SYNTHESIS OF RESEARCH ON LAND USE AND LAND COVER DYNAMICS IN THE ETHIOPIAN HIGHLANDS

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ABSTRACT

Improving the understanding of land use and land cover dynamics can help in projecting future changes in land use and land cover and to instigate more appropriate policy interventions for achieving better land management. Currently available catchment scale studies about land use and land cover change have previously not been synthesized at a larger scale for a more general understanding across the Ethiopian highlands. This review of land use changes attempts to provide an overview of the long term trend of land use and land cover changes in the Ethiopian highlands. The time considered for this review is from 1868–2008, divided into two time intervals. The first interval spans the period 1868–1980 and the second 1980–2008. It was found that there has been a substantial decline of shrublands, woodlands and forest cover and drastic expansion of cultivated land in the Ethiopian highlands from the 1860s to the 1980s. The land use and land cover change from the 1980s–2000s showed continued decline of shrublands and forest cover, but improvements in vegetation cover in some areas. The expansion of cultivated land continued to very steep slopes and marginal lands. The land use and land cover change in the Ethiopian highlands has affected the basic natural resources by causing surface runoff, decreased water retention capacity, decreased stream flow, loss of wetland and drying of lakes. Population growth in the densely populated Ethiopian highlands is one of the most critical drivers of the observed land cover dynamics because the livelihood of almost the entire rural population is dependent on agriculture. In the Ethiopian highlands, arable land expansion has reached the upper limit of the extent. Therefore, the livelihood of the growing population, particularly in rural areas, can only be met by increasing land productivity through intensification of agriculture and by diversifying the means of income such as by creating off-farm job opportunities.

Keywords: Land degradation, land use change, land cover change, Ethiopian highlands, Ethiopia.

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1. INTRODUCTION

Human beings have modified natural environments to obtain food, fibre and other essentials for several thousands of years. Today, however, the rates, extents and intensities of human pressure on land is by far greater than before, affecting the status, properties and functions of ecosystems, which in turn affect the provision of ecosystem services and hence human well-being (Ellis & Pontius, 2007). This notion has been demonstrated by Global Forest Resources Assessment (FAO, 2000) that estimated the net global change in forest area between 1990 and 2000 at around -9.4 million hectares per year, and counted the net loss of forests for the 1990s as a whole as 94 million hectares. According to this assessment, the overall natural forest loss is high in the tropics. The UN Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005) Ecosystems and Human Well-being series, (Volume 1), also indicated that the current rates of land cover change are greatest for moist tropical forests and for temperate, tropical, and flooded grasslands (Hassan, Scholes & Ash, 2005). These changes cause great environmental concerns as they contribute to local and regional climate change, biodiversity loss, soil degradation and the pollution of water, soils and air (Ellis & Pontius, 2007; Chase et al., 1999). Example:

> Changes in land use between 1850 and 1980 are estimated to have increased the global areas in croplands, pastures, and shifting cultivation by 891, 1308, and 30×10^6 ha, respectively, reducing the area of forests by about 600×10^6 ha, releasing about 100 petagram of carbon (Pg C) to the atmosphere, and transferring about 23 Pg C from live vegetation to dead plant material and wood products. (Houghton, 1995, p. 275).

Land use and land cover changes affect ecosystems in two major ways. The first is the direct effect on aquatic and terrestrial ecosystem change and the second is changing the climate by contributing to carbon emission. Therefore, the interest in land use and land cover change is driven by impacts on fundamental ecosystem characteristics and processes, including the productivity of the land, the biological diversity, and hydrological cycles and on climate (de Sherbinin, 2002).

Since the 1970s concerns over land use and land cover change emerged in the research agenda on global environmental change (Lambin, Geist & Lepers, 2003). The main focus of researchers and policymakers around the world has become both monitoring and mediating the negative consequences of land use and land cover change and sustaining the production of essential resources (Ellis & Pontius, 2007).

