields. Generally, farmers use 3 to 5 tons/ha in Zia, but some farmer innovators used 5 to 12 tons/ha (Hien and Ouedraogo, 2001). Most studies use the cereal yields obtained on surrounding fields to compare yield levels (e.g. Hassane et al. 2000[63], in Niger). As Zia in Burkina Faso or tassa in Niger are mainly used to rehabilitate heavily degraded land, yields there are 0 kg/ha. Planting pits alone offer several agronomic advantages over conventional ploughing. First, water harvesting in the pits focuses available moisture on the cereal crops and enables plants to survive long dry spells. In addition, dry-season land preparation for planting pits enables farmers to plant early, with the first rains. They thus enjoy a longer growing season than under conventional tillage where farmers cannot begin land preparation until after the rains have begun. As a result, evidence suggests that pits alone generate yield gains over conventional ploughing, though these gains vary substantially across soil types and seasons. Amidst wide variation, Roose et al. (1993)[64] find that Zia pits alone achieved an average gain of only 38 kg/ha in white sorghum yields over two seasons in two locations in Burkina Faso. Using a regression analysis, Kaboré (2000)[65] found that

Impact of Zia on	Impact on land management
Crop yields and household food security	Zia pits alone increased sorghum yields by 310 kg/ha compared to the non-Zia situation in the village of Donsin, which had recently adopted this technique. Zia combined with contour bunds showed an even greater increase in yields (+ 710 kg/ha). When combined with manure or inorganic fertilizer, the Zia pits typically generate even larger gains. In Niger's Illela district, for example, cereal yields on untreated fields averaged 125 kg/ha over a six-year period. Yields rose by an average of 388 kg/ha in pitted fields with manure. The Zia pits with manure achieved systematically higher yields than adjacent untreated fields and also higher than the average cereal yields for Illéla district. With an additional dose of inorganic fertilizer, in combination with the pits and manure, average yields rose by 640 kg/ha compared to the control plots. In Burkina, Zia pits plus compost achieved yield gains of 372 kg/ha, roughly ten times the output gains under Zia pits alone. The additional gains due to the addition of inorganic fertilizer proved biggest in years of good rainfall while in other years the additional yield would not be sufficient to cover the costs of nonorganic fertilizers. Similar trials over two seasons, in Mali, indicate that Zia pits plus manure increased sorghum yields by an average of 719 kg/hectare (Wedum et al., 1996)[66]. Are gains in yields due to the Zia or to the manure used? It is the concentration of water and nutrients in the planting pits that make the difference. During an impact assessment of SWC, agroforestry and agricultural intensification in 5 villages on the northern part of the Central Plateau of Burkina Faso, farmers agreed unanimously that SWC and in particular Zia had had a positive impact on household food security (Reij et al. 2001). In years of good rainfall many farmers now produce a small surplus of grains, which provides a buffer in years of low rainfall. This picture also emerged in Niger where farm families with SWC produced an estimated surplus of 70% in years of good rainfall, while they had an estimated deficit of 28% in years with low rainfall (Hassane, et al. 2000). An important question is whether yields can be maintained at a higher level over a longer period. Roose et al. (1993) found a substantial decline in yields in the second year, which could not only be explained by a 100 mm lower rainfall. The use of a small quantity of mineral fertilizers substantially increases yields of grains and stover.
Soil fertility	The ferrallitic soils of Burkina's Central Plateau are generally poor in nutrients and in water-retention capacity. Average sorghum yields in the Yatenga area have increased from an average of 594 kg/ha in the 1984-88 period to 733 kg/ha in the 1995-2001 period. For millet these figures are 473 kg/ha and 688 kg/ha14 (Rein and Thiombiano 2003)[67]. High population densities make fallowing impossible and virtually all soils are cultivated continuously. Mando (2003)[68] compared soil fertility parameters of soils treated with Zia respectively and 5 years ago. For instance, the organic matter content increased from 1 to 1.4 % and nitrogen increased from 0.05 to 0.8 %. Farmers usually apply manure or compost once every two years. A key advantage of Zia is that the organic fertilizers are concentrated in pits and not spread over a field.
Farm forestry *Continue next page ->*	The manure and compost used in *Zia* contain seeds of trees, shrubs and grasses. As a result, pitted fields show substantial regeneration of woody and herbaceous species. Farmers selectively protect species regenerating naturally. Protection of natural regeneration on treated fields contributes more to tree cover than planting of trees under village forestry projects. After two years Roose at al. (1999) identified 23 herbaceous species and 13 species of trees and shrubs on an initially barren field, indicating that the *Zia* contributed to the re-vegetation of barren land.

Impact of Zia on	Impact on land management
Farm forestry	Ousseni Zorome, a farmer innovator living close to the regional capita of Ouahigouya, counted only 9 trees on 11 ha of degraded land he started to reclaim in 1983. Now he has about 2000 trees representing 17 species on these fields (Sawadogo et al. 2001). The previously mentioned farmer-innovator Yacouba Sawadogo (see main text) has used pits to systematically grow trees and shrubs on his fields.
Changes in livestock management	Many farmers who have undertaken SWC, and in particular *Zia*, claim that they have invested more in livestock since they started these activities. This is because SWC has substantially increased the production of fodder, which makes it possible to increase livestock numbers; but this requires improved availability of water at village level. Food deficits are smaller and in good years small surpluses are produced for investment in livestock and hence increased quantities of manure production (Reij, et al. 2001).
Local impact on groundwater levels	Currently, all wells and boreholes in villages using *Zia* have water during the entire dry season. In several villages included in a study on long-term economic and environmental change on the northern part of the Central Plateau of Burkina – though not in all of them – levels of water in wells have improved substantially during the last 10 to 15 years (Reij 1983).
Socio-economic impact	Every farmer can master improved traditional planting pits, yet the indications are that rich and average farmers use this technology more than the poor, as they have more family labour or are able to hire labour. Poor families are more likely to benefit from project-supported construction of stone bunds, which is usually done by groups of farmers on blocks of land selected for this purpose. Such blocks of land include fields of small farmers as well as fields cultivated by women. The broader question is whether other SWC techniques have contributed to reducing rural poverty or not. Using their own criteria to define wealth, which are mainly related to the level of food security, the villagers of Ranawa (Zodoma Province, Burkina) estimated that the number of poor families decreased by 50% between 1980 and 2001 (Ouedraogo, M. et al., 2002). This was largely due to the wide range of SWC activities undertaken in this village since 1985, which has led to the progressive rehabilitation of about 600 ha of degraded land, most of which was previously unproductive. The environmental and socio-economic situation in this village was dire in the early 1980s. Recurrent drought and important food shortages caused 49 families to leave the village between 1970 and 1980 (25% of all families) and settle in Ivory Coast or in more fertile and higher rainfall parts of Burkina Faso. All wells ran dry shortly after the end of the rainy season and women had to walk 5 km to fetch water in a neighbouring village. Since SWC activities began in 1985, not a single family has left its home in this village. Due to SWC, more land is cultivated and yields have increased, which has led to a substantial improvement in household food security and a systematic protection of natural regeneration. Important stands of trees grow on what used to be barren land. Livestock numbers have increased substantially and livestock management has changed from extensive to semi-intensive.
Microeconomics of *Zia* *Continue next page* ->	According to some SWC specialists, economists and other scientists, SWC in semi-arid regions may prevent a yield decrease rather than bring about a significant yield increase (e.g. Brons et al. 2000)[69]. When asked about the impact of SWC on yields, farmers in the northern part of the Central Plateau (Burkina) systematically reported not only higher yields, but also increased yield security, more water in their wells, a stronger growth of trees and a higher production of fruits (Reij, et al.

Impact of Zia on	Impact on land management
	2001). Improved traditional planting pits make it possible to rehabilitate strongly degraded land. Without pits, yields on heavily degraded land are 0 kg/ha and every kilo of sorghum, millet, cowpea or maize harvested on this land is perceived as additional to what they would harvest otherwise. Strictly speaking this is not correct, because the labour allocated to rehabilitated land may lead to lower use of labour on existing fields, and hence to lower yields on these fields. In fact, farmers who can afford it re-introduce a short fallow on part of their existing fields in order to improve soil fertility and to facilitate regeneration of trees and shrubs. Variable costs include the amortization of tools used to produce the compost, the cost of maintenance of compost pits, the cost of emptying the pit, and the costs of transporting the compost to the fields. These costs are derived from Sidibe et al. (1994),[70] who measured them in villages in the western part of Burkina Faso. Labour requirements for digging the *Zia* and putting crop residues and other organic material into the pits are based on the availability of resources (Roose et al. 1999)[71]. Sidibe et al. (1994) measured the labour requirements for digging the compost pit and filling it. Crop yields and prices vary from season to season. In 1989 an IFAD-funded SWC project in Niger's Illéla district sent 13 farmers on a study visit to the Yatenga region, where they observed *Zia* and other conservation practices. 1990 was a drought year and only fields treated with pits produced a harvest. From this moment on the practice of pit digging became increasingly popular and farmers started buying degraded land to rehabilitate these. Prices for degraded land doubled between 1992 and 1994. Buying and selling of degraded land is not an isolated phenomenon in Illéla and in neighbouring districts of Niger; many farmers are involved in the land market (Hassane, et al. 2000)[72]. According to Roose et al. (1993) *Zia* function best in areas with a minimum of 300 mm and a maximum of 800 mm rainfall. According to Burkina Faso's National Action Plan to Combat Desertification, the environmental situation on the Central Plateau continues to degrade. Researchers have underestimated the economic and environmental impact of investments in SWC practices.

11.6 Overall assessment of soil and water conservation measures

11.6.1 Tools to assess effects and impacts of SWC

There is no shortage of well-described participatory investigation tools such as PRA, sample surveys, stakeholder analysis, social mapping, matrix / preference ranking, Venn diagrams, focus group discussions, key informant interviews, transect walks, wealth ranking, etc. But often neither time nor capital is available to carry out such studies, and practitioners have to rely on their own knowledge or on quick (and necessarily incomplete and sometimes misleading) assessment methods. In general, an active inclusion of local stakeholders in the planning process and the involvement of local knowledge in SWC are absolutely essential to increase acceptance of measures and understanding of their functioning. Social networks can facilitate innovations; the development of knowledge and sharing of that knowledge can also increase social acceptability.

When talking about acceptability / acceptance, we do not mean "adoption" of proposed standard SWC technologies but constant "adaptation", i.e. the continuous process of participatory technology development, a procedure of learning with phases of modification, assessment and improvement. The spider diagram (*Figure 11.7*) is an instrument to visualize changes during such a process of learning. Preparation for the assessment involves selection of a meaningful set of indicators that can describe the "issue" under consideration at an early stage of cooperation (for more examples see Chapter 12). After selection, the rating of each indicator needs to be agreed upon: what is considered the best, good, bad, very bad effect. Finally, measurements and observations will be carried out, and results will be interpreted. More information on the single steps can be found in Chapter 12. The selection and rating of indicators seems to be the domain of researchers who have to answer a specific research question. However, in a general development context, it is very important that other stakeholders be involved in selecting and rating the indicators, because development and sustainability are normative issues that involve the personal judgment not only of researchers!

The example in Figure 11.7 is based on an extensive survey in a regional setting. It shows the results of a rating of three conservation practices: traditional, *fanya juu,* and grass strips. The rating was done together with local farmers. Two indicators in the Figure each represent the ecological, economic and social dimensions of sustainability for these practices. While ecological and economic indicators were measured on plots (*Table 11.8*), assessment of the social acceptability of SWC relies on informal discussions with farmers. The social indicator "compatibility with cultural values" (estimated percentage) mainly refers to religious restrictions for specific farming activities that may interfere with SWC activities. The social indicator "integrability into the farming system" (estimated percentage) summarizes conflicting issues mentioned by farmers, such as:

- Rat / weed concentration in and around the terraces
- Water-logging above the SWC structures
- Fertile soil misused as construction material
- Narrow spacing conflicting with the ox-plough practice
- Maintenance of terraces conflicting with open grazing practice
- Permanent SWC conflicting with fragmentation and small size of farm plots
- Terrace construction conflicting with other requirements of farm labour

Table 11.8 Rating of indicators

Dimension	Indicators	SWC measures		
		Traditional farming	Fanya Juu	Grass strip
Ecological	Soil loss (t/ha)	42	15	4
	runoff (mm)	183	112	58
Economic	Crop yield (barley, t/ha)	1.9	0.9	1.2
	Biomass production (t/ha)	4.2	2.5	3.1

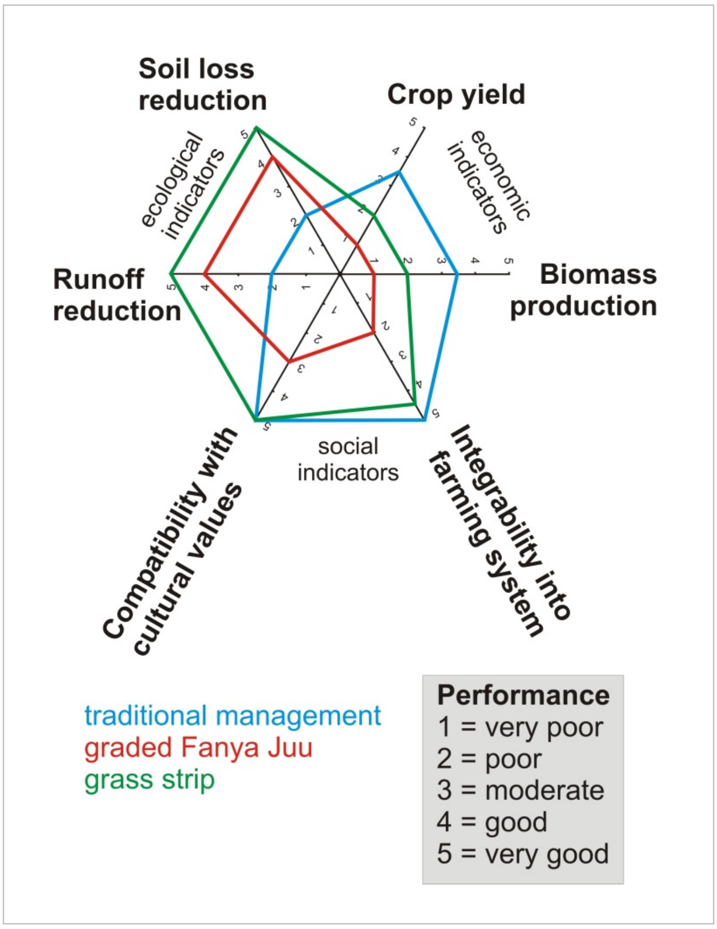

Figure 11.7 Comprehensive assessment of different SWC measures (Database Afdeyu)

The rating of indicators can first be expressed in the respective measurement units (t/ha, mm), but later harmonisation of all scales and transformation into classes (for example, 5 classes) without units is required for the sake of comparison and better communication. Farmers and researchers do have problems understanding each other's assessments, particularly if they use similar terms for different issues. Therefore, a number of different ratings are proposed here (*Table 11.9*). For example, the best possible achievement of each indicator – e.g. no soil loss – is given the rank "5". It could also be classified as 100% achievement of the optimum (e.g. 100% soil loss reduction), or be linked to the normative statement "very good." Similarly, an unsatisfactory achievement of each indicator is given the rank "1" – e.g. the highest erosion rate observed. It could also be classified as less than 20 % soil loss reduction, or be linked to the normative statement "very bad."

Table 11.9 Example of different ratings without using measurement units

Rank	% Achievement of "optimum"	Judgment
1	20%	Very bad
2	40%	Not satisfactory
3	60%	Average
4	80%	Good
5	100%	Very good

The effects of three management and SWC practices (*Figure 11.7*) can be interpreted as follows:

- Naturally, traditional management (= no SWC treatment) is 100% integrated into the farming system and 100% compatible with cultural values. Production of the concerned crop is not excellent but can be considered average in the area. The greatest deficits are high runoff and soil loss rates.
- The Fanya Juu effect represents a typical example of a "repair mentality." After assessing the traditional management, a focus was laid on improving the weak points only, in this case the ecological effects of soil loss and runoff reduction. As a result, compared to the traditional practice, Fanya Juu was successful only in ecological terms, while the social and economic dimensions were neglected, which is indicated by rather poor acceptability by farmers.
- The grass strip seems to be a more acceptable alternative, provided that production could be increased. Compared to the Fanya Juu, grass strip is less conflicting in social terms and not as effective in ecological terms. But with little improvement it has a good potential to receive desirable ratings for all indicators and dimensions.

The *Fanya Juu* example shows that each measure must always be assessed holistically. This means that the effects in all three sustainability dimensions must be observed simultaneously because they are inter-connected. For example, there is no acceptance without economic viability, however ecologically beneficial a measure might be.

The number of indicators in a spider diagram is not restricted to six. There is also no obligation to have an equal number of indicators in each sustainability dimension, but it is essential not to ignore any dimension. The most important aspect is to select a meaningful set of indicators that can be communicated to the farmers, and that best represent farm "reality." As a rule it can be noted that:

- The lower the number of indicators, the clearer the resulting recommendation, but the more unrealistic it will be. For example, if we assess different SWC measures using only one indicator – e.g. soil loss reduction – the one measure with the lowest soil loss could be clearly recommended. But using one indicator also means ignoring potential negative economic and social side effects, which disqualifies this seemingly clear recommendation as unrealistic.
- And vice versa, the higher the number of indicators, the more realistic the assessment, but the more unclear the recommendation might be. For example, considering

the six indicators used above, the assessment better reflects farmers' reality, but it does not necessarily lead to a clear-cut recommendation. The result is likely to be a comparison that balances several positive and negative effects of different measures. This does not – and should not – provide an extension worker with a ready-made opinion for what to do now; it is rather intended to help farmers decide what measures could be suitable in their situation.

11.7 Questions and issues for debate

1. Figure 11.7 is based partly on measurements and partly on statements. The rating of each indicator includes personal judgments ("good", "bad"). What is your opinion: can a researcher who tries to be objective in his / her research tolerate personal judgments as an integral part of such assessment? Why should he / she do that? How can we avoid such assessments being dominated by the personal preferences of individual stakeholders?
2. Even well-intended interventions will always have negative side effects. To accept this and to monitor both positive and negative impacts is part of a process of learning and continuous adaptation of technologies to changing circumstances. But true learning requires transparency. For example, a subject matter specialist can never have the same deep insight as a local farmer and will consequently make mistakes when designing appropriate SWC. This presents the specialist with a dilemma. On the one hand, admitting mistakes and drawing the necessary conclusions would be an important part of the learning process, but he/she might also be blamed for making mistakes and face the consequences. On the other hand, if the specialist ignores own mistakes, the farmers will have to bear potential negative consequences. How would you handle this dilemma for yourself?

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Chapter 12

Livelihoods and Farming Systems in Eritrea

12.1 Introduction

A farming system is defined as a cluster of individual farm systems that have similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions of households (FAO 2000.)[1]. The classification of the farming systems has been based on the following criteria:

- Available natural resource base, including water, land, grazing areas and forest; climate, of which altitude is one important determinant; landscape, including slope; farm size, tenure and organization;
- Dominant pattern of farm activities and household livelihoods, including field crops, livestock, trees, aquaculture, hunting and gathering, processing and off-farm activities; and taking into account the main technologies used, which determine the intensity of production and integration of crops, livestock and other activities.

In Eritrea, there are six agro-ecological zones (Chapter 3), which are more or less homogeneous in terms of farming systems. These zones are:

1. The sub-humid area (eastern escarpment, including green belt)
2. The moist highlands (central and southern highlands)
3. The arid highlands (north midlands)
4. The moist lowlands (the south-western lowlands)
5. The arid lowlands
6. Semi-deserts (coastal plains and north western lowlands)

The following section is adapted from the Agricultural Sector Review and Project Identification (FAO, 1994, Annex 1[2]).

12.2 Farming systems in the semi-deserts

Coastal plains

This area stretches from the coast up to 600 m above sea level, and includes the depression in the Bada area (70 m below sea level). The coastal plains are hot and dry with less than 200 mm annual rainfall and a potential evapo-transpiration of over 2,000 mm. The area is sandy and desert-like with low hills and ridges interspersed with gently sloping land, parts of which have a potential for spate irrigation. The main soil types are highly saline gleyic- and ortho-solonachaks, containing soluble salts harmful to agriculture. Andosols also occur, and these have good agricultural potential if irrigation is possible. Crop production is impossible without irrigation, and natural pasture resources are poor. Overall there is a great diversity in livelihood systems:

- Artisanal fisheries and backyard livestock mixed with sea-salt production and
- petty trading in coastal areas
- Nomadic pastoralism
- Port-based urban economic activities
- Spate irrigation-based agro-pastoralism
- Nomadic and semi-nomadic pastoralism
- Semi-commercial agriculture
- Rainfed mixed agriculture
- Semi-sedentary agro-pastoralism in highlands and lowlands
- Transhumant agro-pastoralism

The main production system in this area is agro-pastoralist, where livestock is the most important component and crop production (mainly sorghum) is possible only with supplementary spate irrigation. A characteristic feature of this system is the annual migration of people and livestock from the lowlands to the upland areas starting in mid-April. Families return to the wadis for the beginning of ploughing and sowing in mid-September. Spate irrigation makes use of short-duration spate flows in otherwise dry wadi beds and exploits the local deposits of deep, highly fertile alluvial silts adjacent to the wadi flood plains. The principal objective is to divert and control sufficient water from the floods to enable bunded fields to be flooded to a depth of over 1 m. This water soaks into the deep soils and provides residual moisture on which crops such as sorghum can survive. When moisture levels permit, the sorghum crop is ratooned and a second harvest of grain is possible. When the floods have been particularly good, farmers may plant maize instead of sorghum because of the greater yields that can be achieved. Minor crops include maize, pearl and finger millets, sesame, groundnut, beans, cotton and vegetables.

Fisheries around islands and along the coast

Eritrea has a coastline of almost 1000 km on the Red Sea, including the Dahlak islands in the central part. These islands are formed on raised coral reefs; their topography is flat to undulating plains with altitude ranges of 0-50 m above sea level. The climate of these islands is semi-desert with mean annual rainfall less than 50 mm. Although arable crop production is impossible, the inhabitants keep a limited number of goats for milk and meat. These livestock graze on the limited pasture resources mainly composed of Acacia species. They are engaged mainly in fishing and small-scale trade between the coastal areas and Massawa. They bring their produce to Massawa where new fish landing sites are available. Historically, most of the coastal population were herdsmen wandering between the highlands and the lowlands. However, this trend has dramatically changed in recent years with the expansion of various fish landing sites in strategic locations in Gelelao, Wekiro, Sheeb and Marsa Gulbub.

Despite their proximity to the sea, most of the local communities have depended on livestock production – mainly goats, sheep, and camels. In recent years, however, this trend has changed and these communities have diversified their mode of production to include fishing as a supplementary source of income or use it for household consumption. In view of the importance of the fishery industry, efforts are underway to improve the fishing facilities at strategic locations to enable small-scale fishermen to collect and sell their harvest to markets. Several fish landing sites have been constructed and made operational. These sites are equipped with storage facilities and are located in the port city of Massawa and the small villages of Wokiro, Foro and Gelealo.

Artisanal fisheries and backyard livestock mixed with sea-salt production and petty trading in coastal areas

This livelihood system covers the coastal areas of the southern Red Sea. The residents depend on livestock and livestock products, fisheries and, to a considerable extent, salt production. In addition, communities along the coastal areas depend on income from trade and sales of handicrafts. Along the coastal areas, the topography is flat to undulating plains with altitudes ranging from 70 m below sea level to 200 m above sea level. The climate is semi-desert with mean annual rainfall of less than 200 mm. Although arable crop production is impossible, the inhabitants keep a limited number of goats and sheep for sale and household use. Camels are reared for transport, milk, and meat during marriage and burial ceremonies. The livestock along the coastal areas graze on limited pasture. The browse species in this zone include acacia and various mangrove species. The inhabitants of these areas also engage in fishing. Historically, a larger proportion of the coastal population have been engaged in fishing and collection of other sea food. Income from the sale of salt is one of the major sources of livelihood of the communities. Historically the communities exchange salt for cereals, pulses and coffee.

Nomadic and semi-nomadic pastoralism in the inland

This livelihood system is found in areas that run parallel to the coastal areas. The area is inhabited by nomadic and semi-nomadic pastoralists. It is dominated by undulating plains with outwash fans sand dunes, and river banks with rich vegetation cover. In some places the landform is a complex of colluvial plains, outwash fans and low hills, as well as flat to undulating plains. In Debubawi Keih Bahri there is a semi-nomadic way of life in most of sub-zones including Arae'ta and the mid-central part of the zone. The remaining part of the population combines livestock and trade (6%). Since agricultural production in the zone is negligible, households' primary food sources come from purchase of food from other regions of the country or abroad (Ogbazghi 2005[3]). Nomadic people get cash from the sale of livestock products such as butter in the nearby markets. There are marked differences in the amount and distribution of rainfall, which ranges between 50 and 350 mm. Hence, seasonally the population moves to higher altitudes in search of water and pasture for their livestock.

The vegetation cover within this livelihood system is mainly composed of shrub land, scattered woodland, and palm trees along the seasonal rivers (wadis). In recent years, limited agriculture using spate irrigation has been practiced along the river banks where they grow sorghum. It is covered with sparse vegetation along the river banks of the seasonal wadis. The ground water allows limited semi-commercial irrigated agriculture (onion, tomato and okra are the main crops). Pastoralist communities frequently graze their livestock in this area, particularly during the dry season when there is ample water and browse for their livestock. Because of the limited vegetation cover, this livelihood system offers a niche to the pastoral communities residing in its environs. Nonetheless, there is a marked difference in the availability of pasture as one moves from the south to the northern part of the southern red Sea zone. Hence, in the nomadic communities the households migrate with their animals in search of suitable pasture area, while the semi-nomadic population leave their households in permanent settlement and the migration is limited to animals and able members of the households.

Spate irrigation and agro-pastoralism

The spate irrigation-based farming system is widespread in the northern Red sea zone. As the area receives mean annual rainfall of less than 200 mm and evapo-transpiration is more than 2000 mm, rainfed arable crop production without irrigation is impossible in most places. Hence, in the spate irrigated fields, farmers grow maize sorghum, water melon, tomato and sesame. The soils of the area are coarse-textured with sandy, loamy texture, mostly alkaline outside the irrigated areas and very low in organic matter, whereas in the irrigated fields alluvial deposits brought by the seasonal streams flowing from the highlands dominate the soil.

The seasonal '*wadis*' originate from the highlands of the eastern escarpment of Eritrea. In the northern coastal areas, the major floods are: Labka, Wadi-Laba and Mai-Ule, Wekiro, Dogoli and Ruba Hadas. These floods are the main sources of spate irrigation in the various spate irrigation areas (e.g. Labka, Sheeb, Gedged, Shebah, Adi - Shuma, Metkel Abet, Gahtelay, Wekiro, Imberemi and Gelealo).

In this spate-based mixed agriculture farming system, livestock (e.g. camel, sheep, and goats; crop production) are combined with spate irrigation and sorghum production. Recently, vegetables such as water melon and tomato have been introduced (Haile et al 2006[4]). Farmers use the cut and carry system where fodder/forage from the irrigated fields is carried to homesteads to feed their animals. During the off-season some farmers migrate to higher altitudes to avoid the heat, particularly from May to September.

The natural vegetation in this area includes some useful plant species. These species supplement the diet of the local communities. During the dry season they provide animal feed as browse and sources of wild fruits and drinks extracted from the young shoots of Doum palm. Moreover, the local vegetation is used for construction of diversion canals, production of farm implements, and house construction. In the absence of modern veterinary service, local communities use herbal ethno-veterinary medicine and human medicine to treat various diseases.

The north-western lowlands

The north-western lowlands of Eritrea border with the Sudan. Altitudes are between 400 and 1,500 m and the climate is hot and arid with an average annual rainfall of less than 300 mm. Evapo-transpiration is between 1,500 and 2,000 mm. Rainfed crop production is generally not possible without irrigation and because of this the pasture resources are poor to moderate. Prevalence of malaria combined with the poor agricultural potential has resulted in a low population density. Lopping trees as livestock fodder during the dry season is a common practice. In recent years, areas of riverine forest and some woodlands have been converted to irrigate fields for vegetables. The main production system is a nomadic pastoralist one very similar to that found in the south-western lowlands. The nomadic people keep mixed herds, mostly camels, cattle and goats, and make long journeys in search of pasture and water. Non-wood forest products also make a significant contribution to the rural livelihood of the local communities (Ogbazghi 2005)[5]

12.3 Farming systems in the sub-humid area (eastern escarpment including green belt)

The eastern escarpment stretches from north-east to south-west between the coastal plains and the highlands. It has an altitude range from 600 m to the highest peaks of Eritrea at more than 2,000 m. This zone is a unique area as rainfall exceeds 1,000 mm in a few pocket areas (green belt). It encompasses numerous micro ecological zones determined by the interrelationship of altitude, rainfall, exposure and soils. Micro-climates in the belt range from sub-humid temperate to humid tropical. The relief is steep and requires terracing for sustainable farming. The "green belt" differs from all other zones as it is able to support permanent crops such as coffee without irrigation because of the bimodal rainfall pattern. Other areas in the eastern escarpment are drier than the "green belt", but still not as dry as the coastal plains.

The green belt

The "green belt", while of considerable interest, is of limited economic importance in terms of agriculture. This is because the area is small and has steep slopes that demand expensive soil and water conservation interventions. This area contains the 53,000 ha of remnant coniferous forest that once covered much of the Eritrean highlands. Thus the area is of interest from the point of view of conservation. The main production system is mixed farming with permanent tree crops such as coffee and annual crops such as wheat, barley, maize and sorghum as well as different pulses and vegetables. Livestock are kept. Farmers from elsewhere in the highlands and western escarpment also use the area a transit route for seasonal migration to the eastern lowlands.

Transhumant agro-pastoralism

This livelihood zone is predominantly found in the sub-humid agro-ecological zone of the region which is located in the central eastern escarpment of Eritrea bordering with Zoba Anseba, Debub and Maekel. The dominant slope range is 8-100% with an altitude range of 600-2600 m. These areas receive mean annual rainfall of 700-1100 mm per year with mean potential evapotranspiration of 1600-2000 mm. There are two growing periods (summer rains and winter rains) with a dependable growing period of 60-210 days.

The natural vegetation is dominated by disturbed *Juniperus procera* and *Olea African* species. Maize, sorghum, Barley, tomato, and various pulses are grown under rainfed conditions. The area is also suitable for perennial tree crop production such as coffee, orange lemon and banana at lower altitudes.

