# 12 Land Degradation and Sustainable Land Management in the Highlands of Ethiopia

Hans Hurni[1], Solomon Abate[2], Amare Bantider[3], Berhanu Debele[4], Eva Ludi[5], Brigitte Portner[6], Birru Yitaferu[7], and Gete Zeleke[8]

## Abstract

The Ethiopian Highlands cover over 50% of the country and are home to more than 90% of Ethiopia's population of over 80 million people (estimate for 2010); 60% of the livestock and 90% of the area suited for agriculture are also located here. Although more than 90% of the Highlands was once forested, today a mere 20% of this area is covered by trees, and the percentage of forest cover is less than 4%. This is evidence of a high incidence of degradation of vegetation in the past, which has continued to the present. Land-use and land-cover changes have been particularly dynamic in the 20th century, during which climate change also began to have effects; wildlife in natural habitats have been restricted to those few areas that were preserved naturally due to rugged topography or natural aridity. Soil erosion has been severe throughout the Highlands, but mainly on agricultural land; the current severity and extent of soil degradation seriously threaten food security. In response, a number of soil and water conservation measures have been successfully implemented over the past 35 years in some parts of the Highlands. This is highly encouraging, but greater emphasis must be given to conservation in the coming decades.

**Keywords:** Ethiopian Highlands; research partnership; land degradation; land-cover change; sustainable land management; soil and water conservation; protected area management.

## 12.1 Introduction

### 12.1.1 The Ethiopian Highlands

The Ethiopian Highlands are defined here as an area extending from about 1000 metres above sea level up to the highest peak in Ethiopia, at 4533 m. In this zone there are normally sufficient rainfall and suitable temperatures for rainfed agriculture. Due to temperature constraints, the upper limit of cropping lies at about 3800 m, while the lower limit is defined by dryness, which makes rainfed cultivation impossible in areas below about 800 m on the western side of the Highlands, and below 1200 m on the eastern side. Given these boundaries, favourable agro-climatic conditions prevail over an area of 570,000 $km^2$, or 52% of the country (Hurni 1998). Human-induced climate change has been impacting agro-ecological belts since about the 1970s, a fact that is evident not only in terms of rainfall variability but particularly in terms of observed temperature increases (Hurni 2005). This has considerable implications for the suitability of agricultural cropping patterns for crops such as coffee (Rüegsegger 2008).

In 2007 about 84% of the Ethiopian population, or about 64 million out of about 77 million persons, lived in a rural environment (extrapolated from CSA 2006), mostly in the Highlands; at the same time, the Highlands are also where most of the urban population lived. The rural population has grown from approximately 12 million people around 1900 to approximately 64 million in 2007 (Hurni et al, in preparation), while the urban population increased from nearly 0 to about 13 million in the same period. Farm sizes today are less than one hectare per household on average; the livestock population, while considerable and exceeding the capacity of grazing land, is still insufficient to provide enough labour to plough the land. Farm productivity is at a minimal grain output between 0.3 and 1.5 tonnes per hectare, and land degradation due to agricultural practices is widespread, amounting to an average of over 40 tonnes of soil lost per hectare of cropland every year (Hurni 1993).

Sustainable management of natural resources, particularly soil and water, is of utmost importance to Ethiopian agriculture. Since the inception of agriculture several millennia ago, little has been done by peasants and societies to conserve natural resources, as land was abundant. The Highlands were deforested for agriculture, a process that was intensified especially in the past century when the population started to grow exponentially. Conservation measures on agricultural land were applied in very few instances only, and had to be introduced on a broader scale by the government and by foreign programmes in the aftermath of the great famine of 1972–1973, which was drought-induced but caused by a lack of political response.

### 12.1.2 Key issues in land degradation and sustainable land management

According to the Millennium Ecosystem Assessment (MA 2005) the term ‘land’ includes renewable natural resources, i.e. soils, water, vegetation and wildlife, in their terrestrial ecosystems. Land degradation, in turn, includes all processes that diminish the capacity of land resources to perform essential functions and services in these ecosystems, i.e. deforestation, loss of biodiversity, soil degradation and disturbance of water cycles. Sustainable land management consists of technical and institutional measures initiated by individuals or societies to maintain land productivity and other functions of land resources for present and future generations.