In sub-Saharan Africa, a combination of growing populations and land degradation are increasing the vulnerability of people to both economic and environmental change (Millennium Ecosystem Assessment, 2005). Land degradation is a serious problem in Africa, but it is most severe in the densely populated highlands of East Africa (Pender, Place & Ehui, 2006). The Ethiopian highlands are among the most densely populated agricultural areas in Africa (McGinley, 2008).

Ethiopia has experienced recorded anthropogenic interference on ecosystems through land use change for four to five decades (Hailu, 2000). Environmental degradation is one of the major constraints impeding sustainable development in Ethiopia, which can be expressed in terms of land and water resources degradation as well as loss of biodiversity (Teketay, 2001). Most researchers are increasingly realizing the contribution of land degradation towards declining agricultural productivity and continuing food insecurity (Taddese, 2001).

Knowledge of land use and land cover change, both on a local scale and a wider scale, is essential in decision-making in relation to a wide range of issues, such as for reversing land degradation, deforestation, and climate change. Improving the understanding of land use and land cover dynamics can lead to the projection of future land use and land cover change and to more appropriate policy interventions for achieving better land management (Lambin et al., 2001).

Furthermore, studying historical trends aids in the understanding of possible future choices and is fundamental to development planning and the analysis of land-related policies (de Sherbinin 2002; Tekle & Hedlund, 2000). ‘‘Failures to understand or acknowledge the historical background, the driving forces, and the local variations in land use in different communities have often resulted in implementation of unsuccessful strategies” (Sandewall, Ohlsson & Sawathvong, 2001, p. 55). Appropriate land use policies are essential for successful recovery or restoration of land (Lambin et al., 2003).

In Ethiopia, many researchers have studied land use and land cover change at the local level, mostly on a catchment scale. This review of larger scale and existing catchment scale studies attempts to provide a holistic understanding that can help to formulate effective policies to achieve better land use management in the Ethiopian context.

Objectives

The research reported had the following objectives:

1. To review research on the long term trend of land use and land cover change for the highlands of Ethiopia over a period of one and half centuries (1860s–2000s)
2. To review the major effects of land use and land cover change
3. To assess the impact of population growth on land use and land cover change in Ethiopia

These objectives were developed using the following key research questions:

What is the general trend of land use and land cover change in the Ethiopian highlands?

Is there a specific trend of land use and land cover change in the Ethiopian highlands?

Did many years of interventions aimed at altering natural resource degradation change the trend of land use and land cover dynamics?

Which major natural resource components are highly affected by the land use and land cover change in the Ethiopian highlands?

How are these natural resources affected by land use and land cover change?

What are the main drivers of land use and land cover change in the Ethiopian highlands?

2. METHODOLOGY

The review analyses the long term trend of land use and land cover change in the Ethiopian highlands from 1868–2008 with the time range divided into two intervals. The first interval spans the period 1868–1980 and the second 1980–2008. For simplicity, all land use and land cover change studies in the Ethiopian highlands, under this review, are categorized into six different geographical areas.

For each time interval and area category, the results are presented in figures and tables explaining changes within the investigated area using available literature. Finally, the results of the reviewed materials are discussed and used to draw broader based conclusions for the land cover change in the Ethiopian highlands.

The narrative synthesis method was used for this review research. According to Popay et al. (2006) narrative synthesis "refers to an approach to the systematic review and synthesis of findings from multiple studies that relies primarily on the use of words and text to summarize and explain the findings of the synthesis." (p. 5) Based on this method the followings steps were used for this review.

2.1 Searching and arranging the available relevant literature

The search for available literature on land use and land cover change and the drivers of the change and its effects in the Ethiopian highlands was carried out in the following way:

Google scholar was used as the main search engine, literature from scientific journal articles were searched using a range of key words which relate to Ethiopia, the Ethiopian highlands, land use change, land degradation, land cover change, etc. Later, for abstract and full text downloading, Hvar.is, which is the Icelandic countrywide access portal to electronic databases and e-journals which automatically links to Google scholar and different library data bases such as Web of Science, Science Direct, etc., was used. After retrieving information about major studies the materials were arranged in a personal Endnote library database. Additional references were identified using the bibliographies cited from the retrieved literature.