The main livestock are cattle (Arado breeds, goats and sheep). There is seasonal migration of people and livestock from the lower altitudes of the northern Red Sea and Anseba zones. The migration from the lower altitudes to the highlands is mainly to avoid the heat of the summer, while migration from Anseba zone is mainly for grazing and cultivation of crops. The local inhabitants are relatively well off as they are able to grow various vegetables and fruits for consumption and the market.

During the rainy season migrating populations harvest wild fruits such as cactus fruits (*Opuntia ficus indicia*) as well as wild vegetables. The farmers in neighbouring areas earn their livelihood by selling cactus fruits for a period of 2-3 months either for sale or local consumption.

12.4 Farming systems in the moist highlands

The central highland zone lies at an altitude of over 1,500 m. It receives 500 mm of annual rainfall, has a warm-to-cool semi-arid climate and potential evapotranspiration ranging between 1,300 and 1,800 mm. The area normally receives rain for about three months from June to mid September. There are occasional showers in March and April, which are used to plant long-season crops. Predominant soils are chromic, eutric and calcic cambisols of a strong brown and red colour and with good agricultural potential. Population density is very high. The southern part of the highlands receives more than 700 mm of rainfall and has a lower population density.

Land degradation is worst in the central and northern highlands. A long history of cultivation, grazing and fuelwood and timber harvesting without recycling of nutrients or management of organic matter has resulted in poor soils and depleted vegetation. In this area, there are two main production systems. These are a rainfed-cereals/pulses-based system and an irrigated-horticulture-based system (FAO 1994, Daniel 2008[6]). Additionally, semi-sedentary agro-pastoralism is practiced but is of less importance.

Semi-sedentary agro-pastoralism system

The population mostly depend on livestock for their livelihood. The major livestock are cattle, goats, and sheep. They usually move with their animals between the western escarpment and the coastal area depending on the availability of pasture. Besides livestock production, the population also practice limited rainfed agriculture to grow cereals such as sorghum and barley in their home villages. Wild and domestic honey, wild fruits, and vegetables constitute part of their diet or are sold in the local markets. The livelihood of the population is not homogenous as there are people who do not own livestock. For instance, women-headed families and the elderly depend on their fellow community members and internal differentiation in the society is therefore high.

The rainfed-cereals/pulses-based system

The rainfed-cereal/pulses-based system is based on the cultivation of a single cereal and/or pulse crop during the wet season with considerable reliance on residual moisture for the later part of the crop's growth. The amount of land available for each family is very limited, varying between 0.5 and 2 ha and with an average of about 1 ha. Farmers grow a mixture of crops as a strategy for spreading risk and to satisfy diverse family requirements. Barley, wheat and taff are the main cereals, while finger millet, sorghum and maize occupy small areas. Amongst the pulses cultivated in rotation with cereals, chick-peas dominate, followed by field beans and field peas. Oilseeds such as linseed and nihug are also grown but on relatively small areas.

The system relies heavily on animal power for land preparation (oxen), threshing (oxen) and transport (donkeys and horses and mules). The availability of oxen determines the timing of ploughing and planting during the short rainy season. The livestock population in the highlands has decreased significantly as a consequence of the recurrent drought, war, and population pressure. To complement income from crops, farmers also rear sheep and goats and backyard poultry.

The irrigated-horticulture-based system

The importance of small reservoirs for the local population in most semi-arid environments cannot be over-estimated. Water stored in these reservoirs allows for year-round irrigated agriculture for some farmers and ensures that there are little or no domestic and drinking water shortages for the local population during dry periods.

Many reservoirs have been constructed in Eritrea and especially in the central highlands since the Italian colonial era. The Upper Anseba Catchment, with a total area of 633 km^2, is located in the central highlands of Eritrea. A total of 49 reservoirs have been constructed in this catchment since the 1930s (Daniel 2008). In the rural areas rainfed and irrigation agriculture are the main economic activities of the population, whereas in the urban areas, particularly in Asmara, the population is primarily dependent on the availability of water for domestic use, which is increasingly becoming a scarce resource. Among the various uses, water for the purpose of growing agricultural products has become a major issue in Eritrea today as rainfall is inadequate and uncertain over large parts of the country.

The irrigated horticulture-based system is practised by a minority of farmers who have been able to invest in the development of irrigation using the water stored in reservoirs or dig wells and pump water to irrigate their crops during the dry season. On the irrigable plots of land, they cultivate vegetables and on the remaining land cereals under the previously described rainfed system. The main vegetables grown are potatoes, tomatoes, green peppers and onions. They can be grown almost all year round, but farmers avoid having crops in the ground between January and February because of the risk of frost.

12.5 Farming systems in the arid highlands (north midlands)

The northern midlands are situated at an altitude 1,500-2,000 m, receive less than 400 mm rainfall, and have a low population density. The area is dominated by hills and mountains. The valley allows limited agricultural development. The farming system in this area is semi-nomadic and nomadic, with goats as the dominant livestock.

This livelihood system is found in the Adobha, Nakfa and Afabet areas. It is dominated by undulating plains with outwash fans and river banks with rich riverine vegetation cover. It is also found in the northern semi-desert area of the northern Red Sea zone at an altitude of about 400-600 m, with thick to sparse vegetation along the river banks of seasonal rivers. The ample groundwater allows limited semi-commercial irrigated agriculture to grow onion, tomato and okra. It is also frequently visited by pastoralist communities to graze their livestock, particularly during the dry season, where they get ample water and browse for their livestock. Because of the thick vegetation cover in some areas, this livelihood system offers an excellent niche to the pastoral communities residing in its environs. The main assets for the inhabitants are livestock. Nonetheless, most of this population are poor with no access to other sources of livelihood.

The western escarpment lies at an altitude of 600-1,500 m and has a warm-to hot semi-arid climate. This area is a transition zone between the highlands and the western lowlands in terms of climate, population density and farming systems. The soils are similar to those found in the highlands.

The dominant production system is agro-pastoralism in which farmers combine farming with livestock husbandry (Haile et al. 1996[7], 1998[8]Haile et al. 1995[9]). Farms are larger than in the highlands, averaging 2-3 hectares. The main crops are sorghum, finger millet, taff, maize, oil crops such as sesame and Nihug, cowpeas and chickpeas. Given the more abundant grazing resources in this area, the herds of cattle, sheep and goats are also larger. Highlanders bring down their herds of cattle to the western escarpment seasonally to take advantage of the better grazing. Shortage of fuelwood is less acute than in the highlands.

This livelihood system is found in the south-western parts of the central highlands. It includes highlands and lowlands. These inhabitants live in villages (semi-sedentary agro pastoralists) with some movement between the upland and the Barka, Anseba, and Gash rivers. During the dry season some members of the households migrate with their livestock to grazing areas, mainly to the Barka, Gash and Anseba rivers.

12.6 The moist lowlands (south-western lowlands)

This area is relatively flat, hot and semi-arid, and lies at an altitude of 600-750 m. Heavy Vertisols are predominant. The population density, both of people and livestock, is relatively low, with trends towards an increase. Extreme climatic variations do not occur and the rainfall, though only 400-600 mm, is relatively reliable. There are four main production systems:

1. Nomadic pastoralist
2. Semi-sedentary agro-pastoralist
3. Crop/livestock mixed production
4. Commercial farming

Nomadic pastoralism

The nomadic people are in most cases on the move in search of pasture and water for their herds almost throughout the year. Most of the livestock are kept under a highly mobile nomadic pastoralist system. Many of the animals in this area come from the highlands for the dry season and stay to browse the riverine vegetation or migrate further into neighbouring countries. Camels are the preferred species because of their resistance to drought and they are easier to feed during dry periods.

Semi-sedentary agro-pastoralism

The semi-sedentary agro-pastoralist system is predominant in the area but may not easily be differentiated from the nomadic system. During the rainy season, homesteads are established close to a mountain and near the sites where sorghum, pearl millet, okra and sesame are planted. These sites are relatively permanent as the families remain there until the crop is harvested. They return each year to plant and harvest crops. During the rainy season, most of the livestock are kept near the homestead, but at the beginning of the dry season people move with their herds to the dry-season sites. Later in the dry season, one male family member will take the cattle further south in search of pasture while the rest of the family stays at the dry-season site and later moves to the rainy-season site to prepare for the cropping season.

Camels provide milk and are also used for long-distance transport of goods in trade where goods are exchanged for food and other household needs. They are also used for ploughing. With the aim of maintaining their stock, farmers slaughter or sell the males, with a few being kept as breeding stock. Sheep and goats are sold whenever the need for cash arises. Donkeys are kept for short-distance transport of water and firewood by the women to help them with household chores.

Currently there is increasing competition for land between the agropastoralists and commercial horticultural that is being expanded along the major rivers, which are the most important dry-season grazing reserves in the area. The proposed national park is also located within this system, with the likelihood of competition between biodiversity conservation and wild animals.

Crop-livestock mixed production

In the crop-livestock mixed production system people do not shift homes. Crop production is more important than the livestock component. The livestock herds are similar to those found in the agro-pastoralist farming system but with a tendency to keep fewer camels and larger herds of cattle. Ploughing is carried out with oxen instead of camels, though the use of camels for ploughing has increased recently because of the losses in cattle caused by prolonged drought. The main crops grown are sorghum, pearl millet and sesame, which are all drought-resistant. They are never intercropped. Traditionally in this system, farmers have developed an important complementary activity: irrigated small-scale horticulture. The most common crops are tomatoes, onions, bananas and peppers, all irrigated by open shallow ditches along the river beds.

Commercial farming

Since independence, commercial farming has been developed as a result of a policy of land distribution in the form of medium- and large-scale land concessions. Concessions may be for large-scale rainfed production of sorghum and sesame or for irrigated production of fruit and vegetables to supply the local markets and to boost export. The commercial enterprises have been developed by the government as well as by some private farmers with adequate financial resources, since large investments are necessary to start production. The area covered by irrigated agriculture has been on the increase since the early 1990s.

Table 12.1 Most important livelihood systems in Eritrea

Traditional agriculture	Rainfed cereal cultivation
Mixed agriculture	Combination of crops and livestock, with crops being more important. May include garden irrigation in places
Irrigated-commercial	Irrigated and diversified crops (vegetables, fruits), market-oriented
Traditional spate irrigation and agro-pastoralism	Growing crops by diverting seasonal flood along the river basin
Rainfed commercial	Rainfed cash crops, market-oriented production
Agro-pastoralism	Combination of livestock and crop activities, with dominance of livestock
Pastoralism	Based on livestock rearing
Sedentary pastoralism	Livestock rearing without migrating
Temporarily migrating pastoralism	Livestock rearing with seasonal migration
Fisheries	Artisanal fisheries and backyard livestock mixed with sea-salt production and petty trading in coastal areas

12.7 Questions and issues for debate

1. Taking the description of the various farming systems in Eritrea, do you think that this classification system adequately addresses the issue on the ground? What modifications would you suggest to improve the classification system?
2. What are the differences between livelihood systems and farming systems? Taking a selected area, create a livelihood farming system analysis.

3. Do you think that the existing agro-ecological zones represent distinct farming systems? If not, what better approaches would you propose?

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Chapter 13

A Holistic Approach to Developing Sustainable Land Management Projects

13.1 Proper planning

The way in which SLM projects are identified, prepared and implemented affects the nature and characteristics of development processes in a particular area. Thus, proper project planning and preparation should involve an inclusive and systematic appraisal of all the relevant aspects. The range of stages through which the planning of SLM projects proceeds from inception to implementation is part of a "Project Cycle". The project cycle can be explained in terms of five phases (*Figure 13.1*).

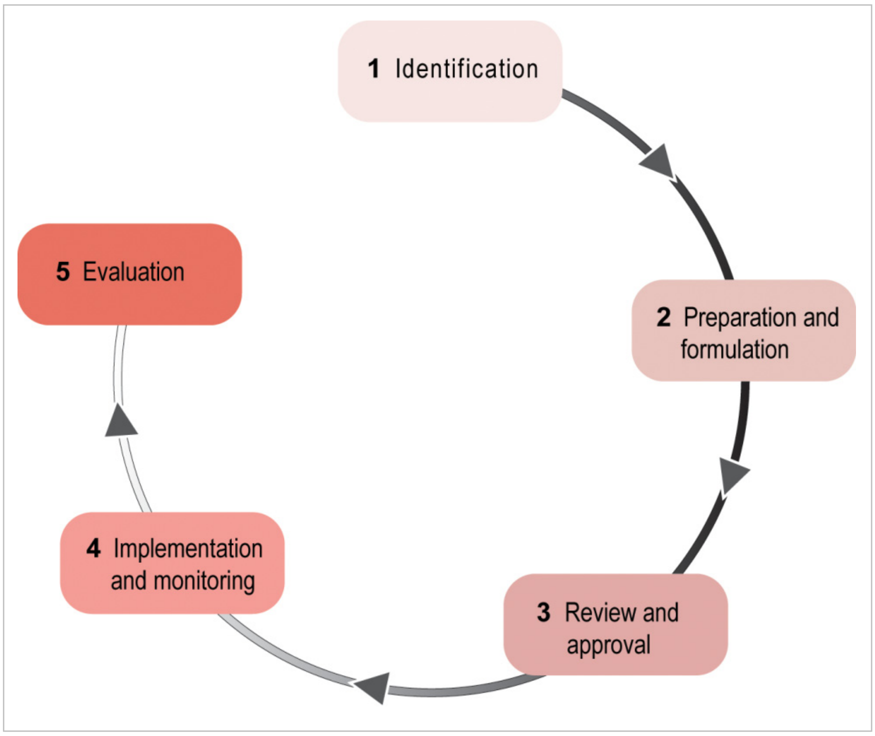

Figure 13.1 Summary of the project cycle

1. **Identification** is the generation of the initial project idea for the purpose of proposing potential SLM projects and making preliminary preparations;
2. **Preparation and formulation** is the carrying out of feasibility studies and analysis of the SLM project from technical, financial, economic, gender, social, institutional and environmental perspectives;
3. **Review and approval** is the writing up of a complete project proposal for securing approval and for implementation and arrangement of sources of finance;

4. **Implementation and monitoring** is implementation of project activities, with on-going monitoring of progress and feedback; and
5. **Evaluation** is periodic review of the project with feedback for next project cycle.

Table 13.1 Basic tasks associated with the project cycle

Project Cycle	Basic Tasks
Identification	Identification of activities, or ideas for activities, which are deemed useful for inclusion in an initial project outline. The outline should be established in a participatory process including relevant stakeholders (i.e. target population).
Preparation and formulation	Preparation of a project proposal that addresses all relevant themes (aims, objectives, deliverables, time and financial frame, roles of project partners, etc).
Review and approval	Finalisation of project proposal together with the key project partners, and negotiating approval through review and feedback loops (e.g. with local population, administration, donors, etc). Feasibility of the proposed project is a key question at this stage of the project cycle.
Implementation & monitoring	Execution of project activities as foreseen in the proposal. Key importance in SLM: have the target community participate in project implementation and monitoring!
Evaluation	Appraisal of whether a project reaches its aims or not.

13.1.1 Identification

Which project ideas exist? Whose needs do they reflect? How do they reflect the needs of the local community?

Checklist for project identification

- Have the priorities been identified and incorporated in the project?
- Have all stakeholders been involved in the process of identifying project options?
- Have stakeholders identified ways in which they can contribute to the project?
- Have the project options been appraised in the light of relevant criteria?
- Have opportunities for addressing strategic gender needs been identified?

- Has the sustainability of the project after implementation been addressed?

Project identification means proposing projects that can help to achieve sustainable land management and improve people's livelihoods. It is an integral part of the macro-planning exercise, with agricultural and natural resources information and strategies as the main source of project ideas. Local leaders could have a number of suggestions about where SLM projects should be carried out. Ideas for new projects also come from proposals to extend existing SLM programs. Suggestions for new projects usually arise because of the emergence or prevalence of fundamental socio-economic problems related to land degradation at national, regional or community levels. Project identification consists of the following steps:

- Proposing potentially socially beneficial projects, while setting clear project objectives and identifying the target groups;
- Establishing the feasibility of the project based on financial, economic, social, gender and environmental perspectives and its compatibility with a country's /region's or a community's development objectives; and
- Emphasising the urgency of the project in the context of the country /region's or community's current socio-economic situation.

Potential project identification can originate at the macro and micro levels. At the macro level, project ideas emerge from a number of sources:

- National, regional and sectoral plans and strategies supplemented by special studies, often called opportunity studies, conducted with the explicit aim of translating national and sectoral programs into specific projects.
- Identification may also emerge as the result of constraints in the development process due to shortages of essential infrastructural facilities and social problems, particularly in rural areas; a government's decision to correct social and regional inequalities or to satisfy basic needs of the society;
- Possible external threats that make it necessary for a project to aim at achieving such things as self-sufficiency in basic materials, as in food, energy, transportation etc.; unusual events such as drought, forest fires and floods.

At the micro level, project ideas originate from:

- Identification of the unsatisfied demands or needs of a local community;
- Desire of local communities to enhance their development and improve their welfare and livelihoods.

The identification and preparation of projects at local level offers significant advantages. Projects can be identified as arising from, and responding to, local needs, priorities and circumstances:

- Development of a local capacity not only to formulate and evaluate SLM projects, but also to manage own development process in a wider sense; and

- Promotion of a balanced spread of infrastructure such as the construction of soil and water conservation infrastructure for food security and environmental protection.

13.1.2 Project identification process

Situation analysis is the systematic collection and evaluation of past and present economic, political, social, environmental, and technological data. It is aimed at (1) identification of internal and external forces that may influence the organization's performance and choice of strategies, and (2) assessment of the organization's current and future strengths, weaknesses, and opportunities.

Project identification begins by conducting a situation analysis at the national, regional or local level. The situation analysis defines the current situation of a community, taking into account a range of aspects, including physical (the location of the community, availability of land and water, types of soils, slopes, etc.) environmental (forests, rainfall distribution), and socio-economic and cultural (availability of markets, current earnings of members of the community, migration, group solidarity, etc.). The latest country reports and statistics on social and economic issues, including gender and poverty, are important sources of information in conducting a situation analysis. Gender analysis is the centrepiece of a situation analysis. It adopts a systematic approach in identifying and examining the impacts of SLM projects on the different members of a community.

13.1.3 Review of the situation analysis

Stakeholders are individuals or organizations who, directly or indirectly, stand to gain or lose from a given development project. Distinctions can be drawn between primary stakeholders who are directly affected and would include the principal project beneficiaries, secondary stakeholders who are indirectly affected, and key stakeholders who are the agents of change. Who are the stakeholders? What do they have at stake? Are the stakeholders gender-sensitive? What are they willing to invest in change? What benefits are they likely to realize?

Stakeholders vary according to the nature of the problem to be addressed. Of particular interest in a socio-economic analysis at the local level is the composition of stakeholders. Households also vary in terms of sex of household head, marital status, resource endowment, and productive activities, whilst communities differ in location, resource endowment, and access to infrastructure and services.

13.1.4 Stakeholders' priorities

From the review of findings, several themes will emerge which could be developed into SLM project proposals. In order to understand the rationale underlying the development of a specific SLM project option, it is necessary to answer the following questions. What are the core problems? What are the effects of the problem? What opportunities exist to overcome the problems? What are the assumptions associated with addressing these problems? Moreover, it is likely that priorities will have to be established between the different project options due to constraints imposed by resources, money and time.

Box13.1 Identification of project based on core problems

A regional administration has established that the long-term goal is to improve the quality of life of rural women in many villages. After reviewing the findings of the situational and gender analyses, three core problems emerged: lack of income-generating activities for women in rural communities; high incidence of poverty in woman-headed households; and lack of access to credit for households headed by poor women. After reviewing the problems and analyzing the alternatives in light of various criteria, the administration and the community proposed establishment of income-generating projects for rural women by introducing a horticultural crop production scheme through irrigation.

Identification test

A project is said to have passed the identification test and be ready for detailed preparation when the following conditions are met:

- The major options and alternatives have been identified and some initial choices made;
- The principal institutional and policy issues affecting the project outcome have been identified;
- The proposed project is expected to be justified, given rough estimates of the expected costs and benefits;
- There is a justifiable expectation that the project will have adequate support from the relevant authorities, other stakeholders and the intended beneficiaries;
- There is compatibility with a country's national or regional development objectives; and
- Gender and environmental aspects have been considered in project identification.

The process of project identification is concluded with stakeholders identifying ways in which they can contribute to the project and areas in which external assistance is required. Stakeholder contributions to support the implementation of a project will strengthen their commitment to the project and their association with the benefits generated.

13.2 Preparation and formulation

Upon the completion of project identification, the last stage in the process is preparation of a draft SLM proposal. This is a short concept proposal that lays out preliminary ideas, objectives, strategies, outputs and activities of the project.

13.2.1 Elements of project formulation

- **Authority and project sponsor**: any project must have an authority who is ultimately responsible for sponsoring it;
- **Customer**: a project must always have a clearly identified customer or beneficiaries;
- **Objectives**: well-defined objectives for a project help to provide direction and focus on outputs as well as to prioritize and organize the works;
- **Scope**: any project is formulated with a defined scope in terms of departments, people, locations, regions, businesses and products;
- **Constraints**: project formulation clearly defines the constraints that are likely to arise during project formulation.
- **Costs**: these signify the budget of a project, which incorporates all anticipated costs during the lifetime of the project;
- **Resources**: these include non-monetary resources such as the staff required for the project and the office where the project will be located;
- **Deliverables**: outputs a project is expected to deliver during its lifetime;
- **Project phases and time -scale**: the main phases of the project and the time required for each phase should be properly identified. Phasing a project enables the work to be seen in understandable components.
- **Risks**: During project preparation and formulation the following steps should be considered to reduce the impact of the risks:
    - Identification of the risks;
    - Assessment of the chance of each occurring;
    - Identification of measures which can be taken to prevent them occurring;
    - Assessment of the impact on the project if the risks do occur; and
    - Identification of contingent arrangements, which can reduce their effects if the risks do occur.
- **Roles and responsibilities**: the roles and responsibilities of each stakeholder involved in the project preparation and formulation should be specified in order to reduce delays in project implementation. The main role and responsibility is:
- **Investment decision-making** (investment decision maker) – takes investment decisions based on affordability and cost justification.

13.2.2 Project document formulation

Project preparation, formulation, and project document formulation are simultaneous processes. Once the project is approved and implementation arrangements are agreed upon, the proposal is transformed and expanded into a project document. The project document is a summary of the situation assessment, justification and strategies for achieving the targeted changes, which come from each step taken through the project cycle phases 1 and 2.

Box 13.2 Project proposal main headings

1. **Introduction**: brief overview of the document
2. **Background**: context of project, process of project identification
3. **Project rationale**: justification for the project, project objectives
4. **Project activities and outputs**
5. **Beneficiaries**: stakeholders
6. **Sustainability and risks**: how is the project going to be sustained?
7. **Project implementation**: institutional information, work plan, personnel, other resources, monitoring and evaluation
8. **Project costs and funding**: budget

Review and approval

Let us assume an expert team has established that the long-term goal was to improve the quality of the rural community in general and rural women in particular. After reviewing the findings of the situational and gender analyses, three main problems were identified in the project proposal:

- Income-generating activities for women in rural villages;
- Access to credit for the women-headed households; and
- On -farm income-earning opportunities for the rural communities.

During the discussions, both women and men also placed high priority on improving the livelihood of women-headed rural households. At this stage, project approval bodies taking into consideration the feasibility of the project critically review the prepared project document from technical, financial, economic, social, and environmental and even gender perspectives. Feasible projects are approved for implementation. Upon receiving the project proposal, the project is critically evaluated, taking into consideration the following basic issues:

The extent to which the objectives of the project conform and contribute to national or regional development objectives;

- The extent to which the results identified are realistic, achievable and sustainable;
- The extent to which gender and poverty perspectives are reflected in the project;
- The capacity of the implementing partners to undertake the project; the level of risk in full project implementation; and the extent to which the proposed intervention is sustainable and replicable.

13.2.3 Gender benefit analysis from the project

Project identification thus amounts to proposing projects that can contribute to achieving specified development objectives. The implementation of the identified project is expected to benefit women-headed households in terms of generating more income and improving the livelihood of the children in terms of access to education and health services, better clothing and improved nutrition. Indicators are targeted in terms of quantity (number of trainees, quality (skill) target group (beneficiaries), time needed for training (duration), location (site) and project life.

13.2.4 Project appraisal during preparation and formulation

Project preparation and formulation involves a number of sequential appraisals, which justifies a project's viability before it is approved and implemented:

- Feasibility analysis /study
- Economic: cost-benefit analysis
- Social cost: benefit analysis
- Environmental impact analysis

Feasibility analysis - Project feasibility is a test where the viability of the investment is evaluated based on comprehensive secondary data. At this stage, the identified project is examined to determine whether it is feasible or not, and to provide stakeholders with a basis for deciding whether to proceed with the project.

- Does the project conform to the development and environmental objectives and priorities of the specific country?
- Is the project technically sound?
- Is the project administratively manageable?
- Is there adequate demand for the project's outputs?
- Is the project financially justifiable and feasible?
- Is the project likely to be sustained beyond the intervention period?
- Does the project address gender issues?

Market feasibility: a market feasibility study aims to assess the sales potential of a proposed project's product.

Technical feasibility: In analyzing the technical feasibility of a project, the following factors need to be analyzed: availability of commercially exploited technology and transferability of the technology into the local environment.

Financial feasibility: From a financial point of view, investment is a long-term commitment of resources made with the objective of producing and obtaining net profit in the future. In order to judge a project from a financial angle, detailed information about several factors is required. A project is said to be financially feasible if the sum of the discounted cash flow /revenue is greater than the sum of the discounted cash outflow (both current and capital investment expenditure) over the life of the project (i.e. net present value > 0)

13.2.5 Economic cost-benefit analysis

In financial analysis, the difference between the cash inflow and outflow shows whether the project is financially feasibility and can be implemented. Such an analysis reflects the point of view of the project promoter or owner of the project. Wider national, social and environmental aspects are not taken into account at this stage. A project's financial profitability is therefore of limited value. A separate economic cost-benefit analysis is required in order to justify a project's feasibility, where both benefits and costs are valued from the point of view of the economy as a whole using shadow prices.

13.2.6 Social cost-benefit analysis

Both financial and economic analyses focus on efficiency of resource allocation as the sole criterion of attractiveness in the appraisal of a project. However, the distribution of benefits among different social groups, different regions and different uses in terms of consumption and savings is also an important issue in government development policy. For example, assume a project has the same financial and economic benefits if implemented in either a poor or a rich region of a country. Based on social equity (redistribution of income), the project is more socially attractive/desirable if it is implemented in the poor region because it will narrow the uneven distribution of income between the regions. In general, many public projects such as rural transport, rural electrification, rural water supply, and rural health services where the majority of the poor population of a developing country lives tend to be socially attractive.

13.2.7 Environmental impact analysis

Project appraisal has thus to take into consideration the impact of a project on the environment (water, soil, air, forest, wildlife, etc.). Environmental impact analysis should be done particularly for major projects which have significant environmental implications, such as irrigation schemes, and environmentally polluting industries such as bulk drugs, chemicals, leather processing, brick factories, dairy farms, etc. From an environmental point of view, projects are not only judged by their rate of return but also by their impacts on the environment. When environmental protection is one of the major objectives of a government, a project will be more attractive if it has the minimum negative impact on the environment, i.e. if it is the least polluting of the water, soil and air or does not have adverse affect on a country's forests and wildlife resources. To this end, investors will be required to respect the environmental policy of a country and to formulate company-level environmental policies and honour these policies to safeguard the environment.

13.3 Implementation and monitoring

13.3.1 Implementation

Implementation is the most important part of the project cycle. This stage witnesses the birth of the project. At this stage, the project, which was previously on paper, becomes a reality. It mainly involves setting up the project facilities. There are other special jobs in project implementation such as project organization, project management, and site supervision. Translating an SLM proposal into a concrete project might prove to be complex and time-consuming. The project leader has to ensure that the project is implemented as per the specification and involvement, planning and appraisal stage. The success of project implementation often depends on the quality of project planning before the project begins. The following checklist can be used as an SLM project manager's reference guide in planning for effective and efficient project implementation.

6. Have all relevant stakeholders been consulted and are they familiar with the project?
7. Have the roles and responsibilities of implementing partners clearly established?
8. Do the stakeholders have the technical and human capacities to undertake the project?
9. Have the priorities and needs of a country been incorporated in the project?
10. Do the relevant government bodies support project implementation?
11. Has a gender interest been incorporated in the project document?
12. Has the linkage to poverty alleviation been analyzed and incorporated?

Important stages of project implementation

1. Approval of government authority: this involves submission of project documents and obtaining approval for implementation;
2. Project engineering design: this is the preparation of blueprints and plant designs, site engineering, and selection of specific machinery and equipment (if needed);
3. Negotiation and contracting: is concerned with negotiation and drawing up of legal contracts with respect to project financing, acquisition of technology, construction of building and civil works, provision of utilities, supply of machinery and equipment, marketing arrangements, follow-up, deployment of manpower by contractor, handing over the site to the contractor, finalization of sources of financing for procurement of the required facilities;
4. Project operations – (e.g. construction): this is concerned with site preparation groundwork, construction of buildings, erection and installation of machinery and equipment, inspection, test trials, i.e. preliminary acceptance test of SWC technologies and approaches and performance guarantees;
5. Plant commissioning – at this stage the project starts.

13.3.2 Monitoring

A major aspect of project implementation is monitoring. Monitoring is a continuous process that aims primarily to provide project management and give the main stakeholders early indications of progress towards achieving project objectives. Project managers monitor expenditure, activities, output completion and workflows against their implementation plans, output delivery and the progress made towards achieving the results and objectives according to their anticipated milestones or benchmarks.

Progress analysis during project implementation through monitoring serves to validate the initial assessment of relevance, effectiveness and efficiency or to fill in the gaps. It may also detect early signs of the project's success or failure. Monitoring assists project managers and implementing agencies to address any impediments to progress and make adjustments so that results can be achieved within the designated timeframe.

13.4 Evaluation

Evaluation is a time-bound exercise that attempts to assess the relevance, performance and success of current or completed projects, systematically and objectively. Evaluation determines to what extent the project has been successful in terms of its impact, effectiveness, sustainability of results, and contribution to capacity development and improvement of livelihoods. Evaluation can be done midpoint or at the end of the project. Evaluations at the midpoint of the project also provide timely learning that can suggest mid-course adjustments. When carried out after project completion, evaluation can contribute to extracting lessons to be applied in other projects.

