

**Landscape Dynamics and Sustainable Land Management in  
Southern Ethiopia**

**Dissertation**

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## Summary

Landscapes have undergone unprecedented changes in Chench and Arbaminch areas, Southern Ethiopia, during the last century. Yet there exist well-established land-use systems and a wealth of local experience in maintaining and managing landscapes. The major objective of the study is to explore the dynamics of landscapes in a chronological and spatial order to identify trends, driving forces and impacts of land use systems, land cover and landscape structures during the last century in Chench and Arbaminch areas. The methods used in the study include detailed field and lab investigations including  $C^{14}$  dating, satellite image interpretation, interviews and group discussions.

The results of satellite image analysis (images from 1972, 1984 and 2006) show that cultivated land was expanded by 39 % from 1973 until 2006, but farming land per capita decreased enormously. In the same period of time, grassland as the main fodder resource for livestock shrank by 69 % – thus causing a huge decrease in livestock. Similarly, forest cover shows a 23 % decline from 1972 until 2006, with the most significant change from 1986 to 2006. Cultivated land scarcity and fragmentation can mostly be related to demographic pressure, which was exacerbated by government policy, the land tenure system, and the nature of subsistence agriculture.

Changes were most intensive in the lowland; remarkable episodic forest changes also occurred, suggesting nonlinear spatial and temporal forest cover dynamics. According to farmers, the main driver for deforestation is agricultural land expansion, in response to local population increase and decline in agricultural production. Growing fuel wood demand, locally and in nearby towns, is another chief cause.

Farmland scarcity has already caused farmers to cultivate marginal land areas and fragile ecosystems. This coupled with deforestation and cattle grazing in the remaining forestland, resulted in a decline in soil fertility and an increase in soil erosion by water. Gullying is one of the common and widespread processes of erosion in the area. Gully systems are characterized by the cyclic succession of phases of entrenchments with aggradations and with stability and soil formation. The extension of areas that are affected by gullying has increased dramatically over the last five decades. Gullies are highly modified and altered landscape elements, which in turn have immense implications on the environment and livelihood of the people. Gullies caused stripping of large amounts of soil from the highland and also water availability in the soil for plant growth is reduced. In addition, siltation of irrigation channels and weirs at the lowland is one serious obstacle for agriculture.

The farmers, however, were resourceful and gathered a wide range of experience and developed skills over millennia to cope with the problems associated with population density and scarce resources. Despite the recent disruptions, they have used intensive cultivation systems, integrating crop-livestock practices and cultivated diversified crops such as “demographic” (very productive) and drought tolerant plants. Moreover, terraces were built along contours, and used – as radiocarbon dating proves – over the last eight centuries, particularly in Dorze-Belle, Chench. These indigenous terraces are thus dubbed a success

story to manage the environment over generations and as a survival strategy for life on the steep mountains.

Moreover, the people of the area have long had rules and regulations to maintain the sacred forests, woodlots and stands of trees around the homesteads and in the farm fields. Trees are an important part of farm activities and social systems. The effective traditional types of land use make the area under investigation one of the least affected by the recurrent famines in Ethiopia. Thus these practices should be promoted and advanced. The design and implementation of sustainable environmental planning and management should integrate local knowledge and practices.

## **Zusammenfassung**

Die Landschaften in den Regionen Chencha und Arbaminch, Südäthiopien, haben in den vergangenen einhundert Jahren beispiellose Veränderungen erfahren. Dort existieren etablierte Landnutzungssysteme und eine Fülle lokaler Erfahrungen in der Unterhaltung und dem Management von Landschaften.

Das zentrale Ziel der vorgelegten Arbeit ist die chronologische und räumliche Erforschung der Landschaftsdynamik, um Trends, Antriebskräfte und Auswirkungen von Landnutzungssystemen und Landschaftsstrukturen für das vergangene Jahrhundert in den Regionen Chencha und Arbaminch zu identifizieren.

Die applizierten Methoden umfassen detaillierte Feld- und Laboruntersuchungen einschließlich  $C^{14}$ -Datierungen, die Interpretation von Satellitenbildern, Interviews insbesondere mit Bauern und Gruppendiskussionen mit Entscheidungsträgern.

Die Resultate der Satellitenbildanalyse (Aufnahmen von 1972, 1984 und 2006) belegen, dass die Ausdehnung des Ackerlands von 1973 bis 2006 um 39% zunahm, die Ackerfläche pro Kopf jedoch zeitgleich stark abnahm. Im selben Zeitraum nahm die Ausdehnung des Weidelands um 69% ab, begleitet von einem starken Rückgang der Haustierzahlen. Entsprechend nahm die Waldbedeckung von 1972 bis 2006 um 23% ab. Der intensivste Rückgang vollzog sich von 1986 bis 2006.

Der Mangel an Ackerland und die Zersplitterung der Fluren steht vorwiegend in Verbindung mit dem demographischen Druck, der durch die Politik der Regierung, durch das System des Landbesitzes und die Merkmale der Subsistenzlandwirtschaft verschärft wurde.

Die Veränderungen waren am stärksten im Tiefland des ostafrikanischen Grabenbruchs. Bemerkenswerte episodische Veränderungen vollzogen sich bei der Waldbedeckung. Sie belegen nichtlineare raumzeitliche Prozesse. Bauern berichten, dass die Hauptursache der Entwaldung in dem stark wachsenden Bedarf an Ackerland liegt, der vom Bevölkerungswachstum und den sinkenden landwirtschaftlichen Erträgen ausgelöst wird. Der verstärkte Bedarf an Brennholz ist ein weiterer wesentlicher Grund.

Der Mangel an Ackerland hat dazu geführt, dass Bauern nunmehr auch marginale Standorte und fragile Ökosysteme in Kultur genommen haben. Diese Entwicklung zusammen mit der Entwaldung und der zunehmend intensiveren Beweidung der Restwälder führt zu einer Abnahme der Bodenfruchtbarkeit und einer Zunahme der Wassererosion. Schluchtenreißen ist häufig im Untersuchungsraum. Die Schluchten durchlaufen wiederholt Phasen der Eintiefung und der Sedimentation, unterbrochen von Phasen mit Bodenbildung unter Vegetation. In den vergangenen fünf Jahrzehnten hat sich die von Schluchtenreißen betroffene Fläche dramatisch ausgedehnt. Schluchten sind komplexe Landschaftselemente, die eine große Bedeutung für die Umwelt und die Lebensgrundlage der Bewohner haben. Das Schluchtenreißen bewirkte im Tiefland Sedimentation in den Bewässerungskanälen und an den Wehren sowie damit eine starke Behinderung der dortigen Landwirtschaft.

Die Bauern gingen in der Vergangenheit – auf der Grundlage Generationen übergreifender Erfahrungen – sehr sorgfältig mit ihren begrenzten Ressourcen um. Trotz der jüngsten Umbrüche nutzen sie intensive Landnutzungssysteme, integrative Tierhaltungskonzepte und



kultivieren sie eine hohe Zahl an verschiedenen Kulturfrüchten, darunter auch hochproduktive und dürreresistente Pflanzenvarietäten.

Sie bauten Höhenlinien parallele Terrassen, die sie – wie Radiokohlenstoffdatierungen belegen – über Jahrhunderte nutzten, insbesondere im Raum Dorze-Belle bei Chenchä. Diese ursprünglichen Terrassensysteme sind eine Erfolgsgeschichte und vorbildliche Überlebensstrategie. Sie belegen das erfolgreiche Management intensiv genutzter Steilhänge über lange Zeiträume.

Die Bewohner hatten Regeln etabliert und über lange Zeit eingehalten, die die heiligen Wälder, kleinere Wäldchen und Bäume an ihren Häusern und in der Feldflur schützten. Bäume sind ein bedeutender Teil des bäuerlichen und des sozialen Systems. Die effektiven traditionellen Landnutzungsformen führten dazu, dass das Untersuchungsgebiet zu den in der Vergangenheit am wenigsten von Hungersnöten betroffenen Regionen Äthiopiens zählte. Daher sollten die traditionellen Landnutzungssysteme konsequent und behutsam weiterentwickelt werden.

In das Design und die Implementierung einer nachhaltigen Umweltplanung und eines nachhaltigen Umweltmanagements sollten das traditionelle lokale Wissen und die lokalen Landnutzungspraktiken über partizipative Verfahren integriert werden.



## **Chapter 1**

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### **Introduction**

## **Introduction**

Agricultural landscapes and forestland in Ethiopia underwent unprecedented changes (particularly during the last century) due to the dynamics of political, demographic, socio-economic, and cultural factors. However, the type, direction and rate of the changes have to be investigated in detail.

Governmental awareness and recognition of the problems of land degradation in Ethiopia started with the 1970s famine. There was a general consensus in the government that the famine event was associated with deforestation and soil degradation. As a response, massive soil water conservation activities were carried out to mitigate land degradation, with the assistance of international organizations. Was the soil water conservation program with a top-down approach and a low level of involvement of the farmers in planning and implementing soil conservation measures effective and successful? Have the farmers of Ethiopia been aware of the problems of land degradation, even before the government recognized the problem? Did the farmers use measures to halt soil degradation and to manage forest resources over generations? These are important research questions that should be addressed.

Landscape development and human activities have also been rapidly changing during the last century in Chenchu and Arbaminch areas in Southern Ethiopia. As a result soil degradation is prevailed in the area and becomes one of the most serious threats in terms of agricultural production, food insecurity and development challenges. Hence, an historical investigation of landscape development, which took place during this period of time, is of a paramount importance to provide valuable information for decision makers, land use planners, and environmental managers who need to make sound decisions. During the past century in particular, there has been a very significant development of agricultural landscapes. During this period, three different political regimes emerged and deployed different ideologies and differing agricultural land utilization and land policies. The regime changes were radical and the impacts were reflected in resource utilization and management. Furthermore, population growth was very rapid. The last century was therefore a period of dynamic socio-economic and political changes, which played an immense role in modifying landscapes.

On the other hand, farmers have developed and practiced various traditional mechanisms to cope with the challenges of population pressure, environmental degradation, and food insecurity (low productivity) over a long period of time. However, the agricultural system and the mechanisms against adverse conditions have not gained attention and appreciation by planners and researchers. For instance there is an important lack of studies, which investigate the importance of terracing in the area.

Thus, the study of the long-term landscape dynamics has multifold significances such as adding scientific knowledge about land uses, landscape structures and land management. The long-term perspectives of the landscape management are also guiding efforts towards sustainable land management systems. Moreover, the present investigation is important since today many cultural landscape practices are on the verge of disappearance due to cultural assimilation and integration, coupled with the high dynamism of the political and economic conditions. Furthermore, the investigated area is marked by a high diversity of physical and socioeconomic environments. For example, the altitude ranges within a short horizontal distance of only 20 km from 1,100 m in the rift valley to 2,300 m above sea level in the highland. I.e. there exists an enormous diversity in topography, climate, soils and vegetation

in the research area. Moreover, there is also a spatial variation on types, magnitude and severity of soil degradation. On the other hand, there is a strong linkage between land use, landscape structure and the people. This is also an important premise to investigate site specific and spatial interlinking of landscape dynamics.

## **2. Objectives and Research Questions**

The major objective of the study is to explore the dynamics of landscapes in a chronological and spatial order to identify trends, driving forces and impacts of land use systems, land cover and landscape structures during the last century in Chench and Arbaminch areas, Southern Ethiopia. Hypotheses, scenarios and research questions were formulated for the analysis and evaluation of man-environment interactions and for strategies of sustainable landscape management.

Hypothesis 1: Decline of agricultural production and farmland scarcity has had a strong influence on the dynamics of agricultural and forest landscapes during the last centuries in the research areas.

Hypothesis 2: Increase of population density and intensified land use has accelerated soil degradation drastically since the mid 20<sup>th</sup> century in the research areas.

Hypothesis 3: The problems of unsustainable land uses are well perceived by the community. It responded to the problems through different traditional approaches and practices since long past (e.g. indigenous soil and water conservation technology). But the practices are not appreciated and widespread.

The specific objectives of the study are:

- The exploration of the rate and magnitude of the spatial-temporal patterns of land use and land cover and their driving forces (such as biophysical and socioeconomic processes, policies and livelihoods).
- The assessment of the impacts of the landscape dynamics on the magnitude and the spatial-temporal variability of soil degradation.
- The exploration of the knowledge and perception of the local people on landscape dynamics and their strategies and practices to cope with demographic pressure and scarce resources.
- The assessment of the resilience and stability of the traditional land management knowledge within the context of farmers' awareness of land degradation (soil erosion, soil fertility) and local knowledge on managing soils, forest and grazing land.
- The exploration of the origin, development and characteristics of indigenous soil and water conservation measures such as strategies of sustainable land management and livelihood.

### **Specific Research Questions**

1. What are the trends and patterns of the dynamics of land use systems, land cover and landscape structure and their driving forces?
2. Why is the recent rate of landscape change so high? Were there comparable rates of changes in the past?

3. How did the land use systems and landscape structure affect soil degradation?
4. To what extent do people perceive the problems of soil degradation (sheet, rill and gully erosion, soil fertility)?
5. What are the determinant factors that affect the sustainable land management measures?
6. How have farmers responded to the effects of the dynamics of land use systems, land cover and land structure?

## **Methods (Overview)**

Multi- and interdisciplinary research methods and a holistic analysis have been involved in collection, organization and analysis of both the historical and contemporary data on the land use systems, land cover and landscape structure from geoarchives, laboratory analysis, remotely sensed images, public, agencies and documents. Detailed field investigations and measurements on soil erosion and deposition processes in a chronological and spatial order have been carried out. Charcoals samples have been analyzed and dated. Satellite images of the different periods of time have been used to analyze the magnitude and rate of land use and land cover dynamics. In depth semi-structured interviews were carried out with 120 households. To cover the different agro-ecological zones, areas that belong to the highlands, middle altitudes, and lower elevations were selected. Group discussions with key representatives were also held to document the causes of soil degradation, the perception and responses of the people to landscape dynamics. Details about the methods used can be found in the following chapters.

## **Thesis outline**

The thesis constitutes two parts. The patterns, driving forces and impacts of landscape dynamics are presented in part I (Chapter 2 through 4) and the interaction to landscape changes and sustainable land management are presented in part II (Chapter 5 and 6). The extent and trends of changes of agricultural land use systems and driving forces were studied in chapter 2. The strategies and approaches of the local people in response to agricultural landscape dynamics were also presented in the same chapter. Chapter 3 presents the dynamics of forest cover, the drivers that cause deforestation, the consequences of deforestation, the status of the present forest and the local people's knowledge and experiences in forest management. In chapter 4 the formation, processes, causes, impacts and attempts to combat gullying are studied. Chapter 5 deals with farmers' awareness in identifying the severity, dynamics and causes of soil erosion and soil fertility decline as well as grazing land deterioration and deforestation. The resilience and stability of the traditional land management knowledge are also addressed in the same chapter. Chapter 6 focuses on the origin, development and characteristics of the indigenous soil and water conservation technology and evaluates the effectiveness and determinants of the sustainable use of the measures. Chapter 7 draws the conclusions of this study and suggests future research areas.

## Chapter 2-----

### **Dynamics and Driving Forces of Agricultural Landscapes in Southern Ethiopia – A Case Study of the Chencha and Arbaminch Areas**

## **Dynamics and Driving Forces of Agricultural Landscapes in Southern Ethiopia – A Case Study of the Chencha and Arbaminch Areas**

### **Abstract**

Agricultural landscapes in Ethiopia have undergone unprecedented changes. The direction of change, however, is unsustainable as manifested in land degradation, biodiversity loss and low agricultural productivity. The objective of this study is to examine the patterns and trends of agricultural landscape development and responses of the local people within the framework of the dynamics of demography, socioeconomic conditions, politics and natural resources in the Chencha and Arbaminch areas during the last century. Information on cultivated and grazing land areas was acquired by satellite image interpretation. Interviews and group discussions provided important information on agricultural land use systems and document the responses of the people on the land use changes. A review and an analysis of secondary sources and documents of past studies were also used for trend analysis as a baseline and a supplement to oral history. The results show that cultivated land was expanded by 39% from 1973 until 2006, but per capita farming land holdings decreased enormously. In the same period of time, grassland as the main fodder resource for livestock shrank by 69% thus causing a huge decrease in livestock. Cultivated land scarcity and fragmentation can mostly be related to demographic pressure, which was exacerbated by government policy, land tenure, and the nature of subsistence agriculture. The farmers, however, were resourceful and gathered a wide range of experience and developed skills over millennia to cope with the problems associated with population density and scarce resources. They used an intensive cultivation system, various soil management practices, and cultivated diversified crops such as “demographic” (very productive) and drought tolerant plants. This type of land use makes the area one of the least affected by the recurrent famines in Ethiopia. Hence, the agricultural system in the study area has been sustainable for a long period of time. However, these traditional land use activities and land management practices have been deteriorating recently. Farmers have been forced to cultivate steep slopes, wetlands, and grasslands, whereas the practice of fallowing and the application of manure have declined. The diversification of crops has also been reduced and in some cases replaced by monocropping. Indigenous or local crop varieties have been neglected. Land use planners and environmental managers should take local knowledge and innovation into account in order to make sound decisions for the future.

**Keywords:** agricultural landscape • land use changes • socioeconomic driving forces • traditional land management • sustainable land uses • Ethiopia

### **1. Introduction**

Ethiopia is one of the locations on the globe where first plant domestication and the origin of human food production took place. The country is also one of the 12 Vavilov centres for its rich crop genetic diversity (Ehret, 1979). The existence of a favourable climate, often high soil fertility, and good topography conditions enabled the evolution of agriculture, genetic diversity and long term habitations (McCann, 1995). Agriculture was the basic supporter of a



large population and the foundation of the economy over a long period of time. At present, it is the source of livelihood of 85% of the total population (66 million) who live in rural areas (CSA, 2006). It also accounts for 50% of the GDP, 90% of exports and 85% of total employment (MEDaC, 1999). Small holder agriculture dominates, is subsistence-oriented, and dependent on rainfall. This small scale agriculture accounts for 90% of total croplands and 90% of agricultural output (Mulat et al., 2004). Nevertheless, the contribution of the agricultural sector to food security and economic growth is declining and failed to meet the food requirements of the growing population. In the period between 1960 and 2002, agriculture grew at the rate of 1.35% per year, while the population grew by 2.71% on average per year. This data shows that the agricultural sector obviously failed to feed the growing population. On the other hand, agricultural landscapes in Ethiopia underwent unprecedented changes (particularly during the last century) due to the dynamics of political, demographic, socio-economic, and cultural factors. However, the direction and rate of the change is not sustainable (McCann, 1995; Mulat et al., 2004; Rahmato, 2009).

The extent of available agricultural land in Ethiopia has enormously increased, particularly during the last hundred years. From 1900 until 1989, about 4.7 million households required arable land for cultivation (Hurni, 2007). Since 1900 about 23 M ha of forest land were cleared, mainly driven by a conversion to arable farmland (EFAP, 1993). More recent satellite image analysis of the period between 1973 and 1990 for the entire country also revealed that about 2,4543km<sup>2</sup> of forest (2.14% of the total forest resources of the country) was cleared, mainly because of the demand for acreage (Resuing, 2000). Moreover, a considerable portion of grassland was also shifted to cultivated land (Benin et al., 2001). In the period between 1961 and 2002, areas fit for the cultivation of cereals, pulses, and oil seeds increased from 5,440,000 ha to 7,812,000 ha, which amounts to about a 44% increase land for cultivation (Mulat et al., 2004). Various case studies in different parts of the country also report an increase of plough land. A case study in North Western Ethiopia demonstrated an increase of acreage from 39% to 77% in the period from 1957 to 1995 (Zelege and Hurni, 2001). In South West Ethiopia another study also revealed an increase of cultivated land from 27% to 63% in three different but adjacent sites from 1957 until 1993 (Reid et al., 2000). Similarly, in the South Central Rift Valley a high deforestation rate of 13.8% was calculated for the period from 1972 until 2000. This change was mainly caused by a conversion to farmland. On the other hand, in some case studies it was reported that the change to cultivated land has been very minor since the 1980s because there is no more suitable land left that can be converted (Tekle and Hedlund, 2000). This also implies that the upper limit of possible arable farmland has been reached and that no further expansion can occur in some regions of Ethiopia.

Notwithstanding the general increase of land for cultivation in the country, per capita land holdings are declining. The national per capita land holding rate ranged to maximally 3 ha and below in 1960 with regional variations (Arsi 2.5 to 3 ha; Gojam 2 ha, Welo and Tigray 1.5 ha and in regions where enset (*Ensete ventricum*), is grown less than half a hectare). In the same time period, 14% to 20% of farmers were landless alongside those with petty holdings in Northern Ethiopia (Rahmato, 2009). Before the end of the last century, approximately 39% of farming households worked less than 0.5 ha and about 89% worked less than 2 ha. Only 0.75% of the farmers cultivated more than 5 ha. There are also regional variations in land holdings. For example, in the south about 56.4% of farmers operated on land with an overall size of 0.1–0.5 ha (CSA, 2006; Rahmato, 2009).

The decrease of farmland per capita is attributed to a rapid population growth, a lack of off-farm employment opportunities, and a lack of rural urban migration due to economic stagnation (Mulat et al., 2004; Samuel, 2006.) The total population of Ethiopia increased from about 12 million in 1900 to about 26 million in 1970 and over 77 million in 2007 (CSA, 2006; Sahilu, 2003). Likewise, the rural population has grown from about 12 million in 1900 to 64 million in 2007 (Hurni, 2007; CSA 2006). The rural portion of the population decreased from about 98% in 1900 to about 90% in 1970 and about 85% today, although it grew from ca. 2.3 million households in 1900 to ca. 4.7 million in 1970 and to ca. 11 million households in 2000 (Hurni, 2007). With the current growth rate (nearly 3%), the rural population is expected to reach about 85 million by 2018, which will also bring about a growing number of land-short and landless rural residents.

Farmland scarcity has already caused farmers to cultivate marginal land areas and fragile ecosystems. Moreover, it is also possibly a reason for the reduction and abandonment of fallowing practices and crop rotation. This, in turn, resulted in a decline in soil fertility and an increase in soil erosion. The problem of soil erosion in Ethiopia is one of the serious threats to agricultural land maintenance and food security. The estimated annual soil loss in Ethiopia amounts to 1.5 billion tons, of which 50% erodes from croplands where soil loss by water may be as high as 296 tons ha<sup>-1</sup> year<sup>-1</sup> on steep slopes and soil nutrient losses may be as high as 80 kilograms of N, P, K per ha and year or more. In general, half of Ethiopian highlands are moderately to severely eroded (FAO, 1986; Hurni, 1993; Pender, 2001; Lemenih, et al., 2005). The annual cost of soil erosion for the national economy of Ethiopia is about 1.0 billion US dollars (Sonneveld, 2002). The degradation of soil results in a deficiency of nutrients, a decline in water holding capacity, problems of rooting anchorage, tillage difficulties, drainage problems, and flooding. These negative developments eventually result in a decline of fertility of the soil, an increase in a susceptibility to crop failures, and ultimately in the collapse of food production ending in famine. This is partly manifested in a decline of agricultural development and overall food insecurity in Ethiopia during the last fifty years.

At present, Ethiopia is one of the largest food aid receivers in the world. From 1945 to 1954 Ethiopia was self-sufficient and an exporter of food crops, mainly cereals. During this period, Ethiopia exported about 154,000 tons of cereals given the shortage of food grain after the Second World War (Rahmato, 2009). However, the situation reversed and Ethiopia started to import food crops as of the second half of the 1950s. Subsequently, the World Food Program began to operate and to expedite food aid to Ethiopia in 1965. Since then Ethiopia has remained one of the largest food aid recipients. Between 1985–2000 Ethiopia received about 700 000 tons per annum, which represents about 10% of the national food grain production. The largest amount of food aid, 26% of the total domestic food production, was received in 1984 due to the worst drought that affected over 14 million people, 22% of the total population of the country. Food aid has increased by an average growth rate of about 2.5 % per year from 1980 to 2001 (Clay et al., 1999; Devereux, 2000; Mulat et al., 2004).

In order to overcome food insecurity problems and to maintain natural resources, various plans, programs, and policies have been formulated and implemented over the last century by different governments that have ruled Ethiopia, during the Imperial period from the 1920s–1960s, during the phase of the military government - the *derg* - from the 1970s–1980s, and during the incumbent government from the 1990s–present. Despite sporadic positive effects, the various governments were neither able to meet food demands nor to maintain the

environment (McCann, 1995; Mulat et al., 2004; Rahmato, 2009). The policies and the strategies of the governments were impaired by various problems, some of which were common throughout the different regimes. The main constraints of the policies as summarized by Rahmato (2009) include 1) the derivative nature of the policies as mainly based on the interests of the IMF and the World Bank, 2) a non-participatory, rather top down approach, and 3) a non-consultative decision-making process lacking a broad-based approach. For instance, soil and water conservation attempts by the *derg* as well as by the present government have not been successful mainly due to the top down planning approach and the absent participatory nature of the program (Bewket, 2007; Admassie, 2000).

Nevertheless, different localities have developed and practiced various traditional mechanisms to cope with the challenges of population pressure, environmental degradation, and food insecurity (low productivity) over a long period of time. One of the cases in point is the study area Chench and Arbaminch in Southern Ethiopia. The area is characterized by a high population density (within a range between 300 to 400 persons per km<sup>2</sup>) and the land holding rate was less than half a hectare in the 1960s, which has been surpassed by the carrying capacity since then (Rahmato, 2009). The farmers, however, are resourceful, gathered a wide range of experience, and developed skills over millennia to cope with the problems associated with population density and scarce resources (Jackson, 1972; Jackson et al., 1969). They have used an intensive cultivation system, various natural resource management practices and cultivated diversified crops. “Demographic” i.e. drought tolerant plants such as *Ensete ventricosum* were used, which make the area one of the least affected by the recurrent drought in Ethiopia. As Rahmato, (2009:35) has succinctly put it: If these intensive agricultural techniques and discrete innovations had not been practiced in the area over centuries, the people would not have survived. However, this agricultural system and these mechanisms against adverse conditions have not gained attention and appreciation by planners and researchers. Hence, there are only very few attempts to investigate and study the state of agriculture land use, land use systems, and the resourcefulness of the farmers in the area (Jackson, 1972; Olmstead, 1975).

Furthermore, there are very few attempts to study the use of agricultural lands and the forces that drive Ethiopia in general, and the study area in particular, on a long term basis. Historical insight on the dynamics and driving forces of agricultural land use is of paramount importance in order to understand current agricultural landscape developments and to determine the state of human-environment interactions. During the past century in particular, there has been a very significant development of agricultural landscapes. During this period, the three aforementioned regimes emerged and deployed different ideologies and differing agricultural land utilization and land policies. The regime changes were radical and the impacts were reflected in resource utilization and management. Furthermore, population growth was also very rapid during these phases. The last century was therefore a period of dynamic socio-economic and political changes which played an immense role in modifying agricultural landscapes (McCann, 1995; Rahmato, 2009). An historical investigation of agricultural landscape development which took place during the last century is therefore necessary to provide valuable information for decision makers, land use planners, and environmental managers who need to make sound decisions.

In light of the above discussion, the objective of the study here was to examine the patterns and trends of agricultural landscape development and the responses of the people within the framework of the dynamics of demography, socio-economic conditions, politics, and natural resources in the Chench and Arbaminch areas in Southern Ethiopia during the last century.

The specific objectives are: 1) a determination of the extent and trends of changes of agricultural land use systems and driving forces, and 2) an assessment of strategies and approaches of the local people in response to agricultural landscape dynamics.

## 2. Methods of the study

### 2.1 Description of the study area

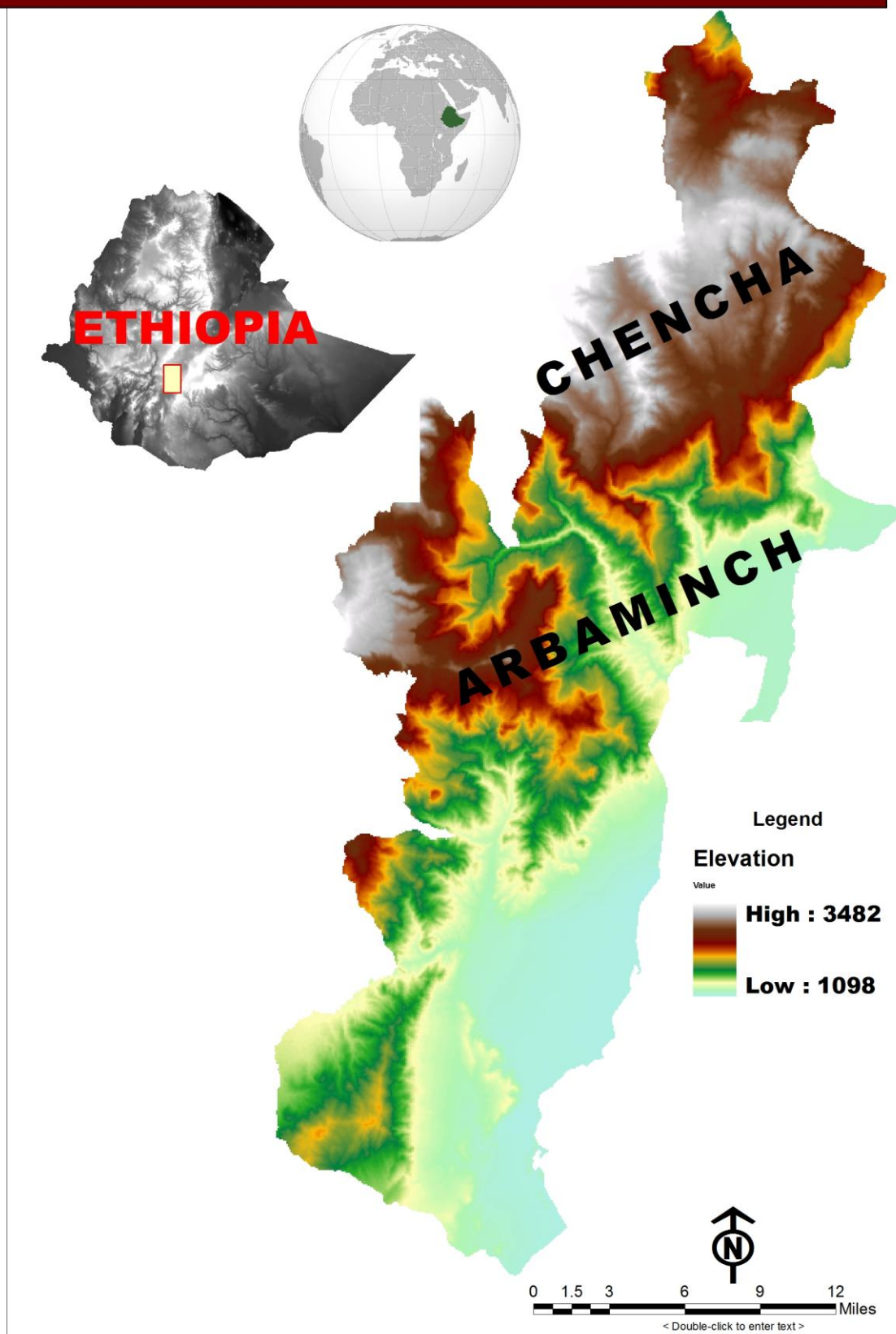
Chencha (6° 15' N, 37° 34' E) and Arbaminch (6° 2' N, 37° 33' E) are located in the Gamo Gofa Zone, Southern Nations, Nationalities, and People's Regional State (Fig. 1). They are situated about 480 km southwest of Addis Ababa and bounded on the east by Lake Abaya and Lake Chamo. The topography is marked by a series of undulating and rugged landscapes, which include, from east to west, the Rift Valley Plain, the escarpment with incised valleys, and high plateaus, which are topped by hills and mountains. The lower part of the study area lies in the plain of the rift valley while the middle and upper parts are situated in the southwestern highlands of Ethiopia. According to the traditional agro-climate classification system, which only considers altitude, the study area lies within a *kola* zone (elevation of below 1500 m a. s. l.), a *weina dega* zone (elevation of 1500 to 2300 m a. s. l.) and a *dega* zone (elevation above 2300 m a. s. l.). However, these diversified landforms are highly interactive and related to each other via drainage systems and socio-cultural conditions.

The mean annual precipitation in Arbaminch (1200 m a. s. l.) and Chencha (2700 m a. s. l.) is 782 mm and 1,392 mm respectively. The rainfall pattern is of a bimodal type. The first rainy season, locally known as *gabba*, occurs from March to June and the peak reaches 148 mm in April for Arbaminch and 185.4 mm for Chencha. The second season, locally known as *silla*, occurs from August to November. The maximum mean monthly temperature in Chencha is 15<sup>o</sup> C in February and the minimum temperature is 13<sup>o</sup> C in October. The average annual temperature of Arbaminch is 23<sup>o</sup> C. There the maximum mean monthly temperature is 26<sup>o</sup> C, which occurs in March and the lowest temperatures are recorded from December to February.

The main soil types in the area are Fluvisols, Leptosols, Cambisols, Acrisols, and Alisols. Natural vegetation is sparse and only small patches, such as sacred forests, are found on the highlands due to the cultivation of most land areas, although eucalyptus trees are common around the homesteads and on community woodlots.

The population of Chencha totalled 134,531 and of Arbaminch 247,915 in 2005 (CSA, 2006). Population density is estimated at about 368 and 205 persons per square kilometre in Chencha and Arbaminch respectively. Scientific investigations prove that the area has been settled at least since about 3360 years cal BP (Arthur et al., 2010). Olmstead (1972) estimated that 5,000 to 35,000 people lived in Chencha area at the end of 19<sup>th</sup> century. The main economic activity of the area is subsistence agriculture.

**Figure 1. Location of the study area**



## 2.2 Methods of the study

### Satellite Image analysis

A time series was created (acquired) from satellite image analysis. Landsat MSS, TM and ETM+ satellite images of the years 1973, 1986, and 2006 were used in conjunction with field surveys. These images were geometrically registered to the 1:50,000 scale topographic map of the area. Agricultural land use was identified from the images by a supervised classification method. Agricultural land includes cultivated lands and grasslands, which are mainly used for grazing. Cultivated land is used for annual and perennial crops. It includes areas currently under crops, fallow land, land under preparation, and homestead land. Data for ground referring (ground truth) were employed from extensive field observations and interviews in 2009 and 2010.

### Household interviews

To cover the different agro-ecological zones, areas that belong to the highlands (*Doko Mesho*), middle altitudes (*Dorze Belle*), and lower elevations (*Chano Chelba*) were selected. From the lists of the households in the kebeles, a total of 120 household heads were randomly selected. The interviews were carried out with the help of assistants. The assistants were college graduates who knew the local languages. Trainings for assistants were carried out conveying ways of establishing contact, methods for conducting interviews, interview procedures, and cultural issues. Interviews were conducted by going to the individual households in the morning and during the afternoon, which are usually appropriate times for the farmers since neither an agricultural activity nor any other activities in which the household head was involved in took place at these times of the day. Interviews were also held outdoors as long as the people were willing to respond to the questions. If the informant was unwilling to give information then she or he was asked to propose someone who would be willing to be an informant. The estimated time to conduct an interview with one household head was about 2 to 2.5 hours. The interviews were carried out from October to December 2009.

Before conducting an interview with a household head, the objectives of the questionnaires were explained to gain the confidence of the interviewee and to avoid fear. The interviewees were also informed about the confidentiality of information and interviewee identity. While conducting an interview different probes were also employed in some cases to obtain clear answers. Every day we summarized the daily activities focusing on the unique matters, which were conveyed to the interviewers during interviews. Accordingly, we drew lessons and devised mechanisms for the activities of the following days.

### Interviews with key informants

The key informants were older people and rituals leaders. The discussions with them mainly focused on what had changed, how changes had occurred, and why changes in the land use systems had taken place in their living area and the surroundings. An event calendar was established as a benchmark for a comparison of landscape transformations over time. People usually remember specific situations by associating them with specific events. One particular type of event was a change of government. In Ethiopia, two major radical governmental changes took place in 1974 and 1990. Moreover, different types of questions pertaining to oral history which referred to situations in the time of their fathers were also raised and discussed.

### Group discussions

Group discussion is an important technique to check and refine the data, which was acquired by structured interviews of household individuals and key informant interviews. It is useful in order to rule out exaggeration or underestimation of the situations. Likewise, the household interviews and the research area were divided into three segments including the Chano Chelba, the Dorze Belle, and the Dokomesho areas. Ten informants were selected from each area. Participants in the discussions were elders (mainly over 50 years of age, both sexes) who could remember and convey past events of agriculture land use. Discussions were carried out based on the check lists.

## 3. Results and discussion

### 3.1 Access to agricultural land - an overview of historical trends

Cultivating crops and livestock rearing have been the dominant economic activities since the beginning of settlement in the area (Cartledge, 1995; Arthur et al., 2010). Thus, access to land for cultivation and grazing are an important basis for the livelihood and income of the people. The right to use, control, and transfer the land (land tenure) is determined by social, political and economic systems that existed during different periods of time. The social and political system that prevailed in the area during the 19<sup>th</sup> century and before was based on a cast system (Olmstead 1975). There were two main classes (social strata), on the one hand a class of citizens (*mala*) and, on the other hand, a class of non-citizens (*ts'oma*). The former included farmers, merchants and weavers, while the latter included potters, tanners, blacksmiths, and slaves. The *mala* was the apex of the society, who controlled the political, economic, and religious systems, and hence possessed large areas for cultivation. Land could only be transferred or accessed to *malas* through buying, inheritance, and share cropping. In the 19<sup>th</sup> century, there were battles among communities situated near each other to obtain greater labour forces in order to expand acreage (Olmstead, 1975). In contrast, land was only allotted to the *ts'oma* to build houses and to cultivate the house compounds (Olmstead, 1975). The land of the *ts'omas* was situated in most cases on steep slopes and on the edges of the mountains, which were marked by low soil fertility. In a recent archaeological investigation, the old houses, which belonged to the artisans (*ts'oma*), were also found on the edges of the mountains (Arthur et al., 2010). Women, irrespective of their social class, were also not permitted to own or cultivate land.

This cast system was abandoned at the end of 19<sup>th</sup> century when the region was incorporated into Ethiopia. Following the integration, different land tenure systems were established. The main systems included the *gabar*, the *balabat* and government or state land. The *Gabar* was the land, which was given to central governmental officials, members of the military, priests, and civil servants. They occupied large areas for cultivation. The *balabat* was the previous king or leader of a community, who also possessed large plots of land. They were also entitled to collect taxes for the central government. Most of the farmers were subjected to cultivate the lands of the *gabar* and the *balabat* and were urged to relinquish a third to a half of what they produced. Informants have also reported that about 50% of the farmland was owned by the *balabat*.

However, the *gaba* and *balabat* systems were abolished during the Italian occupation of Ethiopia from 1938 to 1945. The farmers, who served for the *gabar* and *balabat*, were subsequently permitted to own the land, which they were cultivating and other land as well. This system continued after the Italian evacuation, but the farmers were subjected to pay taxes to the central government. According to Jackson et al. (1969), negative effects of the Italian occupation and tax payments forced farmers to cultivate steep slopes and more grassland.

In the middle of the 20<sup>th</sup> century, a policy was enacted which allowed ex-slaves and women to own land by inheritance and purchase. Nevertheless, discrimination persisted with regard to craftsmen. People still felt that it was a serious refraction of the laws of taboo, if land was allowed to be cultivated by craftsmen. Therefore, craftsmen pursued tannery and pottery vocations and thus gave little attention to land cultivation. In general, during the Imperial period (1920s to 1974) the land tenure system was the most exploitative and left a large number of peasants landless.

However, the land holding systems were radically changed in the mid-1970s by the nationalisation of land by the military regime (the *derg*) that ruled Ethiopia from 1974 until 1991. Land was given to the landless regardless of sex or castes, including the *ts'oma* artisans. Peasant Associations, a low tier of the administrative units, were responsible for administration, distribution, and re-distribution of the land whenever necessary. A regulation was enacted turning all land into state land and abolishing private land. Farmers only had the right to use the land. Land could not be sold or transferred to anybody through sale, lease, mortgage, or by any other means (Rahmato, 2009).

Similar to the *derg*, the Ethiopian People's Revolutionary Democratic Front of the incumbent government that overthrew the *derg* regime in 1991 has implemented almost the same land tenure system, which claims that land is state property. Thus land selling and buying is prohibited. Farmers only have usufruct rights. The only difference from the *derg* system is that the present government allows access to the land by lease, share cropping, and borrowing (Samuel, 2006; Rahmato, 2009).

At present, the main way to gain access to land in the study area is by inheritance and share cropping. Moreover, there was also a redistribution of grassland to farmers in order to provide land to those who were landless. Additionally, land was offered to the soldiers of the *derg* in the low lying areas of the rift valley. However, land inheritance is declining since land shares are too small to be divided. Share cropping rates from the sample study amount to about 20%. There is also very little land rent in the area (close to 10%). In the north in the Amhara region, land redistribution took place but was not welcomed by the majority of the inhabitants because political motives dominated the distribution of the land (Samuel, 2006).

During the interviews of this study, old persons were asked to compare farmland sizes of the past with present sizes. They stated that 70 years ago when they were children a significant portion of the land was covered by forest and grass – unlike today. The extent of cultivated land had enormously increased over time. In particular, steep slopes and lowlands had not been cultivated earlier. Older people suggested that the extent of cultivated land at present is larger than during the Imperial and the *derg* periods. They were unable to quantify the increase.