There have been numerous and controversial debates about explaining land degradation processes in Ethiopia and seeking mitigation options. They have focused on:

1. Approaches applied to implement land rehabilitation activities, e.g. incentive-based approaches (Webb and Kumar 1995; Holden et al 2006); (in)voluntary campaigns; multi-level stakeholder and participatory approaches (Hurni and Ludi 2000); and top-down approaches versus bottom-up and community-based approaches (Alemneh Dejene et al 2003);

2. Priorities and agenda-setting involving land rehabilitation work as well as the general rural development activities and policies of the country (Keeley and Scoones 2000, 2003; Nyssen et al 2004a);

3. Identifying the root causes of land degradation that have an impact on decision-making, e.g. traditional agricultural practices (Hurni 1990), land tenure insecurity (Yeraswork Admassu 1995; Dessalegn Rahmato 2001, 2004) and pressure from accelerated population growth (EHRS 1986).

Considerable efforts have been made to establish monitoring and research throughout the Ethiopian Highlands, particularly at the level of small watersheds, but generalisations about the processes of land use and land degradation, as well as conservation approaches as a whole, have yet to be developed from the case study sites. This requires debates among scientists from different disciplines and other stakeholders at large.

### 12.1.3 Research partnership approaches

Research on processes of land-use change, land degradation and sustainable land management was initiated in the Ethiopian Highlands by the Soil Conservation Research Programme (SCRP) in 1981 in conjunction with the country-wide soil conservation campaign (Hurni 1982; SCRP 2000). Prior to this initiative, only a limited number of studies existed. In 2001, the Swiss National Centre of Competence in Research (NCCR) North-South chose the Ethiopian Highlands as one of its syndrome contexts (Yacob Arsano et al 2004) and initiated a number of PhD and Master's studies on this region, taking a transdisciplinary approach to identify research topics, involving scholars from different disciplines as well as development specialists. The results of these studies constitute the main base of information used here, though emphasis is also given to studies done outside the NCCR North-South programme.

## 12.2 Status and dynamics of land cover, land use and land degradation

### 12.2.1 Deforestation and forest dynamics

Most areas in Ethiopia that currently have more than 3% tree cover are assumed to have been forested about 5000 years ago, before deforestation for agriculture began (Hurni 1987; Darbyshire et al 2003; Nyssen et al 2004b). The north-central Highlands were a focus of agricultural development over the past 2–3 millennia, according to historical records (Bard et al 2000) and carbon dating (Hurni 1987); this was also where most deforestation occurred as early as many centuries ago (Ritler 2001). Today these areas have 3–19% tree cover (Figure 1). By contrast, in the present-day 19–40% tree cover zone, which is found primarily in the western and southern Highlands, heavy deforestation has taken place particularly since the 1950s (Solomon Abate 1994; Gete Zeleke 2000).

Deforestation was always followed by a change in land use and land cover, from forest to grassland and cropland. A particular increase in cropland was observed in the second half of the 20$^{th}$ century, largely at the expense of grassland and forestland – a fact that is widely acknowledged in the scien-