13.5 Approaching sustainability

The term 'sustainable development' and its component 'sustainable land management (SLM)' have been receiving increasing attention in development co-operation and at the global level. However, practical tools that can help local users and multi-disciplinary teams to work together and apply these general concepts at the local to regional levels have emerged only very recently. Hans Hurni (2000)[1] argues that only a comprehensive, participatory approach involving all stakeholders at all levels will have the potential to develop locally useful solutions within a favourable, i.e. 'enabling' institutional environment. Assessment tools require transdisciplinary methods that involve natural, social, and political sciences as well as local knowledge systems. Support services for SLM activities must include monitoring and impact assessment, experimentation with innovative ideas, resource assessment, information, and training.

13.5.1 Sustainability dimensions

Blueprint definitions will not help to determine whether land management in a real-life context – e.g. that of a development project – is moving towards or away from sustainability. In our experience, SLM is best approached through the social/institutional, economic, and ecological dimensions of sustainability. For a rural development project, this means that land management becomes more sustainable if progress can be made in all dimensions and at several levels at the same time. In other words, an SLM project can be considered sustainable when the outputs are socially acceptable, economically feasible and ecologically sound. Project formulation is a process whereby the project promoter makes an objective and independent assessment of the various aspects of an investment proposition or a project idea to determine its viability. It is a systematic examination of the technical, financial, economic, social and environmental viability of the project.

13.6 The need for a multi-level-multi-stakeholder approach

Sustainable Land Management (SLM) aims at ensuring optimal use of land resources for the benefit of present and future generations. Often, it follows land-user-driven and participatory approaches to achieve this aim. Integrated use of natural resources at ecosystem and farming systems levels as well as multilevel and multi-stakeholder involvement is crucial, too. The same holds true for targeted policy and institutional support, including development of incentive mechanisms for SLM adoption and income generation at the local level.

Generally, the application of SLM techniques and approaches requires collaboration and partnership at all levels. It should involve land users, technical experts and policy-makers to ensure that the causes of the land degradation and corrective measures are properly identified. Moreover, it should ensure that the policy and regulatory environment enables the adoption of the most appropriate land management measures.

SLM is very important for sustainable development and plays a key role in harmonizing the complementary goals of production and environmental protection. It involves maintaining long-term productivity of ecosystem functions (such as land, water, and biodiversity) and increasing productivity (quality, quantity and diversity) of goods and services. In order to implement the sustained combination of these SLM objectives, it is indispensable to understand drivers and causes of land degradation and to take into account issues of current and emerging risks because SLM encompasses other established approaches such as soil and water conservation, natural resources management, and integrated ecosystem management and involves a holistic approach to achieving productive and healthy ecosystems by integrating social, economic, physical and biological needs and values. Moreover, it contributes to sustainable and rural development and requires great attention in national, sub- national and community level programmes and investments. Thus, it requires an understanding of the:

- Natural resource characteristics of individual ecosystems and ecosystem processes (e.g. climate, soils, water, flora and fauna);
- Socio-economic and cultural characteristics of those who live in a particular area and depend on the natural resources of individual ecosystems (population, household composition, cultural beliefs, livelihood strategies, income, education levels, etc);
- Environmental functions and services provided by healthy ecosystems (watershed protection, maintenance of soil fertility, carbon sequestration, micro-climate amelioration, bio-diversity preservation etc); and

- A multitude of constraints on, and opportunities for, the sustainable utilisation of an ecosystem's natural resources to meet peoples' welfare and economic needs. Such basic needs include food, water, fuel, shelter, medicine, income, and recreation.

13.7 The role of science in SLM

In some cases, local societies are considered a barrier to development and modernisation. Local people are characterised as a problem because they will usually wish to adhere to their existing ways of life; and local cultures are prejudiced by myth and irrational practices. This view tends to be perpetuated by modern science, presented as a body of "fact" rationally deduced and as the only basis for economic development. It is a science that is based upon high technology solutions, external inputs, and the results of experiments carried out under controlled and usually temperate conditions. Häusler (1995[2]) has presented a useful schema for distinguishing two types of knowledge: Western scientific and indigenous knowledge.

- **Western scientific knowledge (episteme**) analytical, impersonal, universal, cerebral, logically deducted from self-evident principles, communicated in writing;
- **Indigenous knowledge (techne)** based upon experience, personal, particular, intuitive, implicit, integral, and orally communicated.

Under some conditions, interesting interactions may occur between the store of indigenous knowledge and the outputs of Western science that give rise to land-use systems that are apparently sustainable ecologically and appreciated locally (Apfel-Marglin and Marglin 1990[3]). The *Mucuna pruriens* case from Brazil described earlier is one such beneficial utilisation of both knowledge systems. However, conceptually, the two systems provide conflicting analyses and mutually contradictory results. In its relations with developing countries and local cultures, science utterly brands society as '`backward," "primitive," and requiring "appropriate technology." Developing country professionals often take this last term as especially demeaning; it implies that only simple technologies, perhaps technologies that have now been long superseded in the West, are to be promoted, with the implication that local people are too ignorant or incapable of coping with better. However, evidence from local societies themselves, when faced with change brought about by uncontrollable factors such as drought or other sources such as conflict, population pressure, or economic crises is important. It would be wrong to say that peasant populations have all the answers, and that they can cope with all such pressures. Obviously, they cannot face such harsh circumstance that test the very survival of individuals. Take, for example, the social dynamics of groups vulnerable to drought in semi-arid areas (Barraclough 1995[4]): pastoralists and agriculturalists resort to a variety of interesting and intricate strategies, even though many of the alternatives may look distinctly unattractive to them. These coping strategies may include:

Adapting production and consumption patterns: pastoralists in the Sahel have developed sophisticated land-management systems in order to spread the risks associated with drought (Behnke and Scoones 1992[5]). These systems include herd diversification and the maintenance of large numbers of so-called "low quality" animals.

Adopting social structures to assist risk aversion: traditionally, in many pastoral communities, reciprocal obligations between different groups have become institutionalized in order to share risk. In other cases, society has been propelled into private land ownership and intensification of crop production.

Finding alternative livelihoods: peasants can be extremely entrepreneurial in discovering new ways to seek a living. Sometimes, these ways are illegal: growing drugs, smuggling, poaching, and distilling spirits. However, there are also many examples of diversification of activities into new crops, village-based industry, and value-added processing of plants and animals.

13.8 Developing an actor-oriented perspective

Land management for sustainable development is not about finding the right science and the new technology that will solve our problems. The "technology toolkit" approach to agricultural development in developing countries has created as many problems as it has provided solutions. In some cases, it has been bypassed by development, because of inaccessibility to scientifically determined solutions and the inappropriateness of solutions to particular circumstances. The new agenda of farmer participatory land management is about matching existing knowledge - formal and informal - with the vast array of potential combinations of environmental circumstances and socio-cultural and economic situations.

Figure 13.2 Actor oriented pearl millet program in Shebek, Eritrea (Photo by Paul Roden)

For centuries, people have been earning livelihoods from difficult environments. They have been learning all the time; and the products of that learning have been handed down in the form of custom and practice. This accumulated knowledge cannot be reproduced today in modern scientific experiments because of the enormous number of possible permutations of circumstances and the complexity of relevant variables, which affect the outcome of agricultural production. What are the key components of a farmer-participatory approach to sustainable land management? Adapted from the listing of Hinchcliffe et al. (1995[6]), formulated for the particular case of participatory watershed development, we may highlight differences between participatory and conventional approaches as mentioned in Table 13.2.

Table 13.2 Differences between participatory and conventional approaches

Participatory approach	Conventional approach
Local communities are fully and actively involved in the analysis of their land-management problems	Communities may be consulted about their views, but professionals do the analysis.
External support organization is a facilitator of analysis and a catalyst for action. For sustainability, it may assist with creation of local institutions and user groups to manage aspects of the natural resources, and encourage such institutions to develop their own procedures, rules, capital, and operating criteria in order to ensure continuance after external support is withdrawn	Donor support creates new, imposed, and externally financed structures with little linkage to local community or to local government
Information dissemination is by farmer-to-farmer extension and informal networking; the object is to create greater self-reliance and closer collaboration and community dependency; extension agents act as facilitators.	Extension agents through key informants, demonstration plots, field visits, and the media transfer information; the aim is to convince farmers of the importance and utility of the information.
Flexibility and adaptation to local circumstances pervade any recommended technologies and selected crops; individual farmer needs and criteria for choice override technical specifications.	Development of blueprint solutions and recommended practices by professional staff for local people.
Emphasis on sustainability, equity, and access to improvements, not on short-term benefits. Benefits which occur without subsidies, inducements, and external assistance are preferred.	Adoption criteria include technical efficiency, production maximisation, and cost-benefit analysis.

Source: Adapted from Hinchcliffe, 1995

The challenge in land management for sustainable development is to harness the knowledge that is right for the people, and the environment – a knowledge that has been constructed from a diverse and complex set of causalities, and one that has withstood a society that is placing increasing demands on natural resources. Some may conclude from this listing that science is usurped and that myth and local knowledge take its place. However, science has its mythology too, in issues related to conclusions based upon poor measurement, inadequate data, and simple mistakes (e.g. the case of soil erosion (Stocking 1995a[7]). The role of science has to be that of observer rather than manipulator, becoming more socially aware, and accepting interdisciplinary social science as an equal in deriving applicable conclusions, rejecting technical fixes and replacing them with tentative hypotheses and lists of optional strategies. Such a role is less satisfying to those who wish to pontificate. Therefore, the style of science needs to be different – less dictatorial, provisional, greater willingness to learn from others, and less inclined to force its own recommendations.

Given such changes, which are implied in a farmer-participatory approach to land management, there still exists a crucial role for science to describe, understand, and seek explanations for the practices and views of land users. The project searches for ways farmers have learnt how to cope with environmental change and other pressures, principally through utilising variety and diversity in the natural environment. Biodiversity is seen in many small-farm management strategies in the ways that people promote it in their own lands and conserve genetic pools to cover for an uncertain and unpredictable future. PLEC highlights the necessary and radically different approach to science by working with anthropology, the humanities, and socio-economics, as well as interdisciplinary science to find a much more realistic understanding of the complexities of the real world in which we all operate.

13.9 Questions and issues for debate

Suppose you are part of an SLM team of scientists who would like to support the launch of a project for tree planting on the central highlands of Eritrea:

1. List all the stakeholders which should be incorporated in the detailed identifying process: Who are they? How do you avoid missing out one of them (micro-, meso- and macro-level)?
2. What are the questions that should be clarified with each of these stakeholders? (can be done in student group work, each group taking one of the levels mentioned in point 1 above, formulating the questions, and then presenting them to the plenary).

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Chapter 14

Collection of Socio-economic Information for Project Design and Implementation

14.1 Participatory Rural Appraisal (PRA) – Participatory Learning Approach (PLA)

SLM is a common concern; solutions that promote more sustainable action require the active involvement of the entire community, the administration, and development agencies and NGOs active in SLM. Collective action is possible only when all stakeholders develop a clear common understanding of the issues at stake. Relating to information about local communities, there is a general impression that obtaining data is a complicated process using methods such as formal surveys, questionnaires and analyses. Nonetheless, data can be collected from simple methods such as talking to people, walking through the community, and direct observation of the situation on the ground (Bhandrari, 2003[1]). The issue to be addressed is how to collect relevant data quickly and with reasonable cost. PRA and PLW are two related approaches that achieve these aims.

Participatory rural Appraisal (PRA) is a method of data collection commonly associated with action research. It involves local people and outsiders from different sectors and disciplines. Outsiders involve local people in analysing information, allowing them to take responsibility and share their knowledge for planning and action. PRA was developed as a reaction against lengthy academic exercises involving expensive questionnaire surveys on the one hand, and desk-based assessments with cursory fact-finding familiarisation field visits (often referred to as development tourism). PRA thus lies midway between desk-based designs and the tradition of academic research.

14.1.1 Principles of PRA and PLA

Different practitioners may advocate different principles but most would agree to include the following (Conway 1989[2], Bhandrari, 2003): Participatory Rural Appraisal (PRA) can be described as a method of research which empowers local communities to investigate, analyse and prioritise existing problems. Community empowerment, in this sense, is not limited to the analysis of problems alone, but also enables communities to seek appropriate solutions to the problem. PRA is based on the belief that sustainable development can be achieved through the empowerment of local communities to plan and manage the development of their own environment. In PRA mode, the role of professionals is to be learners, convenors, catalysts and facilitators while local people play a vital role in identification and analyses. The following are suggested practices that should be followed in PRA work.

Using optimal ignorance: this refers to the importance of knowing what is not worth knowing. It avoids unnecessary details and irrelevant data. It does not measure more precisely than needed. It optimises trade-off between quality, relevance, accuracy and timeliness.

Offsetting biases: especially in relation to rural development, it is important to be relaxed and not rush; listening not lecturing, and probing instead of passing on to the next topic are important; be unimposing instead of important, and seek out the poorer people and their concerns, without forgetting the rich (and influential). Try to get opinions from all groups.

Triangulation: using more than one and often three sources of information to cross-check answers.

Learning from and with rural people: directly, on the site, and face to face, learning about indigenous physical, technical and social knowledge relating to SLM. Use six helpers: What happens? Why? Who is involved? How does it happen, where and when? Never forget that farmers, for example, are also busy people, so try to meet people when it suits them. Keep in mind that there are at least four squares of knowledge - the challenge is to consider all of them!

Things they know and we know. Shared knowledge (1)	**Things they know but we do not know.** Local, indigenous knowledge (3)
Things we know but they do not know. (expert knowledge)(2)	**Things they do not know and we do not know** (4)

Learning rapidly and progressively: This involves conscious exploration, flexible uses of methods, opportunism, improvisation, iteration, and cross-checking - not following a blueprint, but adapting through a learning process based on the local setting and local informants

PRA, therefore, has the following distinctive features:

Iterative: Goals and objectives are modified as the team realises what is or is not relevant. The newly generated information helps to set the agenda for the later stages of the analyses. This involves the principle of "learning as you go".

Innovative: Techniques are developed for a particular situation depending on the skills and knowledge available.

Interactive: The team and disciplines combine together in a way that fosters innovation and is interdisciplinary. A system perspective helps make communication easy.

Informal: Focuses on partly structured and informal interviews and discussions.

In the community: Learning takes place largely in the field, or immediately after, or in workshops. Community perspectives are used to help find differences in field conditions.

In the literature, PRA is often used interchangeably with RRA (Rapid Rural Appraisal). However RRA and PRA are different despite the similarity in the methods used. Their difference lies in their different purposes and procedures. The most important differences are described in Table 14.1.

Table 14.1 Difference between RRA and PRA

Rapid Rural Appraisal (RRA)	Participatory Rural Appraisal (PRA)
1. In RRA information is elicited and extracted by outsiders. In other words, people go to rural areas, obtain information, and then bring it away to process and analyse.	1. In PRA information is owned and shared by local people. Outsiders (professionals) go to rural areas, but they facilitate rural people in collection, presentation and analyses of information by themselves.
2. The information is owned by outsiders and often shared with rural people.	2. The information is owned by rural people but usually shared with outsiders in project design and implementation.
3. Extractive in nature (data collection)	3. Learning with local people (empowerment)
4. Elicited	4. Information owned by rural people but shared with outsiders.
5. Main actors are outsiders	5. Main actors are local people
6. Long-term outcome: plans, projects, and publications	6. Long-term outcome: sustainable local action

14.1.2 The PRA and PLA toolkit - an overview

Typically, PRA and PLA involve a wide range of sources of information or tools (*Figure 14.1*).

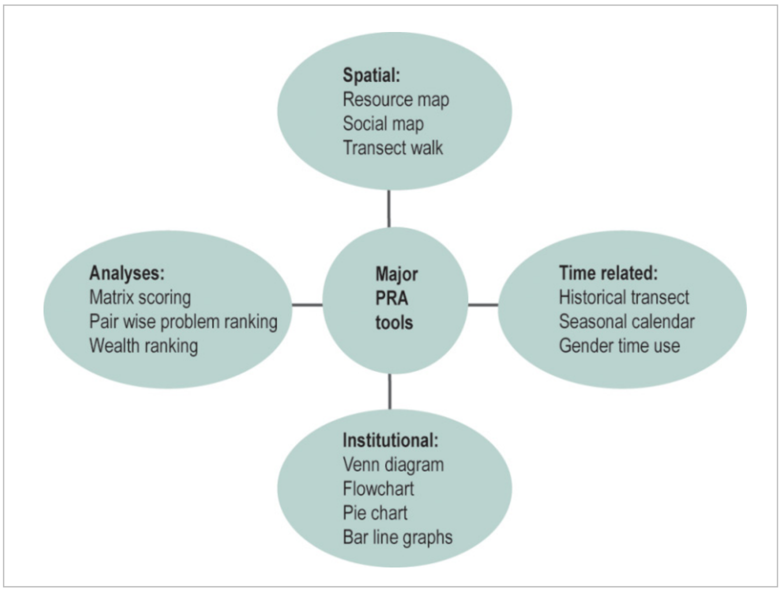

Figure 14.1 Tools commonly used in PRA or PLA (SLM Eritrea)

Secondary data review: Books, files, reports, news, articles, maps etc.

Observation: Direct and participant observation, walking with people, do it yourself (help out a farmer for one day), and semi-structured interviews. If interviews are carried out, they are informal, guided interview sessions where only some questions are predetermined and new questions arise during the interview in response to answers from the resource persons (i.e. those interviewed). The resource persons may be individual farmers or a family, a group of key informants, or members of a community meeting; interviews can be single or multiple (sequence) interviews. The interviews can also be conducted by a multidisciplinary team or by 2-4 persons, and the discussion is led by different people on different occasions depending on competence and topics.

Analytical game: This is quick game to find out a group's list of priorities, performances, ranking, scoring or stratification.

Stories and portraits: a colourful description of the situation on the ground, local history, and trend analyses, etc.

Diagrams: maps, aerial photographs, transect walks, seasonal calendar, Venn diagrams, historical profiles, ethno history, time lines, etc.

Workshops: locals and outsiders are brought together for intense discussion of information and ideas.

Analysing data: It is difficult to suggest a technique for analysing the data and information in PRA, as qualitative as well as quantitative methods are employed. Each technique has its own method of analysis. If complex data are analysed, then every effort should be made to present them in non-technical language. Data and information should be arranged according to category, issues, topic, sub-topic, or question.

For qualitative methods, categorization or grouping of data should be done and the data should be analysed according to category; the category should be inclusive and mutually exclusive. Data could be coded according to inductive category (for open-ended questions) and deductive category for (e.g. farmer, farm worker, non-farmer etc.).

For quantitative methods, simple statistical techniques such as mean, mode, median (which are measures of central tendency), range, variance and standard deviation (measures of dispersion), frequencies, and percentages can be used. Pearson's coefficient of correlation, Chi square, multivariate regression and t-tests can be employed if required.

Report writing: Include some products from field activities as illustrations, such as outputs of analytical games, boxes with good examples, pictures or graphs when necessary. Follow the sequence (field note, fine note and final note). At the end of the day, all team members sit together and consolidate the field notes into fine notes (detailed clearly written and consolidated field notes). The fine note could be structured in chronological order (if details are needed), or according to the topic (if time constraints) or according to the questions or topics discussed

The report should consist of the following:

The problem statement (including the conceptual framework)

- Purpose and scope
- Methodology
- Data and finding
- Implication of the finding
- Summary
- Reference and appendices

What I hear I forget
What I see I remember and
What I do I know.

(Chinese proverb)

Matrix scoring

The aim of matrix scoring is to analyze preferences and to compare different elements against a range of criteria. The method provokes discussion of criteria for selection and discovers individuals' or groups' relative priorities. For example, preference for tree species could be discussed in terms of fodder, shade, fuel, fruit, cost, availability and aesthetics (*Table 14.2*).

Table 14.2 Matrix scoring done by the people of Durko, Eritrea

Species	Fuel	Fodder	Construction	Farm implement	Availability
Adansonia digitata	XX	XXXX	XXXX	XXXX	X
Eucalyptus spp.	XXX	X	XXXXX	XXXXXX	XXXXX
Junipers procera	X	X	XXX	XX	X
Acacia albida	XX	XX	XX	XXX	XXX

Source: Ogbazghi

Pair-wise ranking

This method is often used as a precursor to detailed matrix ranking. For example, crops could be compared for their availability to farmers. If wheat is more available than barley, wheat gets one point, and then points are added, and the crops ranked according to their number of points (*Table 14.3*).

Table 14.3 Pair-wise ranking to compare crops according to their availability (Sesah, Zoba Debub)

Crop	Wheat	Maize	Barley	Sorghum	Millet	Points	Rank
Wheat	–					3	2
Maize	Wheat	–				2	3
Barley	Barley	Barley	–			4	1
Sorghum	Wheat	Maize	Barley	–		1	4
Millet	Wheat	Maize	Barley	Sorghum	–	0	5

Source: Ogbazghi

Percentage ranking

This method generates heated discussions among the group that uses it, before the participants reach consensus – the task is to distribute one hundred pebbles according to their preferences. Example: The problems of a village can be listed and discussed to determine how serious they are – i.e. how participants rank them relative to each other.

Table 14.4 Percentage ranking for problem analysis done by elders at Adi-Gebru

Problems	No of pebbles	Rank
Shortage of water	45	1
Lack of high school	6	4
Lack of clinic	13	3
Erosion	25	2
Famine	6	4
Deforestation	3	6
Lack of mill	2	7

Source: Ogbazghi

Transect walk

This serves to make a spatial analysis of the environment and its conditions (*see Figure 14.2*). The spatial analysis can be combined with a temporal analysis, which shows that resource or resource use dynamics have taken place in a given space, for example a village territory. Transects are always done with local people. Historical transects illustrate changes over time, and help explain why these changes happened, and what their consequences are.

Land use	- Grazing land - Few trees	- Grazing area - Some crop fields	- Dry river bed	- Village area	- Mostly crop field - Some grazing area in between	- Grazing area - Few trees
Problem	- Steep slopes, heavily eroded - Exposed rocks	- Too dry and rocky for crop production	- Widening river bed	- One water well for five villages	- Heavy erosion - Gullies through field	- Steep slopes - Heavily eroded area - Exposed rocks
Intervention	- Terracing needed to protect fields at bottom	- Crop terracing could enrich soil fertility	- Tree planting along river bed	- Additional water wells will be needed at the area	- Crop terracing could prevent erosion and enrich soil fertility	- Terracing needed to protect fields below

Figure 14.2 Graph from a transect walk showing different land use and land cover of a village

Time lines

Time lines deal with temporal analysis on a historical (non-spatial) basis. They outline and analyse key events. Time lines can examine both general issues and specific activities and consider phases or periods of activity/ inactivity as well as individual events. They promote discussion of events, consequences and associated issues in historical context. Dates do not need to be absolute; events can be placed in chronological order. The list below is an example of a time line – in this case of Eritrea as a whole. Such time lines can be established for villages, for households, or for individual persons.

Box 14.1 Eritrean time line

1557 -1875 Turkish occupation
1857 – 1890 Egyptian occupation
1890 – 1941 Italian colonialism
1942 – 1952 British occupation
1952 -1962 Federation with Ethiopia
1961 Start of the Eritrean armed struggle
1967 Exodus of people from Barka to the Sudan
1970 Birth of EPLF
1970 Mass genocide in Ona and Besidira, etc
1978 Strategic retreat of EPLF
1981 The dissolving of the Eritrea liberation front (ELF)
1982 6th offensive of Derg
1987 2nd congress of the EPLF
1988 Defeat of Nadew front (Nacfa front)
1988 Genocide Sheeb
1990 Liberation of Massawa
1990 Feb: areal bombardment of Massawa
1991 May 24th liberation of Eritrea
1991 June 20th first martyrs' day
1993 Eritrean referendum: Eritrea recognised as a nation
1993 The first Eritrean president elected
1994 3rd congress of EPLF (February)
1994 Land proclamation

Seasonal calendars

These show the sequence of activities, for example in farming. The calendars are useful in identifying planting and harvesting times, labour constraints, and marketing opportunities. Changes can be reproduced on a seasonal or monthly basis, indicating relative variation through the year.

Gender clocks; use of time (daily schedules)

Temporal analysis here is done on a gender basis (showing activities of women and men separately), or on a daily basis. For example, daily schedules are used to identify daily labour patterns and other activities carried out during the day (or the night). Presentation can be in the form of a circle or a simple table, such as the one shown above for time lines.

14.2 Baseline studies

Baseline studies combine tools and methods of PRA and PLA, and often combine these with a livelihood approach (Chapter 6). They attempt to establish a sustainability benchmark (environmental, economic, and socio-cultural aspects) against which future change can be measured. These studies therefore involve investigation into physical, chemical, biological, and socioeconomic parameters. Habitat maps are also useful tools with which to assist planning for development and are essential for various resource management purposes. In Eritrea, some baseline studies were carried out (e.g. Stillhardt and Frey 2001[3], Frey et al., 1997[4]). In most cases, the aims of baseline studies are to:

- Produce an exemplary knowledge base for rural livelihood (analysis of status).
- Produce data that can serve as a basis for future monitoring (detecting dynamics and trends).
- Provide local as well as potential investors, development agencies, and others with recommendations for further actions to promote sustainable development.

Baseline studies typically involve a multidisciplinary team of experts (taxonomists, soil scientists, socioeconomics and agricultural experts). In resource mapping, the latest image processing and GIS software can be used to ensure that the data set is up-to-date. The baseline studies can involve gathering social and economic data through rapid and participatory rural appraisal that has added value for beneficiaries for improving awareness of development among the local communities

14.2.1 Example of baseline studies on rural areas in Eritrea

Baseline on Deki Lefay

The goal of this baseline survey was to obtain a sound basis of information as efficiently as possible. From methodological and conceptual points of view, the survey was characterized as a 'Sustainable Development Appraisal' (Hurni, Ludi, 1997 cited in Frey et al, 1997). This tool was intended to provide a basis for improving the process of human development for better sustainability in the study area. It further serves as a baseline for monitoring both changes induced by internal development as well as by the impact of external action. It integrates the external view based on transdisciplinary scientific approaches with the indigenous knowledge base. One of the most important field methods used was discussions and interviews on transect walks with the local people of Deki Lefay (Frey et al., 1997). From a broad set of methods, the following were chosen:

- In-depth interviews for sample household studies
- Interviews with key persons and focus groups
- Informal discussions
- Village meetings/conferences
- Transect walks

- Observations
- Daily reviews within research team
- Mapping and participatory mapping (land cover, land use, natural vegetation, water resources, soils, geology and mineralogy)
- Laboratory analysis
- Assessment of soil erosion (magnitude, susceptibility)
- Measurements (locations with a geographical positioning system)
- Modelling (digital terrain model with a geographical information system (GIS)).
- Use of different classification systems (soil, vegetation, mineralogy)
- Data analysis with the appropriate scientific method

In addition to the fieldwork, supplementary scientific analysis and information gathering was done for analysis of maps and secondary literature, contacts and consultations with resource persons, and joint meetings (with administration, school teachers, etc).

Baseline on Adi Behnuna

A study on tradition in transition relating to rural livelihoods was carried out in Adi Behnuna in the Zoba Debub (Stillhardt and Frey, 2001). The aims of this study were to produce an exemplary knowledge base on rural livelihoods in these areas (analysis of status), to produce data that can serve as a basis for future monitoring (detecting dynamics and trends), and to provide the administration of the Zoba and Subzoba, as well as potential investors, development agencies, and others with recommendations for further actions towards sustainable development.

Figure 14.3 *Women of Adi Behnuna collecting scarce fire wood (Photo by Paul Roden)*

The methodological and conceptual approach of the baseline study followed the principles of the Sustainable Development Appraisal SDA (Hurni and Ludi, 2000[5]). This tool aims to provide a basis for improving the process of human development towards greater sustainability in a defined area. It further serves as a baseline for monitoring changes over time. Field work was carried out during a three-week period by the study team consisting of a multidisciplinary team. During this exploratory field research the following methods were used:

- Village meetings/conferences
- Interviews with key persons and focus groups Informal discussions
- Meetings with local administrators and Subzoba administration
- In-depth interviews with individuals and smaller groups
- Transect walks and Observations
- Cross-checking of information and preliminary results
- Wealth ranking
- Satellite image interpretation
- Mapping and participatory mapping
- Participant observation: living in the village, chatting, celebrating, relaxing, working, sharing meals, etc.

In addition to field work, other methods were applied (laboratory analysis (soil samples), modelling (GIS), analysis of aerial photos (1964) and of satellite imagery (2000), as well as analysis of secondary literature, contacts, consultations, meetings, etc.

A crucial methodological consideration is the fact that the two foreign (Swiss) experts had already conducted several studies like this one in other countries as well as in Eritrea. Their methodological experience and knowledge of the livelihood systems of Eritrean peasant societies enabled more efficient field work, with an on-going planning process in which intuition, shared experience and continuous review helped to produce accurate results and sound, good-quality data. Of course the field work would not have been possible without the knowledge and the assistance of local field assistants, all the other facilitators, and the open collaboration of the local population and the local and regional administration.

14.3 Stakeholder analysis

Stakeholders are defined as those individuals, farmers, groups, and village communities that perceive themselves to be impacted, either positively or negatively, by a decision or outcome and therefore have an interest or stake in that decision, for example relating to land management. In natural resource management, stakeholders typically include resource users, businesses, local residents, interested groups and NGOs, government agencies, community or civic organizations, local people, and academic and research institutions. A stakeholder analysis is generally an integral part of a baseline study, or of a PRA or PLA exercise, and uses the tools and methods described earlier in this Chapter.

14.3.1 Why a stakeholder analysis?

A stakeholder analysis helps to identify the stakeholders in a particular issue and to understand their motivations, desires, influence, and views of future development. Stakeholder analysis can be done quite informally, or conducted more rigorously if great detail on stakeholders is needed. For example, simply identifying and inviting stakeholders may be all that is needed for a small group discussion on a non-controversial topic. For larger group discussions, discussions on controversial topics, decision-making processes, or detailed assessments of the state of natural resources, however, in-depth stakeholder analysis may be necessary. Detailed information gained through a more formal stakeholder analysis can be used in a variety of ways, from deciding where and when to schedule a single stakeholder meeting, to designing and tailoring long-term collaborative and participatory processes in which stakeholders play a key role.