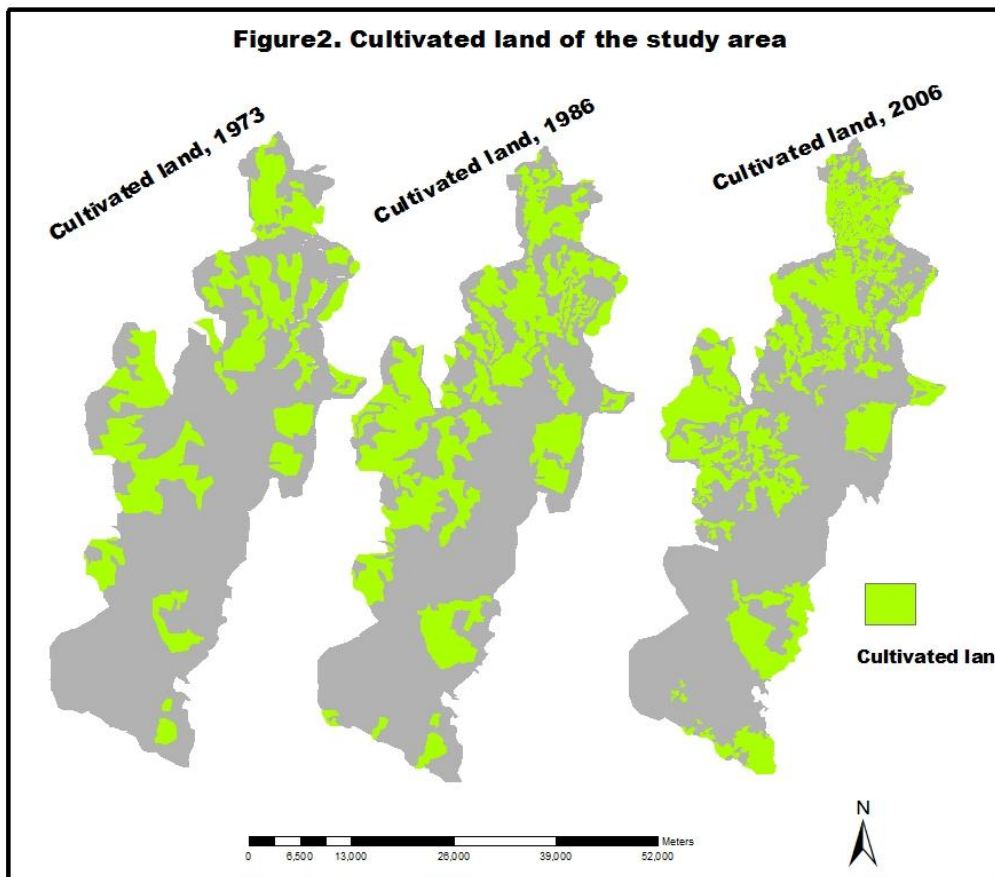


### 3.2 Cultivated land changes during the last four decades

The results of satellite image interpretation show that cultivated land amounted to 57%, 64% and 67% in 1973, 1986, and 2006, respectively. The results indicate that cultivated land has increased by 39% from 1973 to 2006. However, there was no continuous linear increase over time from 1973 to 2006. The small increase in the last four decades was the result of the limited area of land which could be cultivated. This confirms the results of studies that were carried out in Northern and Central Ethiopia (Tekle and Hedlund, 2000; Amsalu, 2006). On the other hand, a large part of the increase of cultivated land in the former period was partly attributed to the radical change of the government. Particularly, the change from the Imperial to the *Derg* regimes in 1974 resulted in the conversion of a large proportion of forest land into cultivated land. Similarly, at the time of the change of the *Derg* to EPRDF in 1991, an overwhelming area of shrub land was converted to cultivated land. These were the periods when there were loose government controls. A similar finding was also reported by Dessie and Carl (2008), showing that a large proportion of forest and shrub land in the Central Rift Valley of Ethiopia was converted to cultivated land during these changes of government.

A high increase rate of cultivated land was reported in the lowland area of the Rift Valley, for example an increase of about 65% between 1973–1986 and an increase of about 21% from 1986–2006. This was mainly attributed to the recent movement of many people from the intensively populated highlands to areas for settlement and cultivation in the Rift Valley. Similar settlement and cultivation of adjacent lowlands was also reported for different parts of Ethiopia (Reid et al., 2000). In contrast, the lowest change in the amount of cultivated land was found in the highland (*dega*) regions with an increase of 28% from 1973 until 2006. This is due to the obvious fact that most of the land which is suitable for cultivation was previously brought under cultivation in these areas.

In 1973 about 8% of all cultivated land acreage in the highlands was situated on steep slopes. Until 2006 it increased to 14% of the total cultivated land areas. First cultivation land was mainly situated on the less inclined foot slope areas. It was then expanded to the plain lands in the valley areas of the highlands. The steep slopes only came under cultivation during the last decades. This has been confirmed by discussions with the informants.



### 3.3 Dynamics of household cultivated land areas and fragmentation since the 1960s

Household holdings of cultivated land have decreased over time despite an increase of the extent of acreage in the highlands. About 30% of interviewed farmers pointed out that their land holdings had decreased by 75% when compared to the *derg* regime period, whereas 45% of the interviewed farmers mentioned a decrease of 50% and 15% of the respondents stated that their holdings had not changed.

The declining trend of cultivated landholdings can also be depicted in a comparative study of the present survey with past surveys. The survey, which was conducted by four members of the Oxford University Expedition in 1968 (Jackson et al., 1969) significantly overlaps with present study sample sites and could therefore be used as a reference for comparison.

According to the Oxford study, cultivated land per household in the highlands was about 1.6 ha on average. The present survey revealed that about two thirds of the interviewed farmers of the highlands own land below 0.5 ha per household. This pattern is similar to a survey of Chench *wereda*. According to an agricultural survey of the country, 56% of the households of Chench *wereda* cultivate areas with sizes below half a hectare (CSA, 2002). However, holdings vary according to the different study sites as shown in Table 1. In the lowlands, the households worked  $\geq 0.5$  ha on average while in the mid-altitudes about 0.47 ha were cultivated.

Table 1. Landholdings of households

	Doko Mesho (highland- <i>dega</i> )	Dorze Belle (middle altitude- <i>woinadega</i> )	Chano Chelba (lowland- <i>qola</i> )
Land size (ha)	%	%	%
< 0.1	9.5	8.1	5.1
0.1-0.5	55.8	62.2	28.2
0.51-1.0	22.4	20.4	41.0
1.01-1.5	9.8	8.1	18.0
1.51-2.0	2.5	1.2	7.7
Total	100	100	100

According to Jackson (1972), the average number of fields per household in the highlands amounted to 4.6 in the 1960s. Some farmers possessed up to 20 farm plots. But more than 50% of the farmers owned less than 4 fields. However, the fragmentation of agricultural land is an important characteristic of the highlands, because fields at different topographical positions were considered to be more advantageous than consolidated land since it allows farmers to grow different types of crops according to different site conditions. Moreover, farmers who owned consolidated cultivated land were locally labelled as poor farmers (Jackson, 1972). The present survey also reported the large number of fragmented landholdings. The average number of fields in fragmented cultivated land areas is estimated at about 5.0 in the upper highlands, 4.6 in the middle highlands, and 3.7 in the lowlands. The maximum walking distance from the house to the farthest field is about one hour.

The large number of fields in the fragmented land areas in the highlands is a result of several factors including long periods of settlement, high population growth, and land inheritance. For example, farmers partitioned their miniscule land plots to the sons when they married and plots are distributed among the sons after the death of the head of the families. A farmer divided his land into equal parts for all sons, for one son or for several sons according to preference. Land distributions during the derg regime and current grazing land conversion to arable land have also contributed to fragmentation. Last but not least, the subjective value of fragmented land over consolidated land by farmers is also another contributing factor to fragmentation. However, it is now also argued that land fragmentation is not convenient for the application of structural soil and water conservation and it also impedes the ox plough.

### 3.4 Dynamics of cropping patterns and crop varieties

In the 1960s, the principal cultivated crops, in terms of area coverage and food importance, included barley, enset, beans, peas, and wheat in the highlands and maize, cotton and bananas in the lowlands (Jackson, 1972). The present survey identified barley, wheat, enset, and apples as the principal crops in the highlands and bananas, lemons, papayas, mangos, maize, and cotton in the lowlands. This survey points out that the dynamics of cropping patterns and crop varieties are dependent on various social and economic reasons as shown in the forthcoming discussion.

### Enset (*Ensete ventricum*)

Enset is the center of agricultural production in the study area. Sometime in the remote past, the enset plant was first domesticated and used as a staple food in Southern Ethiopia in general and in the study area in particular (Westphal, 1975; Cartledge, 1995). It also has cultural and social significance (Olmstead, 1975). Hence, the region is labelled as an enset culture area and the farming system is also known for its enset planting complex (Amare, 1980).

An enset grove planted near homesteads is a widespread plantation pattern in the area. Enset grows with coffee and cabbage at an early stage. It requires a fertile and deep soil. Garden land is usually set aside for enset cultivation as its fertility is maintained by applying large quantities of manure. Moreover, a house is positioned in such a way that the urine of the cattle, which are held in the house, drains directly into the surrounding home garden to enrich the fertility of the soil. Furthermore, home gardens are the areas least affected by soil erosion in comparison with fields outside the compound due to the presence of plant cover by enset and trees. Last but not least, growing enset in gardens close to houses is also significant for harvesting, processing and for the timely transportation of the enset products with minimum labour. Enset harvesting can be carried out at any time of the year except during the rainy season, so people frequently harvest enset when others crops have been consumed. The roots of enset (which include the pseudo stem) is processed, wrapped in large leaves, and then put in pits near the farmhouses and buried in the garden soil. This is very important in order to reduce post-harvest loss, which is common for other crops across different areas of Ethiopia.

Enset provides a higher portion of foodstuffs per unit area than most cereals. Furthermore, enset is also known for its high starch content, yielding 20 million calories per hectare (Olmstead, 1975). High yields per unit area of enset also partially contribute to the support of a dense population in the southern region. The other salient feature of enset is its drought resistance as a result of its deep roots and its capacity to store water in tuberous roots and pseudo-stems. For this reason, it is known as a plant against drought (Shack, 1966) and the area is one of the least affected by drought in Ethiopia.

Enset is also widely used for other purposes (Olmstead, 1975). It is used as wrapping paper, washing detergent, and for the production of strings, umbrellas, seats, and hats. The leaves of enset are also an important animal fodder. Furthermore, enset plays a very significant role in maintaining high environmental quality. It prevents soil from erosion as the leaves capture moisture and the stems lower the run-off. The leaves and residues of enset are integrated into the soil to reach or to maintain high fertility. Enset also serves as a wind breaker and as a shade for other crops which are intercropped with enset.

However, the extension of the area devoted to enset is declining. In the 1960s, the area used to grow enset reached about 16% of the total cultivated land of the highlands (Jackson et al., 1969). At present, enset acreage comprises about 10% of total acreage. According to surveyed households, the main reasons for the decrease of enset cultivation are a decline of soil fertility due to low amounts of manure application, a scarcity of land which forced farmers to cultivate crops with short growth periods, and diseases. Other enset growing regions of Southern Ethiopia, including Sidama, Hadyia, and Wollayita, have also experienced a similar decline of enset cultivation due to land shortages and a substitution of enset by cash crops (Tesegaye, 2002).

### Barley and wheat

Barley is one of the major, long time crops in the highland area. In the 1960s the cultivated land allotted to grow barley was estimated at about 39% of the total cultivated land (Jackson, 1969). Currently, it is still grown on a large proportion of the land (23% of total acreage). Barley is also a dominant crop across Chench *wereda* (SNPPR, 2005). Barley is used for a wide range of food consumption products and in the past it was also used as a sales product, to pay taxes, and to fulfill other social obligations.

Like enset, barley also grows in fertile and deep soil as reported by informal discussions. If manure is abundant, it is also applied to barley fields. But farmers often prefer to apply manure to enset gardens instead of applying it to barley pastures. Two types of barley, white and black varieties, are grown in the area as described by the surveyed households. The yield of black barley is very low, although it is resistant to diseases, particularly to mut. But at present it is under threat of disappearance because of the introduction of newer barley varieties, which give better yields and are thus widely cultivated in the area today.

Wheat is another prevailing crop that presently grows on about 21% of the total cultivated land. In the past it was rarely cultivated and total production was therefore insignificant (Jackson et al., 1969). This can be attributed to a widely spread disease which prohibited its cultivation. However, a new variety of wheat, locally known as *beshekella*, was introduced in the recent past. This variety of wheat is disease resistant and offers high yields per unit area. Consequently, a large area is devoted to growing this grain. Farmers reported that wheat is primarily grown on land which is not used for enset or barley – usually on land with low soil fertility. Wheat is mostly used for making local beer, *borde*.

### Bananas

At present, bananas are grown on three fourths of the total cultivated land acreage in the lowlands. According to an informant, bananas were introduced in the lowland area in the early 1960s. At that time, however, the principal cultivated crop was maize. Other plants such as papaya, lemon, and cotton were also grown. Rice cultivation was also introduced by the government in the 1980s, but it only lasted for a decade. Generally, cropping patterns have changed since the 1990s due to the enormous economic significance of bananas. This caused farmers to replace other crops such as maize and cotton with banana. Moreover, the banana variety which is grown has also changed. Originally, the short carvendise variety was grown in the area. This was later replaced by the *Musa acuminta* variety which is significantly more productive and has a higher market demand.

Banana is a predominant crop at present due to its yields, market demands, and good prices. The area is famous for its banana production and it is one of the biggest suppliers to the largest cities of Ethiopia. Bananas are expedited by the main asphalt road that runs to Addis Ababa and large amounts of ripe bananas are also sold in the towns of Arbaminch and Chench and along the road to people who travel to Addis Ababa and other cities. As a result of high incomes from the banana crop, the region is one of the food secured areas in Ethiopia. Income from bananas has also contributed to improvements of household assets and to the construction of houses with corrugated iron. In addition, it has also created job opportunities for a large number of people mainly from the surrounding highlands.

Irrigation is practiced for growing bananas and other crops in the lowlands. The earlier settlers in the area were people who came from the surrounding highlands. They cultivated

maize along the rivers of Kulfo and Hare by diverting the water from the rivers. Later on, the increased population in the area caused an expansion of cultivated land and an improvement of irrigation systems. Water is irrigated by furrow irrigation and wild flooding. Farmers divert water from the main channels and convey it to the fields via earthen and masonry canals (Bekele, 2001). Weirs along the Hare River were also constructed to regulate the water flow.

However, river water is not sufficient to irrigate all fields during the dry season. This caused the farmers to use the irrigated water according to a schedule two to three days a week. In most cases, they prefer to irrigate their banana fields. On other farmlands they grow crops such as cotton and maize depending on precipitation. However, the yield of these crops is insufficient owing to the irregularities and lack of precipitation in the area. Other constraints that hinder agricultural productivity in the area include flooding that often occurs during rainy periods, gully erosion, and salinization. Despite these problems, the area is generally not affected by recurrent famines unlike other parts of Ethiopia.

### Apples

The significance of apple growing in the Chencha highlands is comparable to the significance of bananas in the Arbaminch lowlands. It is one of the agro-ecologically suitable areas in Ethiopia for apple production. Apple cultivation in Ethiopia is a recent phenomenon. Apples were first grown in the 1950s in Chencha by the Kale Hiwot Church. At first, the church gave apple saplings to a few individuals at a very low price. Later on, the church grew saplings in the localities and a large number of people purchased them at a decent price. People were also trained to propagate and grow apples. Currently, apples are cultivated at every farm homestead and their surroundings. Some farms still have large orchards. Others still cultivate apple saplings whose market value remains high. According to the Kale Hiwot Church report, there are about 70 varieties of apples grown in Chencha today.

Farmers sell apples at a good price mainly to the consumers in Addis Ababa. They also sell apple saplings to the surrounding markets. People living in regions far away also come to buy saplings. Thus, apple cultivation is being spread to other parts of the country as well. The household income of farmers has been improved by apple production. They use their new income to buy cattle and sheep. On the other hand, Freeman (2009) reported some trade-offs of apple cultivation in the area. Thieves, who were not common in the past, steal apple fruits and saplings. In addition, some farmers do not use the income from apples selling for investments and savings, but instead they spend the extra income on household plastic utensils.

Other fruits such as pears, plums, peaches, and cherries have also been recently introduced to the area. Unlike apples, they are not widespread and not yet economically significant.

### Dynamics of crop varieties

Crop species diversity and variety diversity in the area have changed during the last decades. This is due to natural factors and especially due to the dynamics of socio-economic conditions. The dynamics are characterized by an introduction of new varieties and a modification or disappearance of existing ones. Cropping patterns have also experienced changes.

There are many new crops, which have been introduced to the area at different periods of time. Among others, the main new crops were apple, teff, sisal, rice, and different varieties of

barley, wheat, and potato. Teff was introduced at the beginning of the 20<sup>th</sup> century when the area was incorporated into Ethiopia. The cultivation of wheat was initiated in the area at the middle of the 20<sup>th</sup> century. Moreover, rice was imposed by the government for cultivation in the lowlands in the 1980s. The main reason for the cultivation of rice was to use wetlands in order to obtain high yields per unit area and therefore to help the population become self-sufficient food suppliers. However, the cultivation of rice was abandoned when the cultivation of bananas started to dominate the area. The abandonment of rice cultivation was also an indication of farmers reacting against outside pressure. Apples were another new crop introduced to the highlands in the 1950s as stated above.

In addition to these newly introduced crops, a large number of varieties of barley, wheat, maize and other crops were also mainly introduced by the various governments as improved varieties of seed, which were intended to give high yields per unit area. For example, a new wheat variety was introduced in 1984 by the Irish missionary Aba Lambert. This variety is locally known as “*beshikelle*” and is presently wide spread. The people preferred this type of wheat due to its high yield. However, the informants reported that some other introduced crop varieties only perform well during the first two or three years. Afterwards, the crops totally fail to give sufficient yields when a slight variation in precipitation occurs. In contrast, the indigenous (local) crops are more resistant to such variations in climate.

The agro-ecological patterns of crops have also changed. In some cases, plants, which were confined to the lowlands are also grown in the highlands today. According to informal discussions, sweet potato, red pepper, and sugarcane were only grown in the lowlands in the past. But now, these crops are also grown in the highlands. This underlines that the farmers are innovative and open-minded to the adoption of new varieties of crops on their land.

Cropping patterns have also undergone significant changes. Previously, the cultivation of different types of crops on one field (multiple cropping) had become common practice of farmers to spear risks and to fulfil all food requirements from one’s own land. But present cropping patterns are shifting towards monocropping. Banana, which is a prevailing plant in the lowlands, is replacing other crop varieties. Similarly, apple cultivation in the highlands follows suit given its economic significance and farmer interest. However, the replacement of indigenous as well as varieties of crops during a shift to monocropping has several negative biodiversity effects and implications. Moreover, this development has also caused a significant shift in the diet of the people. In the recent past, people on the lowlands were entirely dependent on maize, which they produced in the area. But at present, they buy food items such as *teff*, barley, etc. from the highlands and other parts of the region. Further investigations are required on dietary changes in the area.

Some crops such as sisal (*Agave sisalana*) and rice were introduced into the area, but they soon were abandoned. Sisal was introduced to the area by Italians during the occupation period from 1938 until 1943. But later farmers neglected such new crops. The black variety of barley has also disappeared due to its low output and the introduction of a new type of barley, which gives higher yields. Enset, barley, and potato varieties have also decreased enormously. Area coverage and the frequency of some crops (biodiversity and richness of plants) have remarkably decreased and some are under a threat of disappearance. Maize (*Zea mays*) and sweet potato (*Ipomoea batata*) are disappearing today in the lowland area (Belachew, 2002). The main reasons for these important changes can be attributed to younger inhabitants returning from urban towns to rural areas where they want to grow new varieties of crops,

including cash crops (Belachew, 2002). The highland farmers who moved down to the lowlands of the Rift Valley also changed crops types and varieties. Moreover, the transportation and economic significance of cash crops are also important factors for the disappearance of indigenous crops.

### 3.5 Dynamics of livestock and implications

The number and types of livestock in the investigation area are shown in Table 2. The average level of livestock holdings per surveyed household amounted to 2.59 TLU. The average TLU per household in Doko Mesho in the highlands was (1.6), in Dorze Belle at a mid-altitude (2.1), and in Chano Chelba in the lowlands (3.8). The proportion of different livestock varieties in the total research area includes cattle (46.3%), sheep (36.7%), goats (11.6%), donkeys (2.2%), mules (1.5%), and horses (1.7%). Among the livestock varieties, cattle are dominant in the mid- and low altitudes. Sheep constitute a large proportion in the highlands and 95% of goats are found in the lowlands and at mid-altitudes.

Table 2. Total number of livestock owned by all sampled households

	Doko Mesho (highland- <i>dega</i> ) (40 surveyed households)	Dorze Belle (middle altitude- <i>woinadega</i> ) 40 surveyed households)	Chano Chelba (lowland- <i>qola</i> ) (40 surveyed households)
	TLU	TLU	TLU
Cattle	35.0	62.0	134.0
Sheep	19.2	4.2	2.7
Goat	0.4	3.8	4.1
Donkey	1.6	4.0	7.2
Mule	5.6	3.2	-
Horse	7.2	2.4	-
Total TLU	69.0	79.6	148.0

One Tropical Livestock Unit (TLU) is equal to 250kg. The TLU values for different species of animals are: 0.7 for cattle; 0.8 for horse or mule; 0.5 for donkey; 0.1 for goat or sheep

There are several sources of cattle fodder in the study area and specific feeding routines. Children are responsible for herding cattle. They usually look after the animals from 9 a.m. to 3 p.m. During the day, cattle rest under the shade of trees and in most cases cattle sleep in the same room where their owners reside, but the rooms are partitioned by bamboo dividers. Children are aware of the quality of grasses. Green and tall grass is considered as the best feed for cattle while short and brown grass is seen as poor feed (Cartledge, 1995).

The principal sources of cattle feed in the highlands are pastures situated on the summits of the mountains and on the top of ridges. These grazing areas are common property of the villages to be used by every farmer. They have been used by farmers since immemorial time. The use and management of this grazing land is guided by social rules and norms, which are enforced by elected and hereditary elders. Among others, rules for grazing land include regulations about the planting of trees and house building at the fringes. Fire lilt is prohibited. When the grass is too short, usually at the end of the dry season, grazing is



prohibited. In addition, grazing is also closed at the end of the main rainy season and then reopened during annual *Mesqal* festivities, which take place at the end of September. Consequently, the described grazing land is a suitable area for cattle pastures and poses no problem as in “the tragedy of the commons” (Cartledge, 1995; Ogato, 2006). According to existing norms, grazing is not allowed on cemeteries, church yards, and sacred groves. However, people usually violate these norms and also graze their cattle on these sites.

Beside the described pastures, there are also other pasture sources in the highlands. These include fallow pastures, farmland after the harvest, marsh land, market places, and the borders along roads and paths. Small open fields in villages, locally known as *Dabush*, are also used for grazing in addition to usage for social events, like gatherings or for mourning. Grass under woodlots is also another source of cattle pasture. Stall feeding is a common practice for milk cows, for fattening, and for cattle being prepared for sale or slaughter. Chopped enset leaves and grasses from marsh land are mainly used as stall fodder. The solid remains of local beer are used for sheep fattening. Sheep are also fed with the leaves of *borto* and the new growth of bamboo.

Common grazing land is also an important feed source for cattle in the lowlands. The main grazing pastures are comprised of grassland along lakeshores and on the Rift Valley escarpment. Cattle only graze along the lakeshores during the dry season. During the rainy season, they are only fed at the escarpment since the lakeshores are usually covered with water. The escarpment is highly degraded because of livestock overgrazing. In addition to grazing, the leaves of banana are also used as cattle fodder to a certain extent.

In the area, veterinary services have improved and this is one of the reasons for the relatively high proportion of cattle in the lowlands. Besides veterinary clinics, local cattle medicine also plays a significant role. In the past, however, the cattle disease trypanosomiasis was very common and impeded cattle tending in the lowlands.

With regard to trends of livestock holding, about 50% of respondents in the highlands, 43% of respondents at mid-altitudes and 16% of respondents in the lowlands stated that livestock holding is declining. In contrast, there is a slight increase in the number of sheep in the highlands owing to the comparatively low feeding requirements of sheep, as described by informants.

Despite the various cattle feed sources, the majority of respondents (87%) in the highlands stated that a shortage of cattle feed is the main cause for the decrease of the number of cattle. The mentioned fodder shortage is mainly caused by a conversion of large grassland areas to farmland. This is also attested by satellite image interpretation, which revealed that about 37% of grasslands in the highlands were converted to cultivated land from 1973–2006. Large grassland areas were already converted to cultivated land in the 1960s as revealed by Jackson et al. (1969). In particular, private grazing land was totally abandoned as witnessed by the surveyed households. A major part of the communal grazing land was then converted to cultivated land. Today, further sources of past grazing land, such as grazing inside forests and the use of enset leaves, are also deteriorating. This is a result of a decline of enset cultivation and the domination of eucalyptus trees on forestland at steep slopes which hinders the growth of grass. Furthermore, irrigation of grazing land entirely ceased when grasslands were converted to arable farmland (Jackson et al., 1969), which also implies the deterioration of the availability and quality of feed resources in the area.

One of the impacts of declining livestock is reflected in the availability of manure. For centuries, farmers used manure to replace nutrients that are removed via continuous crop cultivation. Manure is the most important source of nutrient replacement since farmers cannot afford chemical fertilizers. According to the responses of the informants, livestock holding has decreased on average in the region under investigation by about 37%, which is equivalent to 109 TLU. On the average, about 3.2 tons of manure is produced by 1 TLU (ILICA, 1981 quoted by Amare, 1981). The average nutrient content of one kg of manure on small scale farms in Ethiopia constitutes: 21.3g K, 18.3g N, 16.4g Ca, 5.6g Mg, 4.5g P, 10776mg Fe, 777mg Mn, 92mg Zn, and 24mg Cu. Accordingly, in the region under investigation an average annual loss of about 7,400kg K, 6,400kg N, 5,700kg Ca, 2,150kg Mg, 1,600kg P, 3,700kg Fe, 27kg Mn, 32kg Zn, and 2 kg Cu results from the extraction of crops mentioned above. But the constituents of the nutrients vary depending on the availability of feed as testified by experiment (Lupway et al., 2002). Thus, this estimate needs to be validated by further research regarding the availability and quality of feeding. However, the results show that the decrease of animals has significant impacts on the amount of nutrients in the soil, which has ripple effects. The missing nutrients must be replaced by inorganic fertilizers to maintain fertility and to get good yields. However, farmers cannot afford the price of inorganic fertilizers, as mentioned above. Nevertheless, high soil fertility is only maintained when organic matter is added. This dilemma implies that keeping livestock saves hard currency which otherwise has to be spent for the import of inorganic fertilizers from abroad. Otherwise, the structure of soil, which is important for infiltration and for various chemical reactions, will deteriorate significantly. Soil degradation will probably increase during the next years and decades and result in a significant abandonment of cultivated land (Cartledge, 1995).

### **3.6 Trends and determinants of agricultural production**

Farmers consider agricultural production to be “sufficient” if enough is produced to feed family members throughout the year and to also sell some of the produced goods to cover expenses for taxes, school, medicine, clothing and the like. Among the respondents in the highlands, 76% reported that the profits generated from the farmlands are not sufficient for the whole year, about 21% answered that they produce sufficient yields, while the remaining respondents reported that there is no clear trend in agricultural production. The insufficient agricultural production reported by the majority of the farmers is in line with the South Ethiopia Regional report on livelihood and food security (SNNPR, 2005). It categorizes the whole area of the Chenchu wereda to be under “the margin of food security”. A sale of crops by most farmers is induced by the prospect of getting other food items, and not due to surplus products they have produced. The main source of cash for farmers to cover different expenses is derived from selling livestock. Very few farmers get money from off-farm activities. Recently, apple production increasingly emerges as a source of cash income for the farmers. In contrast, the situation is different in the lowlands as the overwhelming majority of respondents (95%) reported that they are self-sufficient in feeding their families and affording their yearly expenses. This is due to the prevailing cash crop production of irrigated bananas, which have a high income per unit area turnover. This is also confirmed in the livelihood and food security report of the South Ethiopia Region (SNPPR, 2005).

As to the trend of agricultural productivity in the highlands, about 82% responded that there is a decline of productivity compared to the last forty years, whereas 11% responded that there

is no decline and 7% said there is no change. With regard to the rate of decline of agricultural production, about 45% responded that there is a high rate of decline, 10% reported a medium decline, and 27% a low rate of decline. The remaining interviewees could not trace the rate of decline because of irregularities in the trend. However, all informants observed an increase in the production of some recently introduced crop varieties such as barley compared to the local indigenous varieties when the right amount of fertilizers is applied and when there is no unusually low rainfall. But the application of fertilizers and improved seed are constrained by the low-income level of the farmers.

Farmers reported different multiple determinants that affect agricultural productivity in the area. The most frequently cited factors are: scarcity of cultivated land (97%), soil fertility decline (87%), grazing land shortage (86%), soil erosion (81%), low fertilizer input (56%), erratic rainfall (57%), lack of improved seed (53%), pests and diseases (17%), and inadequate extension services (23%).

The problem of land scarcity is very acute because existing land is shared and distributed to the children. In the 1960s, Olmstead (1967) and Jackson (1972) already mentioned a high population density in the area. The scarcity of available acreage has increased since then as a result of the high population growth in the area. Moreover, a lack of off-farm employment keeps the people heavily dependent on the cultivation of their farmlands. This is also a factor that contributes to the enormous pressure on the land. The situation is aggravated by land tenure systems and governmental agricultural policies that banned the selling and buying of land. The only way to get access to land is by sharecropping and leasing.

The cultivation of steep slopes in the highland, due to land scarcity, coupled with high precipitation intensities results in sheet, rill and gully erosion. The loss of soil by erosion is one of the main problems in the area. The vulnerability of the soils is accelerated by the low input of organic matter. In contrast, in the past steep slopes were covered with grass and trees, minimizing erosion (Jackson, 1972).

#### **4. Discussion and Conclusions**

The agricultural system of the study area has undergone a significant change during the last century. The extension of farmland increased considerably, but per capita acreage declined. Similarly, available grassland, the main feeding resource of livestock, decreased and caused a huge decrease in livestock. Scarcity and fragmentation of land fit for cultivation are related mostly to demographic pressure which is exacerbated by governmental policies, land tenure, and the nature of subsistence agriculture.

Nevertheless, farmers are resourceful. They gathered a wide range of experience and developed skills to cope with the problems associated with increasing population density and scarce resources. Despite recent disruptions, farmers developed a wide range of local strategies such as cultivating drought resistance plants, growing diversified crop varieties, integrating crop-livestock practices, agroforestry husbandry, and the recent practices of cash crop cultivation. These strategies are coupled with land management practices, such as manuring, crop rotation, fallowing, irrigating pastureland, terracing, and fuel wood usage from eucalyptus and bamboo trees but not from dung or crop residues. These all suggest that the agricultural system in the area has been characterized by a high standard of land resource management and sustainable agriculture practices.

Growing several varieties of crops (crop diversification) was one of the salient features of the agriculture practices in the area over a long period of time. In the lowlands and at middle altitudes, Belachew (2002) identified about 133 different plant species of which 48 species are used as food for humans. Jackson et al. (1969) also reported a wide range of grains, cereals, root crops, vegetables, and stimulant crops that grow in different agro-ecological regions. The varieties of crop species is also high in the area, for instance Samberg (2010) recognized about 65 varieties of barley while Olmstead (1975) observed about 34 varieties of enset. Local farmers also reported that some of the varieties of barley were locally domesticated. Enset is endemic to the area (Cartledge, 1995).

Farmers use various methods to grow these varieties of crops. Intercropping (growing of different crops on the same field in the same season) is one of the systems. For instance farmers grow barley together with kolto, beans, and peas. They also grow enset with taro, coffee, and cabbages. Intercropping has been practiced in the area due to the various advantages that overweigh mono-cropping systems in small holding agriculture. The main benefit is that self-sufficiency can be achieved with farming different types of crops. Moreover, it also reduces or avoids the spread of calamities, since some crops are more resistant to drought while others are less susceptible to the impacts of outbreaks of various pests and crops diseases. The practice of intercropping is also vital in order to grow various crops on sites with different topographies and climates that suit them, thereby maximizing the efficient use of available resources. Furthermore, different crops have different harvesting cycles. Therefore, the people on the land have been successful in feeding a dense population and in overcoming food shortages (Rahmato, 2009; Jackson et al., 1969).

Farmers have also gathered long-term experience in the efficient use of the garden areas close to their homesteads (Belachew, 2002). Except for a small field in front of a house, which is barren or covered by grass in some cases, all other land is used to grow crops. The main crop, which grows close to the homesteads, is enset. As a result, it is not uncommon to find enset groves surrounding the houses in the highlands. Other crops such as peppers, cabbages, onions, garlic, taro, tobacco, pumpkins, and kale are also grown in the gardens. These plants are usually grown intermixed with the early stage of enset. Additionally, some trees are also grown close to homesteads. Most recently, apple trees are grown in the highlands around the homesteads. In the lowlands, people used to grow bananas, vegetables, mangos, and papayas around their homes. Growing crops in gardens has various advantages, for example to control, expand, and use available resources efficiently. Moreover, by growing different trees near their homes and in the fields, the farmers benefit from various advantages of tree cultivation such as fertility input, additional food and fodder resources, shade, wood supplies, and ecological soil and water conservation.

The cultivation of enset is a central farming activity due to its various economic and ecological significances (Olmstead, 1975; Cartledge, 1995). One of the features of enset is its drought resistance. Enset provides a higher amount of foodstuffs per unit area than most other cereals. This has helped to support a dense population in the research area in particular and in the southern region in general.

Livestock tending is the main integral part of the agriculture system in the area. It has played an important economic and ecological role in the area for a long period of time. Cattle supply milk, butter, and meat. They are the most common source of animal protein. Livestock is the

main source of cash used to pay taxes, to buy clothes and to meet other major expenses. Livestock also serves as a type of insurance during crop failures, when farmers sell animals and use the money to buy food. More importantly, livestock is the major source of manure. Manuring is the basis of maintaining high soil fertility and consequently allows the continuity of cultivation. Horses are very important in the highlands for transportation while donkeys are used in the lowlands for banana transportation. Donkeys also play a significant role in petty trading and the transportation of materials to and from markets. In the past, people irrigated grazing land, which indicates resource management skills (Jackson et al, 1969). However, this practice has been abandoned at present since these areas were shifted to land for cultivation.

For centuries, farmers used manure, crop rotation, and fallowing to compensate the extraction of nutrients by growing of crops. Manure is the most important source of plant nutrients in the area. The application of crop residues and compost are also other practices applied to maintain the fertility of the soil. Traditional terracing has also been used to protect the soil from erosion. The application of chemical fertilizers is very limited because of the costs. Farmers cannot afford chemical fertilizers.

The different agro-ecological conditions of the area are suitable for growing many varieties of crops. Crops have also been exchanged between highland and lowland areas. The high interaction among people is attributed to the short distance of less than 30 km between the lowlands and highlands. In the past, for instance, maize was abundantly produced in the lowlands and sold to the highlanders. Similarly, enset and potatoes were produced in the highlands and sold to the lowlanders. As a result, the region was self-sufficient in meeting different food requirements over a long period of time – when they were isolated (Jackson, 1972). Moreover, since the 1960s people wandered from the highlands to the lowlands for cultivation purposes. They used to commute the lowlands during the day and to return at night. Later on, they established permanent settlements in the lowlands and pursued cultivation there. At present, some people from the highlands work in the lowlands as daily labourers, which is also an important source of income for the people.

Farmers are open to adapt new innovations and practices. This has also been a strategy to secure their livelihood. For example apples, bananas, and different varieties of barley and wheat are newly grown crops. This shows that the people are not resistant to new ideas as long as the ideas are socially and economically significant. However, the people are very wary in implementing new practices, particularly if they are not included in planning and implementation. The case in point is the ineffectiveness of the implementation of physical soil and water conservation measures in the area due to the top-down approach applied.

Beside crop growing and livestock tending, very few households are engaged in various off-farm activities. These activities would enable them to generate a complementary income and would serve as a strategy to cope with resource constraints. The main off-farm activities include weaving, small trading, selling wood, and labour work. For example, weaving is an activity which was introduced in the early 20<sup>th</sup> century. It involves cotton spinning, cloth weaving, and product distribution at the nearest markets. Some people also used to move to larger cities to weave cloth there. Originally, only members of the Dorze were known for weaving but later people from other neighbouring villages also became involved in weaving high quality products. Another source of income is small trading, which involves buying fruits and grains at the cheapest market and selling them at other markets with some profit. Moreover, people produce *borde* (local beer) and *areke* (a local alcoholic drink). Firewood

collection in forests and on shrub lands and its distribution in the nearest towns, mainly Arbaminch, is also another source of supplementary income. Generally, only few people move to the nearby urban areas as daily labourers, government employees, and as business traders. This shows that most people live their entire lives in the area where they were born causing high pressure on the land.

Presently, these traditional land use activities and land management practices are deteriorating. The people have been forced to cultivate steep slopes, wetlands and grasslands. The practice of fallowing and the application of manure are declining. The diversification of crops has also been reduced and in some cases has been replaced by monocropping because of the economic value of crops such as bananas and apples. Some indigenous and local crop varieties are becoming scarce. The farming communities have now recognized the impact of the deterioration of agricultural landscapes which obviously results in a decline of agricultural production. Thus, the direction of the changes of agricultural landscapes in the area is unsustainable as manifested in land degradation, biodiversity loss, and low agricultural productivity.

To sum up, the investigation revealed the paramount implications of the locally developed, long-term sustainable land use systems and land management techniques in providing food and material resources to the inhabitants over centuries. Thus, land use planners and environmental managers have to modify their policies to alter the present dynamics of agricultural land use systems. In particular, they have to be aware of vital local knowledge and the skills of the farmers as well as the ability of the latter to accept innovations. It is most important that local people are intensely involved in all development activities, including resource management, planning, and the implementation of changes. Participation is a precondition to re-establish sustainable land use systems and management practices.

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**Chapter 3**-----

**Deforestation and forest management in Southern Ethiopia – investigations in Chench and Arbaminch areas**

## **Deforestation and forest management in Southern Ethiopia – investigations in Chench and Arbaminch areas**

### **Abstract**

Long-term human impacts are considered the prime cause of unsustainable forest exploitation in Ethiopia. Yet there exist well-established systems and a wealth of local experience in maintaining and managing forests. This study explores the trends and driving forces of deforestation, plus traditional knowledge and practices regarding sustainable forest use and management, in the Chench and Arbaminch areas, Southern Ethiopia. Satellite image analysis (images from 1972, 1984 and 2006) combined with field surveys, was used to detect and map changes in forest extent. Household interviews and group discussions with experienced and knowledgeable people were also employed. The results show a 23 % decline in forest cover between 1972 and 2006, with the most significant change from 1986 to 2006. Change was greatest in the lowlands and remarkable episodic forest changes also occurred, suggesting nonlinear spatial and temporal forest cover dynamics. According to farmers, the main driver for deforestation is agricultural land expansion, in response to local population increase and decline in agricultural production. Growing fuel wood demand, locally and in nearby towns, is another chief cause. Despite these issues, remarkable relicts of natural forests remain and trees on farmland, around homesteads and on fields in every village are basic elements of farm activities and social systems. This demonstrates the effect of cumulative traditional knowledge and the long-term local experiences on forest management and preservation. Therefore, these practices should be promoted and advanced through the integration of local knowledge and forest management practices in the design and implementation of sustainable environmental planning and management.

Key words: deforestation; forest; sacred forest; local knowledge; sustainable land management; south Ethiopia

### **1. Introduction**

Deforestation is an old phenomenon in Ethiopia, associated with the old settlements and agricultural practices (Butzer 1981; Hurni 1993). It has been a major environmental and economic problem over a long period time. Unprecedented deforestation, however, is widespread since the beginning of the twentieth century, owing to the dynamic demographic, political, economic and social conditions. At the turn of the twentieth century, 40% of Ethiopia was covered by various types and densities of forest. It was reduced to 16% of the land area in the 1950s and shrank further to 2.7 % in the 1990s (EFAP 1993). According to the forest resource assessment of Reusing (1998), the country has lost about 77 % of its forested area between 1955 and 1979, with a clearance rate of 163,000 ha per year. The FAO (2007) estimated about 141,000 ha annual deforestation. With this rate of deforestation, the country will be devoid of high forest trees within approximately 27 years.

Deforestation is one of the major causes of soil degradation in Ethiopia. Among other factors, soil degradation was one of the causes for the fall of the Axum civilization around 800 AD (Butzer 1981). At present, soil erosion is also a major constraint upon agricultural production and contributes to the food insecurity problems of the country (Hurni 1993; Tekle 1999; Tadesse 2001; Sonnveld 2002). Deforestation is also a threat to biodiversity and genetic resources, such as the loss of the gene pool of original wild populations of *Coffea Arabica*.

Tree species under threat from deforestation include *Juniperus procera*, *Prunus africana*, *Ocotea kenyensis*, *Dombeya aethiopica*, *Dombeya longibractata*, *Hagenia abyssinica*, *Podocarpus gracilior*, and *Cordia africana*. The economic costs of this loss of genetic resources is calculated to be around 0.4 to 1.5 billion US\$ per year (IUCN 2006; Gatzweiler 2007). This clearly proves that the extent of deforestation is a critical environmental and economic problem for the country.