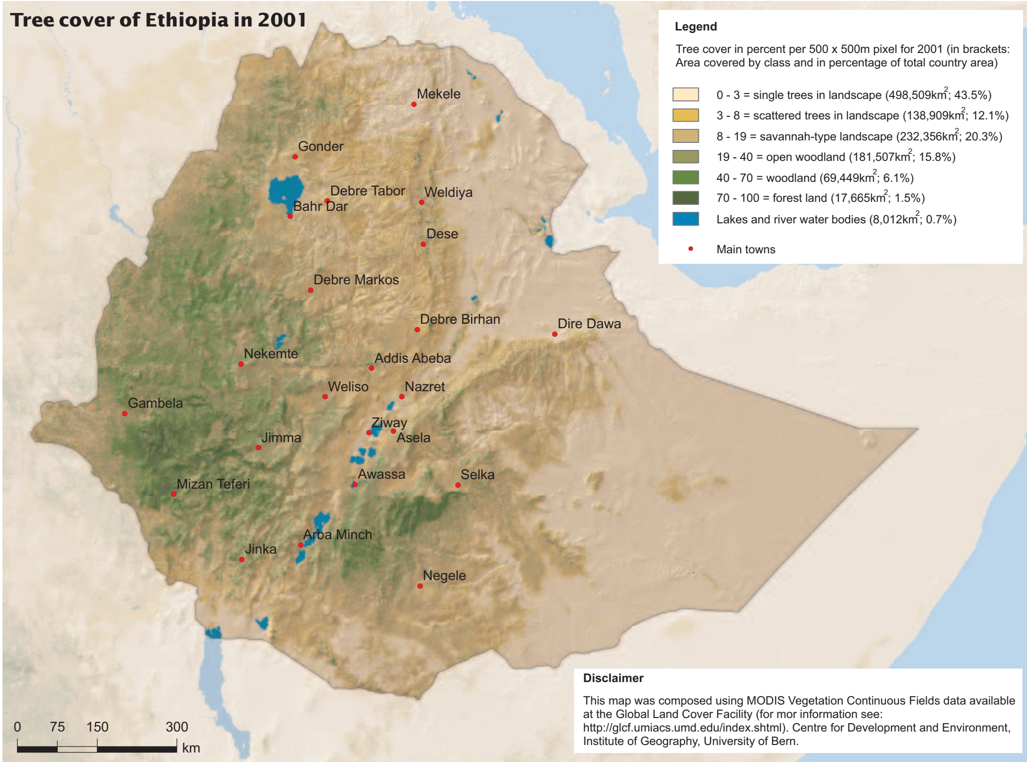


Fig. 1
Tree and forest cover in Ethiopia in 2001 as modified by agricultural activities during about 5000 years. (Map composed by Kaspar Hurni; to be published in Hurni et al, in preparation)

tific literature. During specific periods throughout history entire landscapes were abandoned for a variety of reasons, such as famines, pests or political turmoil, causing the land to regenerate and develop secondary bush and tree vegetation, which was later again slashed and burnt for recultivation; at present, however, this hardly occurs any more.

### 12.2.2 Land-use and land-cover changes

Within the NCCR North-South programme, Birru Yitaferu (2007), Schild (2006), Amare Bantider (2007), Hurni (2005) and Solomon Abebe (2005) studied land-use and land-cover changes as well as their underlying causes. All studies revealed highly dynamic systems, but changes observed among the various land-cover types were not all similar, mainly due to different initial situations. In the recent past, more intense loss of forest cover and expansion of cultivation land coincided with changes in land policies and institutions in the 1970s, 1990s and early 2000s (Amare Bantider 2007).