14.3.2 Steps in stakeholder analyses

In relation to sustainable land management, a stakeholder analysis begins with identification of the stakeholders in the situation of a given village area or local community. This is done using local knowledge of the situation, analysis of stakeholder participation in similar issues, direct interaction with the people in order to identify stakeholders, or allowing stakeholders to self-identify. If greater detail is needed, social science methods may be employed to gain a better understanding of the stakeholders. This include interviews, surveys, focus groups, observation, content analysis of public meeting records and other secondary information, and other methods may be used to generate detailed descriptions of individual stakeholders or the groups that they represent. In-depth stakeholder analyses may use a combination of social science methods and can help address questions concerning:

- Basic stakeholder characteristics
- Affiliation, position
- Level of influence
- Likely degree of involvement in the issue that organized groups of stakeholders represent, for example the group's mission, membership, key contacts, history, authority, scope of influence, and likely degree of involvement,
- Position and interest with regard to an issue (e.g. improving water quality, preserving aesthetics, increasing property value, soil and water conservation, tree planting, etc).

Box 14.2 Strengths and limitations of stakeholder analyses

- Interaction with stakeholders during analysis may help to build rapport and generate public support, and can help design more efficient and effective collaborative processes and more effective programmes including land management.
- Expert consultation may be required for in-depth analysis. Individuals may not accurately represent or have the support of groups to which they belong. Analysis does not necessarily help to predict stakeholder behaviour. Results of analysis will likely need to be revisited after some time has elapsed

A basic stakeholder analysis can be carried out with little more than access to secondary information, or by access to someone with an expert understanding of the situation. In-depth stakeholder analyses that employ social science methods and demand interaction with stakeholders may require consultation or guidance from a social scientist and related tools/methods. Stakeholder analysis is a broadly applicable tool that is conducted using a variety of social science methods as described for PRA, PLA (above), and in Chapter 6 (livelihood approaches).

14.3.3 Wealth ranking as a tool used for stakeholder analysis

The following is an example based on experience collected in wealth rankings in rural communities in Eritrea. For the sake of simplicity, we limit the total number of households in our village to 50. Three groups of informants from the village - normally elderly men and women, who know the village inhabitants well, participate in the ranking.

- Informant group one: 3 men
- Informants group two: 4 women
- Informants group three: 5 persons below the age of 30: 3 women, of which one from a female-headed household, and 2 men

Step 1

Each informant group goes through all 50 households (each written by name on a card), to decide if they are rather wealthy or rather poor. Each informant group can decide how many categories between wealthy and poor they want to create. Each category has its own pile of cards. Ask each informant group to go through all households, and put them on one pile on which they agree. It is important to listen to the arguments for the group's decision, because this informs us about which assets local communities consider important and which not! Once this step is completed, you can prepare a spread sheet as show in Table 14.5

Table 14.5 Field sheets used for collecting the information from the 3 informant groups.

Wealth ranking group 1			
Pile number	**Household Number (written on card)**	**Number of cards**	**Score (100/(number of piles)*pile number**
1 (wealthiest)	7, 8, 13, 20, 21, 28, 32, 40, 49	9	25
2	1, 2, 12, 24, 27, 30, 33, 39, 42, 44, 50	11	50
3	3, 5, 14, 23, 25, 31, 38, 43, 47, 48	10	75
4	4, 6, 9, 10, 11, 15, 16, 17, 18, 19, 22, 26, 29, 34, 35, 36, 37, 41, 45, 46	20	100
Unknown	none		
Remarks	HH no 37 was ranked only after long discussion HH no 13 is said to be a priest. He is well off but the criteria defined for wealth status do not fit his specific situation HH no 40 is the only car owner in the village		
Criteria for categorization			
Owning a pair of oxen			
Owning a car			
The number of different animals owned by the household			
The relation between people working in the field and the total number of people living in a household			
Obtaining income from own, non-agricultural business			
The age of the household head			

Wealth ranking group 2			
Pile Number	**Household Number (written on card)**	**Number of cards**	**Score**
1	1, 5, 7, 8, 13, 20, 27, 28 32, 33, 40	11	20
2	2, 11, 12, 23, 24, 30, 39, 42, 49, 50	10	40
3	3, 14, 31, 38, 41, 45, 47	7	60
4	4, 6, 19, 25, 26, 44	6	80
5	9, 10, 15, 16, 17, 18, 21, 22, 29, 34, 35, 36, 43, 46, 48	15	100
Unknown	HH no 37		
Remarks	Before ranking HH no 21, the women wanted to be sure that this information was confidential. The household head was known among women to treat his wife very badly. Discussions in this group were more intensive and gave more weight to the social status in the village than group 1		
Criteria for categorization			
Number of oxen			
Number of other animals			
Access to safe drinking water (and the distance to the source)			
Food security (number of months dependent on foreign help)			
Children in higher education			
Local social status of the household head			
Access to firewood			
Sex of the household head			

Wealth ranking group 3			
Pile Number	**Household Number (written on the card)**	**Number of cards**	**Score**
1	7, 8, 13, 17, 19, 27, 30, 31, 32, 40, 42, 43, 44, 49	14	33
2	2, 3, 5, 6, 12, 15, 16, 20, 21, 23, 24, 25, 26, 28, 33, 34, 36, 37, 41, 47,	20	66
3	1, 4, 9, 10, 11, 14, 18, 22, 29, 35, 38, 39, 45, 46, 48, 50	16	99
Unknown	None		
Remarks	The age of the household head as well as the age of his (male) children was an important criterion Having many daughters, especially of marital age, lowered the rank Female-headed households are per definition poor		
Criteria for categorization			
Number of oxen			
Number of other animals			
Relatives abroad supporting the household			
Food security			
Access to non-agricultural work (off-farm income)			
Sex of the household head			

Source: SLM Eritrea

Step 2: The ranking

Define the score for every ranked household as follows: [(100/number of wealth groups) * pile number]. With 4 piles (4 wealth groups) the following calculation results: [(100 / 4) * 1 or 2 or 3 or 4.

Write these results on a prepared sheet, as at the left (white) in the table below (*Table 14.6*).

Calculate the total and the mean of all 3 rankings

Table 14.6 The final ranking

Household number	Score wealth ranking 1	Score wealth ranking 2	Score wealth ranking 3	Total	Mean
1	50	20	99	169	56
2	50	40	66	156	52
3	75	60	66	201	67
4	100	80	99	279	93
5	75	20	66	161	54
6	100	80	66	246	82
7	25	20	33	78	26
8	25	20	33	78	26
9	100	100	99	299	100
10	100	100	99	299	100
11	100	40	99	239	80
12	50	40	66	156	52
13	25	20	33	78	26
14	75	60	99	234	78
15	100	100	66	266	89
16	100	100	66	266	89
17	100	100	33	233	78
18	100	100	99	299	100
19	100	80	33	213	71
20	25	20	66	111	37
21	25	100	66	191	64
22	100	100	99	299	100
23	75	40	66	181	60
24	50	40	66	156	52
25	75	80	66	221	74
26	100	80	66	246	82
27	50	20	33	103	34
28	25	20	66	111	37
29	100	100	99	299	100
30	50	40	33	123	41
31	75	60	33	168	56
32	25	20	33	78	26
33	50	40	33	123	41
34	100	100	66	266	89
35	100	100	99	299	100
36	100	100	66	266	89
37	100		66	166	55
38	75	60	99	234	78
39	50	40	99	189	63

Household number	Score wealth ranking 1	Score wealth ranking 2	Score wealth ranking 3	Total	Mean
7	25	20	33	78	26
8	25	20	33	78	26
13	25	20	33	78	26
32	25	20	33	78	26
40	25	20	33	78	26
49	25	40	33	98	33
27	50	20	33	103	34
20	25	20	66	111	37
28	25	20	66	111	37
30	50	40	33	123	41
33	50	40	33	123	41
42	50	40	33	123	41
2	50	40	66	156	52
12	50	40	66	156	52
24	50	40	66	156	52
5	75	20	66	161	54
44	50	80	33	163	54
37	100		66	166	55
31	75	60	33	168	56
1	50	20	99	169	56
23	75	40	66	181	60
39	50	40	99	189	63
50	50	40	99	189	63
21	25	100	66	191	64
3	75	60	66	201	67
47	75	60	66	201	67
43	75	100	33	208	69
19	100	80	33	213	71
25	75	80	66	221	74
41	100	60	66	226	75
17	100	100	33	233	78
14	75	60	99	234	78
38	75	60	99	234	78
11	100	40	99	239	80
6	100	80	66	246	82
26	100	80	66	246	82
45	100	60	99	259	86
15	100	100	66	266	89
16	100	100	66	266	89

40	25	20	33	78	26
41	100	60	66	226	75
42	50	40	33	123	41
43	75	100	33	208	69
44	50	80	33	163	54
45	100	60	99	259	86
46	100	100	99	299	100
47	75	60	66	201	67
48	75	100	99	274	91
49	25	40	33	98	33
50	50	40	99	189	63

34	100	100	66	266	89
36	100	100	66	266	89
48	75	100	99	274	91
4	100	80	99	279	93
9	100	100	99	299	100
10	100	100	99	299	100
18	100	100	99	299	100
22	100	100	99	299	100
29	100	100	99	299	100
35	100	100	99	299	100
46	100	100	99	299	100

Source: SLM Eritrea

Start a new table and rank the households according to the mean rank of the three rankings and build the wealth categories as follows: take the minimum value and the maximum value of the row [mean], calculate the difference between these two numbers, and divide it by the number of groups to be created. In our example:

Min =	26
Max =	100
Difference =	74
Number of groups to be built =	4

=> 74:4=18.5

Add to the minimum (26) the value of 18.5 and you get the maximum for the first category. Then add the same value again and you will get the maximum of the second category, etc.

The wealth categories are marked with different colours on the right side in Table 14.6 above.

Female-headed households are marked yellow on both tables (household number): 4, 6, 9, 10, 15, 18, 22, 29, 35, 41, and 48.

Household number 37 must be excluded because not all informants were aware of it and a ranking was therefore not possible.

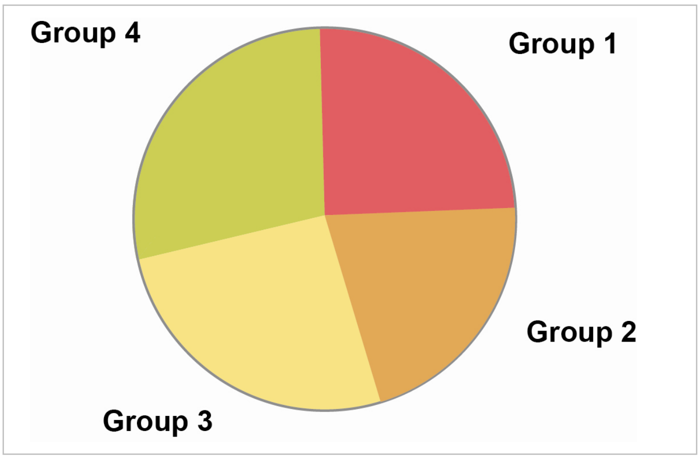

Figure 14.4
Wealth stratification (pie diagram): group 1, for example, includes all household ranked as "wealthy" by the informant groups (interpretation, see text). (SLM Eritrea)

Step 3: The analysis

The simplest way of analysing is to draw a pie diagram to get an idea of wealth stratification. Figure 14.4 presents such a diagram for the example presented above (50 households). It shows that almost 30% of all households are ranked as "poor" (yellow colour). This in itself is important information for any development intervention, including land management. Moreover, the above information helps you to select the "right" people for further investigations – for example, to have a balanced sample of households for interviews, which includes poorer, middle-income, and wealthier households. Attribute the criteria used by the participants for the wealth categories to your results, examine the distribution in the different groups (for example, by examining the number of oxen, food security, etc.) and determine the main differences between the groups.

Add all the information you obtained by observing the process or from additional sources and draw conclusions (e.g. female-headed households, unknown households, stories told about the families, who has relatives abroad, invalids in the families, innovative farmers). It is important to rely only on good-quality and first-hand information. Your interpretation of the results should not be sprinkled with your own opinions or with your personal perception of a situation. Use only facts for the primary interpretation and declare all further personal interpretations as such.

The pie chart above (*Figure 14.4*) also reveals some typical traits of wealth ranking criteria in rural Eritrea:

Main ranking criteria for households in the wealthiest group 1:

- All households in this group own two oxen
- The number of cattle and other animals is higher than in other households
- All camel owners in the village are in this group
- The only car owner is in this group. He offers local taxi services
- The priest is in this category
- The mill-owner is in this category
- In a normal year food is secured for 12 months and small amounts of surplus can be sold on the market
- Some children (boys and girls) participate in higher education

Additional observations: All households in this group are male-headed

Main ranking criteria for households in group 2:

- All households own one ox and have easy access to a second one
- Food sufficiency in normal years is for about 10–12 months
- Access to fuelwood and safe drinking water is assured

- Few boys are in higher education
- The group has elderly household heads with a high social status
- Most have a son or a daughter abroad regularly supporting the household

Main ranking criteria for group 3:

- Most own one ox and have unfavourable conditions of access to a second one
- The households still have one cow, one or two calves, some sheep and goats
- Food sufficiency in normal years is for not more than 10 months
- The relation between productive and non-productive household members is not optimal (often young families)
- Two households are women-headed. One woman is the local shop owner; the other runs a small restaurant.
- No children in higher education but all children in the family attend the local school

Main ranking criteria for group 4 (the poor households):

- No oxen and no easy access to oxen
- No cattle, not many animals at all
- Food security is less than 10 months per year
- Not much support form foreign relatives
- Besides the shop owner and the restaurant owner, all female-headed households are in this category
- Insufficient access to labour
- People who are invalids

14.4 Questions and issues for debate

1. Wealth ranking:
   a) What kind of information can you obtain from wealth ranking? For which purposes can this information be used (note that there are different kinds of information that result from a wealth ranking process)
   b) What are the preconditions for successfully carrying out a wealth ranking? Can you think of conditions in which it does not work?
   c) Have a closer look at the main ranking criteria as chosen by the informant groups, for households, as summarised in Step 3, for wealthy and poorer households: how can these criteria be grouped into livelihood assets (as presented in Chapter 6)? Can you make an asset profile for a poor and for a rich household?

2. Landscape and land use dynamics: You want to learn about the changes that have taken place in an area (village territory and its surroundings) over the last 50 years.
   a) Prepare 10 questions that seem to you to be relevant and important to ask. Do this for yourself and
   b) Discuss your questions in a small group, and agree on a final set of 10 questions
   c) How would you now proceed in a concrete project to get answers to these questions? What approaches, principles, and concrete methods would you use?

3. What are the key principles of PRA and PLA? How are they different from classical scientific approaches? (social and natural sciences!)

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Chapter 15

Compilation and Analysis of Information

15.1 Decision support systems

Data and information on natural resource management studies form the basis for a Decision Support System (DSS). Decision support systems allow exploitation of existing knowledge with a view to setting priorities among key factors with regard to a postulated development objective and discussion of possible strategies for development activities (Messerli, 2000[1]). Depending on the context, a great number of different and more or less sophisticated DSS exist. Johnson and Lachman, (2001)[2] analysed more than 100 DSS tools developed for different purposes in the context of nature and science and came to the conclusion that even among the useful tools it is not easy to select the right one for a certain goal (or research question). Common to all decision support systems is that they try to reduce the complexity of the information collected and support the selection of key elements that trigger a change in the desired direction.

Besides quantitative data, semi-quantitative information and qualitative observations, the DSS contains basic ideas that do not automatically emerge from research but that are based on normative concepts and values. These must be challenged from time to time and be subject of continuous debate. For example, a certain DSS is based on the assumption that prevailing land management is unsustainable (showing indications of resource degradation) and that the vision or goal is more sustainable land management. The term "sustainable", as explained in the previous chapters, reflects a normative concept, a development goal that was globally agreed upon in the 1980s.

A DSS in the context of sustainable development must take account of ethical principles as well. For example, an extension agent who has to fulfil the job of implementing SWC might consider the participation of local land users as an obstacle because it involves numerous consultations, negotiations and possibly conflicts. However, since it is ultimately the land user, his family and livelihood that are directly affected – possibly not only in a positive sense but also by negative side effects – we feel that active participation is an obligation, not a good-will activity carried out by experts and extension workers. This will be more important particularly in communities that are highly decentralized and empowered to hold the extension agents accountable for their actions.

15.1.1 Dealing with research findings

Some general remarks

- Biophysical environments and socio-economic frameworks are diverse and both are subject to changes. There is no standard situation, so do not look for standard solutions or a standard design for interventions. There is also no standard criterion for success but there are some guiding principles that govern interventions. Approaches must meet the needs of a changing world and must be flexible.

- Research findings need to be taken as guiding principles, not as a blueprint for implementation. They do not free project implementing staff and experts from making their own decisions.
- Research findings are not a substitute for land users' involvement. Their participation in decisions concerning their property is inevitable.
- Research findings help to prepare arguments for a discussion with land users; they do not replace argumentation.
- Until now, neither indigenous nor external (scientific) approaches alone have been able to solve all the problems relating to SLM. The goal is a suitable and acceptable compromise between both. Whatever DSS-model is selected, the following procedure is strongly recommended:
    1. Start from indigenous knowledge and technology, because it is already accepted and fits into the prevailing (land management) system;
    2. Look for the most promising indigenous components or technologies;
    3. Look for incremental improvement of these jointly with land users; use their creativity; enhance access to information;
    4. Do not try to solve all in one go, but proceed step by step and encourage the local population to experiment where they can afford it;
    5. Do not restrict yourself to permanent measures, allow more flexible solutions;
    6. Do not regard land users as the problem but as part of the solution.

The following sections describe two already tested tools to support the process of decision-making. Both are participatory and interdisciplinary methodologies and demand high resource input (knowledge, time, flexibility, etc.). **Participatory technology development (PTD)** focuses heavily on local knowledge, which is the basis for any successfully, introduced participatory development. **Participatory sensitivity analysis** (PSA) is a tool for assessing the relations and interrelations of factors within a given system and reducing the factors involved to a manageable and clearly laid out number of key factors to be addressed. The users of this tool still need to decide which way to go, but the PSA supports the decision makers with sound information about promising "entry points".

15.2 Participatory technology development

15.2.1 Historical development

Today, most natural resources scientists are acknowledged as specialists for whom it is legitimate to know progressively more and more about less and less. They are so specialized that participation in research for technology development is considered an infringement on the independence of the specific discipline.

Participatory research, or participatory action research as it is sometimes described, emerged from the work of academics and activists concerned about power relations related to knowledge creation, poverty and class. The approach evolved from international efforts that are often traced to researchers and educators in Tanzania during the early 1970s working to involve community people in research explicitly as partners and decision makers (Miller et al., 2005[3]). Together they investigated and analyzed social problems such as health care, each tapping their own sources of knowledge and experience to create more accurate, collective understanding of issues so that more effective actions could be taken in response. Participatory research takes different forms but usually brings people together with outside researchers and development activists to study issues of common concern and share control over the process of inquiry and action. Like action research, participatory research rejects the positivist notion of one "truth" that should be proven by deductive reasoning and evidence, recognizing instead that knowledge and reality are often socially constructed on the basis of deeply embedded values and worldviews. In contrast to mainstream action research, however, participatory research is explicitly intended to promote more equitable relations of power, and hence is not neutral. For both reasons, participatory research is open to challenges by traditional researchers and development practitioners. Aimed at transforming structures of injustice, it is based on a collective analysis and creation of knowledge that produces new awareness, critical thinking and more effective strategies of social change[4].

Participatory Technology Development (PTD) is a broad term that refers to collaboration between farmers, development agents and researchers in a manner that combines the knowledge and skills of these various actors. Historically, farmers have developed their own deep-rooted research methodologies to cope with the changing environment. The indigenous technologies are the results of this process. Similarly, farmers also cooperated with researchers in the process of technology transfer, since farmers are the custodians of knowledge and practice that researchers use as a basis for developing resource management technologies[5]. The conventional concept of natural resource management is that the role of the researcher is to identify and analyze land users' problems. Solutions should then be developed at research stations and transferred to farmers via the extension service. In this way, the extension service forms a link between the researcher and the farmer and helps the farmer put the new technologies into practice. Implementation was usually supported with incentives in cash or kind.

This traditional approach to the transfer of technologies clearly separated the actors (researcher, extension agent and the land user) and put them into a rigid straightjacket hierarchy in the processes of technology development and dissemination. Information flowed only in one direction (from researcher to extension agent to farmer), making it exceptionally difficult to obtain feedback because such relationships also lacked the capacity for monitoring and evaluation of the impacts of the transferred technology. With this approach, new technologies often addressed the symptoms, neglecting the underlying causes and farmers' constraints. Solutions, which may appear to be technically correct, may not be acceptable to the farmers. The concept is faulty in that it does not permit the free exchange of ideas and experiences between all the stakeholders involved.

If the concept becomes people-centred, traditional vertical hierarchies are minimized if not eliminated. Information flow is free and poly-directional. Farmers become equally empowered partners, and have the opportunity to participate in technology development, from problem identification to implementation. Consequently, they are not only considered recipients but are also expected to play a part in initiating and evaluating technology development. Farmers do not subdivide or segment their farming activities as researchers traditionally do. The whole farm enterprise dictates their thinking. Linkages within the farming system are understood. This wealth of traditional knowledge can then be used in the development and implementation of technologies. An outcome of this concept is that farmers recognize the limitations to their knowledge and traditional technologies to sustain production as pressure on the land increases. Present conditions dictate participatory technology development, with a changed and closer relationship between the traditional institutions of research, extension and farming.

In the "participatory" on-farm research that had been propagated in the farming systems approach, the farmer's role was defined only in terms of approving the delivered technologies by providing their land or service (contractual and consultative) without much involvement in either data collection or interpretation of research results. However, in light of their repeated failure to have an impact on such an approach to research, the role of indigenous practices and the role of farmers in decision-making were gradually given some weight. Researchers also played a role in the development of partnership research and facilitation (collaborative and collegial) of participation by the farmers. In other words, this was a step towards participatory technology development (PTD). It emerged from many efforts to develop more sustainable agricultural systems, mainly in the 1980s (Berhane and Mitiku, 2001[6]). Throughout this period the whole process of sustainability and farmers' participation became a fundamental issue. Working towards sustainability requires understanding of local dynamics, problems and opportunities, development of specific solutions, and empowerment of local organizations, since farmers also have an intimate knowledge of these essential components (Wiesmann, 1998[7]).

The PTD approach places people at the centre of development and works to support people's efforts to achieve their own livelihood goals. At a practical level, this approach can help to address some of the questions about sustainable land management interventions, for example:

1. How does investment in soil and water conservation contribute to sustainable livelihoods, both in the short and the long term? What benefits does it bring (e.g. productivity versus risk reduction)? What triggers the initiation or cessation of activities? What minimum levels of assets or wealth accumulation are necessary to support investment in technologies? Are there policy premises that support or undermine these activities?
2. When do households choose to invest and can they afford to?
3. What are alternative ways (opportunities) to achieve the same outcomes?
4. What is the opportunity cost of investing in sustainable land management?

NGOs have currently used different participatory methodologies. These methods include Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA), which are introduced in Chapter 14, Rapid Assessment of Agricultural Knowledge Systems (RAAKS), Local Level Participatory Planning Approach (LLPPA), and Participatory Demonstration, Extension and Training systems (PADETS). Yet some of these approaches are characterized by incentives (cash and food for work) and campaign work with transfer of technologies as a driving force. No doubt, very few NGOs have made some attempt at PTD approaches (Yohannes, 2001[8]). Today, PTD application in agriculture and natural resource management is given due recognition. The active and joint involvement of the triple allies – farmers, extension workers and researchers – in a decentralized governance system can make the approach attractive and more promising for sustainable land management.

Underlying much of the research and extension work undertaken by experts is the mistaken notion that farmers know little or nothing about soil conservation and therefore have to be shown how to practice it. This neglect of the conservation effectiveness of farmers' own land management practices can lead to the imposition of unnecessary and often inappropriate solutions, even under a decentralized decision making system for sound land use planning if the capacity and the tools to undertake such an exercise are not in place (Fikru et al., 2005[9]) Many authors (Chambers and, Conway, 1992[10]) have shown that farmers often have a good understanding of what is required for sustainable land management, and given the chance, they can develop their own innovative, and location-specific, good land management practices. It is, therefore, important that the specialists open their eyes, and observe what it is that farmers are already doing that conforms to the requirements of sustainable land management, and that they recognize the value of the indigenous expertise and local knowledge, and adapt their own expert advice accordingly (Liniger et al., 2004[11]). However, it should also be underlined that indigenous knowledge is not sufficient as a panacea for resolving SLM issues. What must be emphasized is that researchers who are striving to develop new technologies need to consider the socio-economic conditions of the farming communities and base their new technologies on existing knowledge of the beneficiaries. Furthermore, researchers need to put in place long-term monitoring and impact assessment indicators as part of their efforts to develop new technologies.

The central point of PTD is farmer-led experimentation to find better ways of using available resources to improve the wellbeing of family and community members. The purpose of supporting farmer experimentation is to strengthen farmer's capacities to seek and try out new ideas, so that they are better able to experiment and to adjust to changing conditions (Ouedraogo and Sawadogo, 2005[12]). The purpose is not to convince farmers to adopt a new technology, but rather to encourage them to test new possibilities, choose what is right for their conditions, or adapt the new ideas to their conditions (Van Veldhuizen eta al. 2000[13]). Generally PTD is an approach that involves farmers in developing agricultural technologies that are appropriate to their particular situation.

15.2.2 Principles of PTD

- Participatory Rapid Appraisal (PRA) (Chapter 14) is an integral part of PTD. PTD needs to be seen from the point of view of long-term research undertakings and the requirement for short-term outputs from research to mitigate the constraints of unsustainability. Diagnosing a situation can be a short-term springboard for devising solutions but need not replace the long-term perspective of monitoring the impacts of the technologies developed in a participatory approach.

- PTD is a sustained learning process (learning by doing from real life experience). In this process what is gained in one aspect of the technology could be a failure in other aspects, thereby necessitating changes in the approach to incorporate what is gained and to learn from failures.
- PTD is based on indigenous knowledge and practices as a point of departure. The available knowledge base within the communities is taken as a starting point (entry point) but not as a goal by itself. The spin-offs from research and development studies, notwithstanding their appropriateness, can be an integral part of further enhancement of the technology development process.
- PTD takes local farmer innovators as a starting point. This aspect of PTD is crucial in view of identifying the entry points. Innovative farmers within farming communities can provide insights into what is going on within their context of technology development. How are they identified? What is their power base within the society? Are they innovative enough to improve their livelihoods or try this with all individuals who look for incentives? It may be hard to find such innovative farmers but with appropriate effort it is possible to identify them and make them partners in the development of technologies based on their experiences.
- The different perspectives of individuals and groups are accommodated for wider application. Stakeholder analysis exercises demonstrate that individuals and groups would like to be heard and involved in the process of technology development. The views of the different stakeholders need to be integrated within the process for grounding and benchmarking for further elaboration, enhancement and eventual monitoring.
- PTD is built on a process of discussion, communication and conflict resolution. In such a process it is permissible that differences in points of view might surface and could result in conflicts of interest. There should be mechanisms built into the process to communicate such differences and put forward proposals on how to resolve the conflicts that arise. Bylaws, traditional or otherwise, need to be designed to address such issues within the community and beyond.
- PTD builds on the principle of partnerships between farmers, researchers and extension workers. Partnership is based on mutual respect and trust to facilitate the development, transfer, adoption and adaptation of the technologies designed and implemented jointly. An array of technologies can be developed through the partnership of the actors but farmers need to be empowered to select those technologies that they regard as benefiting them, in both the short and long-term perspective.
- PTD is based on the linkage between indigenous knowledge and formal science, bridging the gaps between conventional mono-disciplinary and transdisciplinary approaches. It may be hard for some disciplines to accept such simplifications but if changes are to be effected by communities in SLM, all relevant disciplines need to work together with farmers.

- PTD focuses on capacity building rather than a specific technical output, so that knowledge and skills are retained at both the local and higher levels. Methodologies and tools used should be sufficiently understood by the partners to enable them to scale up the outputs. If methods and tools are so sophisticated as to be understood only by researchers, the sustainability of the technologies will be undermined right from the beginning.

- Sustainability is the main focus in problem solving, building on what is achieved and adding value to new ideas and innovations.

- PTD is a slow learning process that requires perseverance and reflection by all stakeholders involved. At every stage of the process feedback is essential to take corrective measures in time.

- PTD reinforces the existing creativity and experimental capacity of farmers. It builds human capacity for self-reliance.

- PTD helps empower land users in decision-making through partnership and accountability. All the partners in this process adhere to the principle of accountability in cases of failure and success. Backstopping and support for successful implementation should be provided unhindered.

- Farmers are not expected to approve and apply pre-designed trials but participate proactively in all aspects of the decisions that affect their livelihoods. PTD thus helps farmers to respond to changing conditions.

15.2.3 Major clusters or phases of PTD activities

The PTD approach is not a panacea for the complex agricultural problems faced by rural communities (Yohannes and Herweg, K. 2000)[14]. It has its potentials and limitations, which means that it needs to be gradually improved. According to van Veldhuizen (2000), a close look at the many good examples of interaction between farmers and 'outsiders' reveals a common pattern, which consists of six main clusters of activities.

1. **Getting started**: Establishing contact between farmers and 'outsiders' and agreeing to take the PTD approach to improved land management. This should be expressed at the outset. Understanding of the socio-cultural, economic and biophysical situation of a community will be facilitated through modalities of building trust and confidence among partners. The need for openness need not be emphasized; ensuring that trust and confidence are built needs to be rectified.

2. **Understanding problems and opportunities**: Sharing insights into local agricultural potential and constraints and addressing the felt needs and priorities of the community. Synthesizing the constraints on developing new ideas and insights into the development of technologies to mitigate these constraints.

3. **Looking for things to try**: Selecting best bet indigenous practices and other possibly relevant technologies.

4. **Experimentation**: Improving the capacity and skills of farmers in experimentation. Awareness creation and training of the partner farmers needs to be undertaken

throughout the process. Description of methods and tools for use in experimentation can be easily understood by the farmers if done in simple terms.

5. **Sharing the results**: Stimulating farmer-based extension and diffusion of ideas and technologies. Ways and means of disseminating the results need to be incorporated in the process. Responsibilities of each partner are defined in accordance with the means to be employed.
6. **Sustaining the PTD process**: Institutionalization of the approach in routine work. Once the process is undertaken as either a pilot project or a development program, institutionalizing the whole process within partners' institutions is an important consideration if long-lasting attributes are to be put in place.