Nevertheless, the scope and direction of forest cover changes in Ethiopia has not been well established, requiring further investigations (Wøien 1995; Crummey 2009). This is partly due to the lack of data and reliable records in the country. Most of the studies were based on travel reports and thus provide inconsistent accounts of the forest cover and deforestation. For example, Wøien (1995) reviewed the studies that were conducted from 1961 to 1982. He found that these studies reported the forest cover of Ethiopia at the turn of the twentieth century as ranging from 30 to 48%. Moreover, divergent results were also reported by various recent local studies that were based on the interpretation and comparison of images (aerial photographs and satellite images). Forest cover decline is reported in the studies of Amsalu (2006), Abate (1994), and Tekle and Hedlund (2000). On the other hand, studies that reported an increase of forest cover include Crummey (2009), Bewket (2003), and Woldetsadik (1994). Furthermore, the disagreement regarding deforestation trends is also common among studies that were conducted in the same region – characterized by a similar climate and comparable ecological features. For example, Tekle and Hedlund (2000) reported the decline of forest in the Wello region from 7.5 % to 5.4 % between 1958 and 1986. Meanwhile, Crummey (1998) compared the 1937 photos with those from 1998 and revealed an increase of forest in Welo. Likewise, Zeleke and Hurni (2001) have revealed a considerable decline in natural forest extent in Denbecha, Gojam region, from 27% in 1972 to below 1 % in 1997. Meanwhile, the study by Bewket (2003) portrayed the forest cover in Chemoga, Gojam area, as having increased by 50% from 1957 to 1998. This indicates that the dynamics of forest cover have not been linear, given the diversity of the socio economic and historical conditions of this specific area in particular. On the other hand, there has been little attention paid to the forest dynamics and their drivers in the southern part of Ethiopia (the area on which this study focuses). This clearly suggests that there is a significant need for several detailed investigations. Through such investigations, information will be enriched and refined, and the scope and patterns of deforestation across the country will be established (Wøien 1995; Crummey 2009; Reid et al. 2000).

The most frequently cited causes of deforestation in Ethiopia are the growing need for fuel wood and the demand for land for cultivation and grazing (EFAP 1993; Cheng et al. 1998; Bishaw 2001). Since about 1900, approximately 23 million hectares of forest land were cleared, a process mainly driven by conversion to cultivated land (EFAP 1993). More recent satellite image analysis of the period from 1973 until 1990 for the entire country also revealed that about 24,543 km<sup>2</sup> of forest (2.14% of the total forest of the country) was cleared, mainly due to the demand for cultivated land (Reusing 1998). The proximate cause for the forest conversion to agricultural land in Ethiopia is the increasing human population. The total population of Ethiopia increased from approximately 12 million in 1900 to approximately 26 million in 1970, and further to over 77 million in 2007 (Sahilu 2003; CSA 2006). This population growth resulted in the decline of per capita farmland. Before the end of the last century, about 39% of the farming households cultivated less than 0.5 ha and about 89% cultivated less than 2 ha. The problem of land-shortage is further exacerbated by the loss of farmland and decline of agricultural production due to a significant decrease in soil fertility

and an increasing amount of soil erosion. In order to overcome the problems of land scarcity and to increase yields to sustain the growing population, farmers are intensifying the conversion of forest into cultivated land. The increasing wood demand is another cause of deforestation. Nearly the entire rural population, as well as the majority of urban households, rely on forest resources for their energy needs. The National Energy Balance for 1989/90 also showed that forest products accounted for about 88% of the total energy consumed in Ethiopia, with rural households accounting for about 93% (Mekonnen 1998).

However, the drivers for land cover dynamics in Ethiopia are diverse and complex, varying in space and time. For example, Reid et al. (2000) have identified multiple interacting factors that caused land cover changes in Ghibe valley, southwest Ethiopia. The factors were cattle diseases (trypanosomosis), land reforms, villagization, and droughts, each of which operated at different intensities in different periods of time. Reid et al. (2000) concluded that local human population growth was not a factor causing deforestation. Similarly, Woldetsadik (1994), Wøien (1995) and Bewket (2003) have also reported that population increase was not a factor causing deforestation. Instead, they found that a larger population resulted in greater forest cover. On the other hand, various other studies have reached the contrary conclusion that the growth of human population was the principal factor for deforestation (e.g. Tekle and Hedlund 2000; Zeleke and Hurni 2000; Dessie and Carl 2008). These divergent results indicate that there are diverse and complex factors that have given rise to the forest cover changes in different parts of the country. The combinations, relative importance and interactions of these factors also vary from region to region and over the course of time (Abate 1994; Tekle and Hedlund 2000; Tegene 2002; Bewket 2003). Thus, a generalization regarding the causes of deforestation is hard or nearly impossible to establish.

Despite the long-term problems of deforestation, there is a lack of studies that deal with the history of forest management in Ethiopia (Zewde 1998). Generally, governments' attempts to protect forests and to afforest land are recent phenomena. Fuel wood scarcity caused Emperor Menelik (1889-1913) to declare all forest to be state property and also to introduce eucalyptus tree plantation at the beginning of the twentieth century, with seedlings being distributed to various parts of the country. Scarcity of fuel wood during that time was mainly caused by relocation of the seat of government, which consumed large amounts of wood for fuel and construction (Pankrust 1995). In Ethiopian history, massive afforestation was launched in the 1980s (Zewde 1998). It was a response to the devastating famine that occurred in Ethiopia at that time. There was a general consensus between the government and international donors that the famine occurrence was associated with deforestation and soil degradation. The plan was to afforest the hilly areas and the degraded land. The plantation was carried out through a mass mobilization of the people. During the campaign about 400,000 ha of land were afforested, which accounts for 9 % of the total natural forest area but represents only 0.3 % of Ethiopia's total land area (Vletter 1998). The achievements of the program were lauded as a huge success with regard to the forest management history of the country.

However, it was not without problems. The main constraint of the program was its top-down approach that lacked genuine community participation. Moreover, plantation was carried out on land that was used for grazing in the past. The forest plantation resource contribution to the social and cultural values of the community was also insignificant. As a result it has failed to gain popular support, as witnessed by the removal of forest and poor management of the existing forests; particularly during the government upheaval in the 1990s. The other constraint of forest management is land tenure. In Ethiopia, where land has been state

property since 1974, people did not plant so many trees because they feared that land might be taken by the government and redistributed to others. This situation does not encourage long-term forest management. For sustainable forest management, land tenure should be corrected. Moreover, the approach of the policy should be bottom-up, involving local people in the design and implementation of the forest management plan.

On the other hand, there are well-managed and preserved forests and trees in different parts of the country. For example, the land of the Orthodox Church across the country has been covered with forest and trees over a long period of time (Wassie et al. 2005). Remaining pockets of natural forest in different parts of the country have also been a common feature. These forests have been maintained and preserved by the older generation local to the area (e.g. Zewde 1998; Tekle and Hedlund 2000; Bewket 2003). It is also not uncommon to find trees in the middle of farms in some areas of Ethiopia (Zewde 1998). This clearly indicates the wide knowledge and experience of the local people in the management and maintenance of the forests.

Similarly, the local traditional systems of the people in Chench (focus area of this investigation) have also played a pivotal role in helping to maintain and manage forests. This is manifested by remarkable relicts of natural forest, namely on the summits of the highlands. Trees are in the centre of the agricultural and social system in the area. Farmers integrated trees with crops in cultivated land as they are aware of their enormous benefits. Wood supply, soil fertility improvements, soil and water conservation, fodder for livestock, sheds for livestock are a few among other benefits. The management of forest in the area is also of a great importance in promoting the preservation of biodiversity and genetic resources. This proves the cumulative traditional knowledge and experiences of the local people on forest management and preservation that developed over a long period of time. Conversely, it disproves the long-held view that farmers are ignorant of forest management. The traditional knowledge and practices of forest management in the study area in particular, and in Ethiopia in general, however, have gained very little attention from policy planners and there have been very few attempts at scientific investigation.

The objective of this study was to explore the trends and driving forces of deforestation and the traditional knowledge and practices of the people in sustainable use and management of forest in Chench and Arbaminch areas, Southern Ethiopia. More specifically, the study assessed the dynamics of forest cover, the drivers that cause deforestation, the consequences of deforestation, the status of the present forest, and the local people's knowledge and experiences in forest management.

## **2. Methods of the study**

### **2.1 Description of the study area**

Chench (6° 15' N, 37° 34' E) and Arbaminch (6° 2' N, 37° 33' E) are located in the Gamo Gofa Zone, Southern Nations, Nationalities, and People's Regional State (Fig 1). They are situated about 480 km SSW of Addis Ababa and bounded on the east by Lake Abaya and Lake Chamo. The lower part of the study area lies on the plain of the rift valley while the middle and upper parts are situated in the southwestern highland of Ethiopia. The altitude ranges within a short distance of only 20 km from 1,100 m a.s.l. in the rift valley to 3,482 m above sea level in the highlands.

The mean annual precipitation in Arbaminch (1200 m a. s. l.) and Chencha (2700 m a. s. l.) is 782 mm and 1,392 mm respectively. The rainfall pattern is of a bimodal type. The first rainy season, locally known as *gabba*, occurs from March to June and the peak reaches 148 mm in April for Arbaminch and 185.4 mm for Chencha. The second season, locally known as *silla*, occurs from August to November. The maximum mean monthly temperature in Chencha is 15<sup>0</sup> C in February and the minimum temperature is 13<sup>0</sup> C in October. The average annual temperature of Arbaminch is 23<sup>0</sup> C. There the maximum mean monthly temperature is 26<sup>0</sup> C, which occurs in March and the lowest temperatures are recorded from December to February. The main soil types in the area are Fluvisols, Leptosols, Cambisols, Acrisols, and Alisols. Natural vegetation is sparse and only small patches, such as sacred forests, are found on the highlands due to the cultivation of most land areas, although eucalyptus trees are common around the homesteads and on community woodlots.

The population of Chencha totalled 134,531 and of Arbaminch 247,915 in 2005 (CSA, 2006). Population density is estimated at about 368 and 205 persons per square kilometre in Chencha and Arbaminch respectively. Scientific investigations prove that the area was settled from at least about 3360 years cal B.P. (Arthur et al. 2010). The area is in the centre of the region Gamo-Gofa that is divided into 40 *dere* (small discrete political units). Olmstead (1975) has estimated that 5,000 to 35,000 people were living in the area at the end of nineteenth century. The main economic activity of the area is subsistence agriculture. People mainly cultivate barley and wheat in the highlands and bananas in the lowlands. To a lesser extent they also grow peas, beans, potatoes and tree cabbage in the highlands, and maize and *teff* in the lowlands. Enset is the staple food in the area and central to the subsistence agriculture. Raising livestock is also an integral part of the economy.

## 2.2 Methods

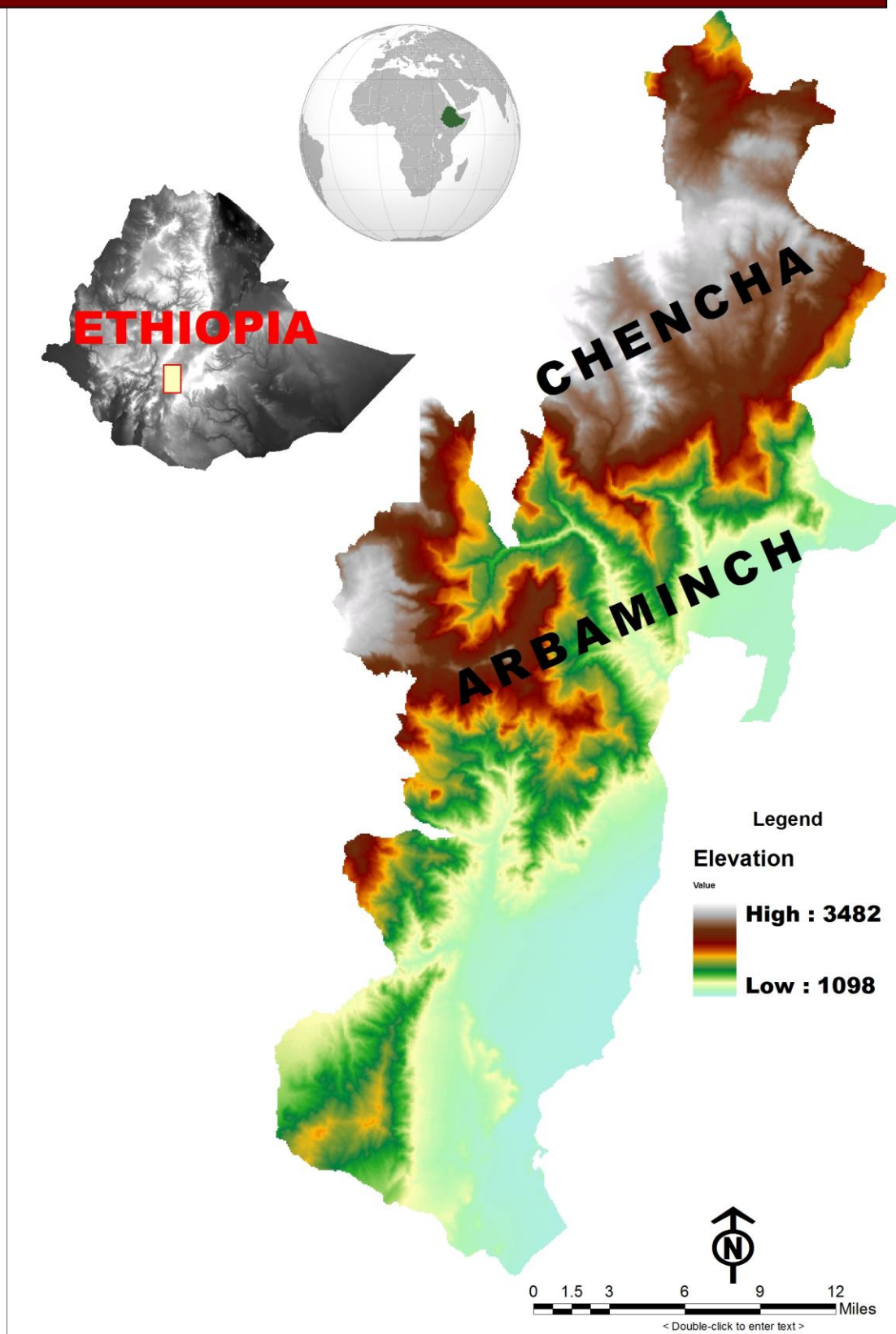
### Satellite Image analysis

A time-series was generated using satellite image analysis. Landsat MSS, TM and ETM+ satellite images from the years 1973, 1986 and 2006 were used in conjunction with field surveys. These images were geometrically registered to the 1: 50,000 scale topographic map of the area. Forest was identified from the images by a supervised classification method. Data for ground referencing (ground truth) were provided by the extensive field investigations, such as observations and interviews in 2009 and 2010.

### Household interviews

To cover the different agro-ecological zones, areas that belong to high altitudes (*Doko Mesho*), middle altitudes (*Dorze Belle*) and lower altitudes (*Chano Chelba*) were selected. From the lists of the households in the *kebeles*, a total of 120 household heads were randomly selected. The interviews were carried out with the help of assistants. The assistants were college graduates with proficiency in the local languages. Training was provided for assistants on ways of establishing contact, conducting interviews, procedures and cultural issues. An interview was conducted by going to the individual household in the early morning and/or late afternoon, when it would be most convenient for the farmers. That is usually when there is neither an agricultural activity nor any other activity in which the household head was

**Figure 1. Location of the study area**





involved. An interview was then held outside the room as long as the people were willing to respond to the questions. If the informant was unwilling to give information, she or he was asked to propose someone who might be willing to be an informant. The estimated time to conduct an interview with one household head was about 2 to 2.5 hours. The interviews were carried out from October to December in both 2009 and 2010.

Before conducting an interview with a household head, the objectives of the questionnaires were explained to make clear the purpose of the interview and to avoid misunderstanding. Interviewees were also assured about the confidentiality of the data they provided. While conducting an interview, in some cases, different interview techniques were also employed to obtain clear answers. Each day the daily activities were summarized, highlighting any unique matters encountered by the interviewers during the course of their work. Lessons were drawn accordingly from these insights, allowing appropriate mechanisms to be devised for the activities of the following days.

#### Key informant interviews

The key informants were the older people and the ritual leaders. The discussion was mainly focused on what, how and why the land-use system changes took place in their living area and the surroundings. The event calendar was established as a benchmark for comparison of transformation of the landscape over time. People usually remember a certain situation by associating it with specific events. One example of such an event was the change of the government. In Ethiopia, two major radical government changes took place in 1974 and 1990. Moreover, different types of questions related to the lifetime of their fathers were also raised and discussed.

#### Group discussions

Group discussion is an important technique to verify and refine the data that were acquired by structured interviews of household individuals and key informants. It is useful in order to rule out any exaggeration or underestimation of the situations. As with the household interviews, the research area was divided into three parts: Chano Chelba, Dorze Belle and Dokomesho; ten informants were selected from each area. Participants in the discussions were elders (mainly over 50 years in age, from both sexes) who could remember and respond to past events of agricultural land uses. The discussion was carried out based on checklists.

### **3. Results and discussion**

#### 3.1 Trends and patterns of deforestation

##### 3.1.1 State of deforestation until the second half of the twentieth century

The state of the forest cover and of the deforestation in the north of Ethiopia was reviewed by Melaku (2003) based on travel accounts. Travellers in the sixteenth and eighteenth centuries reported that there was no forest cover in most parts of northern Ethiopia. They only found forest cover in a few regions, such as Gojjam and the surrounding areas of churches. The eastern part of Ethiopia, namely the Harar region, was also covered by forest in the nineteenth century, but this forest cover was decimated by fire and was subsequently changed to agricultural land at the beginning of the twentieth century. Contrary to the northern regions,

the reports of travelers or expeditions to the south region in general, and to the investigation area in particular, exist only from the end of the nineteenth century onwards. This is because of historical reasons and problems of route accessibility. The reports of the few travellers' accounts, however, only portray the greenness and beauty of the area while providing no data about the forests and wood resources of the area (Jackson et al. 1969).

The social and political system that prevailed in the investigation area leading up to and during the nineteenth century was based on a caste system. There were battles among communities situated near each other in order to gain more labour force for the cultivation of land (Olmstead 1975). This suggests that there was no scarcity or shortage of land that led the people to clear the forests. Rather, the historical sanctuary role of forests and trees was very significant as only traditional religion prevailed in the area during this period. The land which was allocated to second class citizens, locally known as *ts'omas* (including tanners, blacksmiths and slaves), was situated on the steep slopes of the mountains and they were not allowed to encroach on the forest land.

Large-scale clearance and exploitation of forest resources occurred in the region at the end of the nineteenth century. This was the time when the region was incorporated into Ethiopia and different land tenure systems were introduced. *Gabar* was one of the land tenure systems by which land was given to the central government officials, military, priests, and civil servants. The main source of land for *gabar* was forest land and as a result large areas of forest were cleared and converted to agricultural land. Large numbers of soldiers who came to the region had also been accustomed to using wood intensively for cooking, heating and military operations. The impact of the *gabar* land tenure system on forest exploitation and clearance was also a widespread phenomena at the end of the nineteenth and beginning of the twentieth century in the central rift valley (Dessie and Carl 2008). Moreover, the establishment and expansion of new garrison towns, namely Chenchu and Ezo, along with the construction of roads during this period also exerted a high pressure on the natural forests.

Further encroachments upon forests took place during the Italian occupation of Ethiopia from 1938 to 1943. In order to gain popularity from the local people, the Italians demolished the *gabar* system and farmers who were serving the *gabar* were allowed to own the *gabar's* land. In addition, many farmers who also had a legal permit to expand their agricultural land subsequently cleared large areas of forest and converted them to farmland.

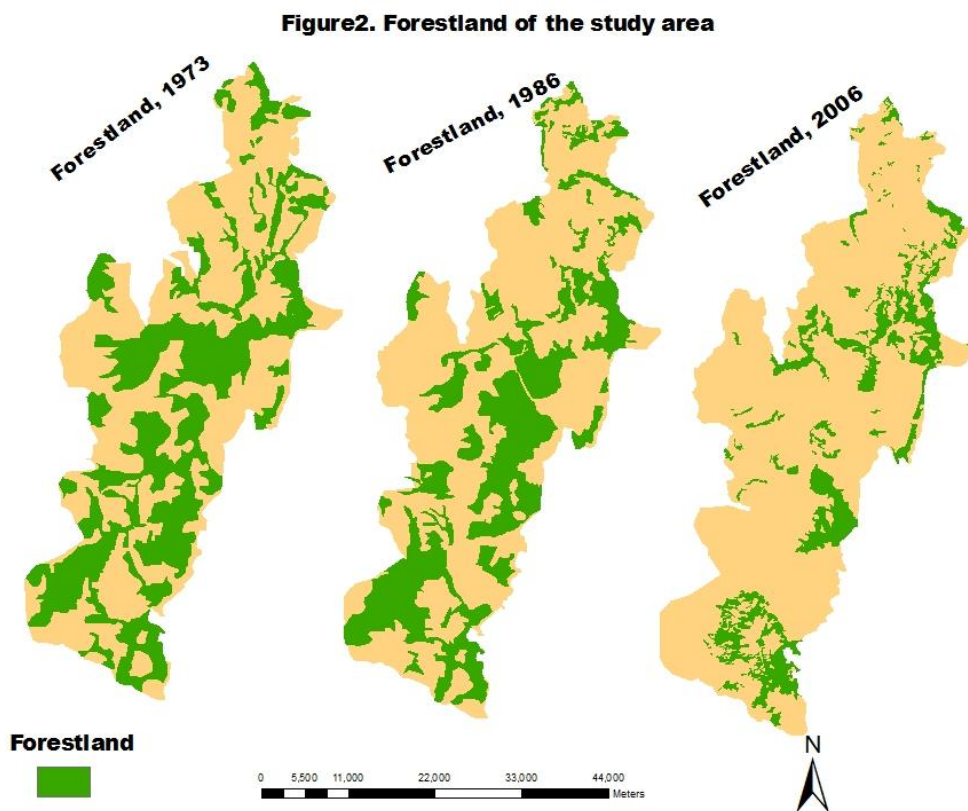
After the Italian occupation ended in 1944, the forest resources were also opened to large-scale exploitation when private individuals took over the ownership of most of the forests in Ethiopia (Zewde 1998). For example, the large-scale mechanized agriculture that was launched in the Arbaminch area resulted in the large-scale clearance of forests. The establishment of Arbaminch town in the 1960s also exerted another pressure on the forest resources of the area. However, in the mid 1970s, the land tenure system was radically changed as all land became owned by the state and the farmers had only usufruct rights. Since then land is state property. This land tenure system does not encourage farmers to invest in the long-term development of their land, and as such they did not plant trees for fear that the land might be taken by the government and redistributed to others.

### 3.1.2 Trends of deforestation since the 1970s

The result of satellite image interpretation depicts that forest accounted for 32%, 24%, and 9% of the investigated area in the years 1973, 1986 and 2006 respectively (Fig 2). The downward trend in forest cover is a widespread phenomenon in subsistence agriculture, characterized by an increase in the demand for cultivation land and for fuel wood. This result is also in line with the reports of various studies which were undertaken in different parts of the country. For example, Dessie and Carl (2008) have demonstrated a decline in forest extent in the Awassa region, southern Ethiopia, from 16 % to below 3 % from 1972 until 2000. Zeleke and Hurni (2000) have revealed a considerable decline of natural forest extent in Denbecha, Gojam region, from 27% in 1972 to below 1 % in 1997.

However, the pattern of decrease in forest cover in our study area was not uniform over time and space. The lower annual decline in the first period (from 1973 to 1986) compared to the second (from 1986 to 2006) period is explained by the massive afforestation program that took place in the area during the late 1970s and early 1980s. This plantation program has contributed to the forest cover and thus lowered the deforestation rate. However, in other parts of Ethiopia the forest cover was increased and deforestation was even reversed due to the plantation of trees that took place in the same period (e.g. Woldetsadik 1994; Bewket 2003).

The high rate of deforestation from 1986 until 2006 is explained by a particular episode in Ethiopian history – the political upheaval of the 1990s. During this time, there was a radical government transition: the present government took over from the Derg (1974-1989).



According to the informants of the current study, this transition time was accompanied by a massive destruction of forests. The principal reason for the clearance of forests was the demand for land for cultivation. Trees were also felled on a large scale for firewood and timber production. At this time, there were only loose institutions and government legal frameworks to control the forests. This massive forest clearance was also an expression of the farmers' dissatisfaction with the afforestation program which took place during the Derg regime. The significant destruction of forests during the transition period was a widespread action everywhere in Ethiopia (e.g Zewde 1998; Dessie and Carl 2008).

Larger-scale forest clearance took place in the lowlands compared to the highlands. This was attributed to the recent movement of people to the lowlands for settlement and cultivation. In the past, settlement in the lowlands was inhibited due to the prevalence of malaria and trypanosomiasis, a disease that affects cattle. Improvements in health facilities and the decline of malaria and trypanosomiasis in the area were therefore the major factor for settlement and cultivation. Similarly, the agricultural land expansion and permanent settlement in the recent past in the Ghibe valley, southwest Ethiopia, was also due to the elimination of trypanosomiasis in the area (Reid et al. 2000). On the other hand, minor changes in the size of forests in the highlands since the mid twentieth century were caused by long-term settlement in the area that contained most of the forest land, which due to its suitability for cultivation and it already being at the disposal of farmers, led to its early transformation into cultivable land.

The changes of forest land in the highlands were marked first by the felling of trees from the adjacent areas of the forest boundary, followed by a select felling of trees inside the forest. Then the adjacent land to the forest was brought to cultivation or used for grazing. Select felling of the forest land caused a thinning of forests and ultimately this land was converted to grazing land and then to cultivation. At present, this same process has also occurred at the middle altitudes, mainly on the escarpments. In the lowlands, forest land has been cleared since the 1970s and then cultivated, as reported by the informants.

### 3.2 Causes of deforestation

Farmers were asked about their opinions on the most important factors that cause deforestation in the study area. They frequently cited (cf. table 1) agricultural land expansion (97 %), fuel wood demand (83%), and settlement (56%).

Table 1- Major causes of deforestation as perceived by respondents \*

Causes	Highland (Doko Mesho) % of respondents	Mid altitude (Dorze Belle) % of respondents	Lowland (Chano Chelba) % of respondents
Expansion of agricultural land	94.0	97.1	99.1
Demand for fuel wood	82.4	86.4	79.0
Settlements	25.1	45.3	96.2
Timber production	19.6	12.3	11.9
Pasture land use	5.8	8.8	15.7
Others	17.8	19.9	21.8

\* Percentage does not add up to 100 due to multiple responses.

## Agricultural land expansion

Cultivated land has substantially expanded at the expense of forests, as expressed by farmers. An increase in agricultural land at the expense of forest land, particularly during the last fifty years, was also a widespread phenomena in different parts of Ethiopia, as reported by various studies (e.g. Zeleke and Hurni 2001; Wasse and John 2007).

According to the informants in the highlands, the main reasons for agricultural land expansion are low agricultural production and population increase. Among the respondents, 76% reported that the produce generated from their cultivated land is not sufficient all year round, about 21% answered that they produce sufficient yields, while the remainder reported that there is no clear trend in agricultural productivity. The insufficient agricultural production reported by the majority of farmers is also in line with the south Ethiopia regional report on livelihood and food security, which categorizes the whole area of the Chenchu wereda as at the margin of food security (SNNPR 2008). Farmers reported different multiple determinants that affect the agricultural productivity in the area. The most frequently stated factors are scarcity of cultivated land (97%), soil fertility decline (87%), grazing land shortage (86%), soil erosion (81%), low fertilizer input (56%), erratic rainfall (57%), lack of improved seed (53%), pests and diseases (17%), and inadequate extension services (23%).

Population growth is among the main causes for the scarcity of cultivated land in the area. The problem of land scarcity has been very acute over time, since the existing land was shared and distributed mainly to the male children. The high population density of the area is not a recent phenomenon, as explained by different studies already in the 1960s (e.g. Olmstead 1975; Jackson et al. 1969). Our present survey also revealed that about two-thirds of the interviewed highland farmers own land measuring less than 0.5 ha per household. These data are confirmed by a survey of the Chenchu wereda by the CSA. According to this agricultural survey, 56 % of the households of the Chenchu wereda have been cultivating areas measuring below 0.5 ha (CSA 2002). However, there are variations in the size of holdings in the different study sites. In the lowlands, a household worked on average  $\geq 0.5$  ha of cultivated land while in the mid altitudes this figure falls to about 0.47 ha.

Thus the present cultivated land is not viable for the production of sufficient food. The problem is aggravated by the very low use of improved seeds and artificial fertilizers in the area. The cost of fertilizer is very high and the farmers cannot afford to buy and use it. Moreover, off-farm employment is uncommon and hence people heavily depend on the cultivation of land for their livelihood. Agricultural land expansion at the expense of forest is therefore one of the main options for increasing agricultural production and meeting the needs of the increasing population.

## Fuel Wood

Fuel wood demand is another chief cause of deforestation. 99% of the farmers interviewed stated that the dominant source of household energy consumption in the area comes from fuel wood. They use wood for cooking, heating, lighting, local brewing preparation and smithing. In the lower area, electricity is used to supply light, whereas in the highlands kerosene provides light during the night time. Smiths have also used charcoal for heating metals, but the proportion of energy from charcoal compared to total energy consumption is minimal. The main sources of wood are the forest (52%), private woodlots (46%) and purchased wood

(2%). Forests along the lakes and the escarpments are the main sources of fire-wood supply in the area. However, dung and crop residues have not been used for fuel energy in this area, unlike in the northern part of Ethiopia. For example, dung is the main source of energy, accounting for 34% of the total energy supply, in Chemoga, Gojam (Bewket 2003).

Fuel wood is also the main source of energy for the surrounding towns, namely Arbamich and Chench. As in the rural area, the majority of the people in the towns use fuel wood for cooking, heating and for local brewing preparation. Electricity is mainly used for light supply. Moreover, hotels and higher education institutions in the town, namely Arbaminch University, Technical Schools, and Teachers College, have been dependent on fuel wood for their energy supply, mainly for catering. The study by Aregu and Demeke (2006) reported that these institutes and hotels were the major consumers of fuel wood. According to the institutes and hotels, the main reasons to use fuel wood include the low cost of fuel wood compared to electricity, the availability of fuel wood, and the good flavor that the food gets when it is cooked using fuel wood. The frequent interruption of electricity supplies was also another limiting factor stated by the institutes and hotel owners regarding their entire dependency on the fuel wood (Aregu and Demeke 2006).

The trend of fuel wood usage has been increasing in the rural as well as urban areas due to population increase. The towns are growing, along with increases in the number of hotels and other service facilities. The number of higher education institutes and their enrolled students has also increased. These factors all point to the high demand for fuel wood for energy supply. Moreover, construction wood demand has also been rising. The main source of timber production is also the surrounding forests.

Selling wood is one of the main sources of income for a large number of people from the rural and urban areas. The income is used to supplement agricultural production in the rural area. At times of crop failures in particular, selling wood is an important means of earning money for survival. Collected wood is sold to town residents, hotels and institutions. The main source of wood for sale is forestland. Wood is also sold from private wood lots.

#### Settlements and cash crop farming

The lowland was covered by forest till the mid-twentieth century. Agricultural practices in the lowlands started in the recent past (Jackson 1972) and resulted in forest clearances. A small number of semi-settled farmers were growing crops using the alluvial soils along the river deltas since the 1950s, according to the informants. Furthermore, the farmers from the highlands moved to lower altitudes for cultivation practices during the day and returned to the highland during the night. They were mainly growing maize, which was sold to the highlanders and also used for their own consumption. The main constraints for permanent settlement in the lowland area were prevailing malaria and trypanosis.

Large-scale forest clearance in the lowlands was associated with permanent settlement that took place in the area from the 1960s. According to the informants, about 150 people formed the first permanent settlers in the area in 1964. These people came from the surrounding highlands as well as other locations. In addition, a fairly large number of people migrated to the area from 1975 for permanent settlement and to cultivate land. This settlement was enhanced by the reduction of malaria owing to improvements in the health facilities.

In the 1980s the then government launched a villegization program in the area. People in the highlands were coerced into settling in the lowlands. The main purpose was to ease the population pressure on the highlands. Upon arrival, the farmers grew maize, cotton, and potatoes; only later were different plants introduced and grown, such as bananas.

Current banana cultivation has been expanding and is also responsible for the recent encroachments into lowland forests. Banana is a predominant crop, cultivated on three-quarters of the total cultivable land, owing to its yields, market demand and price. This has led to the farmers, besides gaining land from forest clearance, replacing other crops such as maize and cotton with banana.

In summary, one of the main reasons for deforestation in the lowlands is settlement, which in turn was caused by different factors such as the decline of malaria, high population density in the highlands, government policy, and the expansion of commercial farming. At present, most of the lowland area is devoid of forest. The remains of forests are found along the lakeshore and the steep slope. These forests are also under threat due to the cutting of fuel wood and forest grazing which hinders the regeneration of forests.

### 3.3 Consequences of deforestation

Soil erosion enabled by deforestation and agricultural land-use is the main reason for the decline of agricultural production in the highland area, as expressed by 85 % of the respondents. The forest cover of the highlands has been decreased enormously in correlation with the increase in cultivated land during the last five decades. The vegetation removal has in turn resulted in the lowering of soil resilience to erosion and has exacerbated soil erosion by water. In addition, the problem of soil erosion in our investigation area has also been exacerbated by cattle grazing in the remaining forestland, owing to the shortage of proper grazing land. The cattle tracks have caused soil sealing, which in turn reduces soil infiltration and subsequently high surface run-off rates occur during heavy precipitation events. A cattle grazing has also reduced vegetation cover density in forestland. Further, farmers have been cultivating the shallow soil, sometimes saprolite, as observed during the field investigations, which has also enabled an acceleration of surface run-off rates. Hence, sheet erosion and rill erosion are rampant in the highlands, particularly on steep slopes. Additional to the investigation area, the impact of removal of forest on soil erosion was also reported by several studies in other regions of Ethiopia (Hurni 1993; Tekle and Hedlund 2000; Tadesse 2001; Sonneveld 2002; Bewket 2003).

Gully erosion is a serious problem in the lowlands in particular. The main reason for the widespread formation of gullies is deforestation along the escarpment which borders the lowlands of the rift valley. According to the informants, more than four decades ago there was no problem with gulying in the area; it started with the clearance of the forest cover on the escarpment. They also stated that the 1990s construction of the road that runs to Chencha town from the lowlands was another cause for the deepening and widening of gullies. The road drainage is insufficient; during extreme runoff events the unpaved ditches bordering the road are too small to cope. Concentrated runoff is no longer led into the forestland after a short distance. As a result, gullies in the area have caused the deposition of a large amount of sediment on the cultivated land, damaging crops.

Deforestation has also exerted significant impacts in terms of the decline, modification and change in the biodiversity of the area. Indigenous trees, which were common in the area in the past, are now endangered due to deforestation. Farmers reported that *Cordia africana* is one of the tree species under threat of disappearance. This tree has diverse functions, namely for making coffins, as roof supports, for building sheds on the agricultural fields, and as raw materials for timber production. The latter use of the tree has led in particular to over-exploitation and is resulting in the threat of disappearance. Bamboo is mainly used for house construction, as well as the establishment of fences. Additionally, it has spiritual significance (Cartledge 1995). Despite this, bamboo is currently declining rapidly in the investigation area, in terms of both extent and in the size of the individual trees. In the past bamboo was allowed to grow for long period of time, while at present early felling is common. This has also caused a change in the type and shape of houses. Due to a lack of bamboo and grasses, rectangular houses constructed with corrugated iron are replacing the upturned basket form of traditional houses. Similarly, the dominant species of swamp and shore vegetation along the lakeshores in the lowland, *Aeschynomene elaphroxylon*, is continuously harvested to make fishing boats, which will endanger the survival of this species in the area as well.

### 3.4 Status of forests and forest management

Travelling from the southeastern to the northwestern part of the study area, i.e. from the rift valley lowlands to the highlands, one is struck by the mosaic of forests, woodlots, and stands of trees around the homesteads and in the farm fields, along with the prevailing cultivated land. The lowland, mainly along the lake, is covered with forests. Mid altitude areas are partly covered with woodland and sparse trees. In the highlands are found sacred forests and plantation forests, stands of trees within grasslands, scattered trees in farm fields and among the homesteads, and woodlots. This clearly proves that trees are prominent parts of the agricultural activities of the area with widespread social and ecological implications. It also shows the people's identity and sense of place (Cartledge 1995) and their harmonious relation with the forest.

#### 3.4.1 Old forests

In the study area there are long-lived sacred forests in the highland, forests along the lakes and stands of trees in the grasslands around every village and in the farm fields.

##### Sacred forests

Sacred forests are patchy remains of older montane forests in the highlands of the study area. Informants cannot trace the origin and age of these forests, as they have existed since time immemorial. The remains of a church which was found inside a sacred forest by ethnoarchaeological investigations gives some hint of the age of sacred forests (informal discussion with John Arthur, Associate Professor, Anthropology, University of South Florida Saint Petersburg – head of the investigation team). This church was among those which were deserted by people coming from the northern part of Ethiopia during the war that took place in the sixteenth century. The war is known as the *Ahmed Gragn* war, in which a large number of orthodox churches were burned and some of them moved southwards – mainly the covenant arks. Sacred forests were among the hiding places for the arks of the covenant. Later on churches were also built inside the sacred forests. This suggests that these forests existed before the sixteenth century in the area.



At present sacred forests are found within the investigation area in eight different places with a total area of about 28.6 ha, as estimated by local people. The area coverage of a sacred forest varies from place to place, with a range of 1 ha to 10.5ha (cf. table 2).

Table 2. Location of sacred forests

No.	Sacred forest name	Area (ha)
1	Doshikie	10.5
2	Negesse	1.5
3	Ewryie	5.0
4	Tsудо	1.1
5	Kencha	5.0
6	Settie	2.0
7	Zaroda and Denzie	1.5
8	Doko Dambo	2.0
	Total	28.6

Sacred forests are situated in different topographic positions. Most of them are found on the summits of mountains and on the plateaus of ridges, for example *Tsудо* and *Negesse* sacred forests. They are also found on other plateau positions and along rivers, such as *Doshikie* and *Ewryie* sacred forests. The density of the forest cover also varies from place to place. In some areas there is a dense forest cover, such as in *Negesse* sacred forest (Figure 3), while in others there are only stands of old trees, such as in *Ewryie*. The surrounding land of all sacred forests is under cultivation. Thus the small sacred forests look like islands within cultivated land.

Shibru (2009) has carried out a preliminary survey to identify the tree species of *Negesse* sacred forest. The study is far from exhaustive but it provides some baseline information on tree species of sacred forests. He has identified about 23 tree species, the most common being: *Juniperus procera*, *Euphorbia spp*, *Terminalia brownie*, *Olea africana*, *Ficus spp*, *Cordia africana*, *Sterculia africana*, and *Acacia abyssinica*.

A sacred forest is a place where sanctuary functions take place. The main sacrificial performances take place just before the beginning of agricultural activities. Sacrifices are also performed when epidemic diseases, rainfall shortages and other natural calamities occur. For the purpose of the sacrificial events different cereals such as wheat, beans, barley and local drinks are contributed and the local people raise money to buy a bull or sheep. Bulls or sheep are slaughtered inside a forest and the blood is spread in the forest and among the people gathered there. The main purpose of sacrifice is to ensure a good coming year in which land will be fertile and bear many crops; that the crops give greater yields, precipitation occurs regularly and woman have babies. However, since the last half of the twentieth century, the sacrificial system was hardly practiced due to government ideology and the growing importance of the protestant churches (Freeman 2009).

Sacred forests are, to a limited extent, also a source of fuel wood and construction materials. However, there is variation in the degree of accessibility to the different sacred forests for obtaining wood. The council of the elder people (spiritual leaders) is based on certain standards. For instance, in *Ewryie* sacred forest, a woman who has given birth to a baby (regardless of sex) is allowed to procure wood for fire and building materials. Her husband, neighbors or relatives can cut wood or collect branches, leaves or twigs. Old people, who lack strength and are unable to work, are also allowed to collect wood from the forest. Meanwhile in *Doshikie* sacred forest, cutting or collecting wood is allowed for a woman who has given

birth to a son, but not for the old people. On the other hand, in *Negesse* and *Tsудо* sacred forests, neither cutting of trees nor collecting of wood is allowed for anybody and it is a taboo.

There is a belief that if a tree is cut or has its twigs, branches or leaves collected, bad fortunes will befall the people, the land and the cattle. In cases where someone violates the rules by cutting or collecting wood and can be identified, he has to pay a sheep as punishment. The sheep will then be sacrificed inside the sacred forest.

Figure 3. Negesse sacred forest



Sacred forests were also used for defense during previous times of war, as witnessed by the well-designed and well-constructed stonewall fortifications inside the forests. According to the older people, the fortification was used for hiding children and woman during the war that took place among the neighboring communities. It was also used for defending against advance attacks. As discussed previously, it was also a hiding place for the arks of covenant of orthodox churches during wartime.

However, sacred forests are not without interference from some human activities in the recent past. One of the threats to the forests has been the informal felling and collecting of wood for fuel, building materials and for sale. In most cases those trees with good market values are selectively felled; for example, the *Hagenia* tree is one of the most exploited tree species and currently on the verge of disappearance from the forests, according to the informants. A large number of sacred forest trees were felled during the government upheaval in the 1990s. Moreover, land around the sacred forests has been put under cultivation in the recent past and there is a fear that the forest area could be further encroached upon in the future. In the past, however, the area that surrounded the sacred forests was used for grazing land. During the last decades most of this grassland was converted to cultivated land due to a shortage of food.