A total of 189 publications related to the broad topic of land use and land cover were found. These publications were further scrutinized and 25 publications that particularly address the specific review research questions were selected.

2.2 Organizing the included studies

The published research found during the search is shown in Table 1, starting with recent literature.

2.3 Synthesis

A summary of the major land use and land cover change results for the study sites and areas for different time periods was outlined, using tables, figures and textual narrations, and the trend of

***Table 1**. Land use and land cover change studies in the Ethiopian highlands used for this review.*

No	Source	Catchment / location	Method of Study	Area (km^2)	Period
1	Gebrehiwot, Taye & Bishop (2010)	Koga watershed/ Blue Nile Basin	AP[1] of 1957 & 1982 and SI[2] of 1986 & 2001	266	1957–2002
2	Gebresamuel, Singh & Dick (2010)	Maileba and Gum Selassa watersheds, Tigray	AP of 1964 &1994 and field survey of 2006	40.8	1964–2006
3	Moges & Holden (2009)	Umbulo Catchment/ southern Great Rift Valley	AP of 1965 & 1972 and SI of 1986 & 2000	25.7	1965–2000
4	Garedew,Sandewall, Söderberg & Campbell (2009)	Arsi Negele district / Central Ethiopian Rift Valley	PFPS[3],SI from 1973, 1986 & 2000 and AP of 1972	1400	1973–2000
5	F. Alemayehu et al. (2009)	The upper Agula watershed/ eastern Tigray	AP of 1965 & 1994 and SI of 2000	145	1965–2005
6	Nyssen et al. (2009)	Northern highlands, Tigray	Repeat ground rephotography	10000	1868–2008
7	Mengistu (2009)	Hare River watershed /Abaya-Chamo sub-basin, southern Rift Valley	AP of 1967 and 1975 SI of 2004	182	1967–2004
8	Tefera & Sterk (2008)	Fincha Watershed/Blue Nile Basin	AP for 1957 &1980 and SI of 2001	1318	1957–2001
9	Munro et al. (2008)	The Central Plateau region of Tigray	Ground-based photographic monitoring	6000	1975–2006
10	Dessie & Christians-son (2008)	Awassa/south Central Rift Valley	Travelers' accounts	–	1900–1972
11	Dessie & Kleman (2007)	Awassa/south Central Rift Valley	AP of 1972 and SI of 1972 & 2000	3060	1972–2000
12	Amsalu, Stroosnijder & Graaff (2007)	Beressa watershed/ central highlands	AP of 1957, 1984 SI of 2000	215	1957–2000
13	Aynekulu, Wubneh, Birhane & Begashaw (2006)	Begasheka Watershed / northern highlands	PGIS[4]	1.7	–
14	Muzein (2006)	Ziway-Awassa Basin/ Central Ethiopian Rift Valley	SI of 1973, 1986 & 2000	–	1973–2000
15	Bewket & Sterk (2005)	Chemoga Watershed/ Blue Nile Basin	AP in 1957 & 1982 and SI of 1998	364	1957–1998
16	Dwivedi, Sreenivas & Ramana (2005)	GamoGofa/ southern Rift Valley	SI of 1994 &1997	1883	1994–1997
17	Tegene (2002)	Derekolli Catchment / south Wollo, Blue Nile Basin	AP of 1957 & 1986 and SI of 2000	15.3	1957–2000
18	Bewket (2002)	Chemoga Watershed/ Blue Nile Basin	AP of 1957 & 1982 and SI of 1998.	364	1957–1998
19	Zeleke & Hurni (2001)	Demebecha woreda/ Blue Nile Basin	AP of 1957 & 1982 and SI of 1995	271	1957–1995
20	Reid et al. (2000)	Ghibe Valley/South west highlands	AP of 1957 & 1973 and SI of 1987 & 1993	2200	1957–1993
21	Tekle & Hedlund (2000)	Kalu District, Wollo/ Blue Nile Basin	AP of 1958 & 1986.	110	1958–1986
22	Reusing (2000)	Southwest	AP of 1971 & 1975 and SI of 1986 & 1990	–	1973–1990
23	Crummey (1998)	Wollo Region/north eastern highlands	Ground repeat photography	–	1937–1997
24	McCann (1997)	Ankober/ Central highlands	19th century travellers' accounts	–	19th century
25	Wøien (1995)	Debre Sina / Central highlands	AP of 1957 & 1986	150	1957–1986