15.2.4 Favourable conditions for PTD

- **Flexibility** in development and extension programs. If the extension system is rigid with several strings attached to it, PTD will face immense challenges. Access to partners and working with partners in mutually agreed interventions focusing on improving the livelihood of the farmers is central to making the process flexible.
- **Decentralization** of decision-making in planning. This might be simplistic in approach but is the most difficult part of implementation. Capacity and the tools for planning should exist at the lower level. If decisions are negatively influenced from above, decentralization becomes a process rather than an output-oriented goal.
- **Regular evaluation** of activities and impacts. Benchmarking changes and monitoring impacts within a time and space framework is essential. Consequently, scaling-up opportunities can be fed into the system.
- **Systematic staff development**: At every stage in the process, those involved in the exercise are able to learn and build capacity for furthering PTD.
- **Discovering new technical options**: Farmers eventually will have menus of options to select from and use based on the resource endowment at their disposal.
- **Storage and use of information**: Databases can be established for further reference, impact monitoring and evaluation. Such data, however, should also consider ease of access, not only by the researchers but also by all stakeholders.
- **Allocation of resources** (training and field operations, considering unforeseen risks). Although PTD might be less expensive than classical approaches to SLM, it comes at a cost. This cost must be borne by the stakeholders.
- **Building external relations** Partners in this process will benefit from experiences with similar undertakings. Exchange visits enhance such relations.

15.2.5 Challenges and limitations

- **Long-term commitment**: Limited organizational support for long-term processes by many development agencies, including NGOs and others, are a real challenge to PDT. Short-term benefits are sought rather than long-lasting perspectives. Farmers' planning horizons are diverse. Partners will be challenged with respect to diversity of views. Adopting the time horizon and perspectives of farmers is difficult but should be accepted.

- **Sustaining the process**: Ensuring the continuity of the positive changes initiated by the community is essential; this may require longer-term backstopping facilitated from outside.
- **Biased towards farmer innovators**: Experimentation in PTD is mainly initiated through agricultural innovation with farmer innovators, which may underestimate community wide-problem analysis. Careful and persistent involvement of all members of the community is essential to avoid the danger of working only with "enlightened" ones.
- **Equity issue**: Innovator farmers alone do not necessarily represent socio-economic and gender reality. All members of the community are stakeholders. They need to be heard and their views taken into consideration.
- **Innovation versus standards**: PTD encourages farmers to innovate, but researchers and extension workers find it challenging to share their standard findings with a wider community. This hinders scaling-up. Attempts can be made through the process to standardize the available technologies in accordance with the specific situations of the communities involved.
- **Establishment of linkages**: Coordination of stakeholders mainly from research and extension in joint experimentation is a very difficult task, as everybody is preoccupied with their own routine activities. But it is important.
- **Harmonization of views**: The challenge is to bring together the different views of the farmers (socio-cultural dimensions) and of Western-biased scientific analysis from extension and research. Dialogue and discussion are therefore essential in order to reduce, or harmonise, diverse views relating to options, procedures, and the scope of activities.

15.2.6 From participatory to transdisciplinary research

In their search for solutions to concrete societal problems, professional development organizations have as a rule been using participatory methods for more than two decades, as this approach has proved very effective (Hurni and Wiesmann, 2002[15]). This means that both the local population and decision-makers are involved in planning and implementing projects. Participatory approaches were also taken up at an early stage in action research, although with considerably more hesitation than in development cooperation. These largely empirical approaches were given a theoretical basis only with the establishment of transdisciplinarity as a concept and approach. In essence, a transdisciplinary approach requires that phenomena under investigation be regarded from a perspective that (a) goes beyond specific disciplines and (b) is based on broad participation, characterized by systematic cooperation with those concerned outside the academic world.

Thus two issues need to be addressed in transdisciplinary research. First, do participatory research approaches adequately meet the requirements of transdisciplinarity, and do they need to be elaborated? Of course this means identifying the limits of transdisciplinarity, and also defining how and where there is an additional need for interdisciplinary and disciplinary methods. Second, the past few years have shown that transdisciplinary research is not only a meaningful addition to individually pursued research in the context of development cooperation, but that it also expands the potential of traditional methods in all other areas of research.

15.3 Participatory system analysis (PSA)[16]

15.3.1 Objective and brief description of the method

A network or systems analysis is more appropriate than a simple cause-effect analysis for understanding how a project context functions, why problems occur, why an intervention does or does not lead to achieving a goal, etc. However, a sound scientific systems analysis would be too costly and too complicated for most development projects. In this sense, the Participatory Systems Analysis (PSA) presented here is a manageable compromise.

PSA has led to interesting results on many occasions. Generally, stakeholders defined important elements of a project context and their relationships during a participatory exercise, based on their specific backgrounds, knowledge, expertise and experiences. After some initial astonishment and learning about how different perceptions of the same context can be, PSA always stimulates fascinating discussions among participants. It is a good starting point for obtaining more complex views of reality, particularly for people with little experience in systems thinking. PSA is a first step towards flexible management of an unpredictable and dynamic project context.

PSA complements problem analysis (e.g. problem tree), serves as a basis for further project planning, and finally, helps to structure the project planning matrix. It is designed to evaluate the relationships among relevant elements within a project context. It reveals which elements can be potential starting points for project activities, and which ones may require further investigation and better understanding.

PSA is neither a mathematical model nor an accurate scientific method and does not reveal a "right" or "wrong" way of looking at a project context. Rather it reflects the perceptions and knowledge of the participants with a view to setting priorities among key factors with regard to a postulated development objective. The more seriously the elements are chosen and their relationships are evaluated, the more realistic will be the results.

15.4 Procedure, steps – and an explanatory example

15.4.1 Setting the stage (1)

- This should be carried out in groups with no less than 5 or 6 persons, in order to incorporate differing points of view and stimulate discussions. Homogeneous groups are likely to arrive at the expected results and may miss the chance to look at the context from different angles! Even though the ratings of the relationships are done jointly, the results can often be surprising and provoke a debate. This may require a repetition of the exercise with improved ratings.
- A participatory systems analysis can be carried out with a random number of elements, but the experience indicates that the optimal number is 12. Less than 12 ele-

ments may not represent the complexity of the context sufficiently, while more than 12 elements are difficult to manage in a short time.

- In order to incorporate the idea of "sustainability", all dimensions of sustainability must be included. In the example, we have selected 4 ecological, 4 economic and 4 social / institutional elements. But the number of elements in each dimension does not need to be 4; it can vary according to the project context. It is more important that no dimension be neglected if sustainable development or sustainable resource management is mentioned in the project goal or purpose.
- The ratings (2 = strong influence; 1 = moderate influence; 0.5 = weak influence; 0.1 = very weak influence) are experiential values and do not reflect scientific knowledge. They may be changed, but this will only influence the scales and not the relative location in the system of co-ordinates. The rating 0 (= no influence) cannot be used because calculations include a division. All elements in a system are assumed to have at least a weak and indirect influence on each other.

15.4.2 Selecting the elements of the project context (2)

The elements of the project context in question are listed. The justification for selection is the basis for a common understanding of why exactly these elements were chosen and how the relationships were estimated. It is particularly helpful at a later stage to refer to such listings when details can otherwise not be recalled (*Table 15.1*).

Table 15.1 Elements selected to run a PSA (an example from Southern Africa)

Selection of important elements in a project context: a smallholder village in the rangelands of the southern part of Africa. The elements represent the three dimensions of sustainability

No	*Dimension of sustainability*	*Element*	*Description / Justification*
1	*Ecological*	*Water availability*	*Low due to rainfall, no maintenance of supply pipeline*
2		*Overgrazing*	*Description / Justification* *Low rainfall and uncontrolled grazing*
3		*Soil erosion*	*High on crop and grazing land*
4		*Water quality*	*Poor because wells are not maintained*
5	*Economic*	*Household (HH) income*	*Low due to declining yields and market prices*
6		*Off-farm jobs*	*Limited, no small-scale industries, handicrafts, etc.*
7		*Crop production*	*Low due to subsistence agriculture, no external inputs*
8		*Distance to market*	*Difficulties in marketing of products*
9	*Social / institutional*	*Level of education*	*Low because teachers not motivated to work here*
10		*Social conflicts*	*Increasing social disparities*
11		*Access to land*	*Limited due to insecure land use rights*
12		*Innovative potential*	*Low due to out-migration of young men*

Source: Herweg and Steiner, 2002

		1	2	3	4	5	6	7	8	9	10	11	12		
														Active sum (AS)	Degree of interrel. (AS·PS)
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
	Passive sum (PS)														
	Activity ratio (AS/PS)														

Figure 15.1 The empty matrix used to list the elements found in step 1. Elements will be listed in the same sequence vertically and horizontally (Herweg and Steiner, 2002)

15.4.3 Determination of the relationships between all elements: completing the matrix (3)

After the elements are discussed and agreed upon and listed in a Table (*such as in Table 15.1*), they need to be rated in order of importance.

For example, possible scores for the ratings could look like the following:

2.0	Strong influence
1.0	Moderate influence
0.5	Weak influence
0.1	Very weak influence

The scores of the rating are then filled into a matrix such as the one presented on the previous page (*Figure 15.1*). To fill in the matrix, it is important to start with **row No. 1 (not with the column!)** as indicated in Figure 15.2 and to ask: what is the "influence" of element No. 1 on elements No. 2 (column 2), No. 3 (column 3), etc. Whether the influence is positive or negative plays only a minor role at the moment. After the rating is completed, each line will reflect the influence that the element in question has on the other elements in the system. This can be called the active character of an element. Similarly, each column reflects the influence of all other elements on the element in question. This can be called the passive character of an element:

No.		1	2	3	...
	Elements	Water availab.	Over-grazing	Soil erosion	...
1	*Water availability*				
2	*Overgrazing*				
3	*Soil erosion*				
...	...				

N.B. Start with **line No. 1** and the influence of element No. 1 on elements No. 2 (column 2), No. 3 (column 3), etc.

Figure 15.2 Guidance how to fill the scores of rating (Herweg and Steiner, 2002)

15.4.4 Calculation of active sum and passive sum (4)

Adding up all values of one line results in the active sum of the element in question:

No.		*1*	*2*		*12*	
	Elements	*Water available*	*Over-grazing*	...	*Innovative potential*	*Active sum (AS)*
1	*Water availability*		2		0.5	11.9
2	...	...		...	...	...

Source: Herweg and Steiner, 2002

Adding up all values for one column results in the passive sum of this element:

No.		*1*	*2*
	Elements	*Water available*	...
1	*Water availability*		...
2	*Overgrazing*	2	
	...		...
12	*Innovative potential*	2	...
	Passive sum (PS)	8.0	...

Source: Herweg and Steiner, 2002

15.4.5 Calculation of the degree of interrelation and the activity ratio (5)

Multiplying the active sum by the passive sum of each element gives its degree of interrelation within the system. This reflects how strongly or how weakly an element is "networking" within the project context. A high degree of interrelation implies, for example, that there are many direct and indirect ways to influence this element.

Dividing the active sum of each element by its passive sum gives its activity ratio. This reflects the proportion of active influences and passive influences in each element and indicates whether an element plays a rather active role (> 1) or a rather passive role (< 1) within the project context. Passive elements, for example, are not the best starting points for changing a context.

No.		1		12		
	Elements	*Water availability*	...	*Innovative potential*	*Active sum (AS)*	*Degree of interrelationship (AS*PS)*
1	*Water availability*		...	...	11.9	95.2
	...	...	...	...	...	...
12	*Innovative potential*	...	...		10.3	80.3
	Passive sum (PS)	8.0	...	7.8		
	Activity ratio (AS/PS)	1.5	...	1.3		

Source: Herweg and Steiner, 2002

Table 15.2 Participatory systems analysis: a complete rating for a smallholder village in the rangelands of the southern part of Africa

No.		1	2	3	4	5	6	7	8	9	10	11	12		
	Elements	*WA*	*OG*	*SE*	*WQ*	*HI*	*OJ*	*CP*	*DM*	*LE*	*SC*	*AL*	*IP*	*Active sum AS*	*Degree of interrelation AS*PS*
1	*Water availability (WA)*		2	1	2	2	0.1	2	0.1	0.1	2	0.1	0.5	11.9	107.1
2	*Overgrazing (OG)*	2		2	1	1	0.1	0.5	0.1	0.1	1	0.5	0.1	8.4	110.0
3	*Soil erosion (SE)*	1	1		1	2	0.1	2	0.1	0.1	0.1	0.1	0.1	7.6	96.5
4	*Water quality (WQ)*	0.1	0.1	0.1		1	0.1	0.1	0.1	1	1	0.5	0.5	4.6	38.2
5	*Household income (HI)*	1	2	0.5	1		0.1	0.5	0.1	2	2	2	0.5	11.7	234.0
6	*Off-farm jobs (OJ)*	0.1	2	2	0.5	2		0.5	0.1	2	0.5	0.5	1	11.2	37.0

7	*Crop production (CP)*	0.1	0.5	1	0.1	2	0.1		0.5	0.1	2	0.1	0.1	6.6	73.3
8	*Long distance to market (DM)*	0.1	0.5	0.1	0.1	2	0.1	0.5		2	0.1	0.1	2	7.6	18.2
9	*Level of education (LE)*	0.5	1	2	0.5	2	1	2	0.1		1	0.1	2	12.2	109.8
10	*Social conflicts (SC)*	2	1	1	1	2	1	1	1	1		2	1	14	170.8
11	*Access to land (AL)*	0.1	2	1	0.1	2	0.1	1	0.1	0.1	2		1	9.5	58.0
12	*Innovative potential (IP)*	2	1	2	1	2	0.5	1	0.1	0.5	0.5	0.1		10.7	94.2
	Passive sum (PS1)	9	13.1	12.7	8.3	20	3.3	11.1	2.4	9	12.2	6.1	8.8		
	Activity ratio (AS/PS)	1.3	0.6	0.6	0.6	0.6	3.4	0.6	3.2	1.4	1.1	1.6	1.2		

Source: Adapted from Herweg and Steiner, 2002

15.4.6 Establishing a system of co-ordinates (6)

In order to get an overview of all elements and their role within the context, the degree of interrelation and the activity ratio are positioned in a system of co-ordinates. This illustrates the "relative" position of each element vis-à-vis the others (Table 15.3).

- The Y-axis has a linear scale, and the length of the axis is determined by the highest degree of interrelation obtained in the exercise (rule of thumb: calculated maximum degree of interrelation + 20 to 30 to round it up).

- To keep the size of the system of co-ordinates small, the X-axis (activity ratio) has a logarithmic scale with a total length of 10, while the middle of the X-axis is 1.

Table 15.3 Setting the coordinates

Co-ordinates			
	Elements	Activity ratio	Degree interrelation
1	Water availability	1.3	107.1
2	Overgrazing	0.6	110.0
3	Soil erosion	0.6	96.5
4	Water quality	0.6	38.2
5	Household income	0.6	234.0
6	Off-farm jobs	3.4	37.0
7	Crop production	0.6	73.3
8	Long distance to market	3.2	18.2
9	Level of education	1.4	109.8
10	Social conflicts	1.1	170.8
11	Access to land	1.6	58.0
12	Innovative potential	1.2	94.2

Source: Herweg und Steiner, 2002

15.4.7 Interpreting the results of the PSA (7)

The system of co-ordinates is divided into four main sectors. Each sector implies a certain character or function (role) within the system (*Figure 15.3*). Note that in reality the "borders" between the four sectors are gradual transitions and not sharp lines. As all numerical values reflect the experience and knowledge of the participants (and not a mathematical algorithm), it is the relative (and not the absolute) position of each element in relation to others that is important! The following four functions (roles) are distinguished within the system:

A **symptom** is an element that is greatly influenced by other elements but may not have much power to change the system itself. Symptoms can be useful indicators of context changes, but development activities in this sector may only amount to a "treatment of the symptom, not the cause".

A **buffer** is characterised by low importance in the context. It is rather unremarkable because it neither influences other elements much nor is it influenced much by others. Development activities in this sector are expected to have little impact on the context.

A **critical element** is an accelerator or catalyst in the system. It changes many things quickly, but may also create many unexpected and undesired side effects. Development activities in this sector can be highly uncertain, and impacts may be unpredictable. Therefore, critical elements have to be treated very carefully. It is particularly important to formulate impact hypotheses for this sector!

A **motor** or **lever** is an active element with predictable impacts. This is the most interesting sector for development activities.

The elements found within these 4 sectors can be characterised as follows:

- Elements in the two sectors on the left (symptom & buffer) are rather passive, i.e. they are influenced by other elements more than they influence others.
- Elements in the two sectors on the right (critical element & motor) are rather active, i.e. they influence other elements more than they are influenced.
- Elements in the two lower sectors (buffer & motor) are rather weakly interrelated.
- Elements in the two upper sectors (symptom & critical element) are rather closely interrelated.

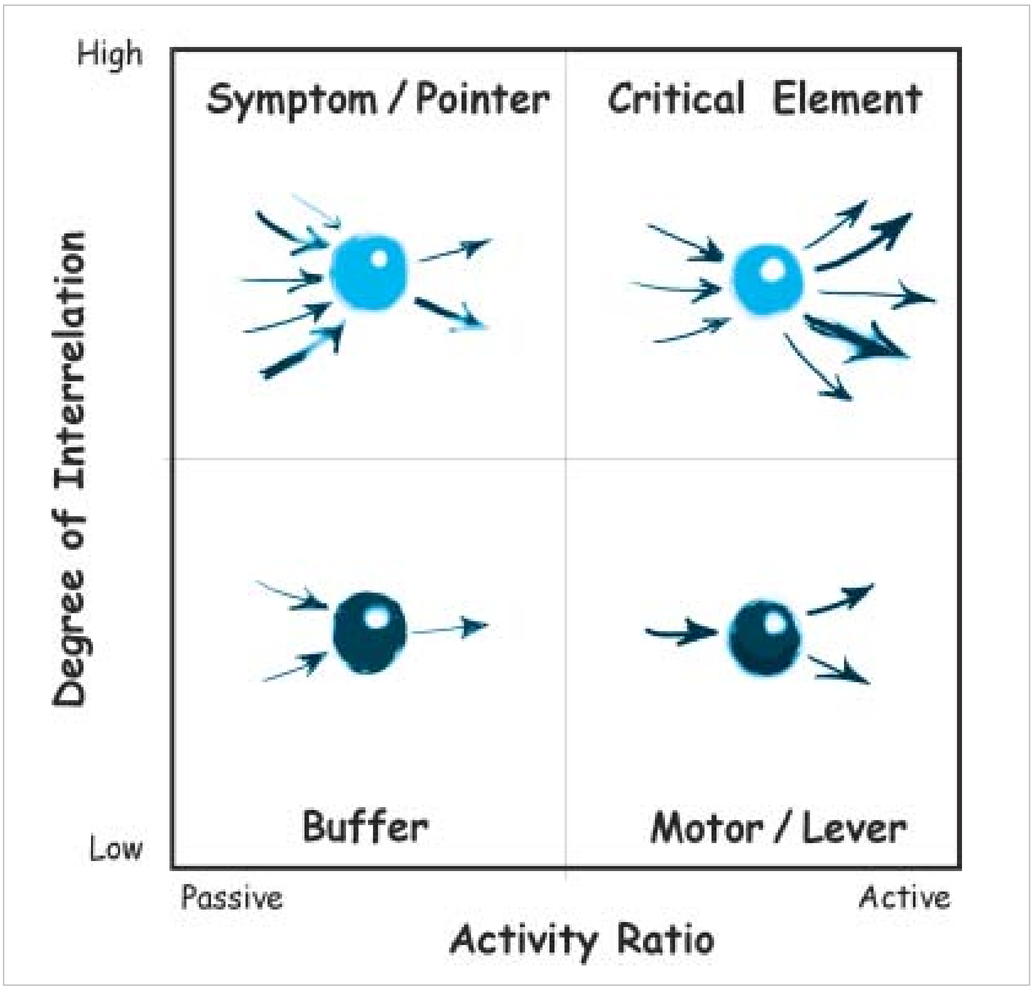

Figure 15.3 The function (role) of the selected elements within a project context (Herweg and Steiner, 2002)

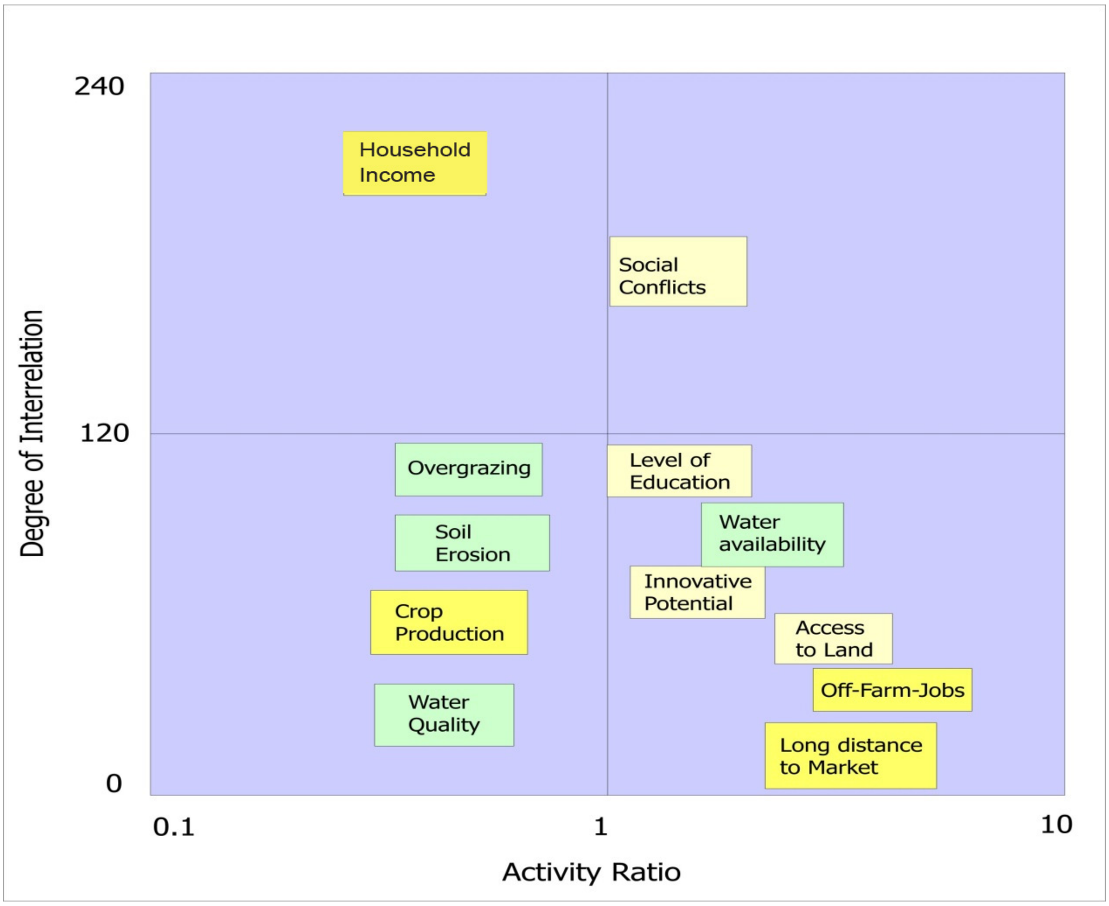

Figure 15.4 *Graph of outcome of the PSA example (the result of a PSA run for the example presented above in a Southern African Rangeland context) (Herweg and Steiner, 2002)*

If the values obtained from the concrete example (South African Rangelands) summarised in Table 15.2 are shown in a diagram (*Figure 15.4*), the results can more easily be interpreted. Here are some key points of interpretation:

- Household income in our example appears to be a **symptom**, which means it can be influenced by many other factors. It would be a good indicator for a change in the project context.
- Most **buffers** are – surprisingly for some people – ecological elements, which means that influencing them would probably alleviate the respective problem (e.g. soil erosion) but not change the context as a whole.
- Social conflicts are a **critical element**. Trying to solve them directly might produce unpredictable positive and negative impacts. This element requires more detailed analysis before intervening.
- **Motors** or **levers** of the system are mostly social, institutional and economic elements. These seem to be promising points of "intervention" for a development project. However, there is a need for careful monitoring to determine whether and how these and all other elements of the project context would change over time.

Interpretation and conclusions based on the exercise are the subject of an open discussion, which automatically leads to the formulation of impact hypotheses. For example, although soil erosion is characterized as a buffer in this case, some stakeholders may insist that it is a serious problem that needs to be addressed. The discussion should then focus on how to approach the problem. Erosion control may eventually be more effective if it is addressed through education and attempts to strengthen the innovative potential of the land users.

15.4.8 Cross-checking the results (8)

Even though the locations of the elements in the system of co-ordinates reflect the group's judgment and ratings, some results seem obvious while others may be surprising, and not everybody may agree. It must be kept in mind that the matrix and the system of co-ordinates reflect the participants' knowledge and perceptions. Therefore, there is no "right" or "wrong" way of looking at the context of a project as such, and nobody can claim to have a complete overview. Disagreements only indicate the need for further clarification and discussion. In this case, the group can cross-check the ratings again (strong, moderate, weak influence) and – if necessary and desirable – modify the matrix. Our experience indicates that this may change some details but rarely gives an entirely new picture of the system. However, the participants themselves must gain this experience in order to come to a common understanding. Disagreement should also be considered as a pool of different development options for a project, which can then be treated as alternative scenarios.

15.5 Questions and issues for debate

1. Carry out a PSA based on a land use system in Eritrea, for example:
    - Select an example of a highland farming community
    - Select an example of a pastoral community in the western lowlands
    - Select an example of a community which practices spate irrigation

Discuss the results obtained according to Figure 15.4 thoroughly!

2. Did you find the insights provided by the above exercise useful? What is the value added by PSA in your experience, after this exercise? What are merits and demerits of this tool?

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[16] This chapter is summing up “Chapter 2, Reviewing Problem Analysis” in Herweg, K. and Steiner, K. 2002: Impact Monitoring & Assessment. Instruments for Use in Rural Development Projects with a Focus on Sustainable Land Management, Volume 2: Toolbox

Chapter 16

Project Implementation and Monitoring

16.1 Impact monitoring and evaluation

Recognizing the important role of indigenous "internal" knowledge in SLM requires simultaneously reviewing the roles of "external" stakeholders such as extension workers, experts (both foreign and national), researchers, etc. As previously mentioned, Sayer and Campbell (2004[1]) recommend "leaving the details of land management in the hands of the resource managers" and emphasizing at the same time that one of the major roles that outsiders can play is to monitor the changes in systems. Parallel to this, there is an on-going discussion among international cooperation agencies and their partners about how to monitor systems changes with the intention of determining the impacts of development cooperation. To what extent do development projects and programs achieve their purposes and reach their goals? Are we doing things right (efficiency) and are we doing the right things (effectiveness)?

A contribution to this discussion is the participatory methodology of Impact Monitoring and Assessment (IMA) described by Herweg and Steiner (2002)[2]. The IMA methodology is a product of an international group of experts from various donor agencies (Herweg et al. 1998)[3], who have designed and applied these monitoring and assessment procedures. Focusing on SLM, IMA provides numerous instruments for predicting, monitoring and assessing positive and negative outcomes (effects) and impacts. It is important to notice that, in contrast to common ex-post impact studies, which are carried out *after* a project is finished, the six steps of IMA provide the user with tools of prediction and learning to improve *on-going* projects and programs.

16.1.1 Clarification of terminology

The terminology used in IMA relates to existing project cycle management procedures. It is important to note that the term "impact" covers quite a wide range of themes, which can be looked at as an impact chain of overlapping and interrelated links (*Figure 16.1*). Most development projects stop monitoring with the achievement of outputs (performance monitoring). IMA, by contrast, moves further by basically asking the questions "what are the consequences of these outputs, what will happen next, will they be utilized, will people find them useful, etc."?

The starting points of an impact chain are the **outputs** (results) that are planned and achieved by a project. A typical output of an SWC project would be "SWC technologies implemented in the project area". But the best technology is useless if it is not applied. So a first indication that an output may create further impacts is its **utilization**, e.g. the application (scaling-up) of a new SWC technology to a wider area. Only through utilization of the technology will the users be able to define the **usefulness** of the output, which includes both benefits and drawbacks. For example, due to a new SWC scheme crop yield may increase or decrease. It is important to keep in mind that, if interventions use incentives such as food-for-work to enhance broader application of a technology, utilization alone may not be an appropriate indication of a positive change. Only usefulness as it is rated e.g. by local stakeholders may reveal a realistic picture. Together, utilization and usefulness are referred to as the **outcomes** (effects, direct impacts) of an intervention. Outcomes imply a process of learning, i.e. people may change their perceptions, attitudes and intentions, and this is the key to triggering further (indirect) **impacts**. For example, increased crop yield certainly indicates a positive outcome, but the products must be marketable to increase the household income. An increased household income may lead to more sustainable land management if part of it is reinvested in the farm. But it may also lead to social conflicts, e.g. if it is spent on alcohol and other unwanted consumption.

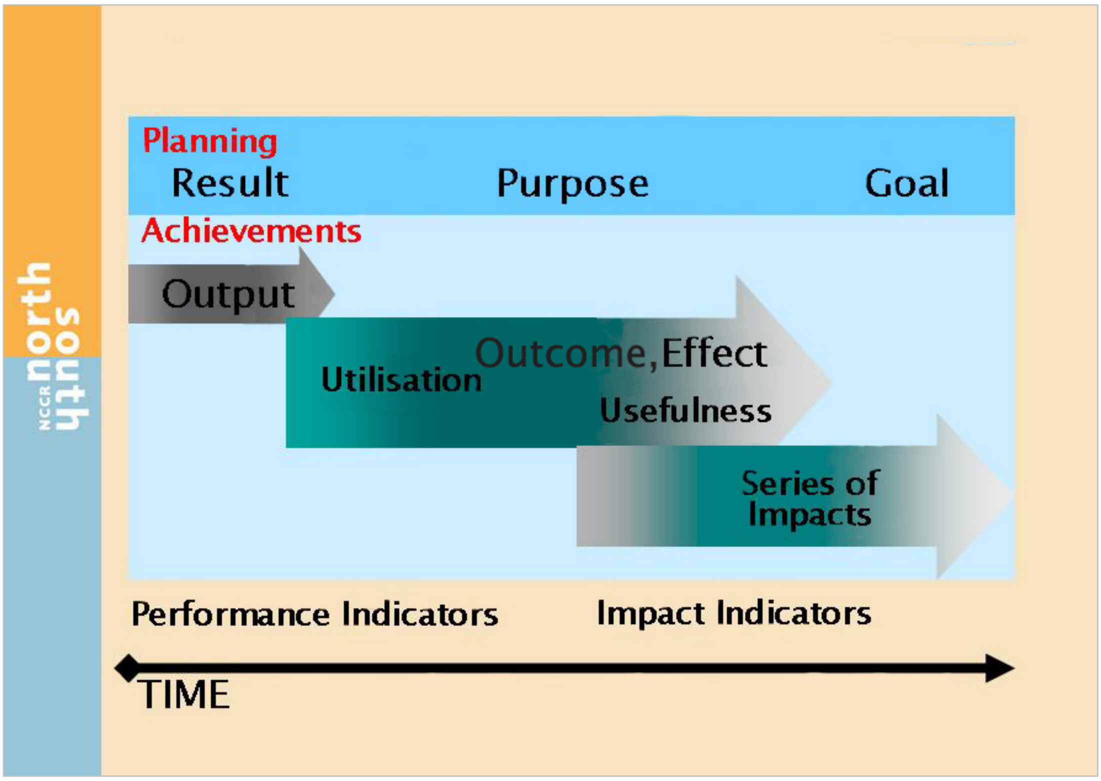

Figure 16.1 Terminology of project planning and monitoring achievements (adapted from Herweg und Steiner, 2002)

This example of an impact chain is not comprehensive but shows that at any point in the chain, there could be both positive and negative effects and impacts. Only long-term monitoring will finally reveal whether or not the outcomes and impacts relate to more sustainable development, as it is often claimed in the overall goals of a project or program. For example, if local people learn how to adapt and integrate new technologies and make their land management both productive and protective, and if this helps them gain self-confidence and further explore their own creative potential, it would constitute a significant contribution to different development goals such as empowerment, poverty alleviation, SLM, etc.