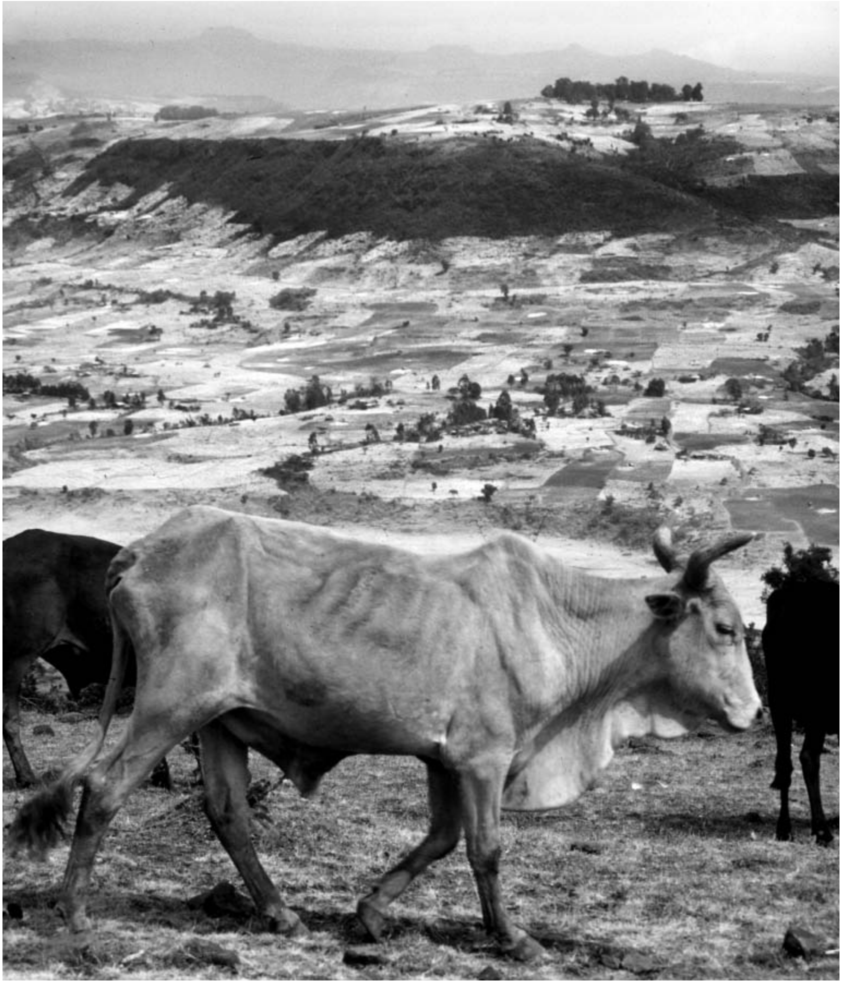

Fig. 2
Intensive land-cover and land-use changes around the Anjeni Soil Conservation Research Programme (SCRP) Research Site in Gojam mainly occurred between 1950 and 1980 according to Gete Zeleke (2000). (Photo by Hans Hurni, 1984)

During the 20th century the highest deforestation rates were found in areas where the forest cover was still between 8% and 40% (Figure 2). Periods of active deforestation occurred during phases of rapid population growth and were coupled with little institutional concern about, or insufficient enforcement of, measures to combat environmental degradation. On the other hand, reduced deforestation and even reforestation were accompanied by increased government support and international assistance, as in the 1980s, but also during the past decade since 2000, when increased government awareness and more conducive approaches were observed, particularly in the Tigray region in the north (Nyssen et al 2009).

### 12.2.3 Wildlife dynamics

The Ethiopian Highlands today are characterised by an extreme sparseness of natural habitats where wildlife could have survived during the extended period of agricultural use over the past 5000 years. Hence current wildlife is limited to animals that are less dependent on natural habitats, such as predators or birds, while ruminants, which depend on distinct habitats, have been reduced to very low numbers or few areas, and in some cases even became extinct long ago. Only a few wildlife habitats have been preserved in their natural form, such as high mountaintops above about 4000 m, steep escarpments on the borders of the Highlands, and semi-arid areas in the lower parts. Well-known places in the Highlands with natural wildlife habitats include the Simen Mountains in the north and the Bale Mountains in the south, both of which have been designated as national parks. Research within the NCCR North-South focused on the Simen Mountains (Grünenfelder 2005; Hurni 2005; Bircher 2006; Schild 2006; Ludi 2007), where some wildlife remained in natural habitats that are unsuitable for cropping due to steep topography, high altitude, or both.

### 12.2.4 Soil degradation due to water erosion

In Ethiopia agricultural land is tilled using an ox-plough system; this exposes the soil to rain, particularly during the onset of the rainy season. The process of soil erosion is a consequence of rainfed farming on steep slopes in the absence of sufficient counter-measures (Figure 3). Soil erosion processes were monitored by the Soil Conservation Research Programme (SCRP), a long-term research network initiated in 1981 (Hurni 1982). Long-term analysis shows that the amount of soil loss on cultivated slopes ranges from a few tonnes per hectare and year (t/ha/yr) to more than 300 t/ha/yr (SCRP 2000). In the long term, an average of approximately 40 t/ha/yr of soil loss was measured on cropland plots, while much less was measured on plots covered by grassland and forestland (Hurni 1993). The impact on soil productivity and agricultural production was shown to be very significant, exhibiting an almost linear correlation with soil depth (Belay Tegene 1990).

In the Ethiopian mountains, soil degradation due to water erosion remains a major threat to sustained agricultural production, as soils on slopes are washed away within a few human generations of land use. Both soil erosion models (Kaltenrieder 2007) and field observations confirm the importance of vegetation cover or, alternatively, structural measures such as soil

Fig. 3
Ploughing a steep slope at the Andit Tid Soil Conservation Research Programme (SCRP) Research Site in Northern Shewa has led to extreme soil degradation, as the area has been agriculturally used for over 600 years. (Photo by Hans Hurni, 1982)

or stone bunds for protecting the soil against degradation. In addition, soil conservation measures have the potential to significantly improve agricultural production (Amare Bantider 2007; Birru Yitaferu 2007), not only in the accumulation areas behind the bunds but also in larger catchments. This has been shown by monitoring yields over extended periods of time (Kohler 2004; Loetscher 2004).