Pasturing a large number of cattle within or along the borders of the sacred forest is another issue; the severe shortage of grassland for cattle means that grazing in the sacred forests serves as a spillway for the cattle feed. It is evident that intensive grazing and forest firing adversely affect the regeneration of trees and other plants. Along footpaths, which are common inside and along the edges of the forests, cattle tracks cause soil compaction. When soils are sealed, rainwater infiltration is reduced drastically and surface runoff is generated in large amounts during heavy precipitation events. As a result, visible soil erosion such as hollow-ways gully erosion is apparent inside and bordering the forests.

Sacred forest degradation has been caused by many factors. According to the informants, the threat of loss of integrity to the traditional culture is one of the main factors posing a risk to the sacred forests. As a result, there are modifications and violations of the rules and regulations regarding the management and use of forests, which were established and practiced by the society in the past. The main cause for the deterioration of local values is the ideologies of successive governments. During the Derg period, the ideology of the government was socialism and thus they banned the practices of various local beliefs across the country. The present government has granted a constitutional right for everybody to practice their own religion or belief. However, the problems of livelihoods, insufficient agricultural production, and scarcity of land, have forced the people to use sacred forests against established norms. Modern transformation and assimilation of cultures and religions and the urbanization processes have also a strong impact on the traditions of the people. For example, some people who went from urban areas, where they worked in off-farm jobs, back to their rural environment do not believe any longer in the sacredness of forests. In addition, they hardly believe in the taboos regarding cutting or collecting wood from a sacred forest – a complete turn from the traditional various local beliefs and attitudes.

#### Stands of old trees

Stands of old trees are often situated in the large grass areas of the study area in the highlands. They are locally known as *Dabush*. The most common trees species of the *Dabush* include: *Ficus species*, *Arundinaria alpina* and *Juniperus procera*. *Dabush* are commonly used for gatherings of the local people that deal with their affairs here. They are also used by government officials for the discussion of issues with the local people. *Dabush* are also used as places for annual festival celebrations such as *Mesqel* (New Year), which takes place at the end of September. They are also mourning grounds. The social role and value of mourning is very significant for the people. Additionally, the *Dabush* also provide fodder for livestock.

Stands of old trees are also found in the compounds of orthodox churches, in cemeteries, markets, and around schools. Trees in the graveyards are considered as sacred trees and thus cutting and collecting fallen wood, twigs, and leaves are prohibited.

#### Forests along lakeshores and near springs in the lowlands

Old forests in the lowlands are found along the shores of Lake Abaya and Lake Chamo. With growing distances from the lakeshores first the density of the forests decreases and then forests are replaced by savanna woodland which is more drought tolerant. The most dominant tree species include: *Diospyros*, *Terminalia bromwni*, *Kigelia pinnata*, *Tamarindus indica* and *Euclia schimperi* (Sormessa 2004).

Forests in the lowlands near to springs also play an important role in regulating water fluxes and sediment transports. It is estimated that there are about forty springs existing inside forests. Forests along the lakeshores and around springs provide impressive scenery that attracts tourists, too. It is also evident that these forests have contributed to the conservation of various plant species.

At present, however, the extent and biodiversity of these forests is deteriorating rapidly. These changes are mainly driven by cultivated land encroachments, grazing beside and within the forests, and the increasing demand for fuel wood. Intensive cultivation started in the lowlands in the 1960s. The increasing number of settlements and the introduction of cash crops resulted in the conversion of large areas of forests to cultivated land. Particularly large areas of forestland were converted to cultivated land during the political upheaval. Moreover, grazing beside and within lakeshore forests is another constraint that affects the condition of the forests.

#### Woodland along the escarpment

The most common woodland trees along the escarpment of the rift valley include: *Acacia tortilis*, *A. nilotica*, *A. seyal*, *Combretum mole*, and *Balanites aegyptiaca*. The people from the lowlands and middle altitudes have accessed this woodland for collecting fuel wood. A large number of people are also making their livelihood by selling wood that has been collected from these places. In the 1970s and 1980s, there were tight rules and regulations on how to cut and use the wood from the woodland and as a result the forests along the escarpment were not intensively exploited. However, the situation changed and deforestation was exacerbated during the transition of government in the 1990s and this forest exploitation has been continued until present. These woodlands also provide pasture for the cattle from the surrounding area. The over-crowded livestock graze inside the woodland during the rainy season when the lakeshores are covered with water.

The woodland along the escarpment is thus one of the most highly exploited wood resources. This has resulted in high surface runoff and flooding that strongly affects the adjacent lowlands during the rainy seasons. Hence, gully erosion and sedimentation are serious problems in the lowlands that hinder agricultural activities and affect the infrastructure. The farmers in the lowlands are also aware of the causes of gulying and flooding. They stated that the massive destruction of forests in the recent past is one of the major causes. On the other hand, the people of the middle altitudes have been using the woodland as a source of fuel wood since the 1960s (Jackson et al. 1969). Thus there is a conflict of interest between the highlanders and the lowlanders. The highlanders see the woodland as a resource to be used for fuel wood, while the lowlanders see this woodland as something to be preserved to protect their land from gulying and flooding.

Figure 4. Old forest in Chench



### 3.4.2 Afforestation

Forests were planted during the massive afforestation programs, known as the “Green Campaign”, which took place across the country in the 1980s. The main objective of these large-scale community forests was to combat soil degradation, to expand forest cover and to protect the existing forests by fulfilling the wood demands. Most of the plantations took place on the top of mountains, on ridges and on steep slopes, namely *Dorze*, *Surra*, *Ezuma*, *Dega Shara*, *Meze* and *Mesho*. A large number of people participated through food-for-work programs. They first constructed terraces, using stone or soil depending on the available materials, and then they planted trees. The dominant tree species in the community wood plots are *Eucalyptus globulus*, and *Juniperus procera*. Other tree species include *Hegannia abssyynica*, *Pinus patula*, and *Cupressus lusitanica*. The total area covered by community forests in 1987 was about 650ha, according to the agricultural bureau report. In general, the community woodlots have brought significant landscape changes to the area.

The majority of the people have a negative view towards the communal woodland due to its impacts on dwindling pasturing land. In the past, before the plantation of trees, the land of the community wood lots was grassland and had been a very important source of pastures for cattle grazing. Additionally, the trees of the community woodlots are exotic, mainly eucalyptus, which does not allow the growth of herbs and grasses, thus impeding cattle grazing. The unpopularity of the community wood lots is mainly derived from the top-down design and implementation of the plantation program. This approach did not allow community participation and thus failed to address the main problems of the community, as reported by various studies across Ethiopia (e.g. Zewdie 1998; Bewket 2003).

### 3.4.3 Household-level planting of trees

Trees are at the center of agricultural practices in the area and thus planting of trees has been a widespread practice for the majority of farmers over a long period of time. The community also acknowledges possession of large areas trees as prestigious and a sign of wealth. Trees are planted on land designated for plantations, in the farm fields and around homesteads (Figure 5).

The predominant farmers have assigned small plots of land for the planting of trees. These lands are usually found on degraded steep slopes, which are marked by poorer soil quality. They are abandoned for cultivation and are no longer used to grow crops. Farmers also plant trees along the sides of paths and road borders, as well as along and inside the gullies.

According to the informants, the dominant types of planted trees are Eucalyptus (according to 98% of respondents) and Juniperus (according to 46% of respondents). The eucalyptus tree was introduced to the area around the middle of the twentieth century according to the informants. The members of a British Expedition, who travelled to the area in the 1960s, also observed eucalyptus at most farmers' homesteads and along the roads (Jackson et al. 1969).

At present the area cover of eucalyptus has increased compared to the past, as expressed by the farmers. This is because of large-scale plantations of eucalyptus trees at the level of individual farms in the mid 1980s. At that time farmers were encouraged by the then government through the supply of free of charge eucalyptus seedlings. Moreover, the people have also been aware of the various benefits of eucalyptus compared to the indigenous trees; above all, the short period of harvest – eucalyptus are coppiced every third year at the earliest. Additionally, eucalyptus requires minimum care and grows in poor environments. At present, eucalyptus trees are also increasingly grown in areas where the land was abandoned due to poorer soil quality and soil erosion, particularly on steep slopes. Eucalyptus trees are thus an important source of wood for fuel, for construction of houses and for sale. However, the people are also aware of the disadvantages of planting eucalyptus trees. Among others, they noticed the high water requirements, depleting soil nutrients and suppression of grass growth, which in turn is a limitation for cattle feed.

Long-lived trees are also common in the farm fields and around homesteads, showing that trees are not only growing on the abandoned farmland. In addition, trees are also planted along borders to mark the boundaries of properties and also boundaries of farmland and grazing land. The most common tree species include *Juniperus procera*, *Erythrina abyssinica*, *Hagenia abyssinica*, *Croton macrostachyes*, *Euphorbia spp.*, *Terminalia brownie*, *Olea africana*, *Ficus soria*, *Cordia africana*, *Sterculia africana*, and *Acacia abyssinica*. In addition, *Moringa oleifera*, and *Coffea arabica* are also planted in large numbers, mainly around homesteads.

Trees have various economic, environmental and social significances for the people. Namely, they are important for daily diets (e.g. moringa), as sources of cash crops (e.g. coffee) and also they provide fuel wood. Trees are also important for beekeeping (apiculture). These trees are also a source of income during crop failures; cash from the sale of wood is used as insurance. Along with their use as fodder for livestock, trees also serve as shade during the high sun period when the land is used for pasturing. The people are also aware of the environmental significances of trees, such as maintaining soil fertility (e.g. *Erythrina*,

Hagenia, and Croton) and as barriers against surface runoff and soil erosion. Furthermore, trees have traditional religious significances, namely they are a place of spirit dwelling and sacrifice (Cartledge 1995). Juniperus is considered as important for rituals and wooden statues. This all clearly implies that trees are at the center of agriculture with additional wider social significances.

Figure 5. Trees in cultivated land



## Conclusion

Using the data from satellite image interpretation, coupled with field observation and socioeconomic survey, the study results revealed that there has been significant forest change in the area since the 1960s. The findings of the study have also demonstrated widespread environmental and economic implications of deforestation in the study area. These include land degradation (sheet and rill erosion in the highlands and gully erosion and floods in the lowlands), sediment deposition at lowland irrigation weirs and channels and threats of disappearance of some tree species (namely *Cordia africana* and *Hagenia abyssinica*).

The downward trend in forest cover is mainly attributed to agricultural land expansion, as a response to the increase of population and the decline of agricultural production in the area, as expressed by the farmers. The increase in the demand for fuel wood in the area and in the surrounding towns, which heavily depend on fuel wood for energy consumption, is another chief cause of deforestation. The recent settlement and cash crop farm expansion in the lowlands also resulted in the massive clearance of forests. Government upheavals, land

tenure, and absence of continuity in forest policy have also compounded the factors for deforestation.

With the growing human population and the shrinking of forests, one is impressed by the mosaics of forests, woodlots, and stands of trees around the homesteads and in the farm fields, along with the prevailing cultivated land in the study area. The rift valley lowlands, mainly along the lake, are covered with forests. Mid altitude areas are partly covered with woodland and sparse trees. In the highlands are found sacred forests, plantation forests, stands of trees in the grassland, scattered trees in the farm fields and along the homesteads and woodlots. Forests have a wide social and environmental significance in the area. For example, sacred forests are used as a place where sanctuary takes place. The main purpose of sacrifice is to have a good coming year, in which land will be fertile and bear many crops, in which the crops will give greater yields, in which precipitation occurs regularly, and in which women have babies. Sacred forests are, to a limited extent, also a source of fuel wood and construction materials. They were also used as a defense at the time of war in the past. The well-designed and well-constructed stonewall fortifications inside the forests are witness to this fact. Sacred forests indicate that much of the area was once, in the distant past, covered by similar vegetation, therefore these forests indicate the floristic composition of the original woodland vegetation. They are the most important refuge for natural resources and sources for seeds of the various indigenous tree species.

Trees are part and parcel of farm activities and social systems. Farmers integrated trees with crops in cultivated land as they are aware of the benefits of trees. Wood supply, soil fertility improvements, soil and water conservation, fodder for livestock, and wood for the construction of sheds for livestock are among the benefits.

This clearly shows the people's identity and sense of place (Cartledge 1995) and their harmonious relationship with the forest. It also proves the cumulative traditional knowledge and experience of the local people regarding forest management and preservation that developed over a long period of time. Thus these practices should be promoted and advanced. The design and implementation of sustainable environmental planning and management should integrate local knowledge and forest management practices, along with correcting the main effects of deforestation.

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**Chapter 4**-----

**Gully system dynamics and human impact in Arbaminch and Chenchu areas, Southern Ethiopia**

## **Gully system dynamics and human impact in Arbaminch and Chencha areas, Southern Ethiopia**

### **Abstract**

Gullying is a widespread phenomena in Ethiopia namely since the mid of twentieth century owing to the dynamics of the social, economic and demographic conditions in the country. Incision-aggradation phases of gully systems are common in areas where gullies are dominant. However, there is only little attempt to study gullies. In addition, most studies only stress the incision phases and use for calculations the rate of soil removal by gully erosion. The objective of this study is to reconstruct the stratigraphy of gully development and to examine the driving forces for the incision-aggradation phases of the gully systems during the last century in Arbaminch and Chencha areas, southern Ethiopia. Field surveys were conducted to determine and characterize the attributes of gullies. The results of the field survey were supplemented by interviews and group discussions. The geomorphological knowledge of the general environmental setting and climate data were also used to augment the interpretations. A gully system with 14 phases of gullying and sedimentation cycles was identified and the chronostratigraphy of the gully system was reconstructed. The results revealed that the gully system is characterized by the cyclic succession of phases of entrenchments with aggradations and with stability and soil formation. Gullies were confined only in few places during the past. However, the extension of areas that are affected by gullying is increasing dramatically over the last five decades. Hence, gullies are common on basaltic soils of the highland, colluvial deposits of rift valley escarpments and alluvial deposits of the lowland. The lowland is marked by semi-arid climate while the highland has a humid climate. The human impact are mainly deforestation, intensification of agriculture, the wrong design of road construction and agricultural terraces, footpaths and cattle tracks are responsible for the dynamics of runoff generation and concentration as well as of gullying. These factors along with steep slopes and storm precipitations triggered the incision-aggradation phases of the gully systems. Moreover, land degradation, a common phenomenon in the areas, aggravated gullying. If the present trend of gullying continues, a large size of land will be abandoned for cultivation and grazing which in turn significantly affects the livelihood of the people and the food insecurity, worsening the present poverty conditions. Moreover gullies are also affecting the roads and bridges. The town Arbaminch is also under risk of gullying and associated flooding. The present survey on gully systems is therefore important to add to the knowledge to gully system dynamics and provide information to the design and plan of measures against gullies. The study also suggests that studies that estimate erosion from gullying only should also take into account aggradation phases.

Key words: gully erosion, human impacts, sediment depositions, soil conservations, Arbaminch, Chencha, Southern Ethiopia.

## 1. Introduction

Gully erosion is not only a recent phenomenon in Ethiopia (Mahcado et al., 1998; Billi and Dramis, 2003; Carnicellie, 2009; Franklin et al., 2011). Gully erosion that occurred during the past 5000 years in the Main Ethiopian Rift was investigated by Carnicellie et al. (2009). Deforestation is also a serious problem in the highlands since 3000 years BP with episodic recoveries of forests (Mahcado et al., 1998; Darbyshire et al. 2003; Nyssen et al., 2004). This verifies that the present small pocket natural (pre-disturbed) forest in northern Ethiopia is secondary vegetation, regrown following deforestation (Darbyshire et al., 2003). The problem of land degradation has exerted adverse impacts on economic, social, political and environmental conditions of Ethiopia over long past. For example, among other factors, soil degradation was one of the causes for the fall of Axum civilization by 800 AD (Butzer, 1981).

At present, gully erosion is a widespread process of land degradation in Ethiopia (Bills and Dramis, 2003). The effect of gully erosion is very significant and threatens the livelihoods and environments of Ethiopia. This is mainly because agriculture is the mainstay for the livelihood of a large part of the population; 85% of the total population is completely relying on agriculture (MEDaC, 1999). Gully erosion negatively affects the agricultural production and grazing land by stripping of soils. It impedes water availability for plant growth and it is changing topography, which makes the eroded land unsuitable for cultivation and travelling. Moreover, the problem of siltation of dams and rivers as a result of gully erosion is also one of the serious problems in Ethiopia (Bekele, 2003).

Nevertheless, less attention has been given to study the magnitude and effects of gully erosion in Ethiopia. The estimates of magnitude and economic costs of soil erosion in Ethiopia (e.g: Hurni, 1988; FAO 1986; Bojö and Cassells, 1995) were entirely based on the measurements of sheet erosion at plot levels and extrapolations using namely USLE-type models. The estimates of annual soil erosion in Ethiopia (1.9 billion tons per year, FAO, 1986 and 1.5 billion tons per year, Hurni, 1988) did not consider gully erosion. Thus, these estimates lack reliability and accuracy on the real actual loss of soil erosion. Moreover, they are also not representative for the large areas of the country, which are marked by diverse slopes, climate, soils and land use activities. On the other hand, soil erosion by gully erosion is a prevailing form of soil erosion in some areas of Ethiopia. For example, Tebebu et al. reported that the rate of gully erosion was 20 times higher than that of rill and interrill erosion in Lake Tana area, northern Ethiopia (2010).

Different studies reported that the intensity of gully erosion in some parts of Ethiopia is among the highest reported on earth. Frankl et al. (2012) revealed that the gullies in Tigray, northern Ethiopia, have a drainage density of 25 m ha<sup>-1</sup> and one of the densest networks on earth. The average rate of volumetric gully head cut retreat in Tigray, northern Ethiopia, was about 47.7 m<sup>3</sup> y<sup>-1</sup> for the period from 1960 until 2010 (Frankl et al., 2011). This rate of gully head cut retreat is seven times higher than the one of the gullies head retreat in areas in Spain. Similarly, Tebebu et al. (2010) also disclosed that the rate of gully erosion in Lake Tana, northern Ethiopia was about 530 t ha<sup>-1</sup> yr<sup>-1</sup> from 2007 to 2008, which is also one of the highest

records on earth; compared with the rate of gullying in different countries as reviewed by Poesen et al. (2003).

Gully erosion is increasing at alarming rates in Ethiopia over the last half of the twentieth century, as reported by several studies. For example, Moges and Holden (2008) disclosed the increase of the rate of gully erosion in an area in Awassa, south Ethiopia, from  $11 \text{ t ha}^{-1} \text{ yr}^{-1}$  to  $30 \text{ t ha}^{-1} \text{ yr}^{-1}$  in the period from 1974 to 2006. Using photogrammetric technique, Daba et al. (2003) depicted the increase of gully erosion in Hararghe, eastern Ethiopia, from  $9 \text{ t ha}^{-1} \text{ yr}^{-1}$  to  $26 \text{ t ha}^{-1} \text{ yr}^{-1}$  from 1966 to 1996. Similarly, Tebebu et al. (2010) have revealed a considerable increase of the area affected by gully erosion in Lake Tana area, northern Ethiopia, from 0.56 ha in 2005 to 1.43 ha in 2008 in an investigation area with a size of 17.4 ha. On the other hand, studies by Nyssen et al. (2004) and Frankl et al. (2011) portrayed that the rates of gully erosion in Tigray, northern Ethiopia, did not show an increase since 1990.

The increasing rates of gullying in Ethiopia since the mid of the 20<sup>th</sup> c are attributed to the changes of land use and land cover, demographic pressures and changes of the government policies (Daba, et al., 2003; Nyssen, 2006; Moges and Holden, 2008). The land use in most regions of Ethiopia is marked by intensive agriculture, deforestation and overgrazing. Land degradation is also prevailing in the cultivated land. Moreover, road construction since the 1990s in Tigray, northern Ethiopia, has also contributed to the gully development (Nyssen, 2006; Frankl et al., 2011, 2012). Vertisols are also appearing as one of the factors that favor subsurface erosion (tunneling) and thus the expansion of gullies (Moges and Holden, 2008; Frankl et al., 2011). Steep slopes and intense precipitation in Ethiopia also favor the formation and development of gullying (Frankl et al., 2010; Moges and Holden, 2008). Extreme precipitation events were the dominant force for cutting and filling of gullies in the main Rift Valley of Ethiopia during the Holocene (Carnicellie et al. 2009). However, in general the vulnerability of the land is the principal factor for the recent devolvement and expansion of gullies in Ethiopia. Sensitivity of land has also been standing out the major factors for gully development in Europe (Lang and Bork, 2006).

The investigated areas, Arbaminch (south Rift Valley) and Chenchu (western highland of Ethiopia) are one of environmentally most sensitive areas of Ethiopia. They are marked by high rates of land use and land cover changes mainly since 1950s. This along with steep slopes and intensive precipitation events resulted in a dramatic increase of gullying in the areas. Aged rills and gullies are still visible, indicating the impacts of the past land use. Nevertheless, there is little attempt to study past gullying. As Carnicellie et al. (2010) pointed out that most of the existing studies on gullies were carried out in northern Ethiopian and less attention was paid to southern Ethiopia. Moreover, gullying cycles are poorly reported in most studies in Ethiopia, focusing only on the incision phases (Nyssen, 2006; Moges and Holden, 2008; Tebebu et al., 2010). However, incision-aggradation phases of gullying are wide spread in areas where gullies are common.

The objective the study is to reconstruct the stratigraphy of gullying and to investigate the human impact on gully dynamics. The study thus attempts to generate valuable information on the formation, processes and causes of gullies. This contributes to the understanding of the interaction of man and nature. Thus it serves as a basis for the policy and environment management planners while planning sustainable use and management of land. Thereby, the study supports to the livelihood of the people and as poverty reduction attempts in the country.

## 2. Materials and methods

### 2.1 Description of the study area

Chencha (6° 15' N, 37° 34' E) and Arbaminch (6° 2' N, 37° 33' E) are located in the Gamo Gofa Zone, Southern Nations, Nationalities, and People's Regional State (Fig. 1). They are situated about 480 km southwest of Addis Ababa and bounded on the east by Lake Abaya and Lake Chamo. The topography is marked by a series of undulating and rugged landscapes, which include, from east to west, the Rift Valley Plain, the escarpment with incised valleys, and high plateaus, which are topped by hills and mountains. The lower part of the study area lies in the plain of the rift valley while the middle and upper parts are situated in the southwestern highlands of Ethiopia. The altitude ranges within a short distance of only 20 km from 1,100 m in the rift valley to 3,482 m above sea level in the highlands. According to the traditional agro-climate classification system, which only considers altitude, the study area lies within a *kola* zone (elevation of below 1500 m a. s. l.), a *weina dega* zone (elevation of 1500 to 2300 m a. s. l.) and a *dega* zone (elevation above 2300 m a. s. l.). However, these diversified landforms are highly interactive and related to each other via drainage systems and socio-cultural conditions.

Rock composition and topography of the rift valley were formed by volcanic processes, rifting, and faulting since the Miocene, while the upper part of the study area was a result of uplifting and volcanic activities that took place in the Paleogene and Neogene periods (King and Brachall, 1975; Grove, 1986).

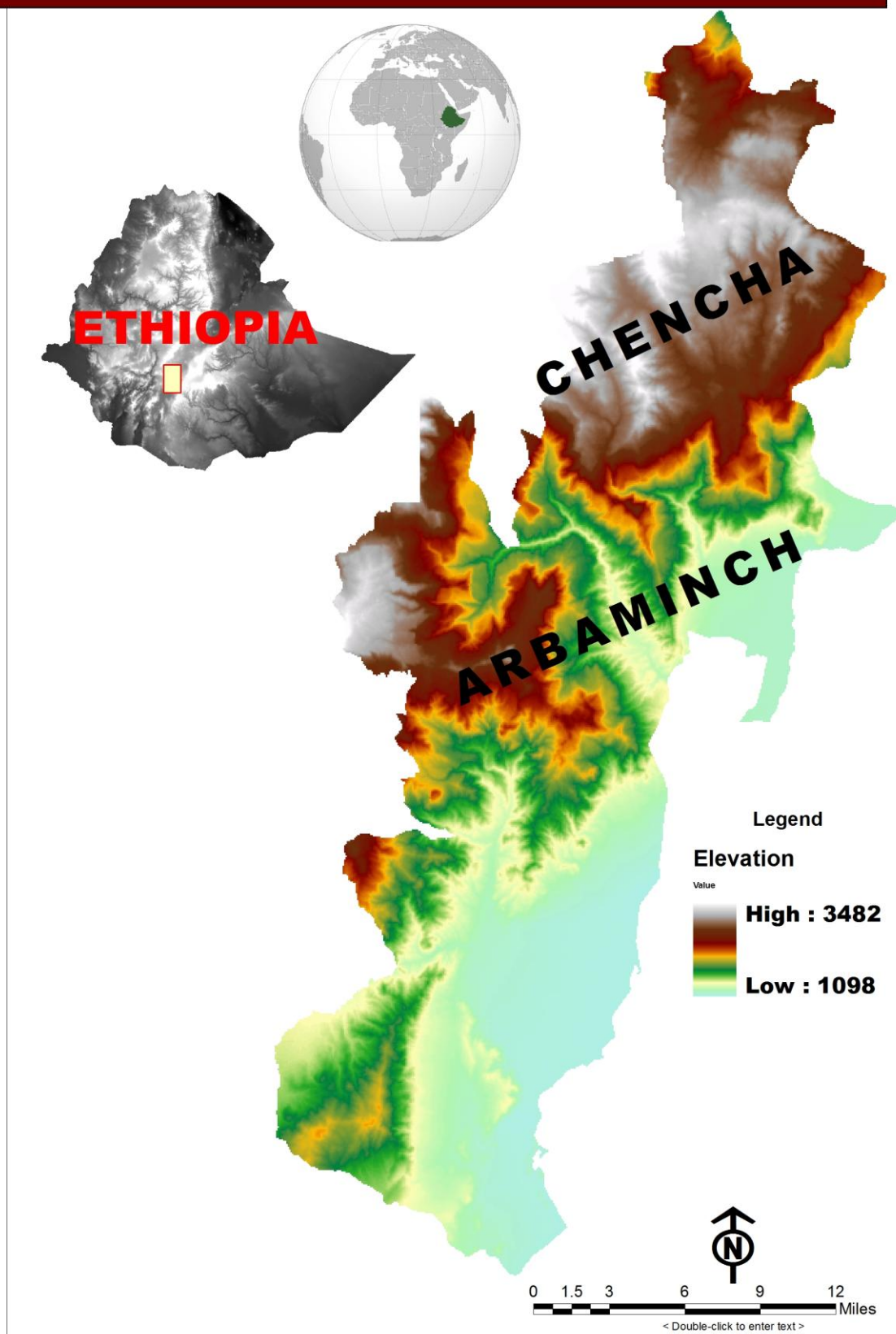
The main soil types in the area are Fluvisols, Leptosols, Cambisols, Acrisols, and Alisols. Fluvisols and Leptosols are found in the highland and lowland areas. Acrisols and Alisols are the dominant soil types in the Chencha area. In the Arbaminch area Cambisols are prevalent. As a result of the high diversity of landforms, rocks, vegetation, and climate, the diversity of soils is very high. Due to the parent materials, the soils of the lowlands are characterized by a high nutrient status and high retention capacities, which are suitable for crop cultivation. However, low soil organic matter, total nitrogen contents, and drainage conditions limit crop cultivation in the area. The shallow depth of Leptosols and Cambisols and their high erosion rates are another constraint for the cultivation of the escarpment. Moreover, a high acidification of the Acrisols and Alisols in the highlands restrict cultivation

Salinization is another limiting factor for crop production and an abandonment of cultivated land in the lowlands with a lower precipitation. The informants reported that about 10% of cultivated land was abandoned due to salinization. This problem is mainly derived from a high groundwater table (which is caused by a lack of effective drainage systems) and by ascending groundwater in silty and clayey soils.

Natural vegetation is sparse and only small patches, such as sacred forests, are found on the highlands due to the cultivation of most land areas, although eucalyptus trees are common around the homesteads and on community woodlots.



**Figure 1. Location of the study area**



The population of the worada of Chenchā totalled 127,193 in 2005 (CSA, 2006). Population density is estimated at about 336 persons per square kilometre. Scientific investigations prove that the area has been settled at least since about 3360 years cal BP (Arthur et al., 2010). The area is in the centre of the region Gamo Gofa, which is divided into 40 *dere* (small discrete political units). Olmstead (1975) estimated that 5,000 to 35,000 people lived in the area at the end of 19<sup>th</sup> century. People mainly cultivate barley and wheat in the highlands and bananas in the lowlands. To a lesser extent they also grow peas, beans, potatoes, and tree cabbage in the highlands and maize as well as *teff* in the lowlands. Enset is the staple food in the area and central to subsistence agriculture. Raising livestock is also an integral part of the economy.

#### Climate and its implications to gullying

Based on palaeolimnological evidence and the levels of the rivers, it was found that the climate was dry and warm in Medieval Times – from AD 1000 to 1270 (Ji et al, 1997; Verschuren et al, 2000). This period was also one of the famous famine periods as documented in the drought and famine chronology in Ethiopia by Degefu (1987). The climate from 1270 until 1850 was relatively wet and favorable for the formation of forests in the highlands, namely (Verschuren et al, 2000; Darbyshire et al, 2003). Since the late 19<sup>th</sup> century, numerous severe droughts conditions were recorded (Degefu, 1987).

It is generally well known that different climatic conditions have exerted impacts on forests, soil formation and soil erosion. For instances, as a result of the changing in climate patterns (trends of climate) the forest cover in Ethiopia has undergone a series of regeneration and losses of forests. This in turn has indirect impacts on the gully development and is creating more susceptible environment for erosion. Climate had been the most prevalence factor for the formation and development gullies during Holocene in the Main Rift Valley (Carnicelli et al., 2009). On the other hand, Nyssen (2004) stressed that since about 2500 BC, human impact became the dominant factor for land degradation in Ethiopia. In the late 19<sup>th</sup> and early 20<sup>th</sup> c gullies were stabilized following the dry conditions in northern Ethiopia (Frankl et al., 2012).

The mean annual rainfall of the investigation areas, based on meteorological records of Arbaminch (1200 m a.s.l.) and Chenchā (2700 m a.s.l.) from 1970 to 2008, varies from 781mm (in Arbaminch) to 1392mm (Chenchā). Elevation is the most important factor for the variation of the mean annual rainfall. Based on the records, two patterns of rainfall can be discerned, bimodal in Arbaminch and monomodal in Chenchā. In bimodal, the main rain occurs during the period from March to June and the peak is in average 148 mm in April. During this period the weather becomes more unsettled, and convergence of southeasterly winds originating from the Indian Ocean with a weakening northeasterly air stream causes heavy rainfall to this area. While the small rainy season (the 2<sup>nd</sup> peak) is in between August and November, at which the peak is in October and amounts in average to 92 mm. Locally the first period is known as *silla* while the 2<sup>nd</sup> peak period is known as *gaba*. The two periods are separated by a dry period.

On the other hand, the rainfall distribution in Chenchā is monomodal, which occurs from April to October. The highest monthly amounts occur in April, which amounts in average to 185.4 mm. It occurs when moist wind from the Atlantic and Indian Oceans converge over the highland. The season here is not as distinct as in Arbaminch.

The rainfall in the rift valley is marked by short heavy bursts with the intensities of up to 100 mm per hour where as on the highlands high intensities may only reach 60-70 mm per hour (Bekele, 2002). The intensity of rainfall is an important factor for enhancing soil erosion. The recent increases of the gullied areas in Ethiopia are linked with deforestation and climate regimes changes (Bill and Dramis, 2003).

The patterns of the rainfall occurrences have impacts on gully formation and expansions. The peak precipitation falls after the long dry period. The dry period (December to February in Arbaminch and Chench) in which the vegetation cover is sparse and it is period of land ploughing. The dry conditions (the low soil moisture content) thus enhance the formation of fissures in the soils. Then the rain falls on soils with low soil aggregate stabilities, low soil moisture content and accelerated erosion rates and gully formation is resulting.

## **2.2 Methods**

The methods used in this investigation include: field observation and description, measurements and interpretation of the preserved sedimentary depositions. Moreover, interviews and group discussions were also employed. The knowledge of topography and familiarity with the area were also very important part of the techniques of investigation.

The lower part of the investigation area, namely the rift valley, has a sufficient accommodation space that is used as a trap of sediments from the surrounding escarpments and highland. Sedimentary deposits are an archive to reconstruct soil erosion and human activities and impacts of climate on erosion and land use practices (Lang and Bork, 2006).

In our investigation area, representative gullies were identified and gully exposures surveyed in December 2008 and December 2009. We measured various attributes of gullies such as length, width, height and gradient. We described sediment characteristics of gully profiles, namely texture, color, plant root density, wood remains, stones and other materials in sediments, and in the gully wall sediments. This information has a paramount importance in determining the processes of erosion and depositions at temporal and spatial aspects.

We have also employed participatory rural appraisal techniques for collecting various information. In this technique farmers describe how they realize the processes and effects of gully erosion on their cultivated land and to the surrounding areas. In discussing with the key informants, checklists were prepared which include the history (the formation and progress of gullies), causes, consequences and the various measures (e.g. soil water conservation practices) to halt gullies. The key informants were the experienced older people and the ritual leaders. The event calendar was also established as a benchmark for comparison of changes of the gullies over time. People usually remember a certain situation by associating it with specific events. One example of such an event was the change of the government. In Ethiopia, two major radical government changes took place in 1974 and 1990. Moreover, different types of questions related to the lifetime of their fathers were also raised and discussed.

Participatory rural techniques are proved to be effective in generating and adopting new technologies for a range of natural resource research, which mainly focuses on raising the livelihood of the poor people (Stocking and Murnaghan, 2000). Various studies in Ethiopia used these techniques to identify rates of gullying in Ethiopia (Nyssen, 2006; Moges and Alden 2008; Tebebu, 2010).

The information, which was derived from the field survey and measurements of gullies along with farmer's discussion, was linked with the general geomorphological setting, climate data, information about land use systems and landscape structure. The reconstruction of characteristics of the climate of the recent past is based on the literature reviews. The Rift Valley is the center to interpret palaeoclimate (Carnicellie et al., 2009). The recent climate data (1970-2008) were obtained from the Ethiopian Meteorological Agency. Finally a stratigraphy was reconstructed based on the processes in a relative chronological and spatial sequence of incisions and aggradations. The causes and consequences of gully erosion and attempts to ameliorate gulley erosion were discussed and suggestions for improvements forwarded.

### **3. Results**

#### **3.1 Chronostratigraphy of Chano Chelba gully system**

In the chronostratigraphy of the youngest development of Chano Chelba System, about 14 phases have been identified and a thick black soil in the interfluvial areas between the gully systems is still preserved. The details of the chronostratigraphy of Chano Chelba are as follows (Figure 2 and Figure 3):

1. The first incision of Chano Chelba gully took place during an extraordinary heavy precipitation event with concentrated runoff. A gully with a width of several decametres and a depth up to 5 m developed (Figure 3: B).
2. In the second phase silty sediments (in small channels with higher velocities of runoff gravel) were accumulated in a thickness of 1 – 2 m during several minor intensive flood events in the first Chano Chelba gully. Several subphases of deposition were identified. Figure 3: C).
3. In a short period of geomorphic stability in the whole catchment of Chano Chelba and in the gully too vegetation has established (Figure 3: D).
4. The woodland vegetation was removed in vast areas of the Chano Chelba catchment and a period of intensive land use in the catchment began (after mid 20<sup>th</sup> century)
- 5.-9. Runoff generation and sheet erosion occurred on cleared slopes. Gravel, sandy and silty sediments were deposited in the Chano Chelba gully during five medium intensive precipitation and runoff events. Some remaining trees were partially buried. (Figure 3: E).
10. During a heavy precipitation event with concentrated runoff the second incision of Chano Chelba gully system took place to a depth of 2 m. Runoff with first a low sediment load concentrated namely on paths which were compacted by humans and animals. (Figure 3: F).
11. Gravel was deposited in the second Chano Chelba gully during several medium intensive precipitation and runoff events in a thickness of 1- 2 m. (Figure 3: G).

12. During a heavy precipitation event with concentrated runoff namely on paths the third incision of Chano Chelba gully system proceeded. The third gully has a depth of 1.5 m. Figure 3: H).

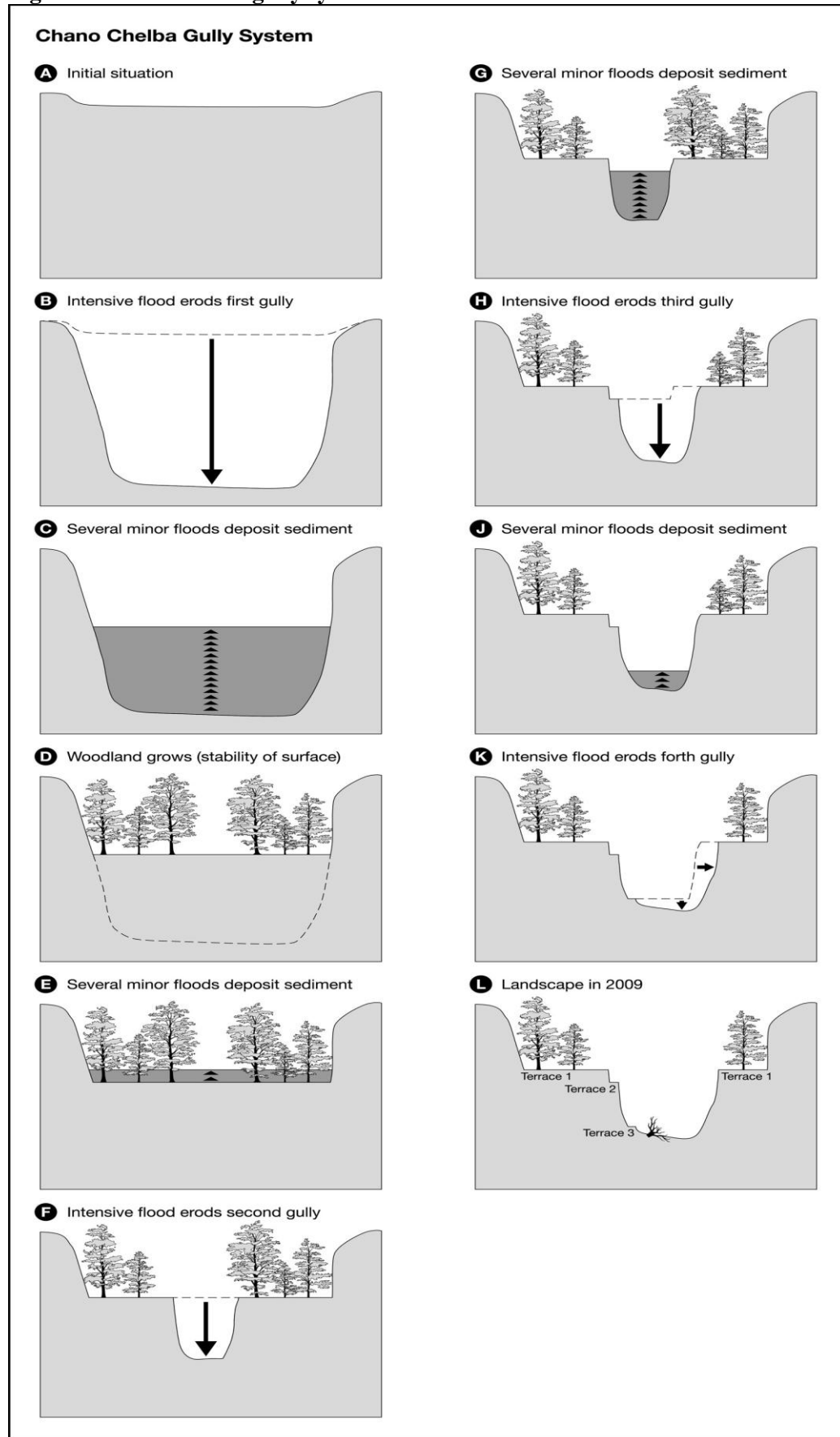
13 During several medium intensive precipitation and runoff events gravel was deposited in the second gully in a thickness of a few decimetres. (Figure 3: J).

14. The forth (and until today last) incision of Chano Chelba gully system occurred during a heavy precipitation event with concentrated runoff on paths recently. The third gully has a depth of several decimetres (Figure 3: K).

**Figure 2 Tree stem covered with sediment deposition in Chano Chelba**



**Figure 3 Chano Chelba gully system**



### 3.2 Zigetie area in Kulfo watershed

Development of the upper segment of a gully system southwest of Arbaminch on the escarpment of the rift valley

At the middle segment of the escarpment a complex gully system was identified. A gully has cut here 3 to 8 m deep into fine-layered sediments, which fill an older gully. The development of the gully system could be reconstructed as follows:

A first gully has cut into not compacted sediments. The age of this first period of gullying is unknown. Then this first gully was filled with thin-layered sediments. The fine layering is the result of several heavy rainfall and thus runoff and hillslope erosion events in the catchment of the gully. Runoff generation, hillslope erosion and sedimentation were enabled by the clearing of parts of the escarpment, which started approximately half a century ago. In middle of the fine layering a large stone was observed, which gravitational processes from the neighboring slope had transported into the gully. Maybe an earthquake has caused the gravitational process. Today the primarily fertile soils on the slopes were mostly eroded. Thus soil fertility on the segments of the escarpment, which were used agriculturally since up to half a century, has been reduced dramatically. At some sites agriculture thus has ended or will end in the near future for a long period of time – until new soils have formed in the bedrock, which is exposed there, namely by chemical weathering processes in several centuries, at least.