16.2 Six steps in impact monitoring and assessment

16.2.1 Step 1: Involvement of stakeholders and information management

Whether outcomes and impacts are considered positive or negative, sustainable or unsustainable, etc., depends on who assesses them (a farmer, his wife, a researcher, a policy-maker, etc.), and his or her interests (economic, social, ecological). An impact may be positive in the view of some stakeholders, while others may consider it negative. Participation is a matter of compromising the various perceptions, attitudes, opinions and objectives of different stakeholders through negotiations in a real-life local context. Stakeholder diversity means managing conflicting interests but also involves a huge potential of choices to solve prevailing problems. An intervention may trigger changes in its context through its outputs. But it is the stakeholders who actually make the changes through social processes such as learning, adaptation, rejection, etc. Therefore it is necessary for stakeholders to be actively involved throughout the entire IMA procedure. Stakeholders bring their deep knowledge and perception of the context into analysis of problems and alternatives (Step 2). They provide their views to help formulate comprehensive impact hypotheses that may otherwise be overlooked by outsiders (Step 3); they provide local indicators (Step 4) and become actively involved in observation and data collection (Step 5). The term "assessment" already indicates the normative character of this method, which means that changes in a local context should not be assessed without local stakeholders (Step 6). Finally, at the end of an intervention phase, it is local stakeholders who should provide new opportunities for improving the work.

IMA is not only a management tool for project staff. For local actors, it can be an instrument for learning about the context in which one is involved. Close involvement by stakeholders during the entire IMA can play a central role in their empowerment. IMA is a contribution to local capacity building because it helps stakeholders to present their perceptions, to analyze, negotiate and make joint decisions. Participatory IMA can even go much further in the sense that stakeholder groups carry out their own impact monitoring. Participatory IMA can only be successful if it is transparent and if the information collected is relevant to and accessible by different stakeholder groups. Therefore, for each group information must be presented in an appropriate and understandable form or media. The means of communication and dissemination of information are determined by the needs of each group. Finally, information must be stored accessibly for everyone who is interested in it. Some guiding questions to be answered in a participatory exercise will help to structure relevant information management, and these questions are a crucial element in Step 1 of IMA:

- Which stakeholders should participate (local land users, women's associations, project staff, university students, etc.)?
- What kind of information can they provide (technical, cultural background, etc.)?
- What kind of information do they need / is relevant to them (technical, economic, etc.)?
- Which form of presentation do they prefer (reports, discussions, etc.)?

- What is the best way to communicate and disseminate the information (leaflets, radio programs, etc.)?
- How can the information best be stored so that it is permanently accessible (databases, files, leaflets, etc.)?

Seeking to involve local stakeholders in IMA, the following questions (IUCN 1997 [4]) can also be used as a guideline:

- How are you doing, how is the ecosystem doing?
- What needs to be done?
- How would you know if things are getting better or worse?
- Where would you get this information?
- Who has the information?
- What would you need to look at in order to find out?
- What would you need to count in order to measure or find out?

16.2.2 Step 2: Problem analysis and identification of core issues

Local stakeholders involved in IMA are confronted with a large number of land management issues (household economy, social obligations, farm management, technical issues, etc.) while experts usually concentrate on their research discipline and professional focus. At first glance, all land management issues seem worthy of consideration in monitoring. However, limited time and budgets make it virtually impossible to cover and monitor everything desirable. If too many details are considered, the overview may be lost and important details may not be covered satisfactorily. The most important and most relevant issues to monitor, the so-called *core issues* of sustainable land management, depend largely on the interests and perceptions of different stakeholders, and perhaps not so much on the rather narrow focus of one group of experts. So identification of the core issues is a first crucial test of participatory impact monitoring in sustainable land management.

Problem analysis, in preparation for a development project, is often conducted under budget constraints and time pressure as a theoretical exercise by experts with limited knowledge of the "area" concerned. Consequently, many projects are based on general assumptions instead of concrete know-how. Local stakeholders in particular have experience in managing their resources. They have opinions about what needs to be done and what should be monitored. As a cross-check on these opinions, other stakeholders, for example extension agents, project personnel, researchers and local decision-makers, are advised to make a preliminary assessment of what they find important. This crosscheck will enable them to formulate their own opinion about the prevailing core issues. However, it should not be forgotten that this represents only one view and is not the only possible perception. It will provide additional alternatives for the general debate with other stakeholders, the aim of which is to reach an agreement on the core issues of impact monitoring of sustainable land management. To analyze complex systems, it is recommendable to use network analysis tools (*Figure 16.2*) rather than isolated linear, causal assumptions.

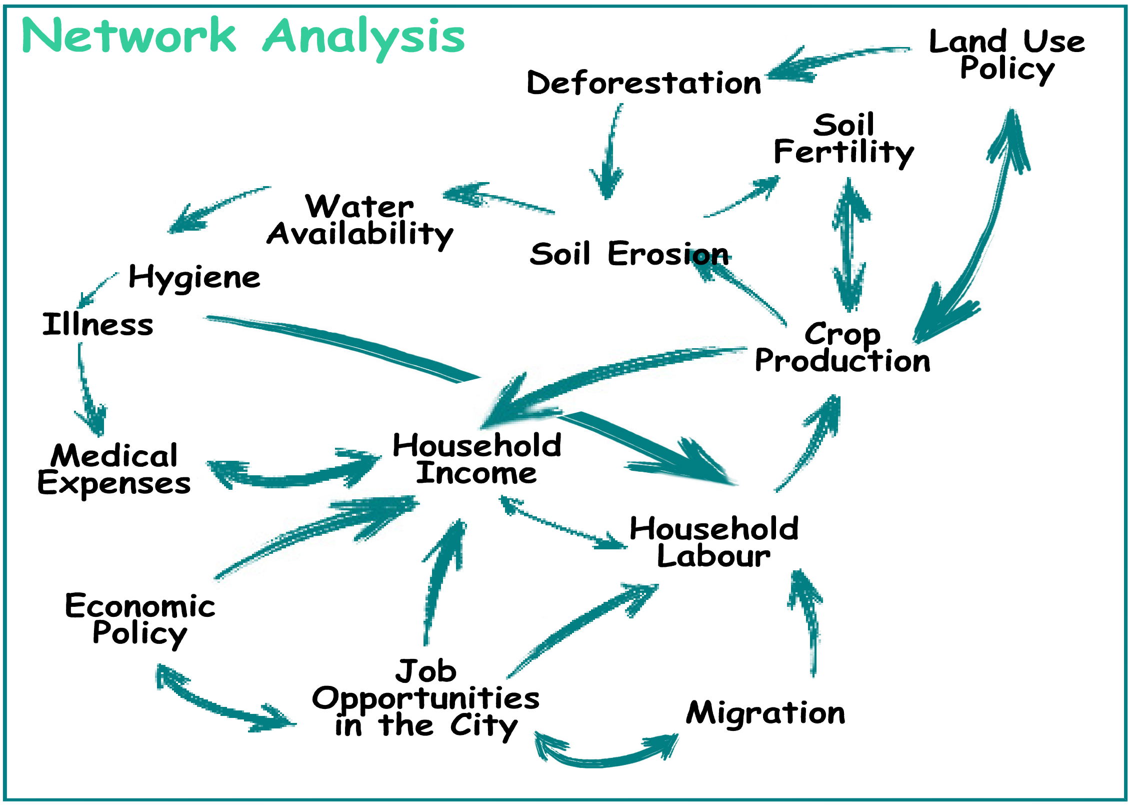

Figure 16.2 *Network analysis (Herweg and Steiner, 2002)*

16.2.3 Step 3: Formulation of impact hypotheses

All stakeholders have their own opinion with regard to interventions that may improve land management and make it more sustainable. It is assumed for the most part that the proposed interventions will have a positive impact. However, experience indicates that, because sustainable land management is a complex system, any intervention will cause more than one outcome or impact, some out of which will be neither expected nor desirable! Likewise, impacts may not be restricted to the specific core issue addressed, but may influence other issues as well. So before starting any intervention, it is essential to estimate different potential scenarios, the so-called impact chains, and to formulate a wide range of impact hypotheses. If this is not done, negative impacts occurring later may keep a project busy with corrective action while the actual goal is no longer in sight.

A wide array of impact hypotheses

All project or program planning documents contain only expected, positive outcomes and impacts. But such wishful thinking serves only to fool us and in the end is also very costly because it ignores the fact that negative impacts are always a reality. It is impossible to predict all impacts, but it is possible to think of some *unexpected impacts*, provided that the stakeholders concerned are involved in project planning. Even if negative outcomes cannot be completely avoided, a project can be better prepared to react. Farmers, when asked what they would expect from a new SWC terrace, would definitely not be misled by the mention of only positive impacts. They would be able to anticipate certain problems that are likely to occur, such as rodents and weeds being harboured in terraces, and water logging above SWC structures.

In the following example, different impacts are predicted by taking hypothetical interventions – terracing on steep slopes as a sustainable land management activity to reduce soil erosion – in a given watershed:

Expected positive impacts:

- For the Ministry of Agriculture, the positive impact would be e.g. achieving great area coverage with SWC technologies, reduced soil loss, and increased productivity.
- For farmers, the positive impact would be increased crop yield and at the same time increased income from incentives and subsidies.
- For a technical project, the positive impact would be that technologies are adopted – one to one, as recommended by the project – by farmers inside and outside the project area.
- For a local small businessman, the positive impact would be an increased demand for tools and inputs so that the supply of agricultural products can be increased as well.

Potential negative impacts:

- For local farmers, the negative impact would be increased labour for soil and water conservation and decreased production.
- For the project (intervention), a negative impact would be payment of incentives becoming more important than a focus on conservation.
- Negative impacts for merchants could include increased competition among suppliers.

Examples

Experiences in project planning and implementation show that there are always unintended (unexpected and negative) impacts. For example, farmers in a watershed were assisted by a project in planting grass on contour bunds in order to provide more fodder and thatching material. Unfortunately, the grass planted harboured snakes and harmful crop pests. Farmers found that the presence of the harmful pests outweighed the benefit of the additional grass. The project is now requested to reconsider the grass program, or look into ways of managing the grass (through species selection, or cultural practices) that will minimize the effect of the harmful pests. This type of on-the-spot analysis of observations of unintended consequences or impacts can directly feed into the project process in order to improve the delivery of outputs. But when deciding on corrective actions, potential detrimental effects must also be estimated by formulating new impact hypotheses.

Observations in a community in the same watershed where a certain fodder crop is being introduced on contour bunds revealed the following: The fodder crop was selected as an indicator of technology adoption and investment in the maintenance of the technology. At the start of the project it was assumed that increased fodder production from the recommended tree would give higher milk yields and increase household income due to an increased demand for milk. However, later research showed that this species had a toxic side effect: Milk production increased at the expense of the reproductive capacity of the livestock. In addition, an external factor – the removal of subsidized government services – made milk production an unattractive commercial venture, and therefore extra fodder production was no longer required. Farmers decided to remove the fodder trees and instead planted sweet potatoes and cassava on their contour bunds, increasing the risk of destabilization of the bunds. Improving this situation would require a thorough understanding of the whole land management system rather than a hasty correction at the spot where the detrimental effect occurred.

Figure 16.3 Discussions about the impacts of an aloe vera project in Kenya (Photo by Hanspeter Liniger)

Prevention strategies

These consequences of an SWC project and its outputs show that a great number of unfavourable or harmful outcomes could either be avoided, minimized, or better responded to if a sound impact chain is elaborated in a participatory manner at an early stage of a project. The impact chain is basically a series of alternative scenarios that tries to connect the outputs of a project with its project purpose (objective) or even the overall goal. The implicit purpose of impact chains is not so much to obtain a scientifically "correct" analysis of a rural context. It is rather an instrument for generating fruitful discussion with other stakeholders and eliciting their opinions, and thus for taking account as much as possible of the unexpected. An example of how to formulate and visualize an impact chain is given in Table 16.1.

Table 16.1 Impact chain – using an example in soil and water conservation

Output	Outcomes / Effects				Impacts			
	Utilization	Usefulness (Benefits / Drawbacks)						
SWC technology implemented	Dissemination of the technology	Crop yield increase				Re-investment in clothing, housing		
		Fuelwood production on bunds	Saved time is invested in horticulture or other productive activities	Production of marketable products		Children attend schools	Market development in the cities	
		Erosion is controlled			Increase of HH income	Reinvestment in better farm management		Decreased resource degradation
	Application of water conservation	Crop yield increase				Reinvestment in livestock		
							Overgrazing	
						Reinvestment in alcohol		
		Water logging	Yield decrease		Decrease in HH income	Increased poverty		Increased resource degradation
		Erosion increase (ill-designed SWC)		Removal of SWC	Sedimentation of water reservoirs	Flash floods	Out-migration	Social conflicts

Source: Herweg and Steiner, 2002

16.2.4 Step 4: Selection of impact indicators

What indicates changes occurring in the context of the interventions introduced? How do we know afterwards which impact hypotheses materialized? What set of indicators will point to changes that may ultimately help to achieve the purpose and goals of more sustainable land management? Each element in the impact chain can theoretically be described by one or more impact indicators, which are a simplified representation of a complex reality. The more the elements of an impact chain can be formulated, the greater the number of potential indicators. Finally, this number has to be reduced to a manageable set of indicators so that the project in question can finance and conduct the monitoring. Indicators not only represent important components of a (rural) context but are also a means of communication between stakeholders. Thus they must be selected jointly.

On the one hand, it is recommendable to have a set of indicators fixed as early as possible, because this helps establish a baseline (reference) for long-term observations. On the other hand, there are good reasons to take time for this selection. For example, a newly established project does not know and understand its context and its stakeholders well. During the lifetime of the intervention the context and the views of the stakeholders change, and so will many indicators. Some of the initially selected indicators may become impractical to observe and need to be changed and replaced with some that better reflect the situation and reality of the changing context. Further, unexpected impacts may require additional indicators at a later stage. Of course, the project cannot afford to delay the definite indicator selection until the end of the intervention. But as a compromise, several months could be ascribed to the process of a participatory search for a set of impact indicators, to adapt the initial selection and to incorporate "emerging" indicators. This is important because it documents the learning process of a project and the stakeholders who are directly or indirectly affected by it.

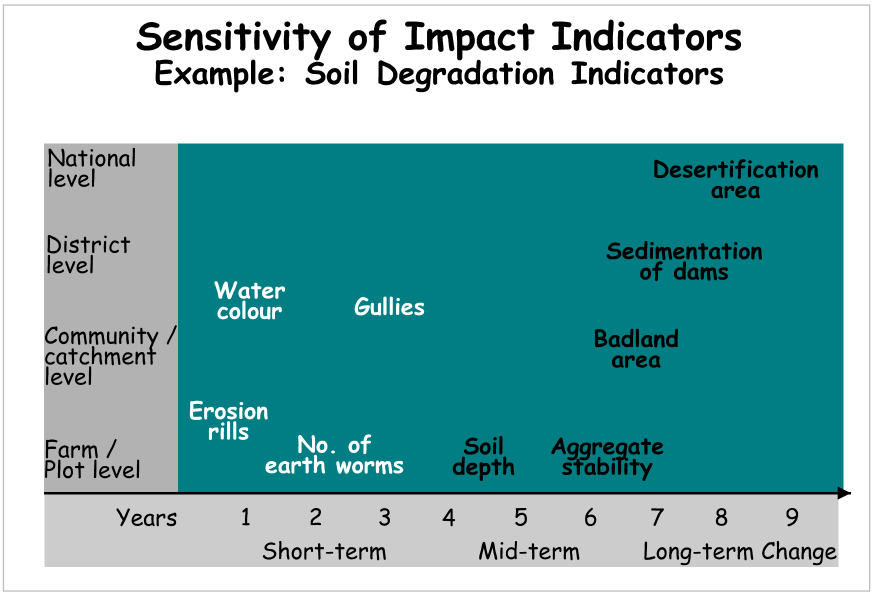

Figure 16.4 Indicator sensitivity (Herweg and Steiner, 2002)

Since sustainability implies a long-term perspective, each indicator should be checked to determine whether it is sensitive to short-, medium-, and long-term changes. In the example provided in Figure 16.4, the sensitivity of impact indicators is represented by the impact in terms of years after intervention, and the level at which the impact is monitored (farm / plot level, community / catchment level, district level and national level). Indicators of short-term sensitivity (1-3 years) will be highly relevant for outcome and impact monitoring and assessment as part of the project's self-evaluation process. They are helpful for immediate correction of project activities that are taking a negative direction.

Short-term indicators can also be monitored over a long period. Indicators that are not sensitive to short- and medium term changes are more important for monitoring far-reaching or late impacts. They only help the intervention to adjust its activities after a few years, or may assist future projects in learning from the past. The extent of erosion rills, the number of earthworms and changes in soil depth and aggregate stability are considered for monitoring at the farm/plot level for both the short- and mid- term impacts. On the other hand, impact indicators such as the extent of the desertification area and the sedimentation of dams will be only monitored at the district and national levels.

Example of indicator sensitivity

The Integrated Watershed Development Projects for the Toker and Dembesai areas are found in the central zone of Eritrea. Their approaches, however, are different. In Toker, the Ministry of Agriculture initiated watershed development through funds obtained from NGOs. SWC interventions were introduced to rehabilitate the degraded land, to increase biodiversity by excluding areas from uninhibited human interventions, and to develop water resources and reduce silt load in the Toker dam which supplies drinking water for Asmara. The Demsebai watershed, on the other hand, was initiated by the Ministry of Agriculture in collaboration with the summer students' programme. The plan of development was drawn through stakeholders' (local farmers, extension workers) involvement at all levels. Funding was secured from the government. Extensive SWC activities are undertaken in the watershed to rehabilitate the environment, introduce vegetative-agronomic measures to improve the fertility status of the soils, and introduce agro-forestry species to contribute to cut-and carry system for stall feeding of livestock and fuelwood production. Both projects have similar objectives and are found in similar agro-climatic conditions with variation in soil types. The question now is what impact indicators would be suitable for monitoring the success or failure of the development activities in these watersheds?

Literature on indicators does not provide a common classification (Dumanski, J. 1997[5]). Instead, there are different ways of perceiving, grouping or categorizing sustainable land management indicators (Herweg, and Steiner, 2002)[6]. *Generic indicators* – sometimes also referred to as *external* indicators – are based on agreements reached by external stakeholders such as project staff, researchers, development agents or policy makers. *Local indicators* (indigenous, site-specific) are mainly used by local actors and vary considerably from place to place. For a common understanding among all stakeholders, it is important to determine potential interactions or links between the local and the generic indicators that basically represent the same aspect. For example, farmers may say that their seeding rate has increased due to overland flow, which basically indicates what researchers call soil erosion. Local indicator plants, for example, point at environmental conditions and succession processes that must exist for a longer time, at the way these conditions are related to current land use practices, and at implications for maintaining soil fertility in the area. Questions to be raised are: Are local indicators valid only for specific times, environmental conditions, and social groups? How, when and by whom are the indicators used? Are there any possible long-term relationships associated with the indicators?

A measurement (often scientific) indicator contains quantitative information based on precise and replicable measurements. Proxy or surrogate indicators have a more indirect relation to the issue (Dumanski et al, 1997a) [7] and may be qualitative or quantitative. Experiential (anecdotal) indicators contain qualitative and semi-quantitative information based on experiences and people's perceptions and attitudes. In general, measurement indicators emphasize objects and often show short-term impacts, whereas experiential indicators emphasize subjective views and frequently reflect long-term changes. An alternative categorization distinguishes strategic and cumulative indicators (Traeger, 1997)[8]. Strategic indicators show a direct cause-effect relationship where one statement or recommendation will be made for each indicator (e.g. soil fertility indicated by crop yield). The cause effect relationship with cumulative indicators is not necessarily direct, and several indicators will be required for each statement or recommendations (e.g. soil fertility indicated by soil organic matter plus available P, N, K plus CEC).

Impact indicators will firstly pertain to the status quo of what they represent (e.g. soil fertility, forest cover, population density). Ideally, impact monitoring of sustainable land management starts with a baseline study prior to any project intervention as a reference for comparison with future situations. Secondly, the same indicators can be used to highlight tendencies and changes if there are at least two observations (e.g. higher available nutrient content, deforestation, increasing population density). The analysis and quality of the impact monitoring in sustainable land management improves through long-term observations. Careful comparison between project- and non-project sites can substitute for time-series analyses to a certain extent. Indicators may also have a normative character because they can be used to evaluate changes (better or worse than before).

The aim of programme monitoring is to assemble a reasonable set of indicators that can provide sufficient information to assess ecological, economic and social aspects of sustainability from the household level to the regional level. Indicators are means of communicating perceptions of sustainability among stakeholders. The type and quality of the information needed for decision-making depends on the specific situation and the expectations of a project. The following (incomplete) list of criteria and questions will assist in defining which criteria are relevant for the indicator selection process in a specific situation (Herweg, et al., 1998)[9]:

- *Validity and relevance*: Are the indicators essential? Does the set of indicators provide sufficient information about the situation observed for making knowledge-based decisions?
- *User-orientation and transparency:* Are the indicators significant for different users? Are they understandable and meaningful for the relevant stakeholders (farmers, land users, policy-makers, researchers, development agents etc.) who need the information? Are there local indicators that can be used? Were indicators selected involving stakeholders or not?
- *Gender-orientation:* Are the selected indictors sensitive enough to bring to light the domains of both men and women so that important gender-specific knowledge bases are not neglected, bypassed or glossed over? Are the indicators consciously constructed to address the gender issues or are they included as a cliché?

- *Practicability:* Are the indicators sufficient, simple, practical and effective in communicating results to and creating awareness among non-technical or non-scientific stakeholders?
- *Policy relevance:* Is there a sufficient number of indicators of importance to policy makers that address environmental issues and require a political resolution?
- *Sensitivity:* Does the set contain indicators that reflect short-term changes in land management to permit quick assessment, or do medium and long-term indicators allow assessment only after a longer time?
- *Reliability:* Are the indicators qualitative or quantitative so that monitoring of indicators by different persons and at different times yields comparable results?
- *Timeliness:* Do the indicators selected provide data that can be analyzed and presented in time for all stakeholders who need the information?
- *Compatibility:* Are the data to be collected and the format to be used compatible with existing data and formats?
- *Cost-effectiveness:* Does the indicator selection imply an agreeable compromise between precision of information, the time and equipment required or available, and the representativeness of data generated and collected?
- *Feasibility*: Can projects or stakeholders make the required inputs (staff, skill, time, funds) available to monitor the indicators according to the time intervals and spatial resolution agreed upon?
- *Sustainability orientation:* Do the selected indicators represent all dimensions of sustainability (social-cultural-institutional, economic and ecological)?
- *Area coverage and hierarchy*: Do the indicators reveal changes at the same spatial decision-making level (field, household, community, catchment, district, etc)?

Using a framework or model to interlink indicators

Although it is not possible to define sustainable land management globally, attempts have been made to address the issue internationally (Hurni, H., Meyer, K. 2002)[10]. It is possible, in turn, to develop a vision of land management at the local level in terms of what is more or less sustainable compared to previous years (Herweg, K., Steiner, K., Slaats, J. 1998)[11]. This vision should be jointly developed with stakeholders, e.g. when planning an intervention. Since different actors have diverse perceptions of what they think is sustainable, it is not easy to select indicators of sustainability (e.g. environmental health). In contrast to this, indicators of unsustainability (poverty, overgrazing, symptoms of resource degradation, etc.) are usually easier to identify. But it must be kept in mind that the absence of indicators of unsustainability alone does not mean that land management is already sustainable. It is therefore important to use both types of indicators.

- *Indicators of environmental health* describe a vision of greater sustainability of land management. They help formulate goals and indicate the directions to take.
- *Indicators of unsustainable land management* suggest that something is going wrong and serve as an early warning system. They show the need to confront problems and

issues so that time can be spent to find reasons as well as potential and workable solutions.

Indicators represent a complex reality. For example, crop yield is mostly taken as an indicator of soil fertility. However, yield is influenced not only by soil fertility but also by many other factors, including pests, diseases, weather variability, crop type and variety used, the socio-economic well-being of the farmers, etc. Therefore, single indicators cannot represent a context sufficiently. Only a set of indicators will provide plausible information about whether land management is moving towards or away from sustainability. In the framework below, SLM is segregated into "fields of observation", classified according to dimensions of sustainability and spatial decision-making levels (*Table 16.2*). Attribution to a particular dimension or level may vary according to the specific project context. Elements can be formulated neutrally (e.g. socio-economic disparities), as a problem (e.g. increased disparities) or as a desired scenario (e.g. decreased disparities). They can also be used in problem analysis (see above, Step 2).

Table 16.2 SLM fields of observation

Level	**Dimensions of sustainability**			
	Institutional	**Socio-Cultural**	**Economic**	**Ecological**
Household (including farm plot level)	▪ Education and knowledge ▪ Access to natural resources ▪ Household strategies ▪ ...		▪ Household income, assets and consumption ▪ Labour and workload ▪ Land management and farming system ▪ ...	▪ State of natural resources ▪ ...
Community	▪ Local leadership ▪ Local institutions ▪ Producer and self-help organisations ▪ ...	▪ Gender issues ▪ Conflict management ▪ Innovation ▪ ... ▪ Social & economic disparities ▪ ...	▪ Markets, prices and credit ▪ Public property ▪ ...	▪ Land use ▪ Water resources ▪ ...
District	▪ Education, training and extension ▪ Land and water rights, tenure ▪ ...	▪ Change in social values ▪ ...	▪ Employment opportunities / migration ▪ Infrastructure ▪ ...	▪ Land cover ▪ Off-site effects ▪ ...

Source: Adapted from Steiner and Herweg 2002

Sustainable land management can be considered one of the ultimate goals and therefore envisaged positive impacts of rural development interventions. Formulated as a goal or purpose, the desired situation might be "land management is more sustainable". But there is a need to clarify what sustainable land management means. Is it increased production, decreased resource degradation, or increased wealth and social wellbeing? Several dimensions of sustainability can describe it: institutional, social (socio-cultural), economic and ecological. The subdivision into dimensions prevents important aspects of sustainability from being forgotten. For practical purposes, some dimensions may be merged later on, such as socio-economic, or social/institutional.

Development intervention may support activities related to all dimensions of sustainability, e.g. to increase the economic and social wellbeing of the population, to strengthen local institutions, and to develop environmental protection practices. The above framework (*Table 16.2*) can be used to develop examples of impact hypotheses and impact indicators. It must be kept in mind that positive and negative formulations are context- and stakeholder-specific, which means they must always be adapted to the situation they are used in. Indicators are inter-linked components and processes in one land management system and not a group of separate variables. Although each single indicator could be interpreted independently, sustainable land management as an entity can only be assessed if its indicators show a meaningful linkage. Therefore, a framework or a structural model will be developed before selecting single indicators. For example, indicators such as "rainfall", "infiltration", "runoff" and "evaporation" are measured in the same measurement unit of "millimetres" (mm). Thus they can be combined in a water balance equation that is, in effect, the quantitative framework or model linking the indicators to the hydrological issue of water balance (Herweg, K., Steiner, K., Slaats, J. 1998)[12]. In the context of sustainable land management, by contrast, one would usually select different biophysical and socio-economic indicators, of both a quantitative and a qualitative nature. The heterogeneous mix requires a qualitative frame or structural model as a meaningful linkage of indicators.

Several potential structural "models" of complex land management reality are described in the previous chapters (Chapter 9). Another option is given below. The Pressure-State-Response Framework (Pieri, C., Dumanski, J., Hamblin, A. Young, A. 1996)[13] (PSR) is an example of a model that can be used to identify core issues involving monitoring and impact indicators. The Sahara and Sahel Observatory (1997) modified the PSR model by adding "driving forces" and identified the following topics for coverage when developing impact indicators:

- *Driving forces* causing pressure on natural resources are population pressure, economic growth, urbanization, policy failures (stagnant technology, delayed intensification), imperfect markets (lack of markets, poor market access), transaction costs, and imperfect information (limited access to information about market opportunities), social inequity, poverty, and political and social instability.
- *Pressure indicators* are changes in cropping techniques, financial position of holdings, fuelwood / charcoal consumption, use of crop residues, use of animal dung for fuel, or price of fuelwood / charcoal.
- *State indicators* are the rate of deforestation, rate of soil erosion, degree of salinization, soil crusting and compaction, crop productivity, livestock productivity, and nutrient balance (on-farm organic matter recycling).
- *Response indicators* are changes in legislation, investments, tree planting, state conservation programs, farmer conservation groups, and farmer adoption of tree planting and soil and water conservation.

To ensure that the indicator set covers all important aspects of sustainable land management, the indicators can be grouped, for example, according to the three sustainability dimensions (ecological, economic, social). The Land Quality Indicator Initiative of the World Bank (Pieri, C., Dumanski, J., Hamblin, A. Young, A. 1996)[14] introduced another grouping with a more economic focus that identified common (generic) and internationally agreed indicators for monitoring and evaluating sustainable land management. It is commonly known as the "5 pillars of sustainability".

Still, the PSR model can be considered fairly deterministic because it emphasizes a reactive chain of enforcement (pressure-state-response). Taking into account the high potential of indigenous knowledge, innovative creativity and individual decision-making of local land users, Hurni and Wiesmann (2002)[15] further extended the model by adding a second string – consisting of more pro-active webs of empowerment – by pairing "pressure" with "potentials", "state" with "dynamics", and "response" with "innovations" *(Figure 16.5*).