### 12.2.5 Water regime and pollution changes

Throughout the Highlands, immediate surface runoff has generally been augmented by intensified land use and advanced soil degradation, thereby benefiting the lowland areas in Sudan and Egypt to which part of the surface runoff is drained. Comparison of long-term data from small test plots throughout the Highlands (Hurni et al 2005), but also in the larger Lake Tana Basin, clearly confirmed this trend, despite the fact that rainfall amounts remained more or less similar during the observation periods of 13 to 44 years (Birru Yitaferu 2007). In terms of pollution, increased soil erosion in the catchments also augmented the sedimentation rates. This poses a problem for irrigation reservoirs in the lowlands, which are being filled with sediment. Soil and water conservation reduces sediment delivery not only on farm plots but, to a lesser extent, in entire catchments (Schum 2004; Admasu Amare 2005).

## 12.3 Drivers and impacts of soil degradation

While the previous section looked at the direct and indirect drivers of land degradation (MA 2005), this section focuses more closely on the drivers of soil degradation by water erosion. This is the key land degradation process in the Ethiopian Highlands once land has been deforested.

In assessments of soil degradation the direct drivers are typically termed 'bio-physical', as they are factors included e.g. in soil erosion models such as the Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978; Hurni 1987; Kaltenrieder 2007). Indirect drivers are usually found in the psychological, social, political, economic and institutional spheres, impacting livelihoods based on rural farming and livestock rearing, as well as in the institutions governing the populations that engage in these activities. Determinants of land degradation were analysed using primary and secondary data at the household and farm plot levels for selected watersheds (e.g. Getachew Adugna 2005).

### 12.3.1 Bio-physical drivers of soil degradation

The most important bio-physical drivers of soil degradation in the Ethiopian Highlands are (a) removal of vegetation cover, and (b) harmful agricultural management practices (Hurni 1990). Relating to (a), negative changes in soil cover are the most important drivers of the increase in natural rates of soil erosion by a factor between 100 and 1000, i.e. from much less than 1 t/ha/yr under natural forestland up to 300 t/ha/yr (Herweg and Stillhardt 1999; Alebachew Mamo 2006) on cultivated or degraded land. Once the vegetation cover is removed, factors such as the steepness, length and shape of a slope become important, as does rainfall erosivity. Another key factor in soil loss modelling is that soils in the Ethiopian Highlands are surprisingly resistant to water erosion due to their favourable depth, texture, structure and organic matter content, which give them good qualities in terms of infiltration and water-holding capacity, at least before they are heavily degraded (Hurni 1987).

Concerning (b), improved agricultural management practices have the potential to reduce soil erosion on farm plots by a factor of up to 100, provided that farmers take appropriate measures to combat soil erosion. Indigenous soil and water conservation practices have been documented; their effectiveness, however, is limited, and their extent is only local and not sufficiently widespread to control soil erosion significantly. Inappropriate infrastructure such as footpaths or steep drainage ditches also contributes to accumulated surface runoff and accelerated soil erosion (Herweg and Stillhardt 1999).

### 12.3.2 Socio-economic drivers of soil degradation

Ethiopian farmers do not perceive soil degradation to be a problem for agriculture, let alone a life-threatening issue affecting the productivity of the soil (Hurni 1979). Of course some runoff processes are perceived as immediately dangerous, e.g. when a gully expands backwards into the back yard of a homestead, which is rare. The psychological factor of individual perception of soil erosion as a non-threatening process can be explained by the slow overall pace of soil erosion; normally, it takes 5–10 human generations of intensive land use before a deep soil is totally exhausted. Consequently, when conservation programmes tried to retain water and sediment in a field by introducing soil and water conservation structures, farmers usually considered this to be a counter-measure against better drainage; they failed to perceive the important beneficial effect of long-term sustainable use of the soil (Herweg and Stillhardt 1999).

From a sociological point of view, many forms of cooperation between farm households exist, particularly in relation to specific farming operations, such as sharing oxen or maintaining common waterways between field boundaries. The latter also helps to reduce the severity of soil erosion. At the economic level, farming was largely subsistence-oriented in the past and remains so in remote areas, where about 80% of Ethiopia's farmers live. Institutionally, land security has not been granted to farmers over longer periods of time, thus preventing them from developing a keen interest in investing in the land for long-term productivity (Ludi 1994, 2002; Amare Bantider 2007). Present land regulations provide relative security, although the land is still owned by the regional states. Moreover, land security has been negatively influenced by political instability.