1: AP=Aerial photography
2: SI=Satellite Image
3: PFPS=Participatory Field Point Sampling
4: PGIS =Participatory Geographic Information System

change was subsequently analysed further. The principal drivers that were explored in most areas studied were noted and used for the synthesizing discussions. Furthermore, the effects of land use and land cover change on major environmental components are also discussed.

3. LAND DEGRADATION IN ETHIOPIA

3.1 Background

Ethiopia, with a total area of 1,221,900 km^2, is situated in eastern Africa and lies between 3°15' and 18° north of the equator; and between 33° and 48° east longitude (Fig. 1). The country is endowed with a variety of agro-ecological zones, and landscapes that vary from lowlands to high plateaus with a diverse terrain which is fundamental to regional variations in climate, vegetation and soil. Ethiopia is Africa's second-most populous country with a population of about 85,237,338 (CIA, 2010). The climate is tropical monsoon with wide topographic-induced variations and elevations that vary from 125 m below sea level to 4620 m above sea level.

Land use in Ethiopia is categorized as 12% arable land, 1% permanent crops, 40% permanent pastures, 25% forest and woodland, and 22% other (Taddese, 2001). The geologically active Great Rift Valley cuts through the country, with periodic earthquakes and volcanic eruptions. Droughts are frequent in Ethiopia. Environmental issues facing the country include deforestation, overgrazing, soil erosion, and desertification.

The Ethiopian highlands, where humans settled more than 5000 years ago, have been facing a serious problem of heavy deforestation and environmental degradation resulting from agricultural exploitation (Hurni, 1982, 1990; Yirdaw, 1996). According to some archaeological and palynological studies, there was a major clearing of the forest about 2000 years ago (Yirdaw, 1996). Therefore, over many centuries, there has been a persistent human impact on the environment with increasing pace from time to time due to increased human demand and population growth.

Fig. 1. *The location of Ethiopia.*

3.2 Land degradation in the Ethiopian highlands

About 75% of sub-Saharan African highlands are located in eastern Africa. The Ethiopian highlands are the largest in Africa, almost half of the African highland area (Gryseels & Anderson, 1983) and also one of the largest highland areas in the tropics (Kloos & Adugna, 1989).

The Ethiopian highlands, the rugged plateau region of East Africa, are divided by the Great Rift Valley into the north-western and south-eastern highlands. The north-western highlands are again divided into northern and southern sections by the valley of the Blue Nile River that has its headwaters in the highlands. The climate is semi-arid on the rift valley floor and sub-humid to humid in the adjacent highlands. The annual rainfall varies from 600 to 800 mm on the Rift Valley floor to around 1200 mm in most of the highlands.

The Ethiopian Rift Valley, which is characterized by a rich fauna and flora, has impressive hydrological networks endowed with a chain of several lakes with very important biological resources. The Ethiopian Rift Valley Lakes Basin (RVLB) is among other Ethiopian highland river basin ecosystems threatened by serious environmental degradation, increased soil erosion, decreased water quality and loss of biological diversity on land and in the lakes (Sissay, 2003).

The Blue Nile River and its tributaries drain through most parts of the central, western and south-western highlands of Ethiopia. In the Upper Blue Nile Basin, high population pressure along with lack of alternative livelihood opportunities and sluggish rural development are causing deforestation, overgrazing, land degradation and declining agricultural productivity (Awulachew, Erkossa, Smakhtin & Fernando, 2009). Most studies of land use and land cover change have been focused mainly in the Blue Nile River Basin and Ethiopian Rift Valley Lakes Basin (Fig. 2).