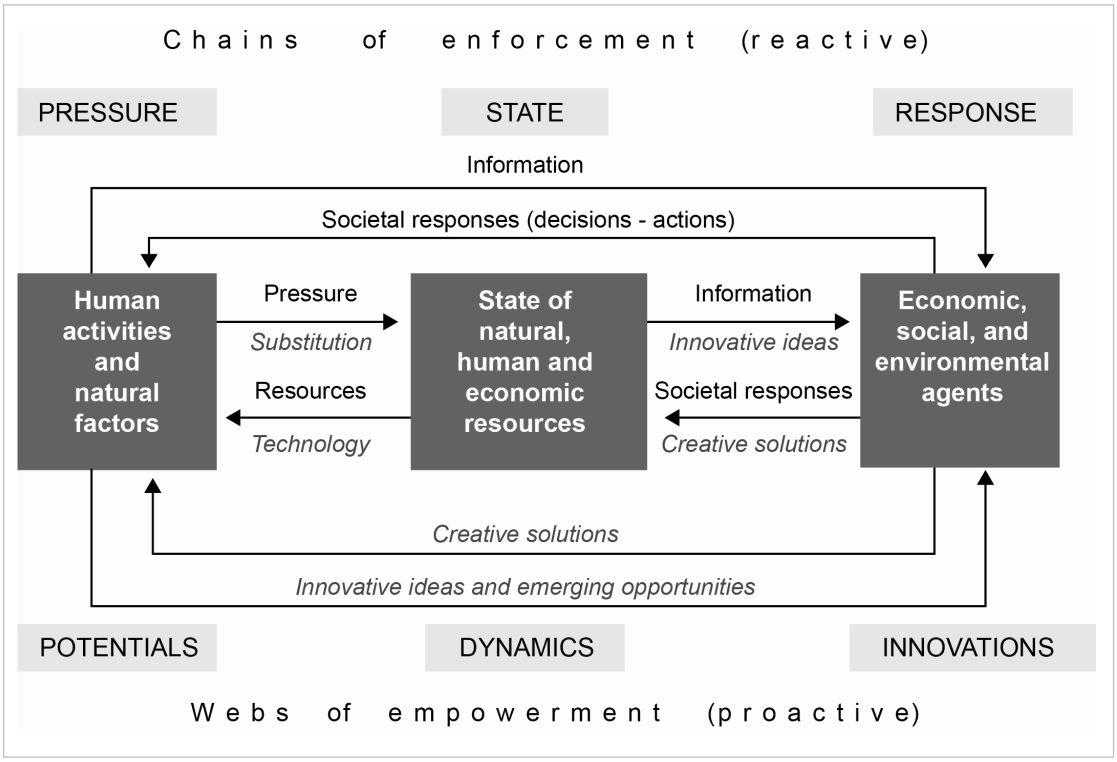

Figure 16.5 An extended pressure-state-response model (NCCR North South, 1999)

Embedding the indicator criteria in a broader context

Besides the importance of an "inner" linkage to the indicator set represented by a structural model, there is also a wider – "outer" – context to be considered:

- The *temporal* point of view: using existing data bases saves time and costs, if the specific choice of indicators, type of data, format and frequency of reporting can be made compatible. If so, this would "extend" the own monitoring period and the initial monitoring would already indicate a trend in land management. Secondary data can consist of activity and evaluation reports of institutions and organizations, information held by individuals, statistics, census results or other monitoring systems. For example, if a project needs rainfall data, the database from the National Meteorological Services Authority can extend the project information base by many years.

- The *spatial* point of view: the indicator set must reflect the fact that a project impact is not necessarily restricted to the project area (on-site) but may reach further (off-site). For example, where terraces are applied (on-site), they may affect the amount of water, soil and nutrients that leave the watershed. Thus people living downstream (off-site) are also affected by these technologies. The selection of representative monitoring locations will help reduce the costs of on-site and off-site impact monitoring of sustainable land management.
- The *hierarchical* point of view: local indicators are site-specific, which may limit the aggregation of information at national level. Nonetheless when selecting local indicators, consideration should be given to whether and how they can possibly be aggregated to become an even more useful tool for decision and policy-making. For example, a local indicator such as the colour of plant leaves can be calibrated with generic soil fertility indicators such as nutrient deficiency, which can be accounted for in terms of cost. In this case, these indicators are useful for calculating the relevance of resource degradation for a national economy.

16.2.5 Step 5: Development and application of impact monitoring methods

How can a rural context – represented by a selection of impact indicators – be monitored and changes be documented? Which methods are applicable within the means and capacities of the intervention? How can methods best be combined? There are usually several ways and methods of monitoring a parameter or an indicator. If highly accurate (scientific) data are required, it is assumed that projects will call upon specialists who apply their own methods. In the event that development interventions do not have the capacity and resources to apply sophisticated methods, a project will have to rely on cost-effective monitoring tools that can be handled in a flexible way by project staff themselves.

In what follows, three types of monitoring methods are described which have a high chance of being applied because they are built on what many projects already practice (Bosshart, 1997d) [16]. These tools can be considered the basis for impact monitoring and assessment, but must also be adapted to the specific context of the intervention in question, in accordance with the impact hypotheses formulated and impact indicators chosen. Therefore, only general descriptions and explanations are presented here.

Triangulation

How good is the quality of the information obtained by the above-mentioned methods? It is assumed that, due to resource limitations, not all projects can afford methods with high accuracy. Therefore the principle of triangulation is used, which combines reliability with participation. This means that all individual perceptions, which are obtained through interviews and discussions, must be crosschecked with the perception of others and, if possible, compared with direct observations.

- **Interviews and discussions** with local stakeholders are the basis for IMA. The information obtained can be very detailed but will be guided by individual perceptions and the different (often hidden) agendas of the stakeholders. Although all kinds of visible and invisible changes might be discussed, socio-economic aspects may dominate. A crosscheck of the information, in particular invisible (e.g. social) changes, can be made through interviews with other stakeholders. Visible improvements or deteriorations can be crosschecked with photo-monitoring and participatory transect walks.

- **Observations** made and discussed during a **participatory transect walk** provide a detailed view, especially of biophysical issues, although social and economic issues can also be addressed. A transect walk highlights the spatial interrelations of soil degradation and nutrient, water and energy flows, etc. Discussions often start with visible aspects but can ultimately include links with invisible aspects. A transect walk is an excellent opportunity to identify local impact indicators. The information can be crosschecked with interviews and photo-monitoring.
- **Photo-monitoring** provides an overview of visible changes in the project context, which may be predominantly related to biophysical and economic issues. But photos require interpretation and further investigation of the background. This can be done through interviews and discussions, as well as during participatory transect walks, depending on which aspects need further clarification.

Interview and discussion

As participatory tools, interviews and discussions cover quite a wide range of indicators. They usually produce qualitative results and also serve as a cross-check on quantitative results, for example from structural interviews or biophysical measurements. The tools are used best in combination with complimentary approaches and methods (triangulation) to ensure the quality of information appropriate for decision-making (Van Veldhuizen et. al., 2000[17], Pretty et. al., 1995[18], Schönhuth and Kievelitz, 1994[19], Werner, 1993[20] , Bollinger et. al., 1992[21], FAO, 1990[22], Albrecht et. al., 1989[23] Chambers et. al., 1989[24]).

Figure 16.6 Participatory assessment of pearl millet, Shebek, Eritrea (Photo by Paul Roden)

Almost all biophysical and socio-economic indicators can also be monitored by obtaining peoples' opinions of them. Discussions can encompass, for example, gender aspects, labour division, workload, wealth, production and market prices, household income, land use and land management, resource degradation and protection, technological and management innovations, etc. Packages such as RRA (Rapid Rural Appraisal), PRA (Participatory Rural Appraisal), and PLA (Participatory Learning and Action) contain many well-tested and cost-effective tools consisting of group exercises, semi-structured interviews, informal discussions and visualization (mapping, modelling, rating matrices, causal diagramming, and mind-maps). They are characterized as rather qualitative approaches combining "optimal ignorance" and "appropriate imprecision". These methods were primarily designed for mutual learning, and therefore assist local people in gaining confidence in conducting their own appraisal and analysis and helping external experts to understand local perceptions (*Table 16.3*).

Table 16.3 Potentials and limitation of participatory methods

Potentials of the method	Limitations of the method
Can be used during all phases of an intervention	Statistical evaluation is not necessarily ensured, data need verification by other methods
Can cover a wide range of indicators	Depends a lot on the behaviour, attitudes, values and beliefs of the surveyor; therefore, quality control is necessary to avoid abuse and to maintain certain professional ethics.
Comparatively cost-effective, rapid, qualitative approach. Integrates local (indigenous) and external knowledge.	Depends a lot on the behaviour, attitudes, values and beliefs of the surveyor; therefore, quality control is necessary to avoid abuse and to maintain certain professional ethics.
Allows in-depth investigation into issues raised by all	PRA methods have to be accepted and must be applicable by local stakeholders
Hidden and glossed aspects of discussions can be discovered that are not obvious at first glance.	Exaggerated, standardized and routine use of participatory methods will saturate people and result in response fatigue
	Even if the methods and tools are allegedly participatory, there must be reflection about what ends are really served by the results

Participatory transect walk and observation

The fact that interviews and discussions with people bring to light useful information for IMA should not lead to the conclusion that direct observations and measurements by project staff or outsiders are no longer necessary! Particularly biophysical and some economic aspects can be directly observed in the field to crosscheck the results of other methods. Potentials and limitations of transect walks are shown in Table 16.4, and a checklist of potential indicators of unsustainable land management is given in Table 16.5. Naturally, such a list must be adapted and possibly supplemented when applied in a specific local situation. A participatory transect walk will not only provide a detailed view of a farm or valley, critical sites of resource degradation and areas of promising management. It will also help to establish connections between those sites, i.e. flows of nutrients, water, sediment and energy. Thus regular transect walks, as well as farm and field visits, are not only recommended to maintain close contact with local stakeholders and their reality. Different indicators and parameters also require different observation times. For example, pests and diseases are observed during the cropping season, production during harvest, soil degradation at the onset of a rainy season, water shortage during the dry season, etc.

A participatory transect walk is conducted by a team to observe and talk about issues of local importance. Experts (outsiders) and local informants (insiders) systematically traverse the area under study. This team is preferably composed of people representing different disciplines (biophysical and socio-economic) in order to cover a wide range of topics during the walk. The walk follows a specific route, e.g. from the highest to the lowest point in the landscape, from the north to the south or east to west, whichever is agreed upon initially by the group. Everything mentioned by the informants and everything observed and questioned by the outsiders is discussed and noticed. The walk supplements information obtained from officials and secondary literature during preparation of the monitoring with subjective and lateral observations and experiences. This method can be used for a qualitative approach as well as for a rapid semi-quantitative assessment.

The participatory transect walk is of particular interest because it offers an opportunity to obtain an overview of perceptible signs of resource degradation that indicate unsustainable land management and pose questions such as: Which degradation processes prevail? When do they occur? Where are the areas of particular hazards (hot spots)? Such indications are a starting point for further informal discussions with local and other stakeholders on the spot, and consequently for understanding different perceptions of the same issue. Socio-economic topics are already subject to interviews and discussions, but may also be taken up during the walk.

How to organise a participatory transect walk:

- Local informants are asked to form an observation team together with outsiders. It is important to have representatives of all stakeholder groups concerned. Development agents with a background in natural resources management are of particular interest since they would have a good perception of the prevailing situation. In the absence of such a subject matter specialist, an agricultural extension agent with strong orientation on land management would be preferable.
- The route is identified by the group, which needs to consider areas where major agricultural activities are undertaken and include different types of land use.
- The team should develop its own norms for group behaviour as a checklist of ensuring participation and meeting individual responsibilities and team obligations.
- The transect walk is planned by defining the subjects to be covered, methods to be used, information and data to be collected. To identify, for example, indicators of unsustainable land management, checklists to be developed will give initial hints

about what to look at. Discussion prior to and during the walk may give further clues about observable symptoms and indicators.

- The timing of the walk depends on the subjects of interest. For soil erosion observations, this can be done where and when erosion indicators are visible, which mostly coincides with the beginning of the rainy season. Crop pests and diseases are preferably observed during the major cropping season, crop yield before harvesting, water problems during dry and wet seasons, and soil fertility during the early flowering stage of the crops.
- During the transect walk new findings are considered and pursued if they seem to be of importance for the overall subject. For example, certain farmers may have introduced a new variety of crop, tried to divert run-off onto their farm, opened a pond for harvesting and collecting flood water for supplemental irrigation, etc.

Table 16.4 Potentials and limitations of transect walks and observations

Potentials of the method	Limitations of the method
Provides a good overview and rather intensive impression of a new location	Subjective information; mapping reveals only what is visible to the person who applies the method
Closely considers the local knowledge base	Qualitative statements, in particular, must be supported by additional investigations
All local land users can participate	
Important new issues arise which may have been overlooked	
Provides basically qualitative results, but some indicators can be quantified	
Signs of unsustainability of land management can be mapped within a topographic sequence, which reveals spatial interrelations of biophysical and socio-economic processes	

- Different land units (slope, level terrain, forest, cropland, natural sites, villages, etc.) and problematic areas (erosion hazard, water shortages, malaria infestation etc.) are distinguished. During the walk, relevant observations are marked on the map and accompanied by extended remarks and descriptions in a field book. Sketches of the area enhance detailed observation more than photos. Like photographs, sketching can be used to visualize impressions or changes after a certain period of time.
- Symptoms of unsustainable land management, for example, will be observed within their topographic sequence, with a continual search for possible interrelations or causes of degradation up- and downslope, or up- and downstream.
- Information is shown on a general transect map. Sketches, photos and notes are used to reflect on the mapping and for discussions with others who did not see the location. Sketches and digital photos can be used on the same day, while conventional photos may take longer to be developed. In view of the long-term nature of impact monitoring and assessment, field maps may need to be redrawn on clean paper while the field impressions are still vivid, preferably on the evening of the field day.

Table 16.5 Participatory transect walk and observation checklist for signs of unsustainable land management

Signs of unsustainable land management	Indicators (what to observe)	*x*
Soil fertility decline	- Changing colour of plant leaves - Reduced plant cover / production - Salt on soil surface - Abandonment of cropland - Soil colour changes - Decreasing root density - Poor soil drainage - Compaction: crust thickness, strength (broken by hand) - indicator plants…	
Degradation of plant resources (possibly as a consequence of soil / water degradation)	- Changing colour of plant leaves (yellow) - Pests and diseases - Low plant ground cover (estimation in %) - Low variety of plants / high variety of weeds (species Composition)…	
Soil erosion by water	- exposed plant roots (cm) - rills, gullies and accumulations (No., density, volume) - reduced topsoil depth (spade or drill) - change in soil colour indicates subsoil exposure - increasing runoff, periodic flash floods (time) - sedimentation of reservoirs, deposition visible during low water table - water turns brown - increased seeding rate - increasing stone cover (topsoil already washed away)…	
Wind erosion	- dust storms, mobile dunes (pegs as reference points) - nutrient depletion (incl. acidity), toxicity (pH)…	
Declining water quality and Quantity	- water has brown colour (soil erosion) - algae - bad odour - months of water shortage - diminishing groundwater table - drying up of wells, springs and rivers - dying trees - more unpalatable weeds – fewer fodder species…	
Degradation of animal resources (possibly as a consequence of plant degradation)	- changing no. of livestock per household or village - malnutrition / shortage of fodder - animal diseases	
Land use changes	- increasing % of cropland - deforestation - shortening fallow period - pasture turned into cropland…	

The list of indicators can be extended or modified to serve project needs.

Photo-monitoring

Development co-operation is intended to initiate changes, and at least some of them should be visible after several years, especially when projects deal with SLM. Rural development projects, for example, should enhance household income and living standards, which would then be visible in terms of better housing and clothing, more children going to school, better means of private and public transport, etc. Similarly, if land and resource management has become more sustainable, it should be evident in improved crop stands, controlled soil degradation, effective conservation measures, etc. Photo-monitoring is a comprehensive method for documenting all visual changes that can be used to cross-check individually perceived changes. See also Table 16.6 for potentials and limitations of the method.

Several series of photos from specific locations and standpoints taken at different times over a longer period will document how things change. Photo documentation can range from overview pictures (e.g. showing an entire slope, valley, farm, village, etc.) to detailed views of specific objects (houses, rooms, people, conservation measures, etc.). Where changes are intended and expected, photos can be taken from permanent standpoints at regular time intervals. Complementary photos can be taken occasionally wherever and whenever unexpected visible changes occur. However, photos alone do not tell much about how and why changes occurred. They provide an overview that requires further discussion and interpretation with stakeholders at regular intervals.

Table 16.6 Potentials and limitations of photo-monitoring

Potentials of the method	Limitations of the method
Comprehensive and fast method	Restricted to visual changes; should be used together with other monitoring methods
Professional manpower or sophisticated equipment would improve the quality but are not necessary (reflex camera desirable, but pocket camera can also be used)	

16.2.6 Step 6: Impact assessment

Preparing the benchmarks (reference values) for each impact indicator in view of impact assessment

How did the context change in the eyes of the stakeholders? What did they learn from these changes? Are these changes positive, negative, satisfactory or not, and how did change happen? Assessments as exemplified by these questions are a process of individual judgment that will reveal many different opinions. Changes in the context of the intervention will then be visualized, for example in a “spider” or “amoeba” diagram (Herweg, and Steiner, K. 2002)[25]. For this purpose, a rating for each indicator is inevitable, e.g. the best possible realistic achievement for each indicator is 5 (very good), and the worst possible achievement is 1 (very bad). It is recommendable to prepare the benchmarks for rating of each indicator already during indicator selection (see Step 4 above) in a debate among all stakeholders. For example, farmers would know how to rate the impact indicator "maize crop yield" from "5" (e.g. > 3 t/ha) to 1 (e.g. < 1 t/ha). Ideally, all stakeholders agree on a common rating for all impact indicators (*Table 16.7*). But it can also be interesting to carry out impact assessment separately for each stakeholder group, and each group's findings will be communicated to the others. It should be determined at what level the assessment will be made (household, community etc.)?

Table 16.7 Example of benchmarks for interpreting impact monitoring results prepared in a participatory manner

Impact indicators	Rating*				
	5 Very good	4 Good	3 Moderate	2 Bad	1 Very bad
Short-term indicators					
Crop yield (maize)	> 3 t/ha	> 2 – 3 t/ha	> 1.5 – 2 t/ha	1– 1.5 t/ha	< 1 t/ha
Household income	>20 % increase	> 10 – 20 % increase	1 – 10 % increase	Stagnating	Decreasing
Women's labour income	>20 % increase	> 10 – 20 % increase	1 – 10 % increase	stagnating	Decreasing
% of farmers adapting new technologies without incentives	> 60 %	> 40 – 60 %	>20 – 40 %	10 – 20 %	< 10 %
Occurrence of pests & diseases	No	Rarely, little evidence	Sometimes, but can be controlled	Control is often difficult	High, every year
Soil erosion (rills and gullies)	No signs of erosion	Smoothened soil surface, but no rills	Sometimes, few rills	Most years, many rills	Every year, rills & gullies
Mid- to long-term indicators					
Household decision-making	Jointly in most households		Jointly in a few households	By men in most households	
% of farmers experimenting with cropping practices	Regular modifications by > 70 %	Regular modifications by > 50 – 70 %	Regular modifications by > 30 – 50 %	Irregular modifications by 5 – 30 %	< 5 %
Boys and girls with school leaving certificate	> 80	> 60 – 80	> 40 – 60	30 – 40	<30
Soil fertility status**	Deep, dark topsoil, high earthworm activity, high root density		Moderately deep and dark topsoil, earthworm activity, root density	Light soil colour, yellow & red plant leaves, no earthworms, low root density	

* N.B: the rating is highly site-specific and requires intensive discussion with stakeholders

** Rating of soil fertility status requires consultation with soil specialists

For example, if there is a great heterogeneity of household categories (such as poor and wealthy households), which is more often the norm than the exception, changes in the farm context should be assessed individually, or at least separately for each household category (Atakilte et al., 2001[26], GoE, 2004[27]). If all households are judged together at the community level, the result will be an average. This average, however, may not reflect important changes in individual households. It will thus be meaningless. After a set of important indicators is selected, an initial observation (monitoring) that takes all of them into account produces the baseline. In the next years to come, monitoring and assessment will only include those indicators that are sensitive to short-term changes. Indicators of medium- and long-term changes can be gradually added after several years. Using the spider diagram (*Figure 16.7*) for visualizing the results of the monitoring, the questions "where are we?" and "where do we go from here?" need to be asked in relation to each selected indicator. A comparison of a recent rating with previous ratings will naturally reveal indicators with detrimental development, or in which little or no "improvement" is considered. In the example (*Figure 16.7, Table 16.7*) this is the case for the indicators "boys and girls with school-leaving certificates" and "household decision-making". When interpreting such figures, the first reaction is mostly to give special emphasis to improving these sectors in the future. Unfortunately, the inherent consequence of this interpretation is often to neglect the other indicator with seemingly better outcomes, which may be a fatal mistake. It should always be kept in mind that the rural contexts under question work like a system where all factors are connected, and where improvements in the entire system cannot always be achieved by direct interventions focusing on the weak points. For example, better education and empowerment of land users can contribute as much to SLM as an appropriate technology. Therefore, while interpreting monitoring results, it is a must to reconsider – or even modify – the systems analysis that was done at the beginning (see IMA in Step 2)!

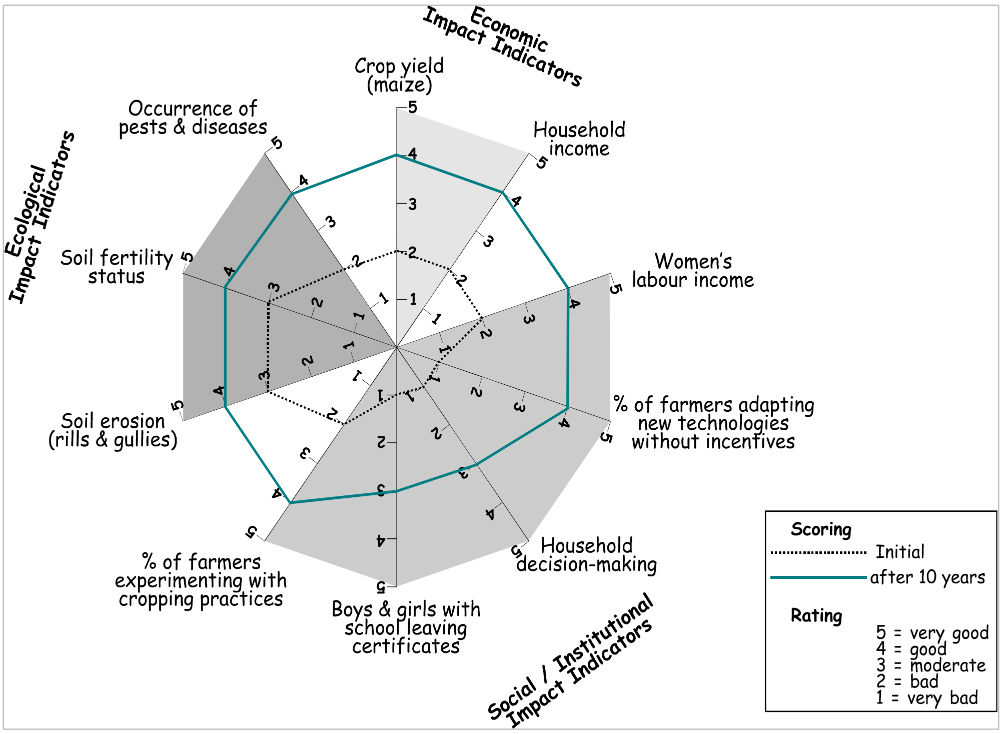

Figure 16.7 *Spider diagram to visualize changes in the indicators observed (Herweg and Steiner, 2002)*

Trying to attribute an impact to a project

While local stakeholders may very much care about a better livelihood in general, they may be less interested to know which project made what contribution to it. A donor, however, needs to justify his own investment to a parliament and to taxpayers back home. Naturally, the spider diagram can only reflect changes covered by selected impact indictors. How can these changes be attributed to an individual intervention or project? Were there additional changes that were not expected and, therefore, could not be monitored? Which changes contribute to the goal of the project? We have to keep in mind that the longer an intervention takes, the more factors other than the project in question will contribute to changing a rural context. This makes it more and more difficult to attribute the new situation to a single factor, such as the project in question, another development program, the national agricultural policy, the world market price, etc. This is referred to as the attribution gap (*Figure 16.8*). Even with costly investigations such as basic research, it will be difficult to tell precisely what exactly a specific intervention has contributed to the change of the context. Therefore, in most cases the challenge is to find plausible relations between the project's outputs and the changes rather than scientific proof.

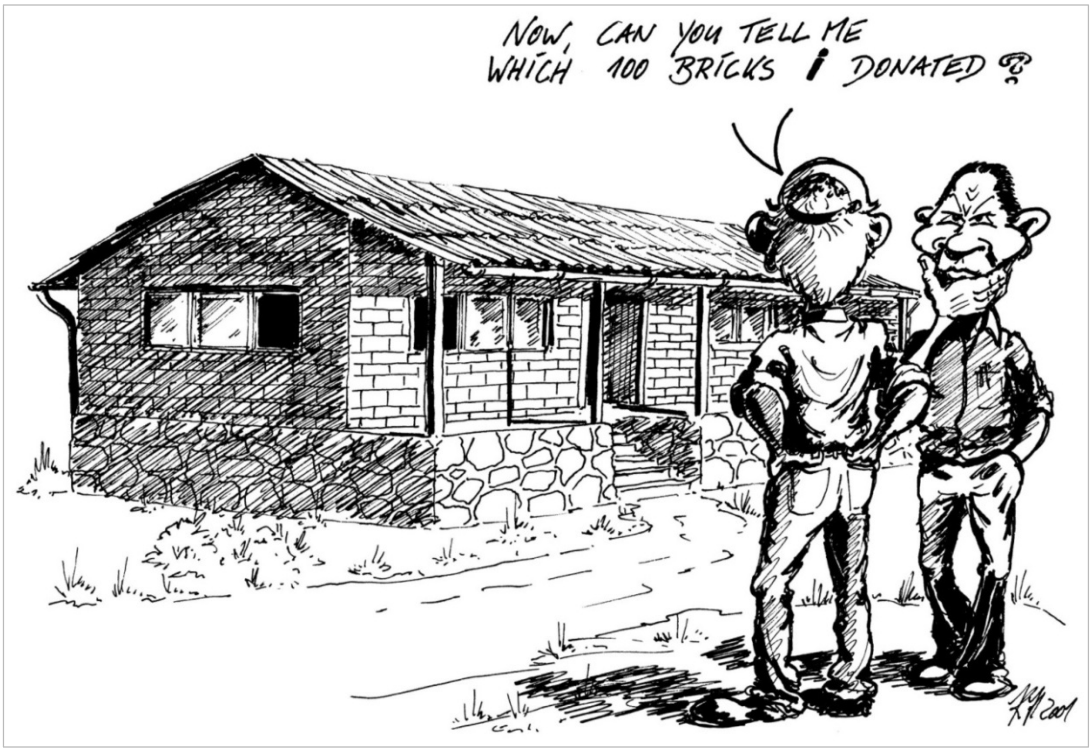

Figure 16.8 Attribution gap: what is a project effect and what is not? (Illustration by Karl Herweg)

At this point, it is important to reflect about the "nature of change". Changes in a context can be considered the result of social processes such as **learning, adaptation, communication, decision, integration**, etc.; i.e. interactions between individuals or groups. The project – or the intervention – "only" tries to trigger or strengthen such processes with its outputs. For example, any new technology must be utilized and found useful (or useless) to be finally adapted or rejected by stakeholders, which is the result of a learning process. Members of a society communicate their experience and learn from it. When the bio-physical environment or the economic situation changes, people adapt their perception and react to it. Our hypothesis is that it is not a technology as such that makes a change, but the social learning that is related to its application! Therefore, a key question of impact monitoring is, whether a project was able – through its outputs – to stimulate changes and social processes such as learning, and whether these processes are likely to help reach development goals.

The following guiding questions can be helpful in attributing changes to project actions (the first two questions have to be answered by stakeholders; the last three questions are subject of interpretation):

- What changes do the stakeholders *recognize* since project activities were started (at the household level, at community level, at other levels)?
- What did stakeholders *learn* during these changes?
- By mentioning lessons learnt, stakeholders point towards important social processes. Which *social processes* do they indicate (individuation, self-determination, empowerment, innovation, adaptation, ethnic integration, participation, social learning, etc.)?
- What *plausible relations* can be determined between the *project (intervention),* the *social processes* and the *changes* in the context? Would the changes have occurred anyway, i.e. even without the project? Which factors have – alone or in combination – contributed to the changes (the project in question, external factors such as policies, other projects, etc.)?
- What is the *connection* between the *social processes and* the *(development) goals*? Which processes should specifically be strengthened in future, which ones better be avoided?

Different examples are provided in **Annex 2** to give the reader an indication of the levels where the indicators are to be applied and the sensitivity of the indicators at a given level. The examples are only a guide, i.e. the formulation of the impact indicators needs to be adapted to the specific area of intervention!

16.3 Questions and issues for debate

1. All development programs set highly ambitious goals, such as poverty alleviation, sustainable management of natural resources, empowerment of marginalized people, good governance, advancement of women, etc. Although many development activities can be called successful at a local scale, the big goals (e.g. the Millennium Development Goals) have not yet been reached, despite more than four decades of development cooperation. Why do you think this has not happened, and how would you estimate the probability that these goals will be reached in the future?

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Annex 1

Sustainable Livelihood Approach (DFID)

This Annex presents additional details about the livelihoods, diversification and survival strategies of rural households. Its key point of departure is that for many such households farming on its own does not provide a sufficient means of survival in rural areas (Ellis 2000[1]). The concept of Sustainable Livelihood (SL) is an attempt to go beyond conventional definitions and approaches to poverty eradication. It offers a more coherent and integrated approach to poverty. The Brundtland Commission on Environment and Development first introduced the idea of SL, and the 1992 United Nations Conference on Environment and Development expanded the concept, advocating the achievement of sustainable livelihoods as a broad goal for poverty eradication. This definition is commonly applied at the household level.

As shown in Chapter 6, livelihoods are the sum of ways in which people make a living. In low income countries, poor families balance a set of food, livestock and income-earning activities. Understanding local livelihoods can reveal how, and why, people survive or fail to survive in difficult times. In normal times, people survive primarily through various means or strategies such as growing crops; livestock raising, hunting and gathering of wild fruits and vegetables; casual labour, trading or bartering; and non-farm income-generating activities. When shocks such as drought, flood, rapid food price increases or conflict occur, these productive activities may be disrupted and the household may not be able to earn adequate income to survive. Its vulnerability increased, the household is forced to adopt other coping mechanisms. Typical coping mechanisms in Eritrea include appealing for food aid, asking relatives for support, falling into unsustainable debt, reducing food consumption, and migrating with part of the household or the entire household to urban centres or other areas where resources are more plentiful.