After the nearly filling of the first gully with fine-layered sediments, a second gully cut into these gully-sediments down to their base. This second phase of gullying was enabled by the construction of a road, which took place in 1981, above in the catchment of the gully. On this road runoff was concentrating and flowing down-road during heavy precipitation events. These masses of water were let concentrated into the filled first gully, and thus caused the incision of the second gully. Without road construction the filling of the first gully would have continued.

In 1986 some areas with intensive gullying and steep slopes on the escarpment were afforested with *Pinus radiata*, *Eucalyptus* spp. and *Corpurses lustanica*. But, as expected, runoff generation on the road and thus gullying downstream continued.

This example of sudden gullying proves the sensitivity of the ecosystems of the escarpment of the rift valley. Forest clearing and then agriculture enabled runoff generation, hillslope erosion and thus a slow filling of the first gully while infrastructure measures immediately resulted in strong gullying. In the uppermost part of a neighboring catchment gully erosion already has removed a part of the road.

After the construction of the road, in the lower segment of the gully system near Arbaminch, flooding, erosion and deposition of sediments caused severe damages. These processes are still active.

### 3.3 Lower Hare catchment

Exposure at the cut bank of river Hare, about 100 m distance to the old road from Arbaminch to Sodo

#### Profile 1

Depth below recent surface	Name of the layer	Short description of the layer
0-79 cm	F4	recent floodplain sediment of river Hare brownish sandy loam and loamy sand, intensive oxidation of iron from 30-79 cm depth
79-92 cm	F3 fAh	humic horizon, which developed in layer F3, floodplain sediment of river Hare, dark greyish sandy loam, medium high content of organic matter
92-202 cm	F3	floodplain sediment of river Hare, from 92-102 cm brownish, from 102-140 cm depth light greyish sandy loam, accumulation of salt
202-239 cm	F2	floodplain sediment of river Hare, greyish loam (similar as F1, separated from F1 by a buried surface on which an acacia tree has grown)
239-(>250 cm)	F1	floodplain sediment of river Hare, greyish loam

#### Facts

Fine soil material was deposited in profile 1, which is situated in the floodplain of Hare river, in a thickness of more than 2.5 m. Loamy floodplain sediments are dominating. In the upper part of the profile runoff intensities have been higher and sand was deposited there. The floodplain sediments contain the lower segment of a buried stem of an acacia tree, which is still in its original position. The acacia tree has started to grow on the top of layer F1 and before layer F2 started to be deposited – a former soil surface, which is buried today in a depth of 239 cm below the recent surface. The acacia tree grew during the period when F2 and the lower part of F3 were deposited. Then, humans have cut the stem and burnt the cut surface, latest after F2 and 55 cm of layer F3 were deposited. The stem has a maximum diameter of 15 cm. Since the tree is not decomposed at all, a young age of the middle and upper part of the sequence (F2-F4) is probable. We can conclude that erosion has increased intensively when the clearing of the woodland on the steep slopes of the escarpment of the rift valley and agricultural land use began some decades ago.

#### Interpretation

Until the mid 20<sup>th</sup> c erosion rates were low in the highland, which is used since a long time agriculturally, and very low on the steep parts of the escarpment, which were mostly covered by woodland that was grazed in a low intensity. Indigenous terrace systems in the highland enabled low erosion rates. In the 1960s the clearing of the steep slopes of the escarpment started and thus intensive hillslope erosion and massive sedimentation in the lower part of the Hare floodplain began. As a result, an acacia tree was partly buried by sediment and later cut by humans.



The extreme intensification of the sedimentation caused severe problems in the wide floodplain of the lower hare River. Sediments covered woodland as well as arable land. Intensive land use had to stop in these areas.

When the soils were totally eroded at several sites of the steep slopes, infiltration capacity was reduced and thus flood intensities increased during the rain seasons. As a result, runoff from the areas with stripped soils has low sediment concentrations and the tributaries and river hare are cutting into the floodplain sediments, which were deposited during the years before. A secondary effect of the intensified flooding is the destruction of several bridges at the main road leading from Addis Ababa to Arbaminch.

Parallel, the land use in the low land surrounding Lake Abaya was intensified since the 1960s. Due to low average rainfall, some areas were irrigated to grow e.g. cotton. Over the years sediments were deposited in the irrigation channels. Thus, their capacities were reduced and the water was spilled over the neighboring areas, causing their gully erosion. Employees of a farm reported that a gully developed in only four years as a result of sedimentation in a irrigation channel.

### **3.4 Ezo Gulle**

Northeast of Ezo Gulle (north of Chenchä) a sequence of nearly parallel gullies has developed during the last four decades. Gullying started with the establishment of a path, which was leading down a steep slope and which was used frequently by humans and animals. Since the weathered bedrock has a low infiltration capacity at this area, runoff generated already during minor intensive precipitation events. When the first gully was cutting in, people and animals continued to use the path. When retreating erosion caused the generation of steep steps in the gully, it could no longer be used as a path. Then, people and animals walked a few metres aside the gully and a new path developed there. Due to the compaction of the soil along the second path runoff generation began there during precipitation events. A second gully started to develop. The evolution of the second gully equalled the first one. After some years, people had to give up the second, now incised path. They used the neighbouring space where the development described occurred a third time, causing the development of a third deep gully. The gullies have cut in the lower and middle slope segments causing the deposition of sediment in the grassland of the adjacent valley. Thus, until today a sequence of gullies has developed only as a result of soil compaction by human activities along small lines.

## **4. Discussion**

### **4.1 Reconstruction of gully formation and development**

Formation of gullies

Our investigated areas, the rift valley (Arbaminch) and the southwestern highland (Chenchä) are marked by various geo-environmental settings that trigger the formation of gullies. They are characterized by high altitude differences within short distances – about 2400 m of elevation difference within 20km distance, but spatially highly interconnected. The disturbances of the natural environment of the highland for instance affect runoff generation that in turn cause gully formation and development at the lowland. The topography of the highland is composed of high plateaus with river valleys, topped by hills and mountains. The

rift valley escarpment and the upper slopes of the mountains are very steep and marked by undulating and rugged surface features. Mountaintops are mostly gentle to almost flat. The valleys of the perennial rivers (Kulfo and Hare) are steep in the upstream (highland) and midstream areas (escarpment) and flat in the rift valley. These topographic features coupled with storm rainfall and land use dynamics make the area susceptible for gully formation.

The rift valley has an important large space that accommodates sediments, which were accumulated during Quaternary period. The climatic conditions, alterations of wet climate followed by dry that occurred during Pleistocene were responsible for sediment accumulation. The sources of sediments were namely the escarpment and highland. Cutting of these sediments by runoff resulted in the incipient and formation of gullies.

The factors that initiated gully formation in our investigation area include: the geomorphological effects of earth quakes, the landform structure, deforestation, roads, footpaths, wrong design of terraces, landslides and, most notably, high rainfall events. Especially at sites where the vegetation was removed and that were compacted by humans and animals or at steep slopes that are used in another way intensively (namely agriculturally) gully formation could be initiated by precipitation, which thus could not infiltrate into the soil. However, the formation of gullies from rills was hardly observed in the study area. Heavy rainstorms are a characteristic of the climate in the area and thus short time heavy rainfall can trigger the formation of gullies on the sites mentioned. The same result has also reported by Bills and Dramis (2004).

Zigethe area, in Arbamich rift valley escarpment, for example, has a prevailing feature of deep tension and desiccation cracks. This geomorphic feature coupled with the heavy rainfall in this area, which resulted in concentrated overland flow in the cracks that penetrated the soil surface, causing the first gully formation in the area in the past. Recently, the road that was constructed in the area in the 1980s to connect Arbaminch with the highland initiated re-incision of the previous filled gully. Subsequently, the high concentration of runoff that flows down hillside leads to the second phase of gully formation in the area. A road that was constructed from Arbaminch to Chenchä in 1990s was also a main factor for the formation of gullies in Chano Chelba area.

Landslides were locally another cause of gully formation in Ezo Gulle area, Chenchä highland. The recent landslides in Ezo Gulle area caused the formation of deep steep sides' scars and hollows, in which surface water concentrated. Moreover, footpaths and cattle tracks have also triggered gully initiation and development in Zollo and Ezo Gulle areas, in Chenchä. The use of footpaths by humans and animals compacts the soil. The compaction resulted in a drastic reduction of the infiltration capacity of the uppermost soil horizon under the paths and thus the generation of enormous amounts of concentrated runoff during heavy rainfall events, leading to gully formation. Moreover, cattle tracks in the woodland areas of the escarpment are also a major cause for gullying.

The following heavy rainfall events resulted in the undercutting of the walls and the bottoms of the gullies that led to their deepening and widening. This also caused the collapse of gully walls. More heavy rainfall events with concentrated runoff coupled with land use changes, triggered more erosion and further deepening, widening and extending of gullies down slope. In addition, the retreat of the head gully cutting was also observed.

In our investigation area, mainly in the rift valley, gullies are marked by alterations of incision followed by aggradation.

#### Incisions – aggradations phases (gully cycling)

The incision of a gully channel was occurred due to the concentrated runoff that cut the unconsolidated deposited materials in the rift valley. Human induced activities such as deforestation, arable land use, overgrazing, footpaths, cattle tracks, and road construction were the main factors that affect the hydrology and runoff of the landscape. This together with intensive rainfall resulted in an increase of the overflow. Moreover, the bare soil of degraded land and – at other sites – a low vegetation cover density during the dry season of the year are also factors for high runoff rates during the rain seasons. Hence, the incision of the gully channel increased in depth, length and width.

The channels formed by the incision vary from place to place in terms of length, width, area and gradient. Generally, the gully channels at the down slope are wider and have lower gradients. On the other hand, the gullies in the highland and on the escarpments are deeper and narrow. This is attributed mainly to the material of the gully cuts. In the upper slope the rocks are dense and more resistant to erosion while at the lower slope the rocks are unconsolidated. Thus the area coverage of gullies is larger at the down slope areas.

Aggradation phases occur in years when the precipitation intensities and thus the runoff rates are lower in the rain seasons. The capacity of the runoff to transport material thus lowers enormously and the process of deposition is accelerated at the less inclined parts of the gullies in the rift valley. Hence, these lower segments of the gully channels are choked by namely fine-grained sediments. The source of these sediments in the gullies at the rift valley is hillslope erosion on the degraded land of the escarpment and on the intensively cultivated highland. In addition, gully bank collapses and the undercutting of the walls are also important ephemeral sediment deposit sites. Aggradations have also formed in the areas during the afforestation of the highland in the 1980s. The high vegetation covers resulted in a low amount of surface flow. Thus gullying declined and the materials that were eroded were reduced enormously.

We have also observed geomorphic stability phases that occurred in between the incisions and aggradations. For example, in Chano Chelba during two phases of geomorphic stability in the catchment of the gully soils were formed under vegetation, namely forest, in the deposited material. The trees were planted and gave a cover for the ground and consequently low runoff generated.

It is evident from our investigation that the gully development had a pattern of cut-and-fill cycles. Gully cycling is marked by the processes of filling, which was taking place during periods of several years, interrupted by individual rainfall and runoff events with incision. For instance in gully system of Zighete area the fillings of the gully was interrupted by a deep incision. The back fillings could have continued for some longer period, if the road had not been constructed. This road was a cause for generating high runoff, which led to the entrenchments. Similar observations were made in Chano Chelba gully system in which depositions or back filling was interrupted by cutting, which was enabled by deforestation, cattle grazing and road construction in the catchment of the gully. We observed four cut-and-fill cycles that occurred during the last century in Chano Chelba. This also shows the

dynamics of the driving factors, which are responsible for cutting and backfilling. The incision-aggradation cycles were also reported for the late Holocene in the central main rift valley (Carnicillei et al., 2009). They stated that gully entrenchments took place at the start of rain fall while gully filling was took place towards drier climate phase and stressed that gulling cycling system of the late Holocene was strongly linked with the climate.

#### Dynamics of gulying

Gullies are expanding extremely in the investigated area during the last five decades. Before, gullies were confined only along the escarpments. In the lowland in particular there was no pronounced gully before the 1960s. This is because the lowland area was not under cultivation before this period of time. At present however, gullies are common across the investigated areas and at different land use types namely cultivated, grazing, bush land and intensively used woodland. They also formed at different slop gradients and topographic positions. On the other hand, attempts to encounter gulying are low. If this trend of gully expansion continues unabated, large areas will be ceased of agriculture.

#### **4.2 Driving forces of gulying**

Intensive rainfall events along with the steep slope are among the factors that enhance gulying in the investigated area. However, generally extreme weather events alone cannot explain the process of the past landscape degradation events. Particularly extreme weather events during the 20th century did not cause intensive gulying in well-managed land (for complete reviews refer Bork, 2004). Thus the disturbances of the natural environment by specific human activities that alter hydrological processes, namely runoff, are outstanding primary drivers of gulying in the study area. These include among others the type and dynamics of agricultural activities, deforestation and high intensity of grazing, and road construction. The ripple effects of soil erosion have also been a triggering factor for gulying.

#### Dynamics of agricultural activities

The cultivated land in the investigated areas has gone in unprecedented change over the last four decades. Cultivated land was expanded by 39% from 1973 until 2006. On the other hand, in the same period, the average cultivated land per household in the highland has decreased from about 1.6 ha to 0.5 ha. Cultivated land scarcity can mostly be related to demographic pressure, which was exacerbated by government policy, land tenure, and the nature of subsistence agriculture. A high increase rate of cultivated land was reported in the lowland area of the rift valley. This was mainly attributed to the recent movement of many people from the intensively populated highland to areas for settlement and cultivation in the rift valley. The expansion of cultivated land was at the expense of the forestland and grazing land. Moreover, sensitive landscapes with steep slopes and wetland were also brought under cultivation. In some cases farmers have also been cultivating shallow soils, sometimes saprolite, as observed during the field investigations. These human activities and human induced process have modified and altered the natural landscape and disturbed the natural equilibrium. This in turn results in the modification of overland flow due to a reduction of the infiltration capacities namely of topsoil horizons and a subsequent increase of the rates and magnitudes of surface runoff. Hence, the formation and enlargement of gullies have enhanced.

Gully erosion in the area is also exacerbated by the changes of land management practices. Among others, manuring, crop rotation, and fallowing have undergone significant changes during the last decades. Most farmers have been used manuring to maintain the fertility of soil over generations. Nevertheless, since the 1960s, the application of manure to gardens and fields is declining. This is mainly attributed to the shortage of livestock. Hence the soil organic matter content of topsoil horizons is deteriorating and subsequently the quality of soil structure is declining, which enhances soil erosion in the area. Crop rotation is another methods used by a large number of farmers in the area to maintain soil fertility over a long period of time. It is characterized by a crop rotation of barley (2-3 years), wheat (2-3 years), bean (1 year), and peas (1 year). However, the frequency of crop rotation is decreasing because of the scarcity of adequate farmland. People increasingly prefer to only grow staple food crops such as barley, wheat and enset. In addition, they also want to maximize the benefits they get from the land by growing cash crops such as apples and bananas, so they devote their fields to the cultivation of these crops only. The decline of crop rotation also resulted in the lowering of nitrogen and organic matter in the soils. Thus the productivity of the soils is enormously lowered and the plant cover density is reduced and subsequently soil erosion is enhanced. Farmers in the highland are also well aware of the benefits of fallowing to maintain soil fertility over a long period of time. When land productivity decreases for a certain period of continuous cultivation, it should be fallowed in order to be regenerated. At present, the land is only fallowed when crop yields significantly decline. Otherwise, farmers continue land cultivation without any interruption. The abandonment of the fallowing affects the nutrient content and structure of the soils and thus aggravates soil erosion.

Moreover, the agricultural bureau of the *Wereda* also introduced terracing in the area in the early 1970s. However, these terraces are not popular among the farmers. Frequently cited reasons for the poor performance of these terraces are their labour intensive construction and maintenance, that space is taken away from agricultural production, the problems of ploughing narrow terraces, and rodents or other pests harboured by terrace walls. Additionally, the structural design problems of the introduced terraces and the top-down approaches to the design and implementation of the plans are other factors. Hence, not maintaining and eventually demolishing terrace walls express the unpopularity of introduced terraces. Some informants even reported that in one specific area the people have demolished seven times the introduced terraces, which were constructed during last the forty years. Cultivated steep slopes without terraces have a huge significance in triggering soil erosion.

Furthermore, the structural design problem also resulted in the formation of gullies in the highland area. During our visit of Ezo-Gulle region in Chench highland we could observe the terracing of a slope by a group of persons. The activities were supported by food-for-work-programmes. First they removed the topsoil. Then they put the soil material from the upslope part of the new terrace to their downslope part. The result was a terrace surface much less inclined as the slope before these activities. The surfaces of the new terraces were all inclined in the direction of the slope. The topsoil, which has been removed earlier, was then put on the surface of the new terrace and integrated into the saprolite. Then, at the lower end of each terrace a ditch with a depth and width of 40-50 cm was opened. The soil material, which was extracted there, was deposited above in a dam. It was planned to stabilize the dams with vegetation later. The ditches were opened for the collection of surface runoff during heavy precipitation events to enforce infiltration. Since several ditches were not installed along the contour lines their bottom was inclined significantly. It can be expected that runoff will flow in those ditches in increasing velocities downslope, causing rill and gully erosion

during the rain seasons. In the same way, farmers in Zollo area also reported that the introduced terraces, which were built in 2004 by food for work programme, caused gully formation and expansion. This is because the wrongly constructed waterways near the introduced terraces. Channels were built on the side of terraces, which do not allow the collection and infiltration of rainwater. Instead long channels parallel to the terrace fields were constructed. A similar case was reported in Tigray, north Ethiopia, about the structural design problems of check dams, which failed not considering important parameters. As a result check dams failed up to 39% after two years of construction (Nyssen et al., 2006).

## Deforestation

Deforestation is a serious environmental problem in the study area. Forest cover has declined by 23% from 1972 to 2006 and the most significant change took place from 1986 to 2006. Change was greatest in the lowlands and remarkable episodic forest changes also occurred. According to farmers, the main driver for deforestation is agricultural land expansion, in response to local population increase and decline in agricultural production. Growing fuel wood demand, locally and nearby towns, is another chief cause. Forests also suffered from recent settlement and cash-crop farm expansions in the lowland, government upheavals, land tenure, and changing forest policies. The vegetation removal has in turn resulted in the lowering of the resilience of the soil to erosion and aggravated soil erosion by water. Hurni (1993) has demonstrated the effects of vegetation removal on soil erosion in Ethiopia. He has estimated the average rate of soil erosion in forestland about 1 ton ha<sup>-1</sup> year<sup>-1</sup> whereas soil erosion in cultivated land as high as 42 tons ha<sup>-1</sup> year<sup>-1</sup>.

The Chenchu escarpment for instance is one of the areas, where wood resources are highly exploited. The people from the lowlands and middle altitudes have accessed this woodland for collecting fuel wood. A large number of people are also making their livelihood by selling wood that has been collected from these places. In the 1970s and 1980s, there were tight rules and regulations on how to cut and use the wood from the woodland and as a result the forests along the escarpment were not intensively exploited. However, the situation changed and deforestation was exacerbated during the transition of government in the 1990s and this forest exploitation has been continued until present. These woodlands also provide pasture for the cattle from the surrounding area. The over-crowded livestock graze inside the woodland during the rainy seasons when the lakeshores are covered with water. This has resulted in high surface runoff and flooding that strongly affects the adjacent lowlands during the rainy seasons. Hence, gully erosion and sedimentation are serious problems in the lowland that hinder agricultural activities and affect the infrastructure. The farmers in the lowland are also aware of the causes of gulying and flooding. They stated that the massive destruction of forests in the recent past is one of the major causes. On the other hand, the people of the middle altitudes have been using the woodland as a source of fuel wood since the 1960s (Jackson et al., 1969). Thus there is a conflict of interest between the highlanders and the lowlanders. The highlanders see the woodland as a resource to be used for fuel wood, while the lowlanders see this woodland as something to be preserved to protect their land from gulying and flooding.

## High intensity of grazing

High intensity livestock grazing has also exacerbated soil erosion in our investigation area. Livestock tending is the main integral part of the agriculture system. It has played an

important economic and ecological role in the area for a long period of time. However, the shortage of cattle feed is one of the main problems, which is mainly caused by a conversion of large grassland areas to farmland. In particular, private grazing land was totally abandoned. The shortage of grazing land forces people to graze their livestock inside the remaining forests. It is clear that grazing inside the forests affect the regeneration of trees and other plant species. The land with the then lower plant cover density is also susceptible for water erosion. Moreover, the tracks of cattle have caused the compaction and sealing of the soil. When soils are sealed, rainwater infiltration is reduced drastically and surface runoff is generated in large amounts during heavy precipitation events. As a result, visible soil erosion such as hallow-way gully erosion is apparent inside and along the forests. Similarly, the paths of sheep were the principal driver in causing gully formation and widening e.g. in Easter Island (Mieth and Bork, 2005).

### Roads and footpaths

Along with deforestation and overgrazing, road construction was also a major factor for gulying in the area. A road that runs to Chench town from the lowland and a road that runs to Arbaminch from Zighetee area in the escarpment, were the major causes for runoff generation during heavy rainfall events and thus for deepening and widening of gullies. In these roads, the unpaved ditches bordering them are too small to collect, infiltrate or remove the surface runoff during extreme runoff events. In addition, concentrated runoff is not lead after short distances into the neighboring forestland for infiltration. As a result, gullies were formed and enlarged. These gullies have also caused the deposition of a large amount of sediments in the cultivated land in the rift valley. Footpaths were also among the factor in enabling gully erosion as we discussed in the preceded section. Nyssen (2004) has also reported the effects of roads on gulying in Tigray, Northern Ethiopia.

### Land degradation

Sheet erosion and rill erosion are wide spread phenomena in the highland, particularly on steep slopes that are used agriculturally. They also resulted in the formation of bare land which is marked by rock outcrops and in some cases compacted soils. The infiltration on such land is very low and consequently generation of over land flow is high. The rivers carry a part of the eroded material to lake Abaya. Thus the colors of the water of the lake are brownish, indicating the color of soils. Thus the colors of the water are brownish, indicating the color of soils. These degradation processes have in turn triggered the gully formation and widening. Similarly, one of the main factors for gully head retreat in Tigray was land degradation (Frankl, 2011).

## **4.3 Consequences of gulying**

The problems of soil erosion and gulying are rampant and affect the environment and livelihood of the people. Gullies caused the removal of large amounts of soils and the subsequent depositions. In doing so, the agricultural activities of the highland from which the soil is removed and the lowland to which the soil is deposited are affected. The impacts of gulying on land alteration and triggering of flooding are also high, for example the frequent occurrence of flooding in the town of Arbaminch. Blockage, cutting of the side of roads and sediment deposits on the roads is another adverse effect of gulling. Namely the road, which runs from Arbaminch to Addis Ababa, is often affected. In general gulying has resulted in a

highly modified and altered landscape that has immense implications on the environment and the livelihood.

The majority of farmers in the highland stated that soil erosion is one of the main reasons for the decline of agriculture production. Soil removal is one of the processes of erosion in the highland area that resulted in lowering of soil depth. Shallow soil is prevalent particularly on the steep slopes of the highland. Shallow soil is marked by poor storage of nutrients and soil moisture. It enhances high surface flow rates and thus a decline in the infiltration of water. As a result, the moisture in soil is low. Moreover, we have observed that people were cultivating the shallow soils with much less fertile sub-soil horizons or even saprolite on steep mountain areas. This type of cultivation has further effects on accelerating soil erosion. Moreover, the costs of replacing of the nutrients, which are removed by soil erosion, by mineral fertilizers are high and often they are beyond the farmers' capacity to afford. All interviewed farmers unanimously pointed out that the shallow soil is formed by soil erosion and thus they found difficulties to grow their variety of crops. Instead they left the soil for tree growth and in some cases this land is left for growing grass.

The deposition of sediment, which was eroded by gullying, has also massive impacts on the agricultural activities in the lowland. Sediment was often deposited on top of the cultural plants and impedes the growing of crops as reported by the farmers. Moreover, deposition of sediment in the irrigation channels of the lowland is also a common phenomenon. Irrigation in the lowland has been practiced over five decades. The total area of irrigation is 1336 ha and about 3246 households are benefiting (Bantero, 2006). In 1996, weirs were constructed along the river Hare to control the flow of water. Major canals were constructed, with a length of 5 km and seven secondary canals, which have a total length of 13 km. The water from the secondary channels is distributed to farmer's farm field. These secondary channels however are not functioning properly because of sediment deposition that filled them. As a result the water capacity of the channels is declining and overflow is occurring frequently. During extreme rainfall events coupled with poor management irrigation water channels were breaking and water flew uncontrolled over the irrigated arable land, causing sometimes gully erosion. Farmers reported that about 1 ha out of 56 ha of cultivated land was abandoned due to gullying. Material that has been deposited in the channels has also to be removed during every rainy season as reported by the farmers. The labor requirement to remove sediment is high. Usually groups, which are facilitated by the local water users committee, carry out the removal. Sediment deposition in dams due to water erosion in the catchment is also a wide spread phenomena for instance in Tigray, Northern Ethiopia (Nyssen, 2004).

Moreover, the effects of gullying are immense in Arbaminch town. The town is the capital city of GamuGofa zone and has a total population of 82,500 (CSA, 2006). Gullies, which were initiated on the foot slope of the escarpment, extended down to the town. Moreover, there are several sporadic gullies in different places of Arbaminch. We also observed high runoff and associated gully formation in the town just after high precipitation events. Flooding that is triggered by gullying has affected the town several times. For instance, a huge damage on livestock and humans occurred during a heavy precipitation event in 2006.

Gullying and associated flooding has also affected the road that runs from Arbaminch to the other cities such as Addis Ababa. The problem of flooding was severe during each rainy period. During rainy seasons it caused the destruction of bridges and thus the blockage of the road. Moreover, gullies cut the sides of the road and then prohibited the passage.



Furthermore, the impacts of gulling, along with soil removal, sediments deposition and aggravation of flooding, caused badland formation, e.g. in Ezo Guelle areas. In this badland all soils are removed and saprolite is extensively eroded. The sediment has a variety of colors such as bright brown and red. This land is impossible to recover – at least for the next centuries. There are also other areas in the region, which are badly affected by gulling and which can be recovered when a large amount of money is invested. Gullies in the lowland are very deep and wide, thus they cannot be crossed by foot. It is reported, that the falling of humans and cattle into gullies caused life damages. Gullies in the lowland have also been expanding over time and taking large amount of land, too. Furthermore, gullies have massive impacts on creating unstable topography, which favors the occurrence of mass movements on environmentally sensitive areas, namely on the steep slopes. In consequence it affects the land availability for cultivation. Erosion sensitivity of the steep slopes largely increases and thus the high probability of huge land loss in the future. The impacts of gullies are exacerbated due to the interconnectivity of gullies.

The badlands, deep and wide gullies and the ripple effects of gullies on mass movements thus affect the land availability for cultivation. This worsens the existing problem of the land shortage. At present in the area the household per capita of farmland is in average close to half a hectare. Gulling thus intensifies the problem of cultivation land shortage. Large areas of cultivated land will also be cut away and not used for cultivation for the foreseeable future if the problem is not unabated. The overall effects of gulling are thus massive on the agricultural production and activities of the areas. The livelihood of the people is highly affected and present poverty conditions would also worsen.

#### **4.4 Attempts to combat soil erosion**

Various attempts have undertaken to combat sheet erosion and gulling in the investigated area. These include afforestation, terracing and setting of gabions. Forests were planted during the massive afforestation programs, known as the “Green Campaign”, which took place across the country in the 1980s. Most of the plantations took place on the top of mountains, on ridges and on steep slopes, namely at *Dorze*, *Surra*, *Ezuma*, *Dega Shara*, *Meze* and *Mesho*. A large number of people participated through food-for-work programs. They first constructed terraces, using stones or soil depending on the available materials, and then they planted trees on the newly established terraces. The dominant tree species in the community wood plots are *Eucalyptus globulus* and *Juniperus procera*. Other tree species include *Hegannia abssyynica*, *Pinus patula* and *Cypressus lusitanica*. The total area covered by community forests in 1987 was about 650ha, according to the agricultural bureau report. In general, the community woodlots have brought significant landscape changes to the area.

However, the majority of the people have a negative view towards the communal woodland due to its impacts on dwindling pasturing land. In the past, before the plantation of trees, the land of the community wood lots was grazed by cattle and had been a very important source. Additionally, some trees of the community woodlots are exotic, mainly eucalyptus, which does not allow the growth of herbs and grasses, thus impeding cattle grazing. The hydrophobic nature of eucalyptus trees accelerates soil dryness and triggers gully development. Studies in Tigray, northern Ethiopia, reported that eucalyptus trees which were planted on the wetland and on soils, which have a vertic property have initiated and aggravated gully development (Nyssen, 2006; Frankl, 2011).

The people's trust in community wood lots has deteriorated and thus they do not care for and protect the woodlots any more. There is also a report of illegal cutting of trees from the community woodlots. Particularly massive forest destruction along the escarpments took place during the government upheaval in the 1990s.

Terracing has been introduced and implemented in the areas during the last five decades. Similarly, the introduced terraces inconvenience farmers – they developed negative attitudes over these terraces. This is because of the structure of the introduced terraces did not consider the existing problems and sizes of the individual farmer's land, instead marked by a rigid design that should be applied according to the universal features of the terrace planning. It has also failed to take into account farmers' traditional knowledge of land management practices. In some cases the design was wrongly implemented and there was an incidence of gully formation at some specific areas, such as Zollo, Chenchu. The negative views on the introduced terraces are not the result of farmers' ignorance but a result of negative experiences and disadvantages of the terraces clearly identified by the farmers. As a result, in most cases terraces are either demolished or hardly maintained. As told by some informants, in one specific area the people have demolished seven times the introduced terraces during the last fifty years. The very low rate of adoption and continued usage of introduced terraces by farmers was also reported for different regions of Ethiopia (e.g. Bewket 2007; Admassie, 2000).

Recently, gabions, cylindrical containers made of thick galvanized wire and filled with stones, have been set on gullies in the lowland. The basic intention of using gabions were to trap sediments and to decrease the velocity of the runoff and thus to stabilize the gullies. Gabions have been implemented in the area with the assistance of Nongovernmental Organizations. Similarly, gabions have also been used in Ferta-Gonder, northern Ethiopia, by the help of German Society for Technical Cooperation, GTZ. The cost benefit analysis of gabions on averting gully erosion was conducted and showed a positive signal (Yitabrek et al., 2012). However, the extent of coverage by gabions in the study area is small compared with the intensity of gully erosion. Combatting gully erosion can only be successful when the whole catchment of a gully system is managed sustainably - thus gabions are only one important measure.

Despite the various measures to reduce sheet, rill and gully erosion as discussed above, gully erosion development is rampant in the areas. Gully erosion occurs in various topographies and at various intensities. Gullies develop in the cultivated land, in the grazing areas, in the fringe and within Arbaminch town, on and near footpaths and roads and at irrigation fields. Thus site-specific attempts to address the problem have a paramount importance and would also be very effective. The key question to be addressed is: How can gully erosion be avoided or at least reduced under the conditions of a densely populated and intensively used area with sensitive soils and steep slopes?

Gullies in Ezo Gulle area already changed to badlands (Figure 4). They lost soils, including saprolite. Thus it is impossible to treat such gullies. The solution to be taken is to plant grass and trees to the immediate closest areas to avoid or minimize further runoff generation and

Figure 4 Gully in Ezo Gulle area



expansion of gullies. Footpaths are responsible for the formation of such gullies and measures should also be taken in the future.

In general, people and animals have to walk from side to side, from village to village. So, the frequency of the use of paths cannot be reduced. Thus only the position of paths can be moved to less sensitive areas. Paths should not lead down a slope following the steepest inclination. They should be installed diagonally leading down from a divide to the valley with a low inclination of each path. Every 5 to 10 m on the uphill side of a path holes should be dug, where runoff could infiltrate during and after heavy precipitation events. During other periods cattle might graze the holes. Thus the length of runoff streams will be reduced and gullying will be avoided. Theoretically a second measure would be to vegetate the area aside a path. But due to the high number of passing animals they would eat any nearby vegetation. This is unavoidable.

Road construction should also be given high attention to reduce gullying in the area. In the road design and construction, people should take into account the rate, intensity and magnitude of runoff. It is recommended that agents who are responsible in road construction have to conduct a sound environmental impact assessment before a road is constructed.

Gullies in Zollo area were formed due to the wrong design of introduced terraces and hence measures have to be taken accordingly. In this regard, lessons can be drawn how the indigenous terraces on steep slopes are constructed, e.g the traditional terraces at Dorze Belle, which are used and functioning well as a protection against soil erosion and land degradation

since at least seven centuries. The traditional terraces are constructed in such a fashion that a channel lets water nearly horizontally at short distances onto each farm field. Stonewalls of the indigenous terraces are also porous to some extent to allow the exfiltration of water. This promotes drainage by increasing infiltration rates, resulting in the improvement of soil moisture contents. As a solution to stabilize the existing gullies, which were induced by the wrong design of introduced terraces, herbs and grasses have to be sown first on the gully walls. After some decades, when the gully walls are stabilized and a humic horizon has developed, trees should be planted. In addition, check dams can also be constructed to reduce runoff velocities and to increase infiltration. Generally, there is hardly any attempt by planners to evaluate the performances of introduced terraces yet. Thus there is a strong need to carry out integrative activities in participation with the experienced farmers which help first to identify the reasons for the terrace failures and then to implement effective systems. High attention should be paid on the design and construction of introduced terraces when mobilizing a mass of people for terrace construction. Terrace monitoring systems should also be installed in order to avoid such errors.

Gullies are deep and wide at lowland and thus neither check dams nor terrace constructions can be remedies to stabilize them. These gullies have also cutting the sides of the roads and so the need to take immediate action before the damage is further aggravated. One part of the solution is thus intensively setting of gabions. The cost of gabions is very high. Farmers cannot afford them. Thus along with the nongovernment organization assistances, the support of the government would also be crucial. In addition, vegetation (first herbs and grasses, which are not grazed, later trees – see above) can also be planted on the side of the gully walls. More importantly planting of trees (excluding eucalyptus on sensitive sites) on the escarpments has a paramount importance to reduce the intensity of runoff and thus gully expansion would be lowered. In afforestation, planting of indigenous trees is advisable because they allow at least partly the regeneration of valuable ecosystem (with its services for all live) and they allow the growth of different understory grass, too. Furthermore, cattle grazing inside the woodland should be restricted and controlled, e.g. by local farmers associations. There should also be some mechanisms for the cattle fodder. For instance, to grow palatable grass inside the forest and to let the people use it by cutting and to carry it outside.

The most important work on preventing of gullying would be implementing watershed management. As gullying is spatially interconnected and runoff is generating in their catchments, too, the measures at watershed level have a paramount significance. Watershed management planning should be based on community participation from the conception phase to implementation, evaluation and maintenance. The knowledge and practices of the local people have a great importance for the sustainability of the land management. In the planning along with soil water conservation measures, livelihood fulfillments and strategies should also be given emphasis. This is because the techniques, which were developed over generations, have deteriorated due to the poor living conditions during the last decades. For instance the enormous decline of the use of manuring, fallowing, crop rotation is attributed to the reduction of agricultural production and scarcity of cultivated land.

## Conclusions

Gully systems in the investigation area are characterized by the cyclic succession of phases of entrenchments with aggradations and with stability and soil formation. Gullies are highly modified and altered landscape elements, which in turn have immense implications on the environment and livelihood of the people. Gullies caused stripping of large amount of soils from the highland and also water availability in the soil for plant growth. In addition, siltation of irrigation channels and weirs at the lowland is one serious obstacle for agriculture. Frequent flooding that is triggered by gullying has also affected the town of Arbaminch during the last few decades. Blockage, cutting of the side of roads and sediment deposits on the roads is another adverse effect of gulling in the area.

In the past gullies were confined only in few places, as reported by the farmers. The extension of areas that are affected by gullying has dramatically increased over the last five decades owing to the dynamics of the social, economic and demographic conditions. These include the intensification of agriculture, deforestation, overgrazing and road constructions. The escarpment and other areas are highly deforested and also used for grazing. The intensity of grazing in the forestland is high, too. According to the informants, before the 1960s, there was no problem of gullying in the area. Gullying started with the clearance of the forest cover on the escarpment. The barren land also aggravated gullying in that rainfall cannot be intercepted nor surface runoff is dissipated in uncovered land. Therefore, the erosive capacity of water flowing down-slope is massively increasing. Moreover, farmers also stated that the 1990s construction of the road that runs to Chench town from the lowlands was another cause for the deepening and widening of gullies. The road drainage is insufficient. Concentrated runoff is no longer led into the forestland after a short distance. Hence, at present gullying occurs in various topographies and with varied intensities. Gullies develop in the cultivated land, along the grazing areas, in the fringe and within Arbaminch, close to footpaths and roads and at irrigation fields. If the present trends continue large amounts of land will be ceased of agricultural production in the near future.

Various attempts have been undertaken to combat sheet erosion and gully development in the area. Afforestation, terracing and setting of gabions are few among others. Despite these various measures, gullying development is rampant in the areas. The top-down of planning and the negligence of the traditional knowledge are the main drawbacks. The questions to be addressed are therefore how can gullying be avoided or at least reduced under the conditions of a densely populated and intensively used area with sensitive soils and steep slopes? Watershed management that is based on grass root level community participation from the conception phase to implementation and maintenance is recommended. Site-specific attempts to address the problem should also be considered. In the planning, along with soil and water conservation measures, there should also be some strategies to release population pressure and fulfilling the livelihood the people.

Last but not least, this study suggests the importance to identify the incision-aggradation phases of gullies while measuring rates of soil erosion by gullying. In the investigation area, further researches need also be carried out on past land uses and their impacts on gullies. The old gullies are visible in area indicating the past land use impacts. The past land use practices have a wide implication on the present occurrences of the gullies in the areas.

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## Chapter 5

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### **Farmers' perceptions of land degradation and traditional land management knowledge in Southern Ethiopia – resilience and stability**

## **Farmers' perceptions of land degradation and traditional land management knowledge in Southern Ethiopia – resilience and stability**

### **Abstract**

Land degradation is the major economic and environmental threat in Ethiopia. Since the 1960s, the various traditional land management systems have undergone unprecedented changes. Within the context of farmers' awareness of land degradation and local responses to the problems, the objective of this study is to examine the resilience and stability of the traditional land management knowledge in Southern Ethiopia, specifically the Chenchu and Arbaminch areas. Data were collected using interviews, group discussions and field observations. Results of the study demonstrate that farmers have a wealth of experience in identifying the severity, dynamics and causes of soil erosion and soil fertility decline, as well as grazing land deterioration and deforestation. In response to these problems, farmers have developed a wide range of traditional land management practices, supported across the generations by the traditional law (*bennee woga*) and norms. However, the recent changes include reduction and abandonment of fallowing, modification of crop rotation and large-scale reduction of manuring. The resilience of the traditional practices for livelihood requirements is the main driving force for the changes. Thus the environmental and land-use management planning should not only consider rehabilitating land based on traditional land management knowledge but also raising its agricultural productivity.

**Keywords** perception • traditional knowledge • land management • land degradation • south Ethiopia

### **1. Introduction**

Land degradation is a serious threat to agriculture and the environment in Ethiopia. The estimated annual soil loss in Ethiopia is 1.5 billion tons, of which 50% occurs in cropland. Soil loss by water may be as high as approximately 300 tons ha<sup>-1</sup> year<sup>-1</sup> on steep slopes and soil nutrient losses may be as high as 80 kilograms of nitrogen, phosphorus, and potassium per ha and year or more. In general, half of Ethiopian highlands are moderately to severely eroded (FAO 1986; Hurni 1993; Pender 2002). The degradation of soil results in a deficiency of nutrients, decline in water holding capacity, problems with rooting anchorage, tillage difficulties, and drainage problems and flooding. These eventually result in the decline of agricultural productivity of the soil, an increase in susceptibility to crop failures, and ultimately in the collapse of food production, ending in famine. Among other factors, soil degradation is a prominent factor for the decline of agricultural development and the rise in food insecurity in Ethiopia over the last fifty years. Agricultural production only fed 46% of the increased population in the period between 1960 and 2000 (Nega 2000) and the remaining population was dependent on food aid. Over the period from 1985 until 2000, Ethiopia has received food aid amounting to approximately 700,000 tons per annum. Food aid has increased by an average growth rate of about 2.5 % per year from 1980 to 2001 (Clay et al. 1999; Devereux 2000; Mulat et al. 2004).

Low agricultural production, coupled with high population growth, resulted in the massive conversion of forest and grazing land to cultivated land, particularly over the last hundred

years. In the period from 1900 until 1989, about 4.7 million households required arable land to cultivate (Hurni 2007). From 1900 onwards, about 23 million hectares of forestland were cleared, mainly driven by conversion to cultivated land (EFAP 1993). Deforestation is one of the major causes of soil degradation, and also poses a threat to biodiversity and genetic resources, such as the loss of the gene pool of original wild populations of *Coffea arabica* (IUCN 2006). Moreover, considerable areas of grassland were also converted to cultivated land; consequently, the reduction of cattle plus overstocking caused grassland degradation (Benin et al. 2001). Furthermore, farmland scarcity caused farmers to cultivate marginal land and fragile ecosystems. Thus, the major challenges in Ethiopia are to address the problems of environmental degradation and simultaneously increase food production for the livelihoods of the majority of the people.