### 12.3.3 Impacts of soil degradation

In a spatial context, the overall progress of soil degradation is relatively slow in the Ethiopian Highlands; this has to do with the fact that even today only about 30% of the Highlands are cultivated, while the rest consists of fallow land, grassland and some forestland. On steep land that is currently cultivated, however, the rate of soil degradation is high in global terms. The bio-physical impacts of soil erosion are both short- and long-term. In the short term, many rills develop on cultivated fields during the rainy seasons, which can damage crop seedlings. In the longer term, the cumulative effect of rill erosion has negative impacts on the soil, reducing soil depth, water-holding capacity, soil fertility and organic matter content or cation exchange capacity, which, in turn, leads to reduced vegetation growth and diminishes crop production. Furthermore, soil accumulation in valley bottoms and at the foot of slopes negatively affects agriculture there as well, and the sediments are prone to gully erosion. Many examples of these impacts have been documented both within the framework of the NCCR North-South programme (Amare Bantider 2007; Birru Yitaferu 2007; Gebeyaw Tilahun 2007; Hurni 2007) and in earlier studies (Hurni 1993; Solomon Abate 1994; Herweg and Stillhardt 1999; Gete Zeleke 2000).

The socio-economic impacts of soil erosion are also considerable, since decline in soil productivity leads to decreased yields (Belay Tegene 1990). This was the case particularly in the last century, during which the rural population of Ethiopia grew by a factor of 5–6 (Hurni et al, in preparation); together with increased pressure on the land and slow economic development, this led to widespread poverty. Increased land-use competition has been observed in the rural context at the expense of forestland and grassland, leading to problems with livestock feed and health, particularly among draught animals (Grünenfelder 2005; Amare Bantider 2007).

### 12.3.4 Farmers' responses to soil degradation

Responses by farmers to soil degradation have been minimal, as expected, despite the obvious cumulative effects of soil degradation and the threat of its acceleration in the second half of the 20th century. A number of known indigenous soil and water conservation technologies and management systems have been documented (Hurni 1984; Krüger et al 1997; Ludi 2002; Amare Bantider 2007; Birru Yitaferu 2007) and partially applied. However, their effectiveness, and particularly their overall extent, are estimated to be less than 10% of what would be needed to reduce soil erosion to tolerable levels (Hurni 1984). The main response to extreme soil degradation is that farmers stop cultivating the land and let it go fallow, in the hope that soil regeneration will take place at an accelerated rate. This process, however, is 10 to 100 times slower than the process of soil erosion (Hurni 1993); thus a 10–100 year fallow period would be needed for every year of cropping. Another strategy is to change land use from cropping to reforestation. Forest plantations, however, require rural access roads for commercialisation; hence this strategy has been implemented only in places where distances to roads were small (Amare Bantider 2007).

## 12.4 Experiences with sustainable land management

Sustainable land management addresses land in its broader sense, i.e. including soil, water, vegetation and wildlife resources and their spatial contexts. Sustainable land management means that land is managed in such a way that future generations will be able to fulfil their needs just as the present generation can (WCED 1987). In this section, however, we will address only those aspects on which NCCR North-South research has focused since 2001: soil and water conservation, protected area management, and improved water management.

### 12.4.1 Soil and water conservation

The need for introducing soil and water conservation measures on agricultural land is an issue of concern not only to the international research and development communities, where the debate originated, but increasingly to Ethiopian scholars, experts, and even farmers (Endris Damtew 2006; Alemayehu Assefa 2007). While food-for-work schemes gradually expanded as of the late 1970s, there was a general lack of guidance regarding what technologies would be most appropriate, and what approaches most suitable (Erny 2004).

From a methodological point of view, it is important to develop further the models used to predict soil erosion processes and the effects of soil conservation technologies (Figure 4). Future models should enable predictions not only within but also outside the catchments where SCRP research sites are located. Additionally, systemic extrapolations can be made based on qualitative assessments (Hurni et al 2008) or by drawing synthetic conclusions (e.g. Hösli 2005; Hurni 2005, 2007). Guidelines for planning, designing and implementing appropriate technologies of soil and water management have been developed since the early 1980s; they were upgraded (e.g. Hurni, in press) and have been widely applied since then.