Depending on where they live and what resources they have (e.g. cash, savings, loans, labour, etc.), different options for survival are available to different people. A group of people living in the same general area who share the same basic means of securing their food and income tend to be impacted by shocks, and respond to them, in similar ways.

Various development organisations (e.g. UNDP, CARE, DFID and SIDA) use SL approaches in different ways. In many ways, the DIA's approach is similar to the Integrated Rural Development approach. The fundamental difference is that the SL approach does not necessarily aim to address all aspects of the livelihoods of the poor. The SL approach serves primarily as a programming framework to devise a set of integrated support activities to improve the sustainability of livelihoods among poor and vulnerable groups by strengthening the resilience of their coping and adaptive strategies. Policy and governance issues are addressed in terms of how they impinge on people's livelihoods. The various support activities are organized as specific programmes, implemented at a district level with ramifications at the community and household levels.

Main elements of the Sustainable Livelihood Approach
The main elements are presented in the Livelihood Framework (*Figure Annex 1.1*). Livelihood assets form the core of the framework. They are presented in more detail in the following paragraphs.

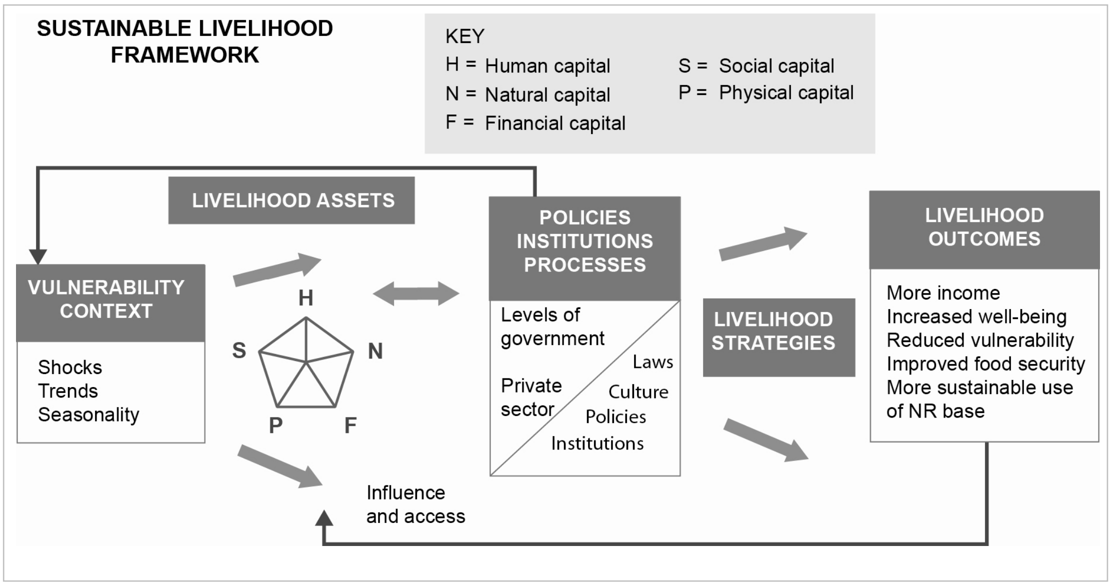

Figure A 1.1 The DFID-Sustainable Livelihood Framework (Source: see Chapter 6)

1. **Natural capital** -natural capital refers to the natural resource base (e.g. land, water, and genetic resources) that yields products utilized by human populations for their survival (Ellis 2000) as well as environmental services (hydrological cycle, pollution sinks, etc.), from which resource flows and services useful for livelihoods are derived. Natural capital is not static nor is its utilization confined to activities such as collecting wild vegetables or hunting wild animals. Natural capital can be enhanced or augmented when it is brought under human control that increases productivity through farming. Forms of natural capital are found between high- and low-potential agro-ecological zones (Ellis 2000). For instance, some hilly areas and mountainous locations represent a rapid change of gradients over a short distance, allowing for highly spatially diverse livelihood niches; other locations, such as semi -arid, flat terrain, allow for less spatial diversity in natural resources-based components of human settlement. Within natural capital, distinctions are made between renewable and non-renewable natural resources.

What is natural capital?

Natural capital is the term used for the natural resources stocks from which resources flow and services (e.g. nutrient cycling, erosion protection) useful for livelihoods are derived. There is wide variation in the resources that make up natural capital, from intangible public goods such as the atmosphere and biodiversity to divisible assets used directly for production (trees, land, etc.)

2. **Physical capital**: Physical capital refers to assets brought into existence by processes of economic production, for example machines, tools, and land improvements such as terraces or irrigation canals. It also includes basic infrastructure and production equipment and technologies which are essential for the pursuit of any livelihood strategy. In economic terms, physical capital is essentially a producer good (Ellis 2000). Important classes of physical capital assets that facilitate livelihood diversification include infrastructural assets such as roads, power lines and water supplies for domestic and irrigation purposes. What are the advantages of physical capital for the livelihoods of rural communities?

What is physical capital?

Physical capital comprises the basic infrastructure and producer goods needed to support livelihoods. Infrastructure consists of changes in the physical environment that can help people to meet their basic needs and to be more productive (affordable transport, secure shelter and building, adequate water and sanitation; clean, affordable energy; and access to information (communications)). Producer goods are the tools and equipment that people use to function more productively. Producer goods may be owned on an individual or group basis or accessed through rental or fee for services.

3. **Financial capital** – Financial capital refers to stocks of cash that can be accessed in order to purchase goods either for production or consumption; access to credit can be included in this category. Neither money saving nor loans are directly productive forms of capital; they owe their role to the asset portfolio of households and to their convertibility into other forms of capital or consumption (Ellis 2000).

What is financial capital?

Financial capital denotes the financial resources that people use to achieve their livelihood objectives. The definition used here includes flow as well as stocks and it can contribute to consumption as well as production. It has been adapted to capture an important livelihood building block, namely the availability of cash or its equivalent, which enables people to adopt different livelihood strategies.

There are two main sources of financial capital.

Available stocks: savings are the preferred type of financial capital because they do not have liabilities attached and usually do not entail reliance on others. They can be held in several forms: Cash, bank deposits or liquid assists such as livestock and jewelry. Financial capital also can be obtained through credit-providing institutions.

Regular inflow of money: excluding earned income, the most common types of inflows are pensions or other transfers from the state and remittances. In order to make a positive contribution to financial capital, these inflows must be reliable.

4. **Human capital** –human capital refers to the level of education and health status of an individual and population. Skills, knowledge, ability to work and good health and physical ability are important for the successful pursuit of different livelihood strategies (Carney 1998). Public education and health are macro-policies designed to raise the level of human capital.

What is human capital?

Human capital represents the skills, knowledge, ability to work, and good health that together enable people to pursue different livelihood strategies and achieve their livelihood objectives. At household level, human capital is a factor in the amount and quality of labour available, which varies according to household size, skill levels, leadership potential, health status, etc.

Human capital appears in the generic framework as a livelihood asset, i.e. as building blocks or means of achieving livelihood outcomes. Its accumulation can also be an end in itself. Many people regard ill-health or lack of education as core dimensions of poverty; hence overcoming these conditions may be a primary livelihood objective.

5. **Social capital** – Social capital refers to the social networks and associations in which people participate and from which they can derive support that contributes to their livelihoods. This is an essential component for activities that require coordinated actions. Social capital is defined by Moser (1998) as 'reciprocity within communities and between households based on trust deriving from social ties'. Of all the assets dealt with here, social capital is the most difficult to describe (Bebbington 1999). This is because a great deal of reciprocity is hidden and emerges only in a serious livelihood crisis. The processes that create insiders and outsiders (Ellis 2000) with respect to social capital are complex and difficult to unravel, but clearly such divisions exist, and they sometimes result in social exclusion of particular individuals or groups within rural communities.

What is social capital?

Social capital represents the set of relationship that people have with other people and groups of people that support or constrain them in earning a living. These relationships can be formal or informal.

It is necessary to look at local patron/client relationships as well as dynamics among powerful community members, the existence of community groups, social and political institutions at local level, traditional trade and other relationships with other communities/groups, social safety nets, and other things.

Combinations – portfolios

Livelihood strategies often consist of combinations of activities which are called 'livelihood portfolios' (Scoones 1998). Livelihood strategies vary between individuals and households depending on differences in asset ownership, income levels, gender, age, caste, and social or political status. A socially differentiated analytical approach to livelihood strategies is thus necessary.

Merits of the Sustainable Livelihoods Approach (SLA)

1. The SLA is a way to improve understanding of the livelihoods of communities, particularly in large and marginalized communities. It draws on the main factors that affect people's livelihoods and the typical relationships between these factors. The framework can be used in planning new development activities and in assessing the contribution that existing activities have made to sustaining livelihoods.
2. There are two key components of the SLA. First, it is a *framework* that helps to understand the complexities of poverty; it provides a set of *principles* to guide action to address and overcome poverty (diagnoses to reduce poverty in marginalized communities). Secondly, the SL framework places people, particularly rural poor people, at the centre of a web of inter-related influences that affect how these people create a livelihood for themselves and their households.
3. Closest to the people at the centre of the framework are the resources and livelihood assets that they have access to and use. These resources include natural resources, technologies, their skills, knowledge and capacity, their health, access to education, sources of credit, or their networks of social support. The extent of their access to these assets is heavily influenced by their *vulnerability context*, which takes account of trends (for example, economic, political, and technological), shocks (e.g. epidemics, natural disasters, civil strife) and seasonality (e.g. prices, production, and employment opportunities). Access is also influenced by the prevailing social, institutional and political environment, which affects the ways in which people combine and use their assets to achieve their goals. SLA is used to identify the main constraints and opportunities faced by poor people, as expressed by them. It builds on these expressed definitions, and then supports poor people as they address the constraints, or take advantage of opportunities (*Figure Annex 1.2*).
4. A set of core principles underlies the sustainable livelihood framework. These include maintaining a focus on people and their strengths rather than looking exclusively at vulnerabilities, taking a wide view of the options for assistance, and making links between local issues and wider concerns about policies, institutions and processes. A livelihoods approach to assessment and programming can lead to better collaboration between providers of support and target communities, a broader and more realistic understanding of local priorities, and thus identification of more appropriate steps towards sustainable land management for poverty elimination.

Strengths and weaknesses

By drawing attention to the multiplicity of assets that people make use of when constructing their livelihoods, the SL Approach produces a more holistic view of what resources, or combination of resources, are important to the poor, including not only physical and natural resources, but also their social and human capital. SLA facilitates an understanding of the underlying causes of poverty by focusing on the variety of factors, at different levels, that directly or indirectly determine or constrain poor people's access to resources, assets of different kinds, and thus their livelihoods. Moreover, it provides a more realistic framework for assessing the direct and indirect effects on people's living conditions than, for example, one-dimensional productivity or income criteria. (Krantz 2001[2]).

The way resources and other livelihood opportunities are distributed locally is often influenced by informal structures of social dominance and power within communities themselves. Gender is an aspect of social relations and to the extent that relations between men and women are characterized by marked inequality and social domination, they are obviously part of the problem (Krantz, 2001).

A	B	C	D	E	F
Livelihood platform	Access modified by	In context of	Resulting in	Composed of	With effects on
	Social relations Gender Class Age Ethnicity etc.	**Trends** Population Migration Technological change Relative prices Terms of trade Macro policy national economic trends etc.		**NR - based activities** Collections (food) Cultivation Cultivation (non-food) Livestock Non-farm NR	**Livelihood security** Income level Income stability Seasonality Degrees of risk
Assets 1. Natural capital 2. Physical capital 3. Human capital 4. Financial capital 5. Social capital	**Institutions** Rules and customs Land tenure Market prices etc.		**Livelihood strategies**		
	Organizations Associations NGOs Local administration State agencies etc.	**Shocks** Drought Floods Pests Diseases Civil wars and other wars etc.		**Non-NR-based** Rural trade Other services Rural manufacture Remittances Food aid Other transfers	**Environmental sustainability** Soils and land quality Water supply Rangeland Forests Biodiversity etc.

Figure A 1.2 A framework for the analysis of rural households (adapted from Carney (1998[3])

The best hope is to ensure that already identified/decided sector development initiatives fit with people's livelihood strategies and make them better at responding to the constraints and opportunities that affect the poor. The SLA, if applied consistently, might be beyond the practical realities of many local development administrations, with the risk that this approach remains an initiative of donors and their consultants (Krantz, 2001).

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Annex 2

Selecting Impact and Outcome Indicators

The role of indicators

Sustainable land management, natural resources management, and sustainable development are high-level development goals and, as issues of great complexity, require consideration of different dimensions, including economic, ecological and social dimensions. It is not possible to define "sustainable land management" globally. But it is possible to develop a vision of land management at the **local level** in terms of what is **more** or **less sustainable**, compared to previous years. Nowadays, the challenge is to find modalities for determining **progress** made on the way to achieving such goals. One of the key aspects in this respect is the **selection, monitoring and assessment of indicators** that represent the reality in a given local context. Two things are important to keep in mind:

- Complex context cannot be described and assessed by "one magic indicator", but can only be represented by a **well-balanced set of indicators** that cover all essential dimensions.
- There is no "standard" set of indicators.

To achieve a reasonable quality of information, a representative selection of indicators and systematic monitoring is required. But not all indicators that are identified can be monitored. The project's means, time and resources on the one hand and stakeholders' interests in IMA on the other hand, will lead to a final selection of impact indicators. Therefore, the challenge is to select a manageable indicator set, a compromise between

- Analysing each and every thing, which would require tremendous financial inputs in terms of research, and
- Making a quick and superficial assessment that produces meaningless information.

In what follows, a number of tools are presented that can help in the search for and selection of a set of indicators appropriate for a given context.

Principles of indicator selection

The following principles and examples can help to make a definite selection of impact indicators:

Principle	Guiding question
Relevance	Is the indicator essential, i.e. does it really provide the information required for making relevant decisions?
Reliability	Is there a need for quantitative or qualitative indicators for a decision?
User-orientation & transparency	Is the indicator understandable and meaningful for the relevant stakeholders (land users, policy-makers, etc.)? Are there local indicators that can be used?
Feasibility	Does the project or the stakeholders have the means, skills and time to monitor the indicator?
Gender-orientation	Does the indicator bring to light gender-specific knowledge and issues?
Hierarchy / area cover-age	Do all indicators reveal changes at the same spatial / decision-making level (field, household, community, catchment, district, etc.)?
Sensitivity	Is the indicator sensitive to short-, mid-, or long-term changes?
Sustainability-orientation	Do the selected indicators represent all dimensions of sustainability (social / institutional, economic and ecological)?

Source for table above and all following tables: Herweg and Steiner, 2002

Considering local indicators

Indicators can be seen as an excellent means of communication between different stake-holders. In the case of SLM, not all relevant local stakeholders such as farmers, herders, forest users, etc. may have been able to participate during indicator selection. In this case it is sometimes useful to get their opinion, e.g. in the form of local indicators that are often hidden to outsiders. If at least some of these indicators are found and incorporated into indicator sets, communication among stakeholders will be considerably facilitated.

Example: *Generic and corresponding local indicators*

Generic indicators	Corresponding local indicators
Soil erosion in t/ha	Increased seeding rate: seeds are washed away as a consequence of soil erosion, and need to be re-sown
Organic matter content, cation exchange capacity, nutrient content (soil fertility indicators)	Indicator plants: these point to locations where soil fertility is high, where the nutrient status of the soil has recovered during a fallow period; where the ground water table is high or waterlog-ging occurs frequently, etc.
Human nutrition	Fat / slim cats and dogs: in villages where the human population does not have enough to eat domestic animals such as dogs and cats will be slim
Increased household income	Men have two or more wives: in some Muslim areas this is a sign of economic well-being

Framework for establishing a set of indicators

Sustainable land management (SLM) is often considered one of the ultimate goals. To be more realistic, we might reformulate it as a desired situation in which "land management is more sustainable". Still, there is a need to clarify what is meant by "SLM". Is it increased production, decreased resource degradation, or increased wealth and social well-being? SLM can be described by several dimensions of sustainability: an institutional, a social (socio-cultural), an economic, and an ecological dimension. Subdivision into the dimensions below prevents important aspects of sustainability from being forgotten. For practical purposes, some dimensions may be merged later on, such as socio-economic, or social / institutional. In the framework below, SLM is segregated into "fields of observation", classified according to dimensions of sustainability and spatial decision-making levels. Attribution to a particular dimension or level may vary according to the specific project context. Elements can be formulated neutrally (e.g. socio-economic disparities), as a problem (e.g. increased disparities) or as a desired scenario (e.g. decreased disparities). They can also be used in problem analysis. This framework is relatively comprehensive, although never complete. Additional fields of observation that are essential in a given local context can be added if necessary.

<table>
<tr><th>Level</th><th colspan="4">Dimensions of sustainability</th></tr>
<tr><th></th><th>Institutional</th><th>Socio-cultural</th><th>Economic</th><th>Ecological</th></tr>
<tr><td>Household (including farm plot level)</td><td colspan="2">Education and knowledge
Access to natural resources
Household strategies
…</td><td>Household income, assets and consumption
Labour and workload
Land management and farming system
…</td><td>State of natural resources
…</td></tr>
<tr><td rowspan="2">Community</td><td rowspan="2">Local leadership
Local institutions
Producer and self-help organisations
…</td><td>Gender issues
Conflict management
Innovation
…</td><td>Markets, prices and credit
Public property
…</td><td rowspan="2">Land use
Water resources
…</td></tr>
<tr><td colspan="2">Social & economic disparities
…</td></tr>
<tr><td>District</td><td>Education, training and extension
Land and water rights, tenure
…</td><td>Change in social values
…</td><td>Employment opportunities / migration
Infrastructure
…</td><td>Land cover
Off-site effects
…</td></tr>
</table>

The following checklists contain potential indicators for each field of observation mentioned in the framework above. N.B.: formulation of the impact indicators needs to be adapted to the specific project situation!

Checklist 1a: Household level	
Fields of observation of SLM	**Impact indicators**
Education and knowledge	% of school children / No. of school drop-outs (separate for boys and girls), No. of people with school leaving certificate
Access to natural resources	No. and size of plots managed by women and men, management of communal land
Household (HH) strategies	HH structure, labour division, changes in perceptions and behaviour, innovations
HH income, assets and consumption	HH income, male and female earnings, gross margins, clothing, housing, nutrition, purchasing power, spending power, months of food security, re-investment in new farm implements, seeds, etc.
Labour and workload	Labour division, labour income
Land management & farming system	Labour income, change in farming system, adapted farming practices, abandoned technologies, application rate of conservation-effective practices
State of natural resources	Soil fertility status, soil erosion, salinity, compaction, water availability and water quality, biodiversity, plant growth, plant cover, pests & diseases, No. and quality of animals

Checklist 1b: Community level	
Fields of observation of SLM	**Impact indicators**
Local leadership	Access to natural resources by women / men, actions taken when local by-laws are neglected
Local institutions	Active participation, survival rates of trees, conservation structures maintained without incentive, representation of social strata
Producer and self-help organisations	No. of farmers associations, representation of social strata
Gender issues	% of women in decision-making institutions and meetings, % of women with land titles; gender-specific access to credit, workload, income
Conflict management	Conflicts over natural resources, taboos with regulatory character, binding local agreements
Social and economic disparities	Wealth, status of minorities, clothing, housing, % of landless people
Innovation	No. of innovative technologies, social status of innovators
Markets, prices and credit	Distance to markets, new shops and business, No. of credits, interest rates
Land use	% of cropland, pasture, forest / bush land & other, visible signs of resource degradation, deforestation rate, cultivation of marginal land, overgrazing, abandonment of cropland
Water resources	No. of people suffering from water-borne diseases; No. of conflicts over water resources, water colour, months when springs and rivers have water

Checklist 1c: District level	
Fields of observation of SLM	**Impact indicators**
Education, training and extension	District radio programmes with environmental messages, farmers' and school children's environmental awareness
Land and water rights, tenure	Environmental laws, regulations, land titles, land price, local taboos with regulatory character, enforcement of regulations
Change in social values	Crime, conflicts between generations; social status of farmers
Employment opportunities / migration	Unemployment rate, vacancies, in- & out-migration, No. of female HH heads
Infrastructure	Access to markets, schools, services, credit, scholars per family, frequency, price and reliability of transport, frequency of power cuts
Land cover	% of crop, pasture, forest land
Off-site effects	Flash floods, sedimentation of dams, water quality, destruction of roads and bridges

The next few checklists contain more detailed examples of SLM impact indicators

Checklist 2a: Institutional, socio-cultural, and economic aspects of SLM	
Institutional / socio-cultural aspects	
Education and knowledge	% of school children / No. of school drop-outs (separate for boys and girls), No. of people with school-leaving certificate, % of illiterate people per social strata, No. of women and men with further education & training, success rate (people trained with certificate), No. of people applying their training, No. of people instructed by those who received training (self-dissemination)
Access to resources (natural, financial, agri-services, information)	No. of households (HH) with owned, rented and leased land, land holding size per social strata (e.g. poor farms, wealthy farms), use of credits, use of production inputs
Institutions, organisational capacity, management	No. of planned development activities carried out, rate of uncompleted workdays, duration of administrative procedures, transparency of administrative procedures, application of laws and by-laws, (e.g. tax recovery, declared and sanctioned violations), public reputation of institutions, No. of binding / respected local agreements on resource use, No. of groups applying sanctions in case of violation of regulations, No. and % of functional organisations, No. of groups initiating self-help activities independent of external assistance
Gender issues	% of female HH heads, % of women in decision-making meetings, % of women with access to land, % of women in land user groups, % of women with access to extension services, % of women with access to credit, average daily workload of men and women, female and male earnings

Economic aspects	
Household income, micro-economy	Net HH income, alternative income options, % of agricultural products sold on markets, gross / net margins of individual (men's, women's) production system components, internal rate of return, purchasing and spending power, No. of (truck) loads with products arriving at local markets, No. of merchants coming to markets, quantity of produce offered on markets, fluctuation of market prices, No. of people with bank accounts, No. of houses with corrugated iron roofs, No. of people with status symbols (e.g. radio, TV, bicycle, motorcycle, etc.)

Checklist 2b: Land use and farm management aspects of SLM		
Land use types	**Environmental health indicators**	**Indicators of unsustainability**
Woodland	Afforestation, high variety of non-timber forest products	Rate of deforestation, illegal cutting
Cropland	Appropriate tillage practices, good crop stand, crop rotation, integrated pest management, integrated soil and water conservation	Monoculture, inappropriate crop rotation, soil-borne parasitic weeds and nematodes, termites and leaf-eating ants, aggressive weed (Imperata, Cyperus), decreasing length of fallow period, absence of conservation activities, abandonment of cropland, cultivation of marginal land (steep land with shallow soils)
Pasture land	Dense plant cover, high variety of species	Overgrazing, rangeland degradation, bare soil, trampled area, poor plant cover, change in species composition, increase of unpalatable species
Farm management	Good efficiency of farm resource management, high gross margins, increasing degree of organisation (farmers' organisations), high return on labour, good input use efficiency, application of conservation-effective practices	Rapid changes in farming system, low gross margins, absence of farmers' organisations, low return on labour, low input use efficiency, no application of conservation-effective practices

Checklist 2c: Ecological aspects of SLM (natural resources)			
Resources	**Indicators**	**Environmental health scenario**	**Scenario of unsustainability**
Soils	Soil fertility, nutrient status (organic matter, acidity), toxicity	Dark, deep topsoil (humus), good drainage, high soil biological activity, earthworm casts, high earthworm density, high crop yield, high root density	Light, pale soil colour, indicator plants, yellow & red colour of plant leaves, small plants, poor soil drainage, no earthworms, low yield, low root density, limited rooting depth
	Creeping soil erosion: reduced topsoil depth (reduced water and nutrient retention capacity)	Absence of unsustainability indi-cations	On-site: smoothened soil surface, accumulations, light soil colour, exposed plant roots, increased seeding rate Off-site: brown rivers, sedimen-tation of water reservoirs
	Severe soil erosion, loss of entire topsoil		Erosion rills, gullies and large concentrated accumulations
	Wind erosion		Dust storms, mobile dunes, accumulations behind wind breaks
	Salinity & alkalinity		Salt, colour of plant leaves, level of salinity in water
	Compaction		Crust formation, increased runoff, less infiltration, difficult to plough
Water	Water availability	Sufficient water	Water shortage: depletion of groundwater table, drying wells, dying trees, increase of unpalat-able species, excess water, increasing runoff, flash floods
	Water quality	Good water quality, good hygiene, clear colour, no odour	Algae, bad odour, brown colour, minimal variety of fish in rivers, human diseases
Vegetation	Biodiversity	Great variety of species	Minimal variety of species, high % of unpalatable species (pas-ture land)
	Biomass and nutri-tive value	Crop residues and dung remain on the field as fertilisers	Low crop yield and biomass, high yield variability, use of crop residues and dung as fuel
	Plant growth	Uniform plant growth, tall & dense stands, green, good crop	Low plant height & cover, pests and diseases, light green or yellow / purple colour of plant leaves, stunted corn, non-homogeneous ground cover
Animals	Quantity	Reasonable herd size, sufficient draught power	Overstocking: low grass cover on pasture land, encroachment on cropland
	Quality	Good livestock appearance, good productivity	Malnutrition & diseases, high mortality, low productivity, fodder shortage

Preparing for impact assessment

Later, when assessing the results of monitoring, changes in the indicators will be discussed and evaluated: are they positive or negative, satisfactory or not, how did changes happen, etc. This is a process of individual judgement that will reveal many different opinions. Change in the context will then be visualised, for example, in a "spider" diagram or other types of graphs. For this purpose a rating for each indicator is helpful (e.g. from 5, "change is considered very good," to 1 "change is considered very bad"). The benchmarks (see example below) for each indicator should already be prepared at this stage, during a debate among all stakeholders. The questions "Where are we?" and "Where do we want to be?" need to be asked in relation to each selected indicator. The best possible realistic achievement for each indicator is 5 (very good), and the worst possible achievement is 1 (very bad).

Example: *Preparing the benchmarks (reference values) for each impact indicator in view of impact assessment*

Impact indicators	Rating*				
	5 Very good	4 Good	3 Moderate	2 Bad	1 Very bad
Short-term indicators					
Crop yield (maize)	> 3 t/ha	> 2 – 3 t/ha	> 1.5 – 2 t/ha	1– 1.5 t/ha	< 1 t/ha
Household income	>20 % Increase	> 10 – 20 % Increase	1 – 10 % Increase	Stagnating	Decreasing
Women's labour income	>20 % Increase	> 10 – 20 % Increase	1 – 10 % Increase	Stagnating	Decreasing
% of farmers adapting new technologies without incentives	> 60 %	> 40 – 60 %	>20 – 40 %	10 – 20 %	< 10 %
Occurrence of pests & diseases	No	Rarely, little evidence	Sometimes, but can be controlled	Control is often difficult	High, every year
Soil erosion (rills and gullies)	No signs of erosion	Smoothened soil surface, but no rills	Sometimes, few rills	Most years, many rills	Every year, rills and gullies

Mid- to long-term indicators					
Household decision-making	Jointly in most households		Jointly in a few households	By men in most households	
% of farmers experimenting with cropping practices	Regular modifications by > 70 %	Regular modifications by > 50 – 70 %	Regular modifications by > 30 – 50 %	Irregular modifications by 5 – 30 %	< 5 %
Boys and girls with school leaving certificate	> 80	> 60 – 80	> 40 – 60	30 – 40	<30
Soil fertility status**	Deep, dark topsoil, high earthworm activity, high root density		Moderately deep and dark topsoil, earthworm activity, root density	Light soil colour, yellow & red plant leaves, no earthworms, low root density	

** N.B: the rating is highly site-specific and requires intensive discussion with stakeholders*
*** Rating of soil fertility status requires consultation with soil specialists*

In preparing to carry out impact assessment, some more important details need to be considered:

- Ideally, all stakeholders agree on a common rating for all impact indicators. But it can also be interesting to carry out impact assessment separately for each stakeholder group, and each group's findings will be communicated to the others.
- It should be determined at what level the assessment will be made (household, community, etc.). For example, if there is a great heterogeneity of household categories (such as poor and wealthy households), changes in their context should be assessed individually or at least separately for each household category. If all households are judged together at the community level, the result will be an average. This average, however, may not reflect important changes in individual households. It would thus be meaningless!
- After a set of impact indicators has been selected, an initial observation (monitoring) that takes all of them into account produces the baseline. In the first years to come, monitoring and assessment will only include those indicators that are sensitive to short-term changes. Indicators sensitive to mid- or long-term changes will gradually be added after several years.

Example: *Assembling a set of impact indicators (supplementary to project planning matrix)*

Project goal: Poverty of the rural population has been reduced and management of natural resources has become ecologically sound, economically viable and socially acceptable.

Project purpose: Crop production of small farmers has increased with environmentally friendly farming practices.

Expected results: (e.g.) new production systems have been developed on-farm; farmers have been trained in concepts and practices of production and resource protection; etc.

Impact hypotheses	Impact indicators*	Sustainability dimensions			Sensitivity			Suitable local indicators	Means of verification
		so	en	el	s	m	l		
Step 3	% of farmers adapting new technologies without incentives								Interviews with heads of farmers' associations and farmers during every field trip
	Crop yield (maize)								Measurement at representative locations, discussions with farmers on their fields
	Occurrence of pests & diseases								Observation during field trips, interviews with farmers during transect walks
	Soil erosion							Erosion rills and gullies	Rills and gullies can be easily observed and reported by farmers during rainy season
	Household income							Tin roof, radio, motorcycle	Observations and interviews with women and their husbands, twice a year
	Women's labour income								Interviews with women, cross-checked with observations
	Household decision-making								Interviews with all household members, cross-checked with observations
	% of farmers experimenting with cropping practices								Interviews with heads of farmers' associations and farmers during every field trip
	Soil fertility status							Indicator plants	Measurement at representative locations every 5 years (soil specialist), annual transect walks with farmers
	Boys and girls with school leaving certificate								School files, discussion with teachers

*Formulation of indicators is preliminary; it needs to be more specific when the selection is finalised

Sustainability dimensions: *so = social / institutional, en = economic, el = ecological*

Sensitivity: *s= short-term, m = mid-term, l = long-term*

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