Governmental awareness and recognition of the problems of land degradation in Ethiopia started with the 1970s famine. There was a general consensus in the government that the famine event was associated with deforestation and soil degradation. As a response, massive soil water conservation (SWC) activities were carried out to mitigate land degradation, with the assistance of international organizations. From 1975 until 1989, terraces were constructed on 1,188,000 ha and about 310,000 ha of land were vegetated. This was probably the largest scale physical reclamation of eroded land in Africa (FAO 1990; NCS 1990). However, in the meantime terraces have been destroyed by local people owing to various reasons, such as structural problems of the terraces, rodent reproduction in the terrace walls, removal of cultivated land by terrace walls, and difficulties in maneuvering plough oxen on terraces. The afforested land was also unpopular because it reduced the area available for livestock grazing and denied access for fuel wood collection (Admassie 2000; Alemneh 2003; Bewket, 2007).

Among several factors that attributed to the failure of the soil water conservation program, the top-down approach is the most significant (Admassie 2000; Alemneh 2003; Bewket 2007). This approach is marked by exclusivity and thus a low level of involvement of the farmers in planning and implementing soil conservation (Admassie 2000). The first assumption of the top-down planning was the universal applicability of the soil and water conservation measures. This means that what works in one place, also works in another place. The second assumption was that local farmers are unaware of erosion and ignorant of its causes and consequences.

However, the people of Ethiopia have long been aware of the problems of land degradation, even before the government recognized the problem. Farmers have been living on the land for centuries and their daily way of life is dependent upon the land resources at their disposal. Thus, their awareness of land degradation is the result of cumulative experiences over a long period of time. The decision of farmers to use and manage the land resources is dependent on their perception of the landscape. Accordingly, landscape change is partly the result of the decisions of the farmers who are responsible for managing the land. Thus perception is one of the factors that determine the state of acceptance and implementation of various land management practices. That is, if the farmers perceive the problems of land degradation – severity, impacts, and dynamics – they decide to use the traditional land management and/or the introduced measures. On the other hand, if the farmers cannot perceive the outcomes of the problems, they do not accept and implement the land management practices.

However, along with perceptions there are also other factors that determine the acceptance, adoption and sustainable use of land management practices. For example, farmers in Humbo-

Wolayita, south Ethiopia (Tegene 1992) and in Gojam, north-western Ethiopia (Bewket 2007) were well aware of the problems of soil degradation but did not implement SWC measures due to technical problems. In addition, despite awareness of the problems of soil degradation, farmers in Umbulo-Awassa in south Ethiopia (Moges and Holden 2007) have not yet implemented SWC because of food insecurity. On the other hand, there are case studies that demonstrate that the perceptions of the problems of soil degradation led farmers in Tigray, northern Ethiopia (Nyssen 2004) to apply SWC. The interplay between perception of soil degradation and implementation of the soil conservation measures proves the role of other factors for farmers' acceptances and adoption of the SWC. It also shows that farmers' perception of the problem varies from place to place depending on the natural, socio-cultural, and economic conditions of the different areas.

The second assumption of the massive SWC programme, that farmers are ignorant of soil degradation problems and measures to combat the problems, has also been ruled out owing to the land management experience of the people. Farmers of Ethiopia are resourceful and developed a wide range of experiences and skills to halt soil degradation and to manage forest resources over many generations. The knowledge is based on the local environmental conditions and has been tested over long periods of time (Westphal 1975). Among the indigenous resource management practices, terracing is the most common and widely practiced in Konso (southern Ethiopia), south Shewa (central Ethiopia) and Hararghe plateau (eastern Ethiopia). Biological measures (intercropping of perennial and annual crops), traditional agroforestry and fallowing have also been practiced in different parts of the country (Kruger et al. 1986; Reij et al. 1996; Osman and Sauerborn 2001). Moreover, there are also well-managed and preserved forests and trees in different parts of the country, indicating the wide knowledge and experience of the local people. For example, forest and trees have covered the land of the Orthodox Church across the country over a long period of time (Wasse et al. 2005). Remaining pockets of natural forest in different parts of the country have also been a common feature (Rahmato 1998; Zewde 1998; Tekle and Hedlund 2000; Bewket 2002). It is also not uncommon to find trees in the middle of farms in some areas of Ethiopia (Rahmato 1998; Zewde 1998). However, in general there were only a few attempts to study the indigenous land resource management practices in Ethiopia, particularly in the present study area, because of a lack of appreciation of by researchers and policy makers (Teketay et al 2003).

The dynamics of socio-economic, political, institutional, and demographic factors which are internal and external to the localities have played an immense role in modifying and changing land resource uses and management in Ethiopia (McCann 1995; Rahmato 2009). Particularly in the past century there have been very significant developments of the agricultural landscapes, forest resources and grazing land. During this period three regimes emerged, namely Imperial, Military and the present government, each with different ideologies, agricultural land utilization, and land policies. The change of the regimes was radical and the impacts were reflected in resource utilization and management. For example, the people's traditional knowledge on land management was highly affected by the land insecurity imposed by the governments. Furthermore, population growth was also very rapid during this period and hence the forest resource management practices in Wello also deteriorated (Zewde 1998).

However, there is a lack of studies in Ethiopia in general, and in the study area in particular, that assess the changes in and resilience of the indigenous land management practices to the

dynamics of social and natural changes. The role of traditional land management practices in combating land degradation has been very significant in the study area for a long time. Thus any changes in the practices will have a far-reaching effect, not only on the land uses and resource status of the area but also on the cultural heritage of the people. This study also assesses the holistic perception of farmers on soil degradation, deforestation and grazing land deteriorations, given the importance of the integration of crop cultivation, livestock raising, and trees to the economy of the people. There are certain studies in Ethiopia that assessed the perception of the people on soil degradation (Tegene 1992; Bewket 2003; Moges and Holden 2007) and on grazing land (Angassa and Oba 2008). However, there has been no attempt that deals with the integration of cultivation, grazing, and forest use. However, this type of study has the potential to reveal the integrated land management of the farmers and their holistic perception of its problems and solutions.

The main objective of this study is to examine the resilience and stability of the traditional land management knowledge during the last century in Southern Ethiopia (Chencha and Arbaminch areas) within the context of farmers' awareness of land degradation (soil erosion, soil fertility, gully erosion) and local knowledge on managing soils, forest and grazing land.

## **2. Methods of the study**

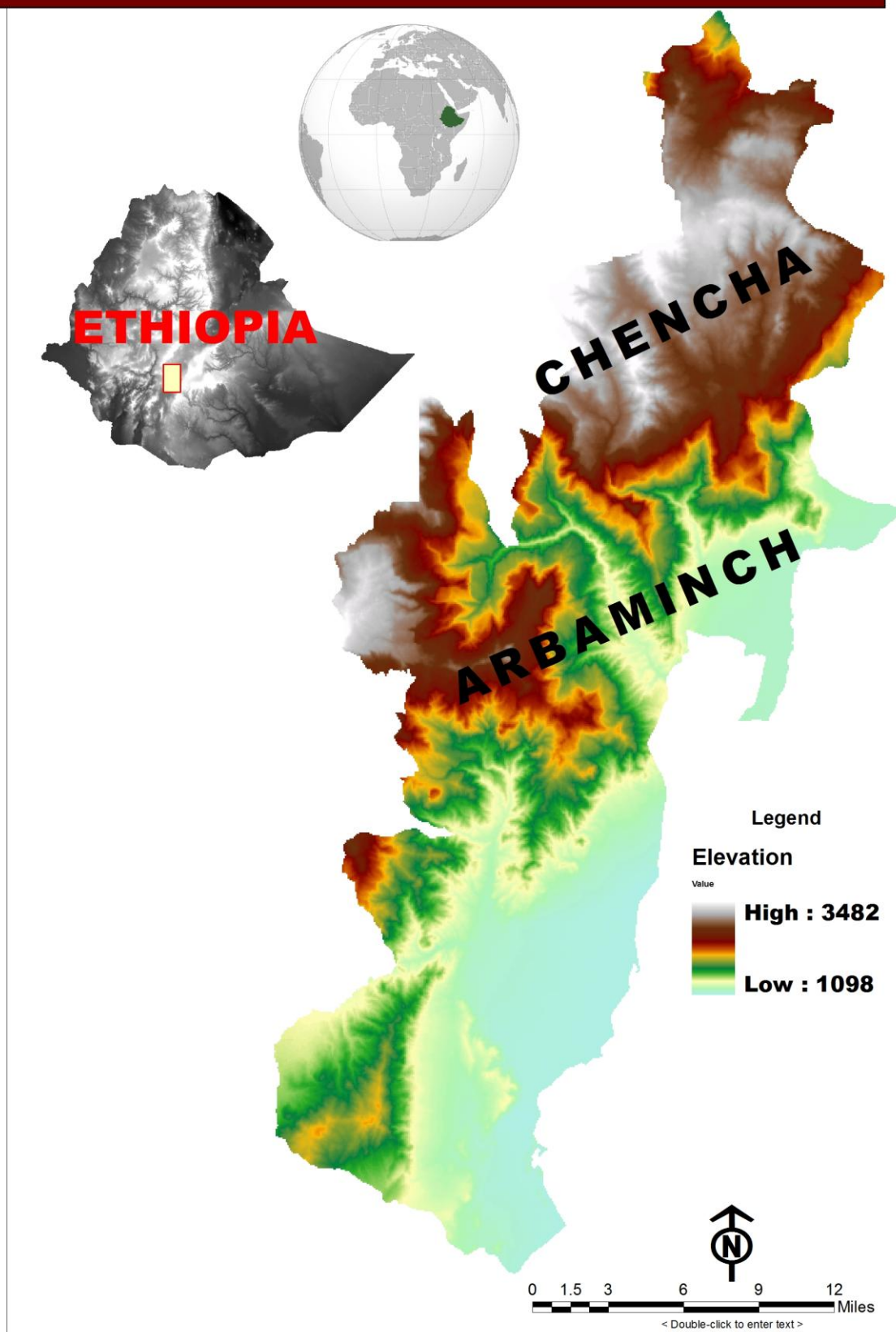
### **2.1 Description of the study area**

Chencha (6° 15' N, 37° 34' E) and Arbaminch (6° 2' N, 37° 33' E) are located in the Gamo Gofa Zone, Southern Nations, Nationalities, and People's Regional State (Fig 1). They are situated about 480 km SSW of Addis Ababa and bounded on the east by Lake Abaya and Lake Chamo. The topography is marked by a series of undulating and rugged landscapes which consist, from east to west, of the rift valley plain with the aforementioned lakes, the escarpment with deeply incised valleys, and high plateaus which are topped by hills and mountains. The lower part of the study area lies on the plain of the rift valley while the middle and upper parts are situated in the southwestern highland of Ethiopia.

According to the traditional agro-climate classification system, which considers altitude only, the study area lies within the *kola* zone (elevation below 1500 m a.s.l.), the *weina dega* zone (elevation from 1,500 to 2,300 m a.s.l.) and the *dega* zone (elevation above 2300 m a.s.l.). For Arbaminch (1,200 m a.s.l.) a mean annual precipitation of 782 mm was measured, while for Chencha (2,700 m a.s.l.) a mean annual precipitation of 1,392 mm was measured. The rainfall pattern is of a bimodal type. The first rainy season, locally known as *gabba*, occurs from March to June and the peak rainfall is 148 mm in April for Arbaminch and 185 mm for Chencha. The second season, locally known as *silla*, occurs from August to November.

In 2005 the population of the *worada* of Chencha was 127,193 (CSA 2006). The density is estimated to about 336 persons per square kilometre. Scientific investigations prove that the area was settled from at least about 3360 years cal B.P. (Arthur et al. 2010). The area is in the centre of the region Gamo-Gofa that is divided into 40 *dere* (small discrete political units). Olmstead (1975) has estimated that 5,000 to 35,000 people were living in the area at the end of nineteenth century. The *dere* was governed at that time by the general assembly and was represented by the high priest, known as *Kao*. At the end of the nineteenth century, however, the region was incorporated into Ethiopia like other southern parts of the country. The main economic activity of the area is subsistence agriculture. People mainly cultivate barley and

**Figure 1. Location of the study area**



wheat in the highlands and bananas in the lowlands. To a lesser extent they also grow peas, beans, potatoes and tree cabbage in the highlands, and maize and *teff* in the lowlands. Enset is the staple food in the area and central to the subsistence agriculture. Raising livestock is also an integral part of the economy. Off-farm activities include weaving and petty trading. The traditional house is made from the stems and leaves of bamboo and looks like an upturned basket. The newly emerging style of housing is rectangular, with walls made of mud and straw and corrugated roofs.

## **2.2 Methods**

An in-depth interview with 120 household heads were conducted that covered different agro-ecological zones: high land (Doko Mesho), middle altitude (Dorze Belle) and lower altitude (Chano Chelba). The interviewees were randomly selected from the lists of the household in the kebeles. The interview questionnaires were composed of both close and open-ended questions that include farmers' perceptions of soil erosion, soil fertility decline, deforestation, grazing land deterioration; measures to halt land degradation and dynamics of land management practices.

The interviews were carried out with the help of assistants. The assistants were college graduates who knew the local languages. Trainings for assistants were carried out conveying ways of establishing contact, methods for conducting interviews, interview procedures, and cultural issues. Interviews were conducted by going to the individual households in the morning and during the afternoon, which are usually appropriate times for the farmers since neither an agricultural activity nor any other activities in which the household head was involved in took place at these times of the day. Interviews were also held outdoors as long as the people were willing to respond to the questions. If the informant was unwilling to give information then she or he was asked to propose someone who would be willing to be an informant.

Before conducting an interview with a household head, the objectives of the questionnaires were explained to gain the confidence of the interviewee and to avoid fear. The interviewees were also informed about the confidentiality of information and interviewee identity. While conducting an interview different probes were also employed in some cases to obtain clear answers. Every day we summarized the daily activities focusing on the unique matters, which were conveyed to the interviewers during interviews. Accordingly, we drew lessons and devised mechanisms for the activities of the following days.

Moreover, three focused group discussions were held. Likewise, the household interviews and the research area were divided into three segments including the Chano Chelba, the Dorze Belle, and the Dokomesho areas. Ten informants were selected from each area. Participants in the discussions were elders (mainly over 50 years of age, both sexes) who could remember and convey past events of agriculture land use. The discussion was carried out based on the checklists that focused on land use history, characteristics, benefits, and limitations of the long term land management practices. Group discussion is an important technique to check and refine the data, which was acquired by structured interviews of household individuals.

### 3. Results

#### 3.1 Awareness of land degradation and perceived causes

##### Soil erosion

The large majority (68%) of respondents to this survey acknowledged the problem of soil erosion on their cultivated land and among them 51% rated the soil erosion as severe (Table 1). The largest segment of interviewed farmers from *Dokomesho* (upper altitude) stated that soil erosion was severe while low numbers of farmers from *Belle* (middle altitude) mentioned such severity. This is mainly attributed to the differences in land management practices, namely traditional terraces which protect against runoff formation and soil erosion processes, which are more common in *Belle* compared to *Dokomesho*. With regards to the trends in severity of soil erosion over the last 40 years, about 89% of the respondents of the lowlands identified an increasing trend. They also pointed out that soil erosion, particularly gully erosion, was especially severe in the last two decades; implying more severe soil erosion in the area at the present time compared to the past. During our field survey, we also observed the recent wider and deeper gullies that threatened the cultivation land and roads.

The most frequently cited indicators of soil erosion by farmers in the highlands (*Dokomesho* and *Belle*) are changes of soil colour, soil texture, soil depth, soil workability and rills. Farmers stated that they frequently observed rill formation on their farmland following the onset of the rainy season. This is the time when the soil is ploughed and ready for sowing. The rain also washes away the sown seeds, showing the high intensity of rain in the area. The colour and texture changes are easily distinguished and evident when farmers plough the eroded land. Different colours and textures of the thin surface layer of the soil, especially on steep slopes, is the result of mixing with subsurface soil material through ploughing. In some instances, we have also observed that farmers have cultivated the saprolite on steep slopes. The removal of the fine texture of the soil by erosion also resulted in soil textural changes. In some cases farmers also observed the domination of stones at the surface as a result of the exposure of subsurface and underlying unweathered material due to erosion. These soil conditions make ploughing difficult. However, the farmers have not stated a deterioration of the water holding capacity of the eroded soil. This is probably due to the sufficient rainfall for the growth of plants and the low temporal variability of rainfall in the area that obscured the effects of soil depth on moisture retention. Farmers also reported the development of gully formation on some slopes due to the inappropriate design of conventional soil and water conservation measures. This is also in line with what we observed in the field. More than 100 persons were involved in constructing bench terraces on a large field and digging one long channel in the direction of the slope that should collect and remove water from the entire terraced field. During the next rainy season surface runoff would have cut a gully into the channel causing flooding on the area below, too. But our assistants from the *wereda* agricultural bureau told the people the right design and they corrected the problem at that site, filling the channel with the excavated material. The design of the introduced soil and water structures is new and it is difficult for the farmers to implement these measures without the assistance of external knowledge from extension workers. This type of problem was also reported by another study (Bewket 2007).

Farmers have also characterized the state of their land based on soil depth, texture, soil colour and workability of the soil. Accordingly, they described eroded land as having thin soil depth,



a coarse texture, a reddish colour and as being hard to plough, while the land which is not seriously affected by erosion was described as having thick soil depth, a fine texture, a brown-reddish colour and as being easy to plough. In addition, farmers have mainly identified steep slope segments as the topographical positions on which severe soil erosion has occurred. Thus, farmers have fragmented their land here. Farmers identified that soil was less exposed to soil erosion along gentle slope segments in the mountains. They also noticed that in the past, soils in most parts (even on steep slopes) were deep, and that these soils had enough depth to support the anchorage of enset roots, while at present the deep soil is found only on the gentle slope segments to which enset cultivation is now confined.

The most commonly cited causes of soil erosion (according to 80% of surveyed farmers) in the highlands were steep slopes and events with high precipitation rates. Steep slopes represent a large part of the highland topography. Precipitation is high and intense here during the rainy season. The removal of vegetation was the second most cited cause of soil erosion (61% of respondents), which was increasingly significant when coupled with steep slopes and intense precipitation. Cultivation of the steep slopes and marginal land caused by the shortage of cultivated land is the main reason for the removal of vegetation; this is also the main cause of accelerated soil erosion.

On the other hand, farmers in the lowlands identified gullies (95% of the respondents) and sediment deposition (87%) as the major soil erosion problems in the area. They also mentioned that the depth and volume of the gullies were increasing at a high rate over the last thirty years. However, there was no problem with gullying in the area more than four to five decades ago. The large majority (91%) of the respondents mentioned that deforestation along the escarpment, which borders the lowlands of the rift valley, was the main cause of gullying. They also stated that the 1990s construction of the road that runs to Chenchä town from the lowlands was another cause for the deepening and widening of gullies; the drainage of the road is not sufficient. During extreme runoff events the unpaved ditches bordering the road are too small. As a result, gullying in the area has caused intensive sedimentation on the cultivated land which is situated below. Sediment was often deposited on top of the cultural plants. In addition, large areas of cultivated land have also been cut away. They cannot be used any more as cultivated land for the foreseeable future. Moreover, sediments have also accumulated at the weirs and in the irrigation canals, affecting irrigation practices. Severe flooding is also another problem that frequently occurs in the lowlands. During every rainy season it causes the destruction of bridges and thus the blockage of the road that runs from Arbaminch to other cities such as Addis Ababa. However, there was no respondent in the lowlands that reported the problems of soil removal by erosion and shallow soil depth. Unlike the highlands, the lowlands are a region where soil deposition dominates instead of soil removal, implying that the types and intensities of soil erosion vary from area to area. Thus the planners should be aware of these spatial variations and site-specific problems of soil erosion while planning.

Table 1: Farmers' perceptions of soil erosion\*

Perception of soil erosion	Highland (Doko Mesho) % of respondents	Mid altitude (Dorze Belle) % of respondents	Lowland (Chano Chelba) % of respondents
Awareness of soil erosion as a problem			
Yes	83	63	68
No	17	37	32
If yes: How serious is the problem?			
High	61	37	54
Medium	26	43	29
Low	13	20	17
Observed changes in the intensity of soil erosion over the last 40 years			
Increase	88	80	96
Decrease	3	14	4
No change	9	6	0
Perceived indicators of soil erosion			
Removal of the top soil	52	43	32
Exposure of the subsoil	76	47	6
Coarse textures	83	87	72
Colour changes	76	52	11
Rills	72	55	82
Gullies	24	31	95
Sediment deposits	11	8	87
Shallow soil depth	87	51	4
Moisture retaining capacity	22	35	16
Ploughing problems	73	67	45
Perceived reasons for soil erosion			
High and intensive precipitation	72	78	61
Soils being erodible	25	33	32
Steep slope	82	89	52
Deforestation and removal of vegetation	63	58	91

\* Percentage does not add up to 100 because of multiple responses

### Soil fertility

Soil fertility decline was identified as one of the serious problems that have affected the agricultural land in the highlands, as expressed by the majority of respondents (Table 2). Almost all respondents confirmed that the fertility of their cultivated land was very low compared to the situation thirty years previously. They have characterized the low soil fertility as resulting in a low plant performance and low yields even during a good rainy season. Farmers have different farm plots and have also categorized the land among their holdings as fertile, moderate and not fertile. They have recognized that soil fertility often decreases with growing distance from their homesteads. They have also grown different types of crops and they manage the land according to the fertility of the soils. The land around

homesteads is fertile due to the application of large quantities of manure in order to grow enset there. Hence enset groves often surround the houses in the highlands. The farm plots which are found at the farthest distance from the houses are marked by poor soil fertility and are often used to grow wheat. Moreover, some farmers have also commented that in the past a small quantity of manure application enabled them to produce sufficient yields, while at present the amount of manure applied to the land should be high in order to get viable yields. The main reasons perceived by farmers for the decline of soil fertility were shortage of manure and uninterrupted cultivation, leading to an abandonment of fallowing practices. Farmers stated that soil erosion was also a factor for the decline of soil fertility, as it caused a removal of fertile surface soil. However, farmers were not aware of soil acidity, which is a serious problem that affects agricultural production in the area (Haile and Boke 2011).

Table 2: Farmers' perceptions of soil fertility loss\*

Perception of soil fertility loss	Highland (Doko Mesho) % of respondents	Mid altitude (Dorze Belle) % of respondents	Lowland (Chano Chelba) % of respondents
Awareness of soil fertility as a problem			
Yes	87	78	32
No	13	22	68
If yes: How serious is the problem?			
High	95	87	18
Medium	5	17	33
Low	0	6	49
Soil fertility changes observed over the last 40 years			
Decreasing soil fertility	97	98	41
Increasing soil fertility	0	2	7
No significant change	3	0	52
Perceived indicators of soil fertility			
Reduced yield	96	98	82
Crop performance	91	89	53
Plant with yellowish colour	83	87	37
Mineral fertilizer is required	86	84	53
Perceived reasons for low soil fertility			
Soil erosion	77	52	31
Uninterrupted cultivation (no period of fallowing)	86	87	61
Low amount of manure application	92	91	56
Decline in crop rotation	74	80	22
Crops residues and dung for fuel wood	7	4	0

\* Percentage does not add up to 100 because of multiple responses.

On the other hand, about 68 % of the respondents thought that there is no fertility problem in the lowlands. This is in line with the fertile nature of the prevailing soil, a Fluvisol. It is characterized by a high nutrient status and high soil water retention capacities and is thus suitable for crop cultivation. Cultivation started in the lowlands during the 1960s, unlike in the highlands where it has been practiced for centuries. However, the dominant problem that deleteriously affects the soil quality of the area is salinization, as expressed by the farmers. This problem is mainly derived from ascending ground water in silty and clayey soils situated in the surroundings of the lakes and in the floodplains of the lowlands, mainly as a result of the lack of effective drainage systems. However, the farmers did not note the causes of salinization.

### Grazing land deterioration

Livestock tending is the main integral part of the agricultural system in the study area. There are several sources of cattle feed. The principal sources are common grazing land, which is mostly found on the summits of the mountains in the highlands and along the lakeshores in the lowlands, and pastures within woodlots and forest. Other pasture sources, such as fallow land, cultivated land after harvest, marshland, market places and the borders of roads and paths, are also important sources. Stall feeding is common for milk cows, for fattening and for cattle prepared for sale or slaughter. Chopped enset leaves and grasses from marshland are mainly used for stall feed. The solid remains of local beer are used for sheep fattening.

The deterioration of grazing land (area of grazing land, inadequate supply of feed, and poor quality feed) was the most widespread problem as expressed by 93% of the respondents of the survey (Table 3). Among these respondents, 74% reported that the problem of grazing land deterioration was severe, while 15% stated the problem was moderate. Nearly all surveyed farmers recognized the dynamics and were aware of the increase in the problem over the last forty years. In the lowlands, however, the problem of a lack of grazing land was not significant compared with the highlands, as demonstrated by the interviewed farmers. 45 % of the respondents in the lowlands mentioned the severity of the problem, compared to 89 % in the highlands (high and middle attitudes).

Shortage of grazing land, inadequate feed supply, and poor quality of grass were the most often mentioned indicators for the deterioration of grazing land. Nearly all respondents claimed that a large proportion of grazing land was converted to cultivated land and consequently a grazing land shortage had occurred. In the past, almost every farmer had possessed his own grazing land to feed cattle. However, at present only a few farmers have private grazing land and the majority of farmers converted their grazing land to cultivated land. Farmers could categorize the quality of the grazing land based on the colour and height of the grass. They categorized green and tall grass sites as good quality land while short and brown grass sites were evaluated as poor quality land. As reported by farmers, the community grazing land has been the most deteriorated pasture land, especially during the dry season. However, farmers did not recognize soil degradation in the grazing land and the impacts of overstocking on herbaceous plants inside the forests. But high livestock stocking, particularly of sheep, inside the forest exerts tremendous pressure on soil deterioration and herbaceous plants.

The majority of respondents (87%) in the highlands stated that a conversion of large grassland areas to cultivated land was the main cause of the shortage of cattle feed. Such a conversion at a large scale also occurred in the 1960s as reported by Jackson (1967). Currently large areas of communal grazing land have also been converted to cultivated land in order to distribute the land to landless people. This is also reported by various studies that were conducted in the area (Ogato 2005). The principal reasons for the conversion of grazing land to agricultural land were population increase and the decline of agricultural production as expressed by the informants. Furthermore, large areas which were used for grazing in the past, were afforested – another cause of shortage of grazing land. The problem of grazing was exacerbated by forestland on steep slopes where exotic trees, predominantly eucalyptus, grow, which prohibits the growth of grass.

Table 3: Farmers' perceptions of grazing land deterioration\*

Perceptions of grazing land deterioration	Highland (Doko Mesho) % of respondents	Mid altitude (Dorze Belle) % of respondents	Lowland (Chano Chelba) % of respondents
Awareness of grazing land deterioration			
Yes	96	98	85
No	3	2	5
If yes: How serious is the problem?			
High	87	90	45
Medium	9	9	53
Low	4	1	29
Changes observed in grazing land over the last 40 years			
Increased deterioration	99	100	98
Decreased deterioration	0	0	0
No significant change	1	0	2
Perceived indicators of grazing land deterioration			
Scarcity of grazing land	93	96	69
Overgrazing of pastures	87	92	78
Insufficient feed	88	89	53
Lack of alternative feed	85	78	46
Quality of feed	75	74	57
Grazing land degradation (soil erosion)	16	21	27
Perceived reasons for grazing land deterioration			
Conversion to agricultural land	75	69	74
Grazing land used for afforestation	53	65	32
Increased number of cattle	32	31	82
Drought	25	26	42
Increased human population	67	71	73
Poor management of community grazing land	41	53	62

\* Percentage does not add up to 100 because of multiple responses.

The shortage of grazing land that resulted in feed shortage and the decline in the quality of feed has caused an intensive reduction of the number of cattle in the highlands. In addition, it resulted in an important change: people now raise sheep instead of cattle. Sheep browse all available leaves in the forest; their feed requirements are lower than those of cattle. However, sheep as a browser have negative impacts on the biodiversity, which is not recognized by farmers. Despite the decline of the extent and the quality of grazing land, the number of livestock increased in the lowland due to the impact of animal health services (vaccinations and treatments), particularly the disappearance of trypanosis. The availability of grazing land in the lowlands is better than the highlands.

## Deforestation

A large proportion of interviewed farmers (57%) acknowledge the problem of deforestation. Among these respondents, 64% conveyed the severity of the problem. The farmers were asked if they had noticed the rate of changes with respect to the extension of forest clearance particularly in the last forty years. In this period two regimes changed land-use and land tenure radically. 56 % of the respondents expressed that deforestation increased at high rate. In our discussion with old people, they also pointed out that most of the land, especially the hilly mountain area, was covered by forest in the time of their parents. However, at present these areas have been brought under cultivation. Farmers are also aware of the increased plantation of forests and household tree plantation over the past three decades. They did not only recognize the changes of the size of forest cover but they are also aware of existing forest deterioration. They described how sunshine could not be seen inside the forests, along the lakeshores for example, in the past but today the sun may heat even the soil surface inside the forest, proving the severity of forest degradation. Furthermore, farmers recognized endangered tree species. They reported that *Cordia africana* and *Aeschynomene elaphroxylon* are tree species which are under threat of disappearance.

The decline of forest cover is a result of the significant changes in farming land expansion (as expressed by 97% of the respondents) along with increasing fuel demand (83% of the respondents) and settlements (56%). They mentioned that the main reasons for agricultural land expansion are low agricultural production and population increase. An increase in agricultural land at the expense of forestland, particularly during the last fifty years, was also a widespread phenomenon in different parts of Ethiopia, as reported by various studies (e.g Zeleke and Hurni, 2000; Dessie and John, 2007). Moreover, fuel wood is the main source of energy for rural people and the surrounding urban population of Arbaminch and Chencha towns. These increasing demands have in turn led to a shortage of fuel wood; subsequently the people have travelled over long distances to collect wood. In particular, women who are responsible for wood collection have to walk for hours to collect it. This is also another hardship for the people. During the last five decades, settlement and agricultural practices in the lowlands have also resulted in massive forest clearance.

Sheet and rill erosion are rampant in the highlands, particularly on steep slopes. Soil erosion enabled by deforestation and agricultural land use is the main reason for the decline of agricultural production in the highland area, as expressed by 85 % of the respondents. The vegetation removal has in turn resulted in the lowering of the resilience of the soil to erosion and aggravated soil erosion by water. Likewise in the investigation area, the impact of forest removal on soil erosion was also reported by several studies in other regions of Ethiopia

(Hurni 1993; Tadesse 2001; Tekle and Hedlund 2000; Bewket 2002). Gully erosion is a serious problem in the lowlands in particular. The main reason for the widespread formation of gullies is deforestation. According to the informants, more than four to five decades ago there was no problem with gullying in the area. It started with the clearance of the forest cover on the escarpment.

### **3.2 Traditional land management knowledge and practices**

#### Soil management

Soil erosion and soil fertility decline are the major land degradation problems identified by the majority of farmers in the highlands, while farmers in the lowlands were aware that gullying and flooding are the main problems that affect their agricultural activities. Nonetheless, 78 % of the respondents in the highlands believed that they could solve the problem of soil degradation, although 22 % of the respondents reported that they found it hard to halt the problems. Conversely, 73 % of the respondents in the lowlands reported that combating gullying and flooding is not likely. Flooding has been occurring frequently and affecting the cultivated land and the roads. Gullies have taken large areas out of agricultural land use. Besides, farmers were not familiar with these problems before the 1990s, when the removal of the forest on the escarpment began. Thus they did not develop traditional techniques to control the problems. With regard to the solutions, most farmers are waiting for the government or non-government organizations to solve the problems. Since the main cause of the problems of gullying and flooding is the removal or high exploitation of the forestland along the escarpments that are situated above the lowlands, farmers in the lowlands do not have any power to stop the destruction, as the areas are not under their control. The remedies to the problems are thus the application of watershed management practices.

In response to the soil degradation problems, farmers have developed and used various traditional management practices evolved over the course of time from the people's farming practices. These management practices provide various benefits such as the reduction of soil erosion and the conservation and enhancement of soil fertility. The main practices include terracing (used by 51% of the surveyed respondents), manuring (used by 75% of the surveyed respondents), fallowing (used by 24 % of the surveyed respondents), crop rotation (used by 44% of the surveyed respondents), and cultivation of grass and trees along strips (used by 45% of the surveyed respondents). Among others, manuring, crop rotation and fallowing have undergone significant changes during the last four decades.

#### Terraces

The traditional terrace, *kella*, was built over generations based on the farmers' perception of the problems, as well as their knowledge, skills, energy, and survival strategies. The main purpose of the traditional terraces is to keep the soil from erosion by water and to reduce the negative effects of surface runoff. Among the surveyed households, about 51 % reported that they have been employing *kella*. In particular, terraces are most widely practiced (by 82% of the surveyed farmers) in the middle altitude, *Belle* area, because of the dominant steep slopes and an abundance of stones. However, soil was also used to construct terraces.

*Kella* are very strong and they last for a long period of time (a minimum of eight years or more without maintenance) as expressed by farmers. These terraces are maintained when they

are broken or sometimes washed down by high amounts of runoff, which usually occurs in April and October. The maintenance is carried out by groups of people. In addition, cattle deteriorate the terraces as they graze on the terrace fields after harvest (they are common property for cattle grazing after harvest). There are usually minor damages to terrace walls due to grazing activities and thus the individual farmers take care of and maintain them during the ploughing time. Labor requirements in constructing and maintaining terraces are very high. There is sometimes a need to bring stones and boulders over long distances. This problem is exacerbated when labour shortages in the area occur due to the migration of persons to other places in search of different jobs. The old people said that their parents worked hard to maintain the terraces, harder than they have done. The old people also reported that the maintenance of terraces is a declining trend, owing to less effort and time devoted to them by the younger generations.

Moreover, the agricultural bureau of the *Wereda* also introduced terracing (conventional terraces) in the area in the early 1970s. However, these terraces are not popular among the farmers, as 75 % responded. Frequently cited reasons for the poor performance of these terraces are their labour intensive construction and maintenance, that space is taken away from agricultural production, the problems of ploughing narrow terraces, and rodents or other pests harboured by terrace walls. Additionally, the structural design problems of the conventional terraces and the top-down approaches to the design and implementation of the plans are other factors. Hence, the unpopularity of conventional terraces is expressed by not maintaining and eventually demolishing them. Some informants even reported that in one specific area the people have demolished seven times the conventional terraces constructed during the forty years of their use. Despite these problems, conventional terrace construction has continued to date instead of evaluating their performance and identifying the reasons for the failures. There is hardly any attempt by planners to evaluate the performance of conventional terraces. Mistakes in the adoption of terraces was also reported for different places in Ethiopia (e.g. Bewket 2007; Admassie 2000).

### Manuring

The overwhelming majority of the respondents (75%) stated that they have used manure in various forms for generations to maintain the fertility of soil. It is an important source of macronutrients such as nitrogen, phosphorus and potassium. This practice is also important in preventing the soil from eroding, through maintaining the soil organic matter content. A good soil structure and soil aggregation, as a result of organic matter, reduces soil erodibility. Thus it improves soil water and infiltration capacities.

Manure is mainly composed of dung and urine of cattle, sheep and horses, household refusal and crop residuals. It is carried by females and accumulated at a few sites near to their houses and on their farmland over a period of one to two months per year. The manure is then spread on the farm fields and turned in by digging; work which the men carry out. There is also a practice of channelling cattle urine from the house to the neighbouring enset groove.

Manure shortage is one of the acute problems in the area. Compared to forty years ago, manure application is declining. About 90% of the informants responded that the decline takes place at a high rate, 8% said that the decline is moderate and the remaining persons stated no significant change in manure application. In the past, manure was applied on large areas of cultivated land. Manure was particularly applied in sufficient amounts on land used



for the cultivation of enset. However, at present, the usage of manure occurs on a selective basis owing to the shortage of manure which prohibits its application at the same intensity across all farmland. Manure is applied preferably on land where enset is grown and – if some manure is left over – on fields with barley. Enset cultivation is only possible with the application of manure, as described by surveyed households. The decline of enset cultivation in the area is also attributed to the shortage of manure.

### Crop rotation

Crop rotation is a temporal system of growing different crops sequentially on the same piece of land. Crop rotation has significant benefits for restoring and maintaining nitrogen since leguminous plants are included in the rotation. Legume plants store nitrogen-fixing bacteria in their nodules. They are also important for reducing erosion by covering the land surface and to increase the organic matter content of the soil. Ultimately, the productivity of the soil is enhanced.

Crop rotation is one of the methods used by a large number of farmers, about 44 % of the surveyed households, in the area to maintain soil fertility. It is characterized by the cultivation of barley and wheat in the first two or three years and then afterwards peas and beans are grown. Besides crop rotation, the farmers also practice mixed cropping, for example cereals (barley and wheat) grown together with beans and peas.

However, the frequency of crop rotation is decreasing because of the scarcity of cultivated land. People prefer to grow staple food crops such as barley, wheat and enset. In addition, they want also to maximize the benefits they get from the land by growing cash crops such as apple and banana. So they devote their piece of land to growing only these crops. They only mix or rotate with beans and peas when they feel the soil fertility has steeply declined and ceased to sustain plant growth.

### Fallowing

Farmers in the highlands are well aware of the benefits of fallowing to maintain soil fertility. When land productivity decreases for a certain period of continuous cultivation, the land should be rested and allowed to regenerate. During fallowing, grass is grown on the formerly cultivated land and it will be used to feed animals in the fields or at their homestead. Fallowing enables the enrichment of nutrients in the soils. In the rotation cycle cereals were grown during the first three years and then the land would lie fallow for three years. In some other places a period of eight years of cultivation of barley was followed by one year fallowing in the past (Jackson et. al 1969). However, the extent of the use of fallowing is decreasing enormously in the area at present; only roughly 24 % of the surveyed households employed fallowing. The majority of the farmers continue the cultivation of land without any interruption till the land is abandoned due to a significant decline in the crop yields. The only source of livelihood earnings for the people is derived from the land and so pursuing cultivation is the only means of obtaining food for survival.

### Grass and Tree Strips along the Contour

Grass and trees strips along the contours are common agronomic practices in the area that contribute to protecting soils against erosion. Grass strips take up only a small amount of

arable land, unlike conventional terraces. Costs of construction and maintenance are much lower than conventional soil and water conservation measures. Grass is also used for animal feed and for house roofing. However, the young grass strips are not effective in protecting the soil from erosive rainstorms, particularly at the beginning of the rainy seasons. Trees and falling leaf litter are also important in maintaining the soil fertility. The most common trees used in the area for soil fertility enhancement include *Erythrina abyssinica*, *Hagenia abyssinica* and *Croton macrostachyus*. Besides soil fertility improvements and halting soil erosion, trees are also used for animal feed and fire wood supply.

### Grazing land management

Grazing land management practices have evolved over a long time owing to the economic and spiritual significances of cattle in the area. Common grazing, situated mainly on the summits of the mountains and on the top of the ridges, is the principal source of cattle feed. The use and management of this grazing land is directed by social rules and norms known as *benne waga*, which are enforced by elected and hereditary elders. Among others, the rules include planting of trees, house building at the fringes, and prohibition of fires on grazing lands.

Moreover, when the grass is too short, usually at the end of the dry season, the elected elders decree the closing of grazing land. In addition, it is also closed at the end of the main rainy season (end of August). During the closed period, the cutting of grass for cattle and the direct grazing of cattle on the land are strictly forbidden. In order to implement the rules, watchmen (known as *kalo mura*) are elected by the community and placed in charge of controlling and observing. The communities are also ethically responsible for protection and they cooperate with the watchmen. A violation of these rules and regulations is considered a serious breach of the traditional law and is taboo to the community. In any case, if the rules are violated the people believe that the failure of crops, epidemics, and other calamities will follow as a consequence. Hence the punishment for those who violate the rules extends as far as to cast them out from the society. They have to accept sanctions against involvement in any social activities, too. However, it is rare to find these breaches of bylaws, particularly in the recent past. This is mainly because the grazing land is common property, used by every farmer of the community without any discrimination.

The grazing land is then reopened during the *Mesqal* time (local annual festivity), which takes place at the end of September. This allows the re-growth of a sufficient amount of grass and protects the grazing land against deterioration. The system is efficient in managing the common property resources and thus there is no problem of “the tragedy of the commons” in the common grazing lands in the area (Cartledge 1995; Ogato 2006).

Grazing land management in the area was also very impressive in the past (Jackson 1967). Most people used irrigation for their grazing land, which was situated along the streams before the 1970s. However, such practices ceased as the land was converted to cultivated land due to the increase of population pressure.

### Forest Management

Despite the growing human population and the shrinking forests, the traditional knowledge and experiences of the local people on forest management and preservation have played an immense role in the existence of forests and trees. These include relicts of natural-sacred

forest, trees in the fields close to every village, and trees on the farmland and around the homesteads.

Sacred forests are patchy remains of age-old montane forests in the highlands of the study area. Informants cannot trace the origin and age of these forests, as they have existed since time immemorial. This suggests that these forests already existed before the sixteenth century in the area. At present sacred forests are found in eight different places in the investigation area with a total area of about 29 ha, as estimated by local people. Sacred forests are situated in different topographic positions. Most of them are found on the summits of mountains and on the plateaus of ridges. Sacred forests are places where the ritual offering of animals takes place. The main purpose of sacrifice is to have a good future year in which land will be fertile and bear many crops, the crops provide greater yields, precipitation will occur regularly and woman will have babies. Sacred forests are, to a limited extent, also a source of fuel wood and construction materials. However, there is variation in the degree of accessibility to the different sacred forests for obtaining wood. Sacred forests were also used as a defense at times of war in the past. The well-designed and well-constructed stone wall fortifications inside the forests are a witness to this fact. Sacred forests have several ecological significances. They indicate that much of the area was once, in a distant time, covered by comparable vegetation and show the floristic composition of the original vegetation. They are the most important refuge of natural resources, and sources for seeds of the various indigenous tree species.