### 12.4.2 Protected area management

The NCCR North-South was engaged in one of the protected areas of Ethiopia in 2004, following up on studies carried out by Swiss and Ethiopian

Fig. 4 Development of bench terraces over a 20-year period from soil bunds that were implemented in 1983, leading to sustainable agricultural production even on this steep slope at the Maybar Soil Conservation Research Programme (SCRP) Research Site in Wello. (Photo by Sabina Erny, 2003)

researchers since 1965. Eva Ludi and her team carried out a study in the Simen Mountains (Grünenfelder 2005; Hurni 2005; Bircher 2006; Schild 2006; Ludi 2007). This study was conducted 10 years after a comprehensive appraisal of sustainable development had been made in the area (Hurni and Ludi 2000). According to Hurni et al (2008), "institutional approaches have changed considerably since the establishment of the Simen Mountains National Park in 1969". Prior to 1990 a top-down approach was used to park management; this sometimes led to violent conflicts. A more decentralised approach was introduced after the change of government in 1991, leading to more participation in management. At the time of writing the present synthesis, the government had prepared a proclamation to once again place the national parks under federal management. The Simen Mountains National Park, however, may continue to be administered by the regional authorities, as the national government acknowledges its successful management during the past 15 years.

### 12.4.3 Improved water management

The introduction of soil and water conservation measures in catchments is assumed to lead to improved water management regimes. Hurni et al (2005), in analysing their long-term test plot experiments, showed how land-use intensification and soil degradation had increased overall immediate surface runoff and sediment concentration in rivers. Birru Yitaferu (2007) confirmed this trend observed in small catchments by providing evidence of increased total runoff in the Lake Tana Basin over the last few decades, despite no change in total annual rainfall. Schum (2004) showed that a small number of precipitation events in the rainy season lead to above-average erosion and account for a large portion of the sediment load. The time during which heavy precipitation occurs appears to be most decisive with respect to annual sediment load. Provided that sedimentation can be retarded, natural lakes could serve as sources of irrigation (Strebel 2007); their water tables may even be modified, as in the case of Lake Maybar in Wello (Strahm 2007), if conflicts over the use of the land and irrigation water can be negotiated and mitigated among stakeholders (Coendet 2007).

## 12.5 Research gaps and questions

### 12.5.1 Ongoing and emerging challenges

The challenges in developing rural Ethiopia lie in increasing productivity in all sectors in rural areas. As underlined by Hurni (2007), "sustainable land management must become the basis of agricultural activity on all land. Policies addressing rural–urban linkages, land tenure issues, and questions of demographic transition, as well as issues of education and health, can be particularly supportive in accelerating this change." This would require a sectoral transition, with less dominance of agriculture and more development of the secondary and tertiary sectors. This would bear the potential of accelerating change, though probably not without generating social and public security problems, which would need to be given special attention. Demographic transition is an additional issue that needs to be taken into account; this transition may lead to new identities, "moving from association with traditional rural Ethiopia to association with a modern, interlinked rural–urban landscape" (Hurni 2007).

### 12.5.2 Research gaps

The following gaps in research appear most important with respect to the Ethiopian Highlands:

1. Locally effective direct and indirect drivers will have to be carefully accounted for in research. Furthermore, it will be important to observe how quickly the sectoral change in towns affects rural settings.

2. Global as well as more indirect drivers will increasingly affect sustainable development in Ethiopia. Climate change, particularly through changes in rainfall amounts and patterns and through temperature increases, will seriously affect agricultural production and ecology in both positive and negative terms that are still unknown. Globalisation in terms of trade, technology transfer and information exchange will become increasingly important and affect both urban and rural livelihoods – areas in which research has a key role to play.

3. A combination of local and global drivers will pose a most likely unprecedented challenge to the Ethiopian Highlands, for which traditional means of governance may not suffice.

Research capacity in Ethiopia is still relatively modest in view of these challenges; its development and appropriate focusing is most timely and important. A number of research questions are currently being addressed and will contribute to sustainable land management in the Ethiopian Highlands (see Box). Research partnerships between institutions in the North and in Ethiopia are a means by which new technologies and local knowledge can be shared in a way that each partner benefits from the relative competence of the other. Lessons to be learned will be pertinent not only in the Ethiopian context, but also for international stakeholders.