Generally, the Ethiopian highlands, which cover about 45% the country's total land area, contain 93% of the cultivated land (Omiti, Parton, Sinden & Ehui, 1999) and are home to 90% of the total population and about 75% of the 33 million livestock population (SCRP, 1996; Hawando, 1997), which is believed to be the largest livestock concentration in sub-Saharan Africa.

Soil degradation in the Ethiopian highlands dates back several thousand years following the introduction of agriculture (Hurni, 1990). Subsistence small holder mixed farming with crops and livestock has a long tradition of farming in the highlands of Ethiopia which greatly altered both the vegetation and the landscape. These causes were enhanced by a persistent increase of human and livestock populations. Severe environmental degradation, mainly deforestation and soil erosion, is more prevalent in the northern and central highlands gradually extending to the southern parts of the highlands (Getahun, 1988; Hurni, 1990). The Ethiopian highlands are considered to be one of the most degraded areas in Africa (El-Swaify and Hurni, 1996). According to Nyssen et al. (2004), land use changes and drought have been considered the two major factors for land degradation and desertification in the Ethiopian highlands.

Fig. 2. The Ethiopian highlands, the Blue Nile and the Ethiopian Great Rift Valley.

4. TRENDS IN LAND USE AND LAND COVER CHANGE SINCE THE 1860

4.1 Review of methods used for studying land use and land cover change

Several methods have been used for acquiring the scene of the landscape in the past in Ethiopia. The earliest documented ground-based photographs containing landscape information about Ethiopia date back to 1868 (Nyssen et al., 2009), followed by aerial photographs taken in the late 1950s and remotely sensed satellite images as early as the 1970s. Visual interpretation and Geographical Information Systems (GIS) have been used for analysis of the information. Repeated photography, mainly used for the purpose of mapping the vegetation cover, is particularly valuable for assessing vegetation change (Crummey, 2009).

In Ethiopia, the aerial photographs with a scale of 1:50,000 were made from 1957–1967, which was the first national aerial survey covering almost the entire territory of a country (Crummey, 2009). Since then, according to the Ethiopian Mapping Agency (EMA), series of aerial photographs of different scales have been taken covering part or most of the country. Many research studies have used the photographs to interpret and analyse land use and land cover change. Since the launch of the first US Landsat satellite in 1972, several researchers in Ethiopia have used satellite imagery for analysing land use and land cover change and other environmental research purposes using various analytical techniques.

The research reviewed here has used various combinations of photographs including three pairs of ground photographs from 1868 & 2008, 1937 & 1997 and 1975 & 2006; the aerial photographs of 1957, 1958, 1964, 1965, 1967, 1971, 1972, 1973, 1975, 1980, 1982, 1984, 1986 & 1994; and satellite images taken in the years of 1972, 1973, 1986, 1987, 1990, 1993, 1994, 1995, 1997, 1998, 2000, 2001, 2004, 2005 and 2006.

The methods used for recording the landscape information depend on the availability of the technology at the time information was obtained and this determine the reliability of the information in terms of landscape details and aerial representation. There are also other methods used as complementary methods which include Participatory Field Point Sampling (PFPS), Participatory Geographic Information System (PGIS), empirical models, field observations/ field surveys and travellers' accounts. The Participatory Field Point Sampling (PFPS) method is based on using the local knowledge by engaging senior key informants from the study area for acquiring information about the past, present and expected future land use on an evenly distributed systematic grid of sample points (Sandewall, Ohlsson & Sawathvong, 2001).

The Participatory Geographic Information System (PGIS) is another method used for assessing the current and past land use and land cover change by involving the local elderly people in producing the graphic representation of the study area using local materials, such as leaves, stones, sticks etc., on the ground and transferring the information into a Geographical Information System (GIS) for further analysis (Aynekulu et al., 2006).