The people of the area have long had rules and regulations to maintain the sacred forests. They established different rules and regulations regarding access to and usage of the wood from the forest. In the case that someone is identified as violating the rules by cutting or collecting wood, he or she has to pay a sheep as punishment. The sheep will then be sacrificed inside the sacred forest. However, the management of the sacred forest and the state of forests are deteriorating.

Similar to the sacred forests, the traditional management practices of the people have also kept stands of old trees, which are often situated in large grass areas in the highlands of the study area. They are locally known as *Dabush* and are commonly used for gatherings of the local people that deal with their affairs. Government officials also use them to meet with local people for the discussion of issues. *Dabush* are also used as places for annual festival celebrations such as *Mesqel* (New Year), which takes place at the end of September. They are also areas for mourning. The social role and value of mourning are very significant for the people. Additionally, stands of trees also provide fodder for the livestock.

Private woodland and tree plantation are another important aspect of the woodland management practices that are worth mentioning. Trees are at the centre of agricultural practices in the area and thus planting of trees has been a widespread practice for the majority of farmers over a long period of time. The community also acknowledges large areas of tree possession as prestigious and wealthy. Trees are planted on land designated for plantations, in the farm fields, and around homesteads.

The predominant farmers have assigned small plots of land for the planting of trees. These lands are usually found on degraded steep slopes which are marked by poorer soil quality. They are abandoned for cultivation and are no longer used to grow crops. Farmers also plant trees along the borders of paths and roads, as well as along and inside the gullies. Trees of old

age are also common in the farm fields and around homesteads, showing that trees are not only grown on the abandoned farmland. In addition, trees are also planted at the limits of properties and farm or grazing land to mark the boundaries.

Trees have various economic, environmental and social significances for the people. Namely, they are important for daily diets (e.g. moringa), as sources of cash crops (e.g. coffee) and they also provide fuel wood. Trees are also important for beekeeping (apiculture). These trees are also a source of income during crop failures; cash from the sale of wood is used as insurance. Along with their use as fodder for livestock, trees serve as shade during the high sun period when the land is used for pasturing. The people are also aware of the environmental significances of trees, such as maintaining soil fertility (e.g. Erythrina, Hagenia, and Croton) and acting as barriers for surface runoff and soil erosion. Furthermore, trees have traditional religious significances, namely they are a place of spirit dwelling and sacrifice (Cartledge 1995). Juniperus is considered as important for rituals and wooden statues. This all clearly implies that trees are at the centre of agriculture with wider social significances, too.

#### **4. Discussion and conclusions**

The majority of the farmers have a wealth of experience in identifying the severity, dynamics and causes of soil erosion and soil fertility decline. The indicators that farmers employed to determine soil degradation are comparable with the findings of researches which were conducted to identify the perception of farmers on soil degradation in Ethiopia (Tegene 1992; Eyasu 2002; Bewket 2007; Moges and Holden 2007). In addition, farmers have categorized their land according to soil erosion intensity and soil fertility status and land-use patterns are also linked to this categorization. Farmers' awareness of the problems of land degradation in the area stems from their long experiences of land-use and land management and their exposure to information. The people have been living on the land for centuries and their livelihoods have also been dependent on the cultivation of crops and livestock rearing (Cartledge 1995; Arthur et al. 2010). These land-use experiences contributed to the farmers' perception of the fertility status of the soils and the intensity and impact of soil erosion on agricultural production. Moreover, steep topography and very intense rains characterize the highland area. Thus the prevailing erosion indicators, such as a series of rills and small gullies on a field, texture changes, and soil depth change, are evident for farmers. Furthermore, the programs of the government to implement soil and water conservation measures in the area since the early 1970s have contributed to awareness among farmers about soil erosion problems, even if the programs failed to win popularity. A similar reported result is that, despite the farmers' perception of soil erosion, farmers did not adopt and expand the conventional soil and water conservation measures (Tegene 1992; Bewket 2007).

However there are some other types and processes of soil degradation on farmland which are unknown to the farmers. For example, soil acidity is one of the main problems of soil degradation the highland area ( Haile and Boke 2011) but the problem was not noticed by the farmers. Soils of the highlands are also marked by deficiencies of potassium and phosphorus. However, for a long time the main deficient nutrients of Ethiopian highland soil have generally been considered to be nitrogen and phosphorus. To this effect, development agents (DAs) of the government's Bureau of Agriculture have recommended farmers to use urea and di-ammonium-phosphate (DAP) mineral fertilizer to improve soil fertility. Nevertheless, the application of DAP did not result in a viable increase of yields, partly because it did not

address the problem of potassium deficiency in the soils (Haile and Boke 2011). Likewise, farmers in the lowlands did not recognize the causes of salinization, which is the dominant problem that affects agricultural production in the area. All these factors suggest the need to undertake scientific investigations to determine the processes and intensity of soil erosion and soil fertility in the area besides the local knowledge. Similar recommendations for linking local knowledge with scientific information were also suggested by various studies (e.g. Elias and Scoones 1999; Moges and Holden 2007).

The decision of the farmers to use and manage the land resources is dependent on their perception of the landscape. To this end, farmers' perception of the problems of soil degradation helped them to develop and apply a wide range of traditional land management practices, namely terracing, manuring, crop rotation, and strips of grass and trees. There is increasing evidence for the benefits of such practices to the farmers, such as the reduction of soil erosion and enhancement of soil fertility, thereby sustaining agricultural productivity.

Farmers were also aware of the seriousness of problems of grazing land deterioration, which affect the raising of livestock. Nearly all surveyed farmers mentioned feed problems as a result of increasing grazing land shortage. This result is congruent with other studies in Ethiopia (Tschopp et al. 2010; Abule 2005; Angassa and Oba 2008). Farmers' awareness of the problem of grazing land deterioration is derived from various economic, social and ecological uses of livestock. Cattle supply milk, butter and meat. Livestock is the main source of the money used to pay tax, to buy clothes and for other big expenses. Livestock also serves as insurance during crop failures. More importantly, livestock is the major source of manure.

However, farmers did not recognize soil degradation in the grazing land or the impacts of overstocking on the herbaceous plants inside the forests. Grazing of cattle inside the forestland is a common practice owing to the shortage of grazing land. Similar findings were also reported by Tschopp et al. (2010). However, the compaction of soils along paths by cattle caused a dramatic reduction in their infiltration capacity and thus enabled surface sealing, runoff generation, and soil erosion in high amounts during heavy precipitation events. Cattle grazing, too, reduced vegetation cover density in forestland. Grazing prohibits the regeneration of tree species and herbaceous plants. It is also evident that overstocking on the common grazing land also causes grazing land deterioration.

Despite the low awareness of the impacts of livestock grazing on land degradation, farmers have been using various grazing land management practices, such as the seasonal closure of grazing. The use and management of the grazing land is guided by social rules and norms know as *benne waga*. Ashenafie and Leader-Williams (2007) reported similar findings for the *Shewa* region in the central part of Ethiopia. They identified the significances and effectiveness of indigenous management of common property over a long period.

The majority of the respondents are aware of the problem of forest decline. The perception of the problem derived from the benefits and services provided by forests. However, the perception of the problem of forest decline varies from place to place owing to the benefits. This is derived from the conflict of interest between the people in the middle altitudes and highlands, which view the forest differently. For example, the farmers in the lowlands are aware of the impacts of the massive destruction of forests along the escarpments, adjacent to the lowlands, due to the resulting gullying and flooding that affects their land. On the other hand, the people of the middle altitudes have been using the woodland as a source of fuel

wood since the 1960s (Jackson et al. 1967). Thus there is a conflict of interest between the highlanders and the lowlanders. The highlanders see the woodland as a resource for fuel wood while the lowlanders want this woodland to be preserved to protect their land from gullying and flooding. Thus the planning of sustainable forest management should take into account and help to solve such conflicts of interest.

With the growing human population and the shrinking forests, one is impressed by the mosaics of forests, woodlots, and stand trees around the homesteads and in the farm fields. Trees are part and parcel of farm activities and social systems. This indicates the cumulative traditional knowledge and experiences of the local people on forest management and preservation that developed probably several centuries ago. Thus the existing forest and the management systems and institution show the people's identity and sense of place (Cartledge 1995) and their harmonious relationship with the forest.

The long-enduring system of land-use and land management that has prevailed in the area contributed to the stability of the management of the resources. The land-use systems also enabled the farmers to adapt to environmental changes and resources constraints. They have also been a strategy to sustain agricultural production in the area over a long period of time. Thus the area was one of the stable areas with regard to resource use and management (Jackson et al. 1969; Cartledge 1995; Ogato 2007).

However, the local management and uses of resources have been modified, changed and abandoned especially since the last quarter of the twentieth century. The reduction and sometimes total abandonment of the use of fallowing, modification of the crop rotation, and the large reduction in the rate of manuring are the major traditional soil management changes. Traditional terraces have also lacked maintenance and only few attempts were made to construct new ones. Moreover, sacred forests and communal grazing land are at risk of misuse and deterioration. Community grazing lands, which have been used as a principal source of pastures, have been converted to cultivated land. In the past farmers irrigated grazing land; however, irrigation entirely ceased when the grassland was converted to cultivated land (Jackson et al. 1969). Private grazing land, which was an important source of cattle pasture, was also almost completely replaced by cultivated land. Alternative sources of graze, such as grazing inside forests and the use of enset leaves, are also deteriorating. The forestland with exotic trees (dominated by eucalyptus) on steep slopes prohibits the growth of grass. This in turn resulted in the shortage of grazing land and the overstocking of cattle, consequently leading to grazing land deterioration.

The unprecedented changes to the systems of land-use and land management are attributed to various factors. Among others, the principal reason for the change in the traditional practices is derived from livelihood activities. The factors for the reduction in and abandoning of fallowing are scarcity of arable land and the decline of agricultural production. Manure application has also reduced at a high rate till the present time due to the dwindling of cattle. This is again due to the conversion of grazing land to cultivated land. The decline of crop rotation practices is also attributed to the scarcity of cultivated land. People prefer to grow staple food crops such as barley, wheat and enset. In addition, they also want to maximize the benefits they get from the land by growing cash crops such as apple and banana. So they devote their piece of land to growing only these crops. Moreover, the lack of off-farm employment keeps the people heavily dependent on the cultivation of their land. This is also a factor that contributes to the enormous pressure on land. In general, therefore, the only source

of livelihood earning for the people is derived from the land and so pursuing cultivation is the only means of obtaining food for survival.

Moreover, the threat of the loss of integrity of the traditional culture is one of the main risks facing the sacred forests and common grazing land. As a result, there are modifications and violations of the rules and regulations for managing and using forests which were established and practiced by the society in the past. The main cause for the local value deterioration is government ideology. During the Derg period (1974-1989), the ideology of the government was socialism and thus they banned the practices of various local beliefs across the country. The present government has granted a constitutional right for everybody to practice their own religion or beliefs. However, the problems of livelihoods, insufficient agricultural production, and the scarcity of land have forced the people to use sacred forests and common grazing land against established norms. In addition, local officials at *kebele* level (the lower administration unit) have also interfered in controlling and managing some sacred forests. The motives of such interferences are to share the benefits of the traditional management of the forests. However, this competition cannot replace the role played by the old people. In addition, modern transformation and assimilation of cultures and religions, as well as urbanization processes, have also had a strong impact on the loss of integrity of the traditions of the people.

Furthermore, the dynamics of land management are also aggravated by land tenure systems and the government agricultural policy that banned sale and purchase of land. Since the land has been state property since 1974, farmers fear to invest in long-term soil water conservation measures, as the land might be taken by the government and redistributed to others. The top-down approaches towards soil water conservation design and implementation did not consider the significance of local land management knowledge and practices. The low attention paid to grazing land management, compared to that of areas for cereal cultivation, by the government is also a factor for the grazing land deterioration (Tschopp et al. 2010).

The changes to systems of land resource management pose challenges for the stability of land resources. They further result in soil degradation, grazing land deterioration and deforestation that risk the collapse of agricultural productivity. Moreover, there will be a loss of traditional land management practices, of the people's identity and their cultural heritage. Thus environmental and land-use management planning should not only consider the rehabilitation of land but also address the main attributes of local management resources, mainly their impact in raising agricultural productivity. Sustainable land management should be based on the participation of local people that recognizes and protects the traditional land management knowledge.

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## Chapter 6

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### **Long-term Indigenous Soil Conservation Technology as a Survival Strategy on Steep Mountains - an investigation in the Chenchu area, Southern Ethiopia.**

# **Long-term Indigenous Soil Conservation Technology as a Survival Strategy on Steep Mountains - an investigation in the Chenchu area, Southern Ethiopia.**

## **Abstract**

In Ethiopia there are various indigenous resource management approaches and practices, which were developed over many generations. The purpose of this study is to examine the origin, development and characteristics of terraces (*kella*), plus their effectiveness and determinants for sustainable use of the of the Chenchu-Dorze Belle area in southern Ethiopia. Field surveys were conducted, determining the various parameters of the indigenous terraces, and collecting samples for soil nutrient analysis as well as radiocarbon dating. To identify farmers' recent awareness and evaluation of the terrace systems, semi-structured interviews and group discussions were also conducted. The terraces were built along contours, from stones. Often slopes are stepped by a series of terraces and bunds. Terraces were built and used – as radiocarbon dating proves – over the last 800 years. The origin and development of the terraces are attributed to historical causes, for example defense, settlement patterns, economic benefits and social organization. The main purposes of indigenous terraces include increasing infiltration, ameliorating runoff and soiling erosion and landscape alteration. The long term continued usage of the indigenous terraces is attributed to social commitments, the structural features of the terraces and the farmers' responses to the dynamics of social and cultural circumstances. The terraces are thus dubbed a success story to manage the environment over generations and as a survival strategy for life on the steep mountains. Thus, there is a strong need to preserve and develop this important cultural heritage and example of sustainable land use and living.

Key words: indigenous terrace; soil and water conservation; survival strategy; sustainable land use; traditional knowledge; Chenchu; Ethiopia.

## **1. Introduction**

Soil and water conservation is a grave concern in Ethiopia owing to the economic significances of agriculture, environmental conditions as well as the current land use and land management practices. Agriculture in Ethiopia is mostly practiced as small-scale subsistence, which contributes to 50 % of GDP, 90 % of exports and 85 % of total employment (MEDaC, 1999). It also accounts for 90 % of the total crop land and 90 % of the agricultural output (Mulat *et al.*, 2004). Sustainable use and management of soil are thus pivotal in order to enhance the immense role of agriculture in the present economic development of Ethiopia.

The agricultural land in Ethiopia has undergone unprecedented changes; an increase in the total area of cultivated land but a decline in the size of farmland per household. The shrinking per capita farmland is attributed to rapid population growth, lack of off-farm employment opportunities and lack of rural-urban migration due to economic stagnation (Mulat *et al.*, 2004; Samuel, 2006). Farmland scarcity has caused farmers to also cultivate the marginal land and fragile ecosystems. Moreover, it is also possibly a culprit, or at least an accomplice, for a reduction and cessation of fallowing practices and crop rotation, resulting in uninterrupted cultivation. Hence, these conditions are also heightening the need for significant soil and water conservation practices.

Agricultural practices in Ethiopia have long been accompanied by soil erosion. The problem of soil erosion in Ethiopia is one of the most serious threats in terms of agricultural production, food insecurity and development challenges. The estimated annual soil loss in Ethiopia is approximately 1.5 billion tons and soil nutrient losses may be as high as 30 kg/ha of nitrogen and 15-20 kg/ha or more of phosphorous (Hurni, 1993; FAO, 1986). The annual cost of soil erosion for the national economy of Ethiopia is estimated at approximately 1.0 billion US dollars (Sonneveld and Keyzer, 2003). The indirect effects of soil erosion, such as siltation of reservoirs, lakes and rivers, are also a serious problem. Soil erosion often results in the decline of agricultural productivity of the soil, increase in crop failure susceptibility, and ultimately in the collapse of food production, resulting in famines. This is also partly manifested in the declining agricultural development and increasing food insecurity in Ethiopia, especially during the last fifty years. Therefore, the major challenges in Ethiopia are to raise the agricultural productivity of the land and at the same time to rehabilitate and maintain the environment.

The government of Ethiopia initiated soil and water conservation measures following the devastating droughts of the 1970s. With the help of international organizations, in the form of food aid and funds, the government of Ethiopia carried out massive soil and water conservation measures using large amounts of resources. In the main, terraces were built in highly degraded areas, on marginal land and along steep slopes with a total length of approximately 1,000,000 km (FAO 1990; NCS, 1990). From 1980 until 1990, roughly 200 million US dollars, and over 30 million annual peasant working days were invested (Krüger *et al.*, 1996).

In the beginning, the results appeared to be astonishing. However, over time it was recognized that the interventions proved unsustainable and unpopular. Most terraces were not maintained and were removed, particularly during the 1990s government upheaval. Various researchers documented that the main attributing factor for the limited success of the soil and water conservation program was its top-down approach (Krüger *et al.*, 1996; Reij *et al.*, 1996; Herweg and Lude, 1999; Admassie, 2000; Alemneh, 2003; Bewket, 2007). Farmers were hardly able to participate in the planning, execution and monitoring of the measures. Their only contribution was labor for the construction, elicited through coercion and payment in food. Local knowledge of soil conservation was ignored and newly constructed terraces often replaced the local indigenous conservation structures. Great emphasis was given to the universal application of the newly introduced terraces; a “one-size-fits-all” approach. Failures of newly introduced soil and water conservation measures were also reported in different other countries, namely Zimbabwe, Nigeria, Cameroun and South Africa (Reji *et al.*, 1996; Showers, 2006).

However, the farmers of Ethiopia have long been aware of soil erosion problems, including their extent, causes and effects. They have also devised techniques to halt soil erosion and to conserve land resources, as part and parcel of agricultural systems. This indicates that most farmers of Ethiopia have been practicing land uses that involve inherited soil and water conservation measures. Hence, there are a wide range of soil management practices, such as structural, agronomic and biological measures (Westphal, 1975; Asrat *et al.*, 1996; Krüger *et al.*, 1996; Million, 1996; Reij *et al.*, 1996; Herweg and Lude, 1999; Osman and Sauerborn, 2001; Bessa, 2003; Mitiku *et al.*, 2006).

Farmers employ biological measures to boost soil fertility. Manuring, use of leaf litter, composting, crop residues, crop rotation, fallowing, mixed cropping, and intercropping are just a few of the many soil fertility management practices. These techniques were used in various ways and magnitudes depending on the severity of soil fertility decline, the topography and the economic significance of the crops (Tegene, 1992; Eyasu, 2005; Moges and Holden, 2007). They are not only used to improve soil fertility but are also important in averting soil erosion, as they provide an important soil protecting cover. They are also sources of organic matter that enhance soil structure and the subsequent impacts on soil erodibility. Trees are also common on farmland owing to their fertility significance and other benefits. Another existing practice is the use of vegetation strips across the slopes to limit erosion (Nyssen *et al.*, 2000).

Traditional structural soil and water conservation measures are also widespread and common in most parts of Ethiopia. The main ones are stone and soil bunds, terraces, ditches, tied ridges, trash lines, furrows, *fanya juu*, and lynchets (Asrat *et al.*, 1996; Krüger *et al.*, 1996; Million, 1996; Osman and Sauerborn, 2001; Mitiku *et al.*, 2006). The types, designs and uses of ISWC measures in Ethiopia are attributed to local ecological and social conditions. For example, they serve for water harvesting in the lowland areas, drain excess water in the highlands, improve drainage, protect soil from erosion on steep or fragile topography, and create new cultivated land where there is scarcity of resources and high demographic pressure. However, the prime reason for using soil and water conservation practices in different areas is to improve the sustainability of livelihoods where resources are scarce and under high pressure (Krüger *et al.*, 1996; Reij *et al.*, 1996). Farmers are thus using various measures in combination in order to enhance the benefits of the ISWC measures and as a livelihood strategy. The most important factors for a continuous successful usage of ISWC measures are resource availability, demographic pressure and social involvements. Krüger *et al.* (1996) pointed out that that fragile environments, pressurized resources and a history of combatting adverse conditions are factors for good development of ISWC measures.

Among others, indigenous agricultural terraces are a well-developed practice in different parts of Ethiopia, namely in Konso (southern Ethiopia), south Shewa (central Ethiopia) and the Hararge plateau (eastern Ethiopia) (Wesphal, 1967; Asrat *et al.*, 1996; Krüger *et al.*, 1996; Besha, 2003; Watson, 2009). The design and construction of these terraces range from rudimentary stone lines to sophisticated terracing infrastructure. Konso in particular is famous for its stone walled terraces. These terraces remain one of the main characteristic features of the landscape, besides their various uses. In recognition of the role played by Konso's traditional stone wall terraces as a part of the cultural landscape they were designated as world heritage by UNSECO in June 2011 (UNESCO, 2011). Other important world heritage cultural landscape features of Konso include dry stone walled towns (local name: *palleta*), the cultural space in the walled towns (*mora*), and the traditional forests. Indigenous terraces constructed with stone walls are also common in a wide range of environmental settings in Africa, namely in Cameroon, Nigeria, Tanzania, and Zimbabwe (Hiol *et al.*, 1996; Igbokwe, 1996; Reji *et al.*, 1996). Agricultural terraces are also an ancient practice outside Africa, used to protect soil from erosion, for water conservation, and in the creation of agricultural fields (Sandor, 2006; Showers, 2006).

Similarly, the study area Chench-Dorze Belle in southern Ethiopia is covered by a series of traditional terraces and bunds made of stones; thus the slopes were converted to a series of steps. Terraces were built over generations based on the farmers' perception of the problems,

as well as their knowledge, skills, energy, and survival strategies. The area is also referred to as megalithic for its ancient stone walled terraces (Jackson, 1972; Jackson *et al.*, 1969). Farmers also practice manuring, crop rotation, fallowing, and tree plantation on farm fields, along with terracing as a survival strategy in steep mountainous topography prone to resource scarcity. There is a lack of investigations into terraces and other indigenous soil and water conservation technologies in the study area. In general, there are limited studies on indigenous soil water conservation in Ethiopia and the studies conducted so far are patchy and scattered. However, Ethiopia is marked by varied ecological and socioeconomic conditions; different places have unique forms of resource management practices. Furthermore, scientific archaeological determination of the age of terraces is also lacking in Ethiopia.

The study of the long-term terracing has multifold significances such as adding to scientific knowledge about terraces with regards to evolution, functions, forms and implications. ISWC with terracing represents the socioeconomic and cultural landscape of the area and so it should be investigated and documented. Moreover, the present investigation is important since at present many cultural landscape practices are on the verge of disappearance due to cultural assimilation and integration, coupled with the high dynamism of the political and economic conditions. Furthermore, the long-term perspectives of the terraces are also guiding efforts towards sustainable agricultural systems. The skills, knowledge, survival strategies and coping mechanisms of farmers have led to sustainable use of the resources for a long period of time. Thus these have multitude benefits, which planners may integrate into agricultural development plans and for the wide adoption of land management practices such as terraces.

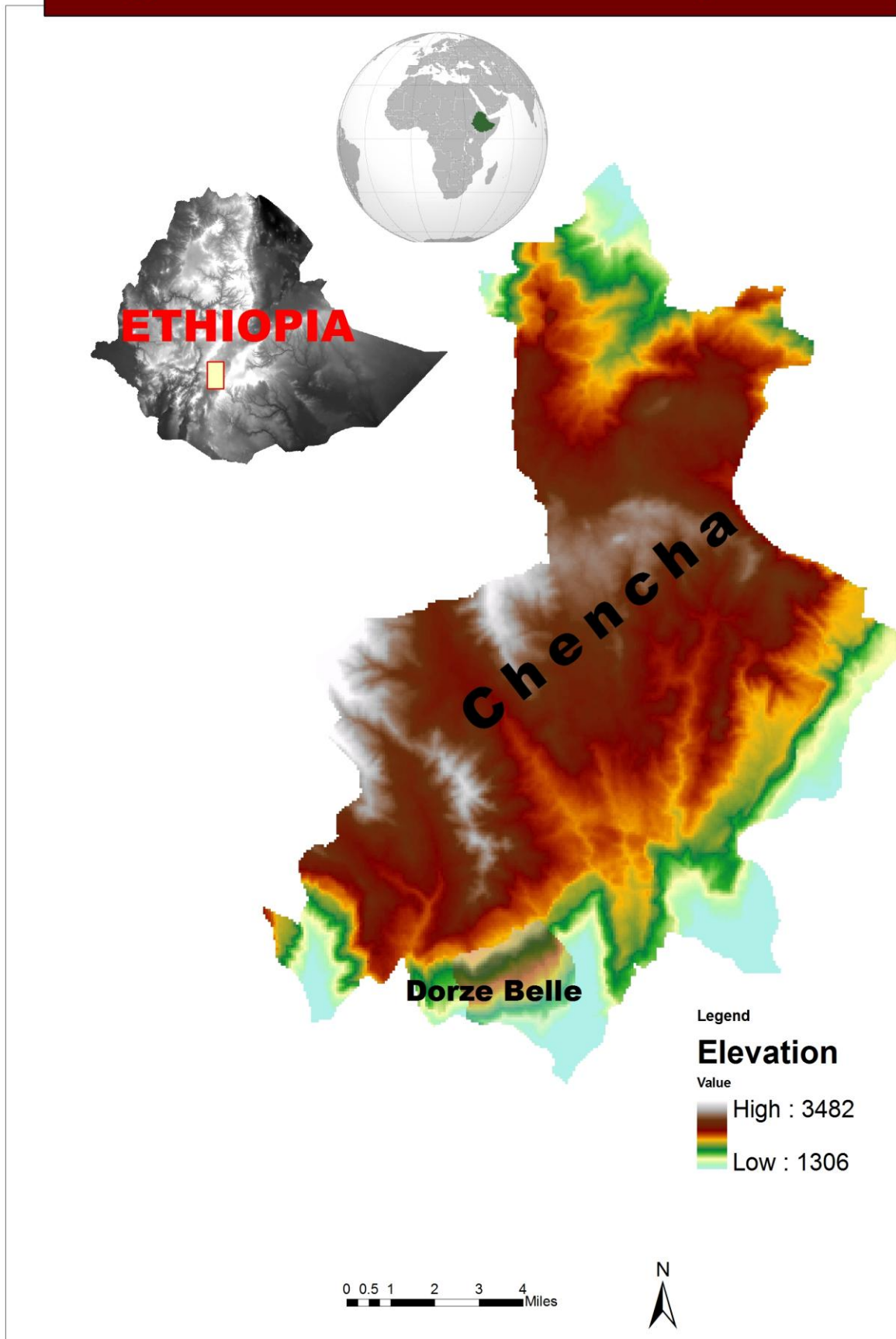
The purpose of this study is thus to examine the origin, development and characteristics of the ISWC technology in the Chench-Dorze Belle area. Moreover, it evaluates the effectiveness and determinants of the sustainable use of the measures. The study draws lessons from the success stories of ISWC experiences and gives recommendations in order to address soil erosion problems and to improve the soil quality.

## **2. Description of the study area**

Chench (6° 15' N, 37° 34' E) is situated in the southwestern highlands of Ethiopia, about 600km south of Addis Ababa (Figure 1). It is bounded by Lake Abaya in the Great Rift Valley and Arbaminch in the east and south respectively. The elevation in the area ranges from 1,300 to 3,482 m a.s.l. Chench is characterized by diversified topography, consisting of the rift valley escarpment, high plateaus topped by hills and mountains, plains, and river valleys). The rift valley escarpments and the upper foot slope of the mountains in the highlands above are very steep and marked by undulating and rugged surface features. Mountaintops are mostly gentle to almost flat. The valleys of the perennial rivers (Kulfo, Hare and Baso) are steep in the upstream area and flat in the rift valley. The highlands are well settled and have long been used for cultivation, while the rift valley escarpments and bottom of the rift valley have not been used because of the rugged topography and harsh environmental conditions, namely a hot climate and the presence of malaria.



**Figure 1. Location of the study area**



The monthly average maximum temperature in Chencha is 15<sup>0</sup> C (occurring in February) and the monthly average minimum temperature is 13<sup>0</sup> C (occurring in October), based on the meteorological measurements taken from 1970-2009 by the meteorological station at Chencha town, at an elevation of 2,800 m a.s.l. The mean annual precipitation for Chencha was measured as 1,255 mm. During the measuring period mentioned above, the annual precipitation varied from 756 to 2,353 mm, showing the high inter-annual variability. The precipitation pattern is of a bimodal type. The first precipitation season, locally known as *gabba*, occurs from March to June and the peak monthly precipitation of 185.4 mm was measured in May. The second precipitation season, locally known as *silla*, occurs from August to November. The highest proportion of annual precipitation (75%) occurs in the *silla* season. Similarly, the precipitation variability within the seasons is also high, with particularly extreme variability occurring in *gabba* season. The agricultural activities of the areas follow the seasonal patterns. As a result, there are two cropping seasons in the area, also referred to

locally as *silla* and *gabba*. In *silla* season, land is ploughed in June/July and crops are planted in July/August and harvested in November/December. However, in *gabba* season land is ploughed in January/February and crops are planted in February/March and harvested in June/July. *Silla* is the dominant agricultural season; it accounts for 65-75% of the total yields in the area. This is attributed to the occurrence of a sufficient amount of precipitation over the required period of time. Additionally, the warm temperatures that come after the planting periods also enhance the fast growth and ripening of crops. In contrast, *gabba* is marked by high variability of precipitation that exerts various adverse impacts on agricultural productivity. The heavy shower at the onset of a rain event erodes the uncovered ploughed soil and washes away the seeds. Furthermore, the ripening and harvesting of the crops of this season coincides with the heavy rain of *kirmet* (the main rainy season) which promotes the occurrence of crops diseases, also resulting in damping-off conditions.

There are four soil units in the Chencha area: Acrisols, Alisols, Fluvisols and Leptosols (FAO, 1997). Among these, Acrisols and Alisols are dominant. They are formed on rolling mountains mainly in foothill positions with slope gradients that range from 5 to 14 %. The parent material of the soils is predominantly basalt colluvium. Good texture, plus high organic matter and total nitrogen characterize the soils, which are widely used for cultivation. However, the reaction of the soils is often acidic as a result of the leaching by high rainfall. They are also marked by low cation exchange capacity (CEC) and base saturation. The cultivation of the soil also causes lowering of the available nutrients, which are the main constraints for cultivation. Acrisols in particular are marked by very low CEC and consequently the soil has a low potential for producing high yields. Leptosols occur on upper slopes of the mountains and on the summits, which are significantly subjected to accelerated erosion. Leptosols are marked by shallow depth and acidity – both are constraints for crop cultivation. Fluvisols occur in the river valleys, which are situated in the semi-arid rift valley. They are deep and consequently they promote moisture and nutrient storage and release. This situation is strengthened by the loamy texture. Fluvisols are friable so easy to cultivate. Moreover, their reaction is slightly alkaline, which is suitable for the growth of most cultural plants.

The population of the *worada* of Chencha in 2005 was 127,193 (CSA, 2006). The density is estimated at roughly 336 persons per square kilometre. Scientific investigations prove that the area has been settled since at least 3360 years cal B.P. (Arthur *et al.*, 2010). The area is in the

centre of the region GamoGofa, which is divided into 40 *dere* (small discrete political units). Olmstead (1975) estimated that 5,000 to 35,000 people were living in the area at the end of the nineteenth century. *Dere* were governed at that time by general assemblies which were represented by the high priests, known as *Kao*. At the end of the nineteenth century, however, the region was incorporated into Ethiopia. The main economic activity of the area is subsistence agriculture. People mainly cultivate enset, barley and wheat. To a lesser extent they also grow maize, teff, peas, beans, potatoes and tree cabbage. Enset is the staple food in the area and central to the subsistence agriculture. Raising livestock is also an integral part of the economy. Off-farm activities include weaving and small-scale trading. The traditional house is made from the stems and leaves of bamboo and looks like an upturned basket

### **3. Methods**

Various methods of data collection and analysis techniques were employed to generate empirical and socio-economic data for the study

#### **3.1 Field survey: Measuring and describing terraces**

A transect walk, as a reconnaissance survey, was undertaken to understand the study area before conducting the detailed data collection. Such a survey is a useful technique to observe and become familiarized with the different features of land-use systems in general and terraces in particular. It is also a basis for determining sites at which measurements should be conducted and also to refine questionnaires for interviews and group discussions. The observation was also based on checklists. Later, repeated visits to farm fields by transect walk were also useful for refining or verifying data collected from interviews and group discussions.

Measurements of different aspects of terraces, namely rise, horizontal distances between terraces, depth of foundations and stone sizes, were undertaken. Moreover parameters which are pertinent to terraces, such as establishment, construction and maintenance processes among others, were described. The forms for measurements and observation of ISWC were adopted from the ISWC inventories format, which was designed to measure ISWC practices in Ethiopia (Krüger *et al.*, 1996).

In conjunction with the measurements and descriptions, informal discussions were conducted with the owners of farmland about the history of the terraces, as well as the advantages and disadvantages of the indigenous terraces over the conventional ones. The information was also used as an input to refine the questionnaire of the interview.

#### **3.2 Household survey**

##### **Interviews**

Forty households were selected randomly that covered the upper, middle and lower foot slopes. The interview questionnaires were composed of both closed and open-ended questions. The interviews were carried out with the help of assistants. The assistants were graduates from a college, proficient in the local languages. Training was provided for assistants on ways of establishing contact, conducting interviews, procedures and cultural

issues. Before conducting an interview with a farmer, the objectives of the questionnaires were explained to make clear the purpose of the interview. Information was collected from a house-hold survey including socio-economic characteristics, knowledge and practices of land management, and features and benefits of indigenous soil and water conservation measures among others.

### **Group discussions**

Three focused group discussions were held, each group comprising 10 to 15 participants, who were elders from both sexes. The discussion was carried out based on the checklists mainly concerning settlement history, evolution, characteristics, benefits, reasons for long-term existences and limitations of the terraces and techniques for construction and maintenances of terraces. The participants were also encouraged to talk freely concerning the ISWC practices. Group discussion is an important technique to check and refine the data that were acquired by structured interviews of household individuals and key informant interviews.

### **3.3 Collection of datable material and $^{14}\text{C}$ analysis**

In a terrace at Chench-Dorze Belle charcoal was identified; samples were taken from two layers for radiocarbon dating. The charcoal samples were dated at the Leibniz Laboratory for Radiometric Dating and Stable Isotope Research, Christian-Albrechts-University of Kiel, Germany. The laboratory used the following procedures (Nadeau *et al.*, 1998): Samples were checked under the microscope for impurities. Then the charcoal particles were purified with 1 % HCl, 1 % NaOH at 60°C and again 1 % HCl (alkali residue). The combustion to CO<sub>2</sub> was performed in a closed quartz tube together with CuO and silver wool at 900°C. The sample CO<sub>2</sub> was reduced with H<sub>2</sub> over about 2 mg of Fe powder as a catalyst to produce graphite. The resulting carbon/iron mixture was pressed into a pellet in the target holder for the AMS-measurement. The  $^{14}\text{C}$  concentration of the samples was measured by comparing the simultaneously collected  $^{14}\text{C}$ ,  $^{13}\text{C}$ , and  $^{12}\text{C}$  beams of each sample with those of Oxalic Acid standard CO<sub>2</sub> and coal background material. Conventional  $^{14}\text{C}$  ages were calculated according to Stuiver and Polach (1977) with a  $\delta^{13}\text{C}$  correction for isotopic fractionation based on the  $^{13}\text{C}/^{12}\text{C}$  ratio measured by the laboratory's AMS-system simultaneously with the  $^{14}\text{C}/^{12}\text{C}$  ratio. "Calibrated" or calendar ages were calculated using "CALIB rev 5.01".

## **4. Results and discussion**

### **4.1 Origin and development of indigenous terraces**

Archaeological and historical records indicate that terracing has been a part of agriculture for millennia. Terraces have been established under different environmental settings for various purposes across five continents and Oceania (Sandor, 2006). But there is no single point for the origin and development of the traditional agricultural terraces; multiple independent origin sites are most likely (Showers, 1996). The discussion on the origin of terraces is diverse. Purposes, construction techniques and materials, as well as the uses of indigenous terraces vary enormously from region to region (Reji *et al.*, 1996; Sandor, 2006; Showers, 2006). Terraces have been used in Yemen for the past 5,000 to 6,000 years, in China for at least 4,500 years, on the island of Cyprus for at least 3,000 years, in Peru, Mexico and Guatemala for approximately 2,000 years and in Tanzania for about 300-500 years (Bork, 2006; Sandor, 2006; Showers, 2006 ).

In Ethiopia, different studies roughly estimated and refereed the age of the terraces to 100 to 400/500 years old (Amborn, 1989; Grove and Sutton, 1989; Sandor, 2006; Showers, 2006). The bases for the estimation of the ages of terraces in Ethiopia were travel accounts, oral history and genealogies. In particular the work of Amborn (1989), who used genealogy and oral history to determine the age of the terraces of the Konso area, has been oft cited by different studies. Such work should ideally have been supplemented with chronometrical and stratigraphical investigations. However the stone walled terraces of Konso have been reworked and thus it is difficult to find untouched areas for radiocarbon dating (Watson, 2009). Thus the estimated ages of terraces in Ethiopia, besides lacking in accuracy, do not represent their real age at different places. Agro-ecological and socio-economic diversity is very high in Ethiopia within short distances. Hence, land utilizations and land management practices are area-specific and vary in different environmental settings.

In light of the previous discussion, radiocarbon dating was undertaken to determine the age and origin of the indigenous terraces in southern Ethiopia, using samples from Chenca-Dorze Belle as an example. Dorze-Belle is situated at the lower border of the highlands, above the steep escarpment of the rift valley. Except for some very flat sites, the area is terraced. Moderately inclined slope segments with large agricultural terraces and steep slope segments with small terraces are interleaved. Here the length of the terraces is mostly less than 3 m and the height of the terrace wall is often 0.7m to 1.5 m, only sometimes reaching up to 3 m.

On one of the steep slope segments a profile was opened at the wall of an agricultural terrace. The terrace has a maximal height of 2.5 m at the terrace wall, a length of 2-3 m in the direction of the slope, and a width of approximately 20 m along the contour. The upper 1.5 m of the profile, directly behind the terrace wall, consists of dark-colored fine soil material with a high content of organic matter. Below this terrace fill, a debris layer was found at a depth of 1.5 m to 2.5 m. Intensively weathered bedrock (saprolite) was exposed below the debris layer at the base of the profile. In the profile at the terrace wall, the fine soil fill and the debris layer were investigated in detail and sampled for nutrient analysis and radiocarbon dating at two depths: Samples were taken in the profile beneath the recent cultivation layer (fine soil material; sampling depth: 30 cm below soil surface) and above the base of the terrace fill (debris layer; sampling depth: 240 cm below soil surface).

The material characteristics of the terrace fill and the terrace wall, which was constructed using local stones, prove that the terrace was built in one event; there are no indications at all that the terrace developed over many centuries. This conclusion from field observations was verified by radiocarbon dating of two pieces of charcoal, which were sampled at the aforementioned depths (Table 1). The AMS-dating of one piece of charcoal, which was found at a depth of 30 cm below the soil surface, resulted in a radiocarbon age of  $795 \pm 30$  BP (Laboratory No. KIA41856). The calibrated age is AD 1,186-1,202 and AD 1,206-1,277 (2 sigma range). Another charcoal fragment, which was found at a depth of 240 cm, has a radiocarbon age of  $815 \pm 30$  BP (KIA 41857). The calibrated age is AD 1,172-1,267 (2 sigma range). These dates prove that the terrace was built in one event or at least over a very short period of time. It was most likely established in the late twelfth century or in the first half of the thirteenth century.

Table 1: Results of the radiocarbon dating of samples from an agricultural terrace in Dorze-Belle

Sample depth	Laboratory No.	Radiocarbon age	Calibrated age (2 sigma)
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30 cm	KIA41856	795 ± 30 BP	AD 1,186-1,202 and 1,206-1,277
240 cm	KIA 41857	815 ± 30 BP	AD 1,172-1,267

This radiocarbon dating attests that the terrace which was investigated in Chench-Dorze Belle is probably one of the oldest relics of agricultural activities in the region. Archaeological investigations prove that the area has been settled since at least approximately 3,360 years cal B.P. and that indigenous crops such as enset were grown here for at least 2,000 years (Arthur *et al.*, 2010; Cartledge, 1999). The remains of a church, which was found inside a sacred forest by ethnoarchaeological investigations, also provides some hint regarding the age of settlements (informal discussion with John Arthur, Associate Professor, Anthropology, University of South Florida Saint Petersburg).

In the group discussions with the old people in Chench-Dorze Belle about the history of terraces and land use systems, they disclosed that the terraces were as old as the agricultural activities in the area. They also pointed out that their ancestors were the ones who designed and constructed the terraces. The old people are well aware of the cultural landscape since information passes from one generation to another. Oral history is thus an important source of information for reconstructing the environmental history. For instance, based on the oral history of the old people in the area, Arthur *et al.* (2010) have identified the site of an old settlement that has an age of about 3,360 years. Moreover, during our field survey we also observed that the rock blocks, which were used for the construction of the terraces, changed color due to intensive chemical and biological weathering processes and lichens that have also grown on the rocks, implying the existence of the terraces for a long period of time.