**Box: Research questions relating to sustainable land management**

- Soil and water conservation: what are the most suitable technologies and approaches for reducing soil erosion and other processes of land degradation to tolerable levels while enhancing the overall productivity of the land for sustainable rural development?
- Protected area management: what institutional mechanisms are most suitable for attaining the goals of conserving wildlife and wildlife habitats while mitigating existing or potential conflicts with local land users and other stakeholders interested in protected areas?
- Water management: what are the most suitable watershed development models that allow more intensive use of the water resources while taking account of climate and global change and fulfilling the needs of downstream users?
- Institutions and staffing: what is the most appropriate institution and staff development policy for proper natural resource management?

## Endnotes

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[1] Hans Hurni is Professor of Geography and Sustainable Development at the University of Bern, Switzerland. He is also the Director of the Swiss National Centre of Competence in Research (NCCR) North-South, hosted by the Centre for Development and Environment (CDE), University of Bern, and responsible for a number of research projects related to natural resource management, soil and water conservation, smallholder agriculture, rural transformation and sustainable development in Africa, Asia and Latin America.
E-mail: hans.hurni@cde.unibe.ch

[2] Solomon Abate holds a PhD in Natural Resources Management from the Faculty of Natural Sciences, University of Bern, Switzerland. He is Regional Coordinator for the Eastern Nile Watershed Programme at the Eastern Nile Technical Regional Office (ENTRO), Nile Basin Initiative, Addis Abeba, Ethiopia, and is responsible for planning, managing and coordinating the implementation of watershed projects and related activities in the region.
E-mail: sabate@nilebasin.org

[3] Amare Bantider holds a PhD in Geography and Sustainable Land Management. Currently he is Assistant Professor at Dilla University, Ethiopia, and coordinating two research and capacity development projects entitled "Water and Environment" and "Doing Development with Young People in Ethiopia". His research interest lies in sustainable land management, with a focus on land-use and land-cover changes, soil and water conservation, and integrated watershed management.
E-mail: amare_zerfe@yahoo.com

[4] Berhanu Debele is Head of the Regional Coordination Office of the Joint Area of Case Studies (JACS) Horn of Africa (HOA) of the Swiss National Centre of Competence in Research (NCCR) North-South, located in Addis Abeba, Ethiopia. His research interests include land evaluation, as well as soils and the environment.
E-mail: nccrhorn@ethionet.et and berhanudebele@gmail.com

[5] Eva Ludi holds a PhD in Natural Sciences and is a Research Fellow at the Overseas Development

Institute (ODI) in London, UK. Her policy-oriented research projects and advisory services focus on natural resource governance, with a special focus on soil, water and protected areas, climate change adaptation in complex rural environments, and livelihoods-focused sustainable development, including support of cash crop-dependent smallholder producers particularly in Ethiopia and other sub-Saharan African countries.
E-mail: e.ludi@odi.org.uk

[6] Brigitte Portner is a research scientist and a PhD candidate at the Centre for Development and Environment, University of Bern. She holds a Master's degree in Geography from the Faculty of Science, University of Bern, Switzerland. She has a particular interest in environmental governance, with a regional focus on Eastern Africa and Central America. Her current research focuses on the impacts of global biofuel demand and production.
E-mail: brigitte.portner@cde.unibe.ch

[7] Birru Yitaferu holds a PhD in Natural Sciences focusing on land resource management. He is Director of Soil and Water Research of the Amhara Regional Agricultural Research Institute (ARARI) in Bahr Dar, Ethiopia. He is currently responsible for a number of research projects and programmes, such as the Nile Irrigation and Drainage Project, research projects on sustainable water harvesting and institutional strengthening, and further watershed-based research.
E-mail: birru_yitaferu2002@yahoo.com

[8] Gete Zeleke holds a PhD focusing on Natural Resource Management, and he is General Manager of Avallo International Research and Development (AIRD), Addis Abeba, Ethiopia. His research interests include assessing soil erosion processes, land evaluation, sustainable land management, and climate change from a natural resource management perspective.
E-mail: gete_2004@yahoo.com or g.zeleke@cgiar.org

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