Farmers also reported that the existing indigenous soil and water conservation technology was originally developed by their ancestors over a long period of time mainly to keep the land from erosion. In our discussion with the farmers from other parts of Chench, where terraces have been part of their agriculture for a long period, they also acknowledged that the terrace technology was adopted from the Chench-Dorze Belle. They all considered the Chench-Dorze Belle area as the center of the technology, from where the terrace concept has been transferred to other places.

In Ethiopia, the site of origin of the terrace has not yet been determined. However, there are different arguments regarding the factors that have attributed to sources of terraces in Ethiopia and in other parts of the world (Krüger *et al.*, 1996; Reji *et al.*, 1996; Showers, 2006). Some stated that the technology might have come to the area via visitors, such as migrants or traders, who crossed the area. The people's exposure to other places can also be a factor in the adoption of the ISWC technology. The government or colonial power impositions to implement soil water conservation measures would also be another reason for the evolvement of the technology. In eastern Ethiopia, for instance, traders brought the stone terraces to Harrage from Arabia when they visited the area in the past (Asrat *et al.*, 1996). On the other hand, the Chench area was closed for a long time as different documents explained (Cartledge, 1999; Samberg *et al.*, 2010). This led to limited interaction with other people and places and thus contributed to the preservation of the natural environment and the indigenous seeds (Cartledge, 1995; Samberg *et al.*, 2010). Generally, the emergence of the indigenous terraces in Chench-Dorze Belle could be attributed to different factors, namely historical, environmental and socio-economic conditions.

According to oral history, there were conflicts and war among the neighboring communities in the distant past in Chenchu and the surroundings. The main purpose of such war was not to gain land for cultivation, but to obtain laborers (Olmstead, 1975). These wars and conflicts forced people to settle on the steep slopes of the mountains to protect themselves from war and to hide from the attacks. The steep mountains are very difficult to move around freely for the invaders. The area thus served as one of the strategic places of refuge from war and as a buffer zone for offense and defense in the war. The people also constructed some defensive stonewalls. The intact stonewalls in various sacred forests of Chenchu area are also evidently defenses related to the conflicts, according to our informants. From this we can hypothesize that one of the causes for settlement in the Chenchu-Dorze Belle area was war, and that the people continued their lives in the area by adjusting the environment.

The topography of the Dorze Belle area is a natural barrier for agriculture and thus another possible factor that forced the people to practice terracing. Very steep slopes characterize the topography and in order to carry out agricultural activities in a sustainable way people had to implement terracing. Agriculture had first been practiced in the area without using terraces. Thus the soil vanished probably in a short period of time. To avoid the abandonment of agricultural activities, terraces were built approximately eight centuries ago. Eroded soils under the terraces, which were dated, prove this.

Moreover, as a result of intensive hill-slope erosion prior to terracing, the rock cover became immense in the area and thus began the need to gather them at certain places in order to create land for cultivation. After a certain period of time, these piles of stones were used to construct terraces. Terracing is thus a coping strategy to overcome constraints of agricultural activities. As stated by Krüger *et al.* (1996), the fragile environment is one of the factors for the development of the ISWC practices in different parts of Ethiopia, namely in Tigray, north Shoa, and Konso.

There had been very limited trade and other off-farm activities in these areas for a long period of time (Cartledge, 1995; Samberg *et al.*, 2010). Weaving is a very recent practice in the area. Thus the people of Chenchu-Dorze Belle were entirely reliant upon agricultural activities for their livelihood in the past. They had to use terraces to grow crops sustainably and to create new land for cultivation in their mountainous topography.

The construction of terraces requires hard work and special skills. Farmers' attitudes and commitments stand out as the most important factors in the construction of terraces, given the high labor and energy requirements. They have long been aware of the negative effects of soil erosion and associated impacts on agricultural activities. Moreover, as a response to the existing problems, such as soil erosion and run-off, and in order to increase the productivity of the land, the people had to devise and adopt various indigenous soil and water conservation measures such as terracing. Thereby, the communities in general and the individuals in particular developed and accumulated experiences, knowledge and skills. This knowledge and these skills were modified and shaped by the dynamics of social, political and economic conditions of the areas. These skills and knowledge also passed from one generation to the next, with each generation contributing some added value. Thus the knowledge is proven and tested over a long time period under different environmental and social conditions. Hence the skills and knowledge of the people evolved over a long period of learning processes that included thorough observation, experimentation and testing – possible factors that contributed to the evolvement of indigenous terraces.

To sum up, radiocarbon dating of the terraces of Chench-Dorze Belle evidenced that terracing is one of the oldest practices that accompany the agricultural activities of the area. Moreover, all the above factors in combination contributed in various ways and intensities to the evolution of terraces in the area. Thus they prove that the terrace technology emerged within the locality. Farmers stated that their ancestors were very wise and hard workers and therefore constructed terraces as a survival strategy for farming on a steep hill.

#### **4.2 Forms and characteristics of indigenous soil and water conservation measures**

Large areas with steep slopes in the cultural landscape of Chench-Dorze Belle are lined by indigenous terraces, which were constructed in the distant past (Figure 2). At present, farmers are also constructing indigenous terraces on those areas which were not covered by terraces in the past, to create cultivable land. They also construct indigenous terraces when they build new houses which are constructed at places that were not previously cultivated or in the farm fields. They also engage in terrace maintenance activities when the structures of terraces are broken by heavy precipitation and run-off or by the tracks of animals. Additionally, farmers were ordered in the 2000s by the local agricultural bureau to construct the introduced terraces in those areas which were not covered by ISWC, mainly in the low-lying lands.

The indigenous soil and water conservation technology of Chench-Dorze Belle is based on stone wall terraces. The main construction materials for terrace walls are stones and bedrock, which are abundant in the area. As stated in the preceding section, the abundance of stones is among the factors for the construction of terraces. The type of the stone in the area is basaltic rock, which was formed during the Tertiary period by volcanic activities that occurred in the area. These stones are compact and solid and thus attributed to the stability and permanency

Figure 2. Terraces in Dorze Belle, Chench





of the terraces in the area. The stones have various sizes and shapes. The size of the stones used for the construction of terraces varies from about 10cm to more than 1m in diameter. People used to collect stones from their agricultural fields and to accumulate them at specific sites to build terraces. These stones are sorted and arranged according to their sizes and shapes that fit together precisely. The bigger stones are used for the bases of the terraces whereas the smaller ones are used for the embankment of the terraces. The different shapes of stones are also important to fit the gaps in the walls of the terraces.

When farmers construct terraces they first excavate trenches up to half a meter in depth. The soil is deposited downslope, just below the terrace wall. In contrast, in the newly introduced *fanya juu* terraces, soil from the trench is thrown upslope. Some portion of soil is used to cement the terrace while the remainder is spread to the lower sides, behind the walls. Then they put the big stones in the excavated trench as a foundation for the terraces. In some cases if they found bigger stones in the trenches, they used them as a base and terraces were built on the stones instead of removing from the ground. In the upper topography, massive bedrock is common and used for the base. On the low-lying land, farmers collect bigger stones from the surface and use them for the base of the terrace wall. Generally, terrace walls can be set into the bedrock or on the soil.

The method of piling stones to build the embankment of the terraces involves placing them with decreasing stone size from the base to the top. If there are gaps in the walls, they are packed with small stones, although in some cases they use soil as a filling to stabilize the walls. The position of the terrace wall is vertical or slightly inclined. It is slanted at the steep slope while it is vertical at the lower slope. The height of the terraces varies from 0.5m to 2m depending on the gradient of the slope, with the height declining in accordance with the slope. Where there is a steep slope gradient, the height of the terraces is increased to retain a high amount of runoff. Along a contour, a single long wall was not built; rather a series of shorter

terrace walls were constructed. This is attributed to the individual farmers' views of the terraces and farm plot sizes. The top of the walls were used to grow grass and trees. The water outlets on the side of the walls were also built to dissipate and divert water flows. In some cases there are spaces between the stones of the terrace walls to allow water to exfiltrate safely.

The distances between the terraces along the slope vary from 3 to 15 m. Larger distances between terraces are observed at lower slope segments whereas short distances are common on steep slope segments. The soil which is accumulated due to slight hill slope erosion just above the terrace wall is brought back to the upper part of the terrace where it was eroded earlier. Due to terracing, the original steepness of the slope was reduced drastically on the terrace surfaces under cultivation. The steep slope segments are thus marked by terraces with higher walls and shorter distances of terrace spacing to protect them from run-off and removal of soils. The soils of the terrace fields are well managed and used to grow various crops and to plant trees.

The construction of terraces needs a large amount of labour; it is time demanding. The role of social organization and the culture of the people is an integral component in constructing and maintaining terraces. People usually construct terraces in groups, known as *debo*. The formation of a *debo* ranges from 5 to 15 people. The members are commonly neighbors and relatives of the one who owns the terraces. The owner should collect stones and put them at different places of the farm field ahead of the construction. This activity is also time consuming and labor demanding. In addition, the owner should also prepare food and drinks for serving those people who are going to engage in terrace construction. Before the people start to construct a terrace, some ritual activities are conducted to enable the terrace to last for a long time. The group members can comment upon and discuss the design of a terrace. If there is some disparity among the group members, the owner is the one who makes all final decisions. The people first dig the soil, then put the big stones in place, and then construct the embankments of the terraces. After finishing the daily work they are invited to food and to the local beer known as *borde*, which is made of barley and wheat. In some cases the local alcohol, known by the name *arekie* and prepared by distillation, is also served. The alcoholic content of *arekie* is higher than that of the local beer. There is a labor division in the construction; women prepare food and drinks, children support by collecting gravel during the construction, and the men do the main construction work and collection of stones. The work can continue after reaching a certain height of the terrace, depending on the available labor and materials.

The indigenous terraces are very strong and last for long period of time, with a minimum duration of more than eight years without maintenance. Farmers maintain the terraces when they are (at least partly) damaged or sometimes washed down by high amounts of runoff, which usually occur in April and October. In addition, cattle damage terraces as they graze on the terrace fields after the harvest. The fields are common property for cattle grazing after the harvest. The damage to terrace walls due to grazing activities is often minor and individuals who own the land or property carry out the maintenance. The women are also involved in the maintenance of the terraces. Children are also engaged in collecting stones for the maintenance. Terrace maintenance is usually carried out during the ploughing period. Sometimes the demolishing of terraces also forces people to construct new ones. In this case, group work is mandatory. If the farmers do not maintain the terraces they know that they will

not get a good yield at the next harvest. So everyone is aware of the importance of terrace maintenance.

Farmers are not only constructing and maintaining terraces to manage the land; they are also using various traditional techniques of soil fertility management for the conservation and enhancement of soil fertility. The main practices include: manuring, fallowing, crop rotation, and cultivation of grass and trees along strips. Manure is mainly composed of the dung and urine of cattle, sheep and horses, household refuse, and crop residuals. It is carried and accumulated by females at a few sites near to their houses and on their farmland during a period of one to two months per year. The manure is then spread on the farm fields and turned in by digging by the men. There is also a practice of channeling cattle urine from the house to the neighboring enset grove. Crop rotation is characterized by the cultivation of barley and wheat in the first two or three years and then afterwards peas and beans are grown. In addition, the farmers are also practicing mixed cropping; for example cereals (barley and wheat) are grown together with beans and peas. Grass and tree strips along the contour are also common agronomic practices in the area. Grass is also used for animal feed and for house roofing. Leaf litter from trees is also important in maintaining the soil fertility. The most common trees used in the area for soil fertility enhancements include *Erythrina abyssinica*, *Hagenia abyssinica* and *Croton macrostachyus*. Leaves and branches of trees are also used for animal feed and trees for fire wood supply.

The practices of soil fertility management are not only used to improve soil fertility but are also important in averting soil erosion, as they provide an important soil protecting cover. They are also sources of organic matter that enhance soil structure; in turn soil erodibility is reduced. A good soil structure also improves water infiltration capacities. However, manuring, crop rotation, and fallowing have undergone significant changes during the last four decades.

Terraces have also undergone dynamic changes to some extent. The changes mainly include the alteration of the distances between the consecutive terraces and the threat of replacing them with newly introduced terraces. The dynamics of terraces are mainly attributed to various factors. Introduction of new technologies, labor shortages, government policy, and economic conditions are just a few among them.

The introduction of the ox plough at the beginning of the twentieth century has resulted in the deliberate removal and dislocation of terraces. In the past, the dominant cultivation technique was the use of hoes; terraces in the area were fixed. The ox plough requires some wider space for the turning of oxen and ease of cultivation. To this effect the farmers demolished some terraces and expanded the fields between the former terraces. In addition, farmers sometime dislocate terraces when soil is accumulated above the wall of the terraces. They often construct new terraces by removing the old ones and extending the space of farm fields between the terraces. The accumulated soils are spread on their farm fields. Moreover, farmers displace terraces when they construct new houses. They often construct terraces at the sides of the new houses. These terraces have higher walls to protect the houses from the run-off from upslope.

The lower part of the area is mainly marked by gentle to flat slope segments and was not covered by the indigenous terraces in the past. However, the governmental local bureau of agriculture, which is responsible for executing the program of soil and water management

practices, has forced the farmers to build the newly introduced terraces. Farmers get food aid and financial incentives by constructing the terraces. These approaches which aim to encourage the constructing of newly introduced terraces can have negative impacts on the indigenous terraces. Farmers may wish to demolish existing terraces on their land and to construct the introduced ones as a means to get food aid and money, since they do not get any assistance by constructing or maintaining the traditional ones. In addition, these approaches may also create the feeling among the farmers that indigenous terraces are not appreciated and valued by the government.

#### **4.3 Functions of indigenous soil and water conservation**

Farmers have been using diversified measures for soil and water conservation in several combinations. Terraces stand out as the most important measure coupled with manuring, crop rotation, fallowing, and tree plantation in farm fields. In doing so, farmers maximize the benefits of the different land management practices and simultaneously implement a survival strategy for life on the steep slopes of the mountains. The most important functions of ISWC in the area are discussed below.

##### **Soil erosion**

The area, with its characteristic mountainous steep slopes and showery tropical storm precipitation, is prone to erosion by water resulting in intensive hill-slope erosion, rill erosion and gully erosion. However, the indigenous terraces, which are widely applied in the area, have played a significant role in creating series of short slopes that avert soil erosion. The initial length of a slope is reduced to short and steep slope segments interrupted by flat terrace surfaces and consequently the erosive capacity of water flowing down-slope is also lowered significantly. In addition, soil erosion is prevented by trees, which are grown on every farm field in the area. Trees intercept the rainfall and dissipate the surface runoff. They are also used as barriers and diverters of the surface flow of water. Moreover, the organic matter of the soils, which is also promoted by manuring, plays a pivotal role in reducing erodibility of the soil. Terraces not only control soil erosion but also enhance retention of the soil which is moved down-slope by runoff. The accumulated soil above a terrace wall is also redistributed in the field. This accumulated soil is often fertile due to a higher content of organic matter and fine soil material.

Soil erosion in the area is thus very minimal and the soil is kept mostly in-situ. As a consequence, the depth of the soil is maintained. Deep soils are an important storehouse of nutrients and water for the growth of cultural plants. All interviewed farmers unanimously pointed out that the main role of terraces is to protect against soil erosion and in effect they stated that they grow various crops on their farmland. On the other hand, we have observed massive soil erosion and as a result the cultivation of much less fertile sub-soil horizons or even saprolite in other steep mountain areas of the Chenchu *woreda* in which there are no terraces.

##### **Run-off and flooding**

Besides controlling soil erosion, terraces also enhance the drainage of the soil by reducing surface runoff. The velocity of the runoff on the segmented slope is very slow. This promotes

drainage by increasing infiltration rates, resulting in the improvement of soil moisture contents. Moreover, the surface water is collected and removed by water channels that are built on the sides of the terraces. They are constructed in such a manner that they let the water flow nearly horizontally across short distances on each farm field. Stone walls of the newly constructed terraces are also porous to some extent to allow the exfiltration of water. Thus, the potential for rill and gully formation in the area is lowered. On the other hand wrongly constructed waterways near the introduced terraces are also a factor in gully expansion at different sites in Chencha. Run-off management thus also has wider off-site implications for watershed management. In areas such as Konso, run-off is harvested and used for crop watering since precipitation is the major constraint for crop growing (Besha, 2003; Watson, 2009).

### Soil fertility

Farmers of Chencha-Dorze Belle are not only constructing terraces and planting trees on their fields; they are also widely practicing soil fertility improvement techniques. Among others the most common practices for boosting soil fertility are manuring and crop rotation. These practices play vital roles in boosting macronutrients such nitrogen, phosphorous and potassium in the soils of the area. Manure also contains additions to the minerals that are exported by crop harvest every year. Since the price of mineral fertilizer is unaffordable for the farmers, the option of using manure is much more feasible. Besides, organic matter is very important in maintaining the soil structure, which cannot be maintained and improved by the application of mineral fertilizers. A good soil structure is very important for allowing the various soil chemical interactions to take place and enhancing the infiltration capacity of the soils. Thanks to these practices the physical, biological and chemical characteristics of the soils are not major constraints for crop-growing in the area. The people are also aware of these practices that have long enabled them to grow various crops. That is why livestock raising is a main and integral component of agricultural activities in the area. Crop rotation, i.e. growing leguminous crops alternating with cereals, is also very significant for nitrogen dynamics in the soil. The practice of combining the terraces with soil fertility management practices is thus very commendable in sustaining agriculture. Various studies have also reported the significance of the traditional fertility management practices in different parts of Ethiopia (Besha, 2003; Eyasu, 2005; Moges, 2007).

### Landscape modification

Indigenous stone terrace walls have a large impact on the modification of landscape in the area. The steep slopes of the area were changed into a segmented topography and thus reduced the slope gradients especially on the cropped and thus erosion-sensitive terrace surfaces. The landscape between the terrace fields has also been altered into a plains topography owing to the spread of the dug out soils and the accumulated soils above the walls of the terrace fields. This has also resulted in the change of the stone wall terraces into bench terraces, creating a level surface between the terrace fields. Moreover, terraces have also enabled an extension of the length of a slope. The development of a terraced landscape took a long time. A landscape is also re-modified when terraces are destroyed and new ones are constructed for various reasons. The landscape alterations have in general had positive effects on creating favorable conditions for crop growth in the past.

## Economic significance and land productivity

In general, indigenous terraces have significant impacts on the creation of a stable topography; marked by a well-managed soil which allows the infiltration of nearly all precipitation and is affected by few mass movements. Through the use of such terraces, cultural landscapes were created many centuries ago for the cultivation of crops in the area, leading to an enormous increase of land availability for cultivation. In addition, the existing landscape was maintained for sustainable production. Had this not been the case in the area, agricultural activities would have been abandoned (collapse of agriculture) due to the erosion-sensitivity of the steep slopes. The positive impacts of indigenous terraces and soil fertility management practices enabled the farmers of the area to optimize the agro-climate features. The area is situated at the border between the highlands and the escarpment of the rift valley, with several varieties of crops being grown in the respective agro-climate regions.

## Social and cultural significance

As previously discussed, the steep slopes of the mountains had military strategic significance in the past; this terraced landscape was very difficult for invaders to enter or cross. Indigenous terraces thus also played a military role in the history of the region.

The indigenous terraces at Dorze-Belle have aesthetic importance, too, as one of the oldest terraces yet investigated in Ethiopia. Viewing such a terrace system in a region where most of the land is degraded was, and remains, phenomenal. Terraces are also aesthetically important as outstanding features which demonstrate human intervention on sensitive steep slopes and the skills required to perfectly craft and use stones.

The significance of indigenous terraces thus goes beyond their contribution to land productivity and economic significance. They are dubbed success stories in which people invested their skills, labors, energy and knowledge in constructing terraces to manage the environment over generations. It also shows the traditions of the people; placing high values on the land and respecting land management practices. The terrace systems are the major part of a cultural landscape which is unique, not only for the region and Ethiopia, but also on a global scale. Thus there is a strong need to preserve this important cultural heritage.

### **4.4 Potentials of indigenous soil and water conservation – farmers' view of terraces**

Farmers have expressed their view that indigenous terraces have multifold advantages which outweigh those of the newly introduced terraces. Two of the advantages of the indigenous terraces are the farmers' familiarity with their design, and the simplicity of their implementation and maintenance. The design of indigenous terraces is based on the individual farmer's perception of runoff, soil erosion, farm plot size, slope gradient and availability of materials. As a result, the forms of terraces (rise, alignments, consecutive distances between terraces, material for construction etc.) vary from one household to another. The introduced terrace design is based on the official manual specification, which is to be applied across the entire country. The development agents, workers of the *woreda* agricultural bureaus, are in charge of implementing the construction plans for introduced terraces. Farmers are to participate in the construction of terraces at least once a week and in return they receive food aid or money.

Farmers are not familiar with the design of the introduced terraces and they reported this to be one of the disadvantages. In order to construct the introduced terraces, the guidance of the extension is vital. In some cases the design was wrongly implemented, causing gullies to form, as was the case in Zollo, Chench. Moreover, the structure of the introduced terraces does not consider the size or existing problems of each individual farmer's land. Instead, they have a rigid design that should be applied according to the universal features of the terrace. It does not also take into account farmers' traditional knowledge of land management practices. As a result, farmers are inconvenienced by the introduced terraces. In comparison, the success story of the US terrace construction in the 1930s resulted from planning approaches which were based on the farmers' field conditions and individual know-how (Showers, 2006). Lack of flexibility is one of the constraints of the conventional soil and water conservation measures, as documented by various studies in Ethiopia (Asrat *et al.*, 1996; Krüger *et al.*, 1996).

Farmers also perceived that indigenous terraces are strong and last for a long time compared to the introduced terraces. This is mainly attributed to the materials and construction techniques; bedrock and larger stones were used as a base or foundation for the indigenous terraces. Smaller stones slake to strengthen embankments. In comparison, the foundation for introduced terraces is commonly placed directly on the soil and they often use soils to construct, as well as cement the walls of, terraces. The period of maintenance also varies between the two types of terraces; the indigenous terraces last for eight to ten years and the introduced terraces for 4 years, according to the farmers. The low interest of the farmers in maintaining the terraces aggravates the problem of the stability of the introduced terraces. In some cases farmers frequently demolish introduced terraces; a development agent told us that in a place known as Mafena Zolo, terraces were demolished seven times since the first introduced terraces were constructed in the 1970s. The lack of maintenance and also demolition are symptoms of non-acceptance of the measures and show the farmers' resistance to this government policy, as reported by various studies (Reji *et al.*, 1996; Showers, 2006).

Farmers also witnessed the role of the indigenous terraces in significantly reducing soil erosion and runoff compared to the introduced terraces. Along with indigenous terraces, manuring, crop rotation, and tree planting on farmland are common practices which also have positive effects in reducing erosion by enhancing the surface cover and soil structure. However, the introduced terraces lack other associated measures such as crop cover and tree plantation, even though they struggle to halting erosion by themselves, as stated by various studies (Sandor, 2006; Showers, 2006). Similarly, Krüger *et al.* (1996), based on plot experiments at different agro-climate regions of Ethiopia, have also reported that the impact of introduced terraces in reducing erosion was not satisfactory.

According to farmers' views, the water channels that were built at the sides of the indigenous terraces have been effective in collecting and removing runoff from cultivated land. In comparison, the unprotected water channels of the introduced terraces are in some cases constructed from upslope to lower slope segments following the direction of the slope; in these cases concentrated runoff is not led to infiltration areas nearby, or into other channels after short distances. This results in an enormous increase of runoff downslope and in intensive gully erosion, as is the case in the Zollo area.

Farmers also pointed out that yields on the indigenous terraced land are better compared to the introduced terraced cultivated land. One of the suggested causes for this is that indigenous

terraces have existed for a long time, and are thus stable and effective in halting soil erosion. Measures such as manuring, crop rotation and farm-level tree plantation, which all enhance soil fertility, are mainly applied to indigenous terraces and less frequently to introduced terraces. This results in boosting the soil quality of indigenous terraces, promoting agricultural production. Moreover, indigenous terraces are significant in effective use of the existing land, as no space is taken out of agricultural production. In addition, unlike the introduced terraces, rodents or other pests are not harbored in indigenous terrace walls. On the other hand, the main focus of the introduced terrace is to restore degraded land in which soil fertility is very low. However, the problem is exacerbated by the lack of integration of soil fertility management practices with introduced terraces. Thus, in order to rehabilitate this land and to get good agricultural production, a much longer period of time is needed.

To sum up the discussion on the farmers' view on the potentials of terraces, farmers have a positive attitude towards the indigenous terraces compared to the introduced ones. This is because of the multifold advantages of the indigenous terraces, such as their impacts on soil erosion and runoff reduction, boosting of soil fertility, and the consequent effects on sustainable agricultural land utilization. Hence farmers adopted terracing technology from their parents which has been continuously used for generations. In contrast, the negative views of farmers towards the introduced terraces, which have been constructed during the last four decades, are not the result of farmers' assumed ignorance but rather of the disadvantages of this type of terrace. As a result, in most cases the introduced terraces are either demolished or hardly maintained. Generally, farmers' positive views on the potentials of the indigenous terraces are reflected not only by social acceptability, but also by their environmental efficiency and economic feasibility, which are basic features for the sustainability of the practices.

#### **4.5 Conditions for long-term sustainable use of indigenous terraces**

The success of sustainable long-term use of indigenous terraces is attributed to different factors. Among others, one factor is the farmers' psychological makeup, which developed as a result of not only possessing the terraces, but also being capable of designing and constructing them. Farmers' terrace design is based on their perception of the pertinent problems, such as soil erosion, runoff, size of farmland, slope gradient, availability of material and labor. These enable the farmers to decide on the various features of the terraces and also their means of execution. They modify or alter the terraces to cope with various environmental and socio-economic dynamics. More than four decades ago, farmers did not face top-down interventions or impositions on design, implementation and evaluation of terraces. These grass-root level problems of identification, planning and execution have massive psychological significance that enhances self-reliance and feelings of empowerment. This is one of the factors for the long-term popularity of this technology.

Flexibility in designing and executing indigenous terraces is characteristic for the area under investigation and also has paramount importance for their sustainable use. A farmer who uses different farm plots at different sites has thus built different types of terraces, based on the slope conditions, soil characteristics and drainage features of the farm fields. Moreover, labor availability and the resources at farmers' disposal are also factors for construction. As a result, there have been continuous processes of building terraces, implying that it is not necessary to finish the work in a single event. Through the continuous reworking, farmers also adjust the terraces to changes in the environment and socio-economic conditions over time. For



instance, farmers removed some terraces and widened the spaces for the ox plough which was introduced in the area at the beginning of the twentieth century. Hence, terrace configurations and forms are not similar across one individual's various farm fields. Flexibility has a number of advantages, such as systematic use of the available labor.

The economic benefits of the indigenous terraces, along with other traditional techniques of soil fertility management, are also the main rationale for the continued use of the technology. These measures have created conducive conditions for the growing of crops and therefore also for the sustainability of the people's livelihood.

Moreover, the unique social organization of the area has played a significant role in the success of the indigenous terraces. The link between the people and the land has been enormous; they put much effort into taking the best care their land. There is a social norm which dictates that if a person does not maintain or construct terraces on his farmland, he is considered a lazy farmer. In addition, the community may also fine or cast out the person from social interaction. This also implies the community's appreciation of agricultural work and the value placed on the land. Social organization has also played a significant role, for example in the long-term sustainable use of the terraces in Konso (Besha, 2003; Watson, 2009).

Furthermore, the indigenous terraces are also imbedded in the culture of the communities. These terraces are testimony to the communities' energetic and hardworking culture. The people are very impressive in building and maintaining such indigenous terraces on mountains on which living could have been very difficult without solid terraces. Therefore, the indigenous terraces are an important part of the land use systems in the area.

#### **4.6 Limitations of ISWC**

Despite their environmental compatibility and socio-economic benefits, the indigenous terraces of Chench-Dorze Belle are not without limitations. The constraints are also problems for the expansion of terraces to other places and may also become threats to future sustainable use of terraces. The main constraints originate from the construction materials and human capital, namely labor and social organization. Issues also arise from the innate problems of the terrace structure. Last but not least, problems associated with the recent changes to land use and land management systems also have adverse impacts on sustainable use of the terraces.

Stone is the main material used to construct and maintain the terraces of Chench-Dorze Belle, as discussed in the preceding sections. However, the availability of stones is one of the factors that limit the expansion of terraces to other places. Farmers in the nearby areas of Dorze Belle reasoned that the scarcity of stones in their areas made them unable to have terraces of the Belle type on their farmland. We also observed stone-wall terrace constructions in specific local parts of the Gulle area in which stones are abundant. On the other hand, there are neither stone-wall terraces nor any other types of terrace in the areas close to Gulle, mainly owing to a lack of stones. Thus, stones are a local limiting factor for terrace construction and expansion. In the future, since nearly all available stones have already been used for the terraces in the Dorze Belle area, most farmers will need to travel long distances when they need to build new terraces.

The construction and maintenance of the indigenous stone-wall terraces involves various activities and thus is highly labor demanding and time consuming. The unique features of the social organization and attitude of the people, however, have overcome such constraints and enabled the construction and maintenance of terraces in the area. On the other hand, in other places the labor and social organization limit the adoption and expansion of the indigenous terrace technology.

In Dorze Belle, labor shortages for the construction and maintenance of terraces are also a recent challenge. This is attributed to the migration of young people to towns for economic reasons. The recent modern transformation and assimilation of cultures and religions, as well as urbanization processes have also exacerbated the problem of land management. For example, some people who went to urban areas, where they worked in off-farm jobs, returned to their rural environment with little interest in the construction and maintenance of terraces. The older people rightly stated that their parents were better at constructing and maintaining the terraces than themselves, with the current younger generation being yet weaker in this regard. This shows that the passion for terracing in the young is not as high as in their forefathers.

The narrow spaces between consecutive terraces are another limitation. As a result, farmers' main means of land cultivation is confined only to the two-pronged hoe. Hoe cultivation is time and energy consuming compared to other means of cultivation. On the other hand, due to the limited space for farm fields between the terraces, it is difficult to implement other devices or techniques such as the ox plough. Moreover, terraces in general can also enhance flooding and gully formation if they are not well maintained (Sandor, 2006; Showers, 2006).

Last but not least, the recent pronounced dynamics of land management and land use systems in the area appear to be the main limitations affecting terraces. Among others, the reduction and abandoning of fallowing and manure application, and the decline of crop rotation practices, are the main limitations. Moreover, the lack of off-farm employment keeps the people heavily dependent on the cultivation of their land and this is a major reason for the enormous pressure on cultivated land. The demographic pressure and changes in land management practices affect the agricultural practices, causing a decline in agricultural productivity. These, in turn, have adverse impacts on the indigenous terraces. The situation therefore calls for an urgent assessment of the root causes of agricultural landscape dynamics and accordingly the devising of knowledge-based policies which take into consideration indigenous techniques and behavior.

## **Conclusions**

Radiocarbon dating of a terrace from Chench-Dorze Belle has provided evidence that the stone-wall terraces have been part and parcel of long-lived agricultural activities in the region. This study is a break-through in determining the ages of agriculture terraces in Ethiopia, which in most cases were reported based only on oral history and travel accounts, lacking the support of empirical investigations.

The origin and development of the terraces on the steep mountains of Chench-Dorze Belle are attributed to historical causes, for example defense, settlement patterns, economic benefits and social organization. Indigenous terraces have various uses, such as soil erosion control, runoff reduction, and landscape alteration. They were designed, installed, constructed, and

maintained by the local people. The locals perceived the problems and they had the skills, knowledge and commitments required to manage the land as a survival strategy for life on the steep mountains. Moreover, along with indigenous terraces, farmers have also used soil fertility management practices, namely manuring, crop rotation and fallowing, to maintain or even to boost soil fertility. The long term continued usage of the indigenous terraces is attributed to social commitments, the structural features of the terraces and the farmers' responses to the dynamics of social and cultural circumstances. Generally, the indigenous terrace systems at Dorze Belle represent a phenomenal sight amongst the surrounding degraded land. Terraces are also aesthetically important because they are outstanding features of anthropogenic alteration of sensitive steep slopes, which required skills in perfectly crafting and using stones.

Farmers also acknowledged the advantages of the indigenous terraces compared to the introduced terraces. They suggested that the indigenous terraces are environmentally suitable, socially acceptable and economically feasible. Lessons can thus be drawn from the success story of the indigenous terraces. Farmers' views, as stake holders, on the performance of introduced terraces also have paramount importance in underscoring the constraints associated with the introduced terraces. Admitting failures would be a juncture point for further improvements. Generally, we recommend that the adoptable and sustainable land resources use and management practices should be strongly based on the local knowledge and practices of land management.

The significance and importance of indigenous terraces thus lies beyond their contribution to land productivity and economic significance. It is dubbed a success story in which people invested their skills, labor, energy and knowledge in constructing the terraces in order to manage the environment over generations. It also shows the traditions of the people, which have placed high value on the land and have respected land management practices. The specific indigenous terrace systems are a major part of the cultural landscape, which is unique not only for the region and Ethiopia, but also on a global scale. Thus, there is a strong need to preserve and develop this important cultural heritage and example of sustainable land use and living.

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**Conclusions**

## Conclusions

The agricultural land use systems and forestland of the study area have undergone significant changes during the last century. Cultivated land has increased enormously over the last four decades. However, there was no continuous linear increase over this period of time (spatially and temporarily). Household holdings of cultivated land have decreased over time despite an increase of the extent of total acreage of arable land in the highland. A large number of fragmented landholdings is also a prevailing feature of the area. The average number of fields in fragmented cultivated land areas is estimated at about 5.0 in the upper highland, 4.6 in the middle highland, and 3.7 in the lowland. Moreover, the diversity of crop species and crop varieties in the area has also changed during the last decades. New varieties of crops were introduced while existing crops were modified or disappeared. The diversification of crops has also been reduced and in some cases has been replaced by monocropping. As to the trend of agricultural productivity in the highland, the majority of the farmers responded that there is a decline of productivity at a high rate compared to forty years ago. Similarly, there is a significant downward trend in forest cover change in the area since the 1960s. However, the pattern of decrease in forest cover in the study area was not uniform over time and space owing to various reasons.

The most cited factors that cause deforestation in the study area are agricultural land expansion, fuel wood demand and settlement. According to the informants in the highland, the main reasons for agricultural land expansion are low agricultural production and population increase. Population growth is among the main causes for the scarcity of cultivated land in the area. The problem of land scarcity has been very acute over time, since the existing land was shared and distributed mainly to the male children. Fuel wood demand is another chief cause of deforestation since the fuel wood is also the main source of energy for the surrounding towns, namely Arbaminch and Chenchu. The lowland was covered by forest till the mid-twentieth century. Agricultural practices in the lowland started in the recent past and resulted in intensive forest clearances. One of the main reasons for deforestation in the lowland is settlement, which in turn was caused by different factors such as the decline of malaria, high population density in the highland, government policy, and the expansion of commercial farming.

Deforestation and agricultural land use dynamics are the main reason for the rampant sheet, rill and gully erosion processes in the area. The vegetation removal from steep slopes and the subsequent cultivation resulted in the lowering of soil resilience to erosion and has exacerbated soil erosion by water. In addition, the problem of soil erosion in our investigation area has also been exacerbated by cattle grazing in the remaining forestland, owing to the shortage of proper grazing land. The cattle tracks have caused soil sealing, which in turn reduces soil infiltration and subsequently high surface run-off rates occur during heavy precipitation events. A cattle grazing has also reduced vegetation cover density in forestland. Further, farmers have been cultivating the shallow soils, sometimes saprolite, as observed during the field investigations, which has also enabled an acceleration of surface run-off rates.

Gully systems in the investigation area are characterized by the cyclic succession of phases of entrenchments with aggradations and with stability and soil formation. Gullies are highly modified and altered landscape elements, which in turn have immense implications on the environment and livelihood of the people. Gullies caused stripping of large amounts of soils from the highland and also water availability in the soil for plant growth. In addition, siltation



of irrigation channels and weirs at the lowland is one serious obstacle for agriculture. Frequent flooding that is triggered by gullying has also affected the town of Arbaminch during the last few decades. Blockage, cutting of the side of roads and sediment deposits on the roads is another adverse effect of gullying in the area. More than five decades ago gullies were confined only at a few places, as reported by the farmers. The extension of areas that are affected by gullying has dramatically increased over the last five decades owing to the dynamics of the social, economic and demographic conditions.

Nevertheless, the majority of the farmers have a wealth of experience in identifying the severity, dynamics and causes of soil erosion and soil fertility decline. Farmers were also aware of the seriousness of problems of grazing land deterioration, which affect the raising of livestock. Nearly all surveyed farmers mentioned feed problems as a result of increasing grazing land shortage. The majority of the respondents are aware of the problem of forest decline. Despite the recent disruption farmers have developed a wide range of local strategies as a response to demographic pressure and scarce resources. These include cultivating drought resistance plants (such as enset), growing diversified crop varieties, integrating crop-livestock practices, agroforestry husbandry, and the recent practices of cash crop cultivation. Enset is a drought resistant plant and provides a higher amount of food per unit area than most other cereals. There are about 48 plant species, which are used as food for humans. Intercropping (growing of different crops on the same field in the same season) is one of the systems to grow these crops. Intercropping has been practiced in the area due to the various advantages that overweigh mono-cropping systems in small holding agriculture. Livestock tending is the main integral part of the agriculture system in the area. It has played an important economic and ecological role for a long period of time. Beside crop growing and livestock tending, very few households are engaged in various off-farm activities. These activities would enable them to generate a complementary income and would serve as a strategy to cope with resource constraints.

Traditional forest management is also another salient feature of the land management practices. Forests, woodlots, and stands of trees around the homesteads and in the farm fields, along with the cultivated land prevailed in the study area. Farmers integrated trees with crops in cultivated land as they are aware of the various economic, environmental and social significances for the people. Namely, they are important for daily diets (e.g. moringa), as sources of cash crops (e.g. coffee) and they also provide fuel wood. Trees are also important for beekeeping (apiculture). These trees are also a source of income during crop failures; cash from the sale of wood is used as insurance. Along with their use as fodder for livestock, trees serve as shade during the high sun time when the land is used for pasturing. The people are also aware of the environmental significances of trees, such as maintaining soil fertility (e.g. Erythrina, Hagenia, and Croton) and acting as barriers for surface runoff and soil erosion.

Farmers have developed and used various traditional management practices evolved over the course of time. The main practices for boosting soil fertility are manuring and crop rotation. These practices play vital roles in boosting macronutrients such as nitrogen, phosphorous and potassium in the soils of the area. Manure also contains additions to the minerals that are exported by crop harvest every year. Besides, organic matter is very important in maintaining the soil structure. Moreover, along with soil fertility management practices, farmers have also used indigenous terraces. Radiocarbon dating of a terrace from Chench-Dorze Belle has provided evidence that the stonewall terraces have been part and parcel of long-lived agricultural activities in the region, over eight centuries. These terraces have various uses,

such as runoff reduction, soil erosion control, and landscape alteration. The long term continuous usage of the indigenous terraces is attributed to social commitments, the structural features of the terraces and the farmers' responses to the dynamics of social and cultural circumstances. Farmers also acknowledged the advantages of the indigenous terraces compared to the introduced terraces. They suggested that the indigenous terraces are environmentally suitable, socially acceptable and economically feasible.

All these locally developed, long-term sustainable land use systems and land management techniques in the study area suggest that the agricultural system has been characterized by a high standard of land resource management, providing food and material resources to the inhabitants over centuries. Moreover, the local peoples practices of e.g. forest management and preservation show the people's identity and sense of place and their harmonious relationship with the forest. The significance and importance of indigenous land management such as the installation and use of terraces lies beyond their contribution to land productivity and economic significance. It is dubbed a success story in which people invested their skills, labor, energy and knowledge in constructing the terraces in order to manage the environment over generations. The specific indigenous terrace systems are a major part of the cultural landscape, which is unique not only for the region and Ethiopia, but also on a global scale. Thus, there is a strong need to preserve and develop this important cultural heritage and example of sustainable land use and living. Thus these practices should be promoted and advanced.

On the other hand, there will be a loss of traditional land management practices, of the people's identity and their cultural heritage. The recent changes include reduction and abandonment of fallowing, modification of crop rotation and large-scale reduction of manuring. The resilience of the traditional practices for livelihood requirements is the main driving force for the changes. Furthermore, despite various attempts by government, sheet erosion and gully development remain rampant. The top-down of planning and the negligence of the traditional knowledge are the main drawbacks. The questions to be addressed are therefore how can soil degradation such as gullying be avoided or at least reduced drastically under the conditions of a densely populated and intensively used area with sensitive soils and steep slopes? Watershed management that is based on grass root level community participation from the conception phase to implementation and maintenance is recommended. Site-specific attempts to address the problem should also be considered. In the planning, along with soil and water conservation measures, there should also be some strategies to release population pressure and fulfilling the livelihood of the people. Therefore environmental and land-use management planning should not only consider the rehabilitation of land but also address the main attributes of local management resources, mainly their impact in raising agricultural productivity.

In the investigation area, further research needs also be carried out on past land uses and their impacts on soil degradation. The old gullies are visible in area indicating the past land use impacts. Moreover, it is important to investigate the impacts of old indigenous terraces on natural resources such as on soil properties, and carbon sequestration. Deciphering the role of climate or human induced impacts on long-term environment history will also play a significant role in determining the landscape development of the area. We also recommend carrying out research on modeling and scenario development on land use systems and soil degradation.