Travellers' accounts are based on recordings of the landscape information, using ground photographs and sketch maps by visitors who travelled to the different parts of the country during the mid-19th and early 20th centuries (Crummey, 2009; Dessie & Christiansson, 2008). The studies used in this review give a good representation of the Ethiopian highlands as seen in the figure below (Fig. 3).

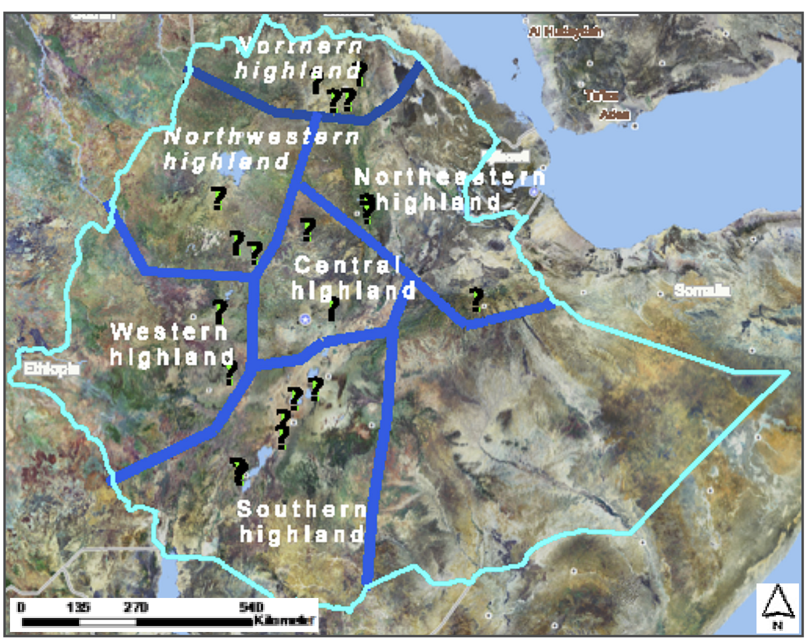

Fig. 3. *The location of sites under review. Note: Highland borders shown on the map are approximations and are not official highland boundaries.*

4.2 Land use and land cover patterns between the 1860s–1980s

During this first time interval (1860–1980s), the year 1868 marks the beginning where information about Ethiopia's landscape was first obtained using ground photography. Therefore, in this section the earliest documented changes from 1860s to 1980s will be discussed for different geographical areas of the Ethiopian highlands.

4.2.1 Trend of land use and land cover change in the northern Ethiopian highlands

Environmental change in the northern Ethiopian highlands in the Tigray region has caused the forest and soil resources to diminish at unprecedented rates for the past half century (Munro et al., 2008). According to Nyssen et al. (2004) long time deforestation, overgrazing and poor management of natural resources have contributed to land degradation in the highlands of the northern Tigray region. Arable land expansion by forest clearing to get more cropland for an increasing number of people and to compensate for low agricultural productivity has been the principal form of land cover change for Ethiopian highlands as a whole and for the northern highlands in particular (Mekuria et al., 2007).

The northern Ethiopian highland (Tigray) has been covered by a very comprehensive set of catchment studies that have been used to assess not only the land use and land cover changes but also the impact of interventions.

A study by Nyssen et al. (2009) on vegetation and land management status in the Tigray region of northern Ethiopia was conducted by comparing a matched pair of photographs; the first taken in 1868, the second a contemporary photograph obtained in 2008. This can be considered the first long term study for land use and land cover change in the Ethiopian highlands. The study assessed the current status of vegetation with the same landscape 140 years ago, using thirteen pairs of landscape photographs. Nyssen and co-workers concluded that the condition of the land in 1868 was already very degraded (Fig. 4).

Munro et al. (2008) conducted a similar study in the central plateau region of Tigray, with 30 year intervals using photos taken in 1975 and 2006, employing a semi-quantitative method of measuring soil loss. The study described the condition of vegetation cover before and during the first part of this period (1970s) as strongly degraded, resulting from the combined effect of recurrent drought, impoverishment, poor land husbandry and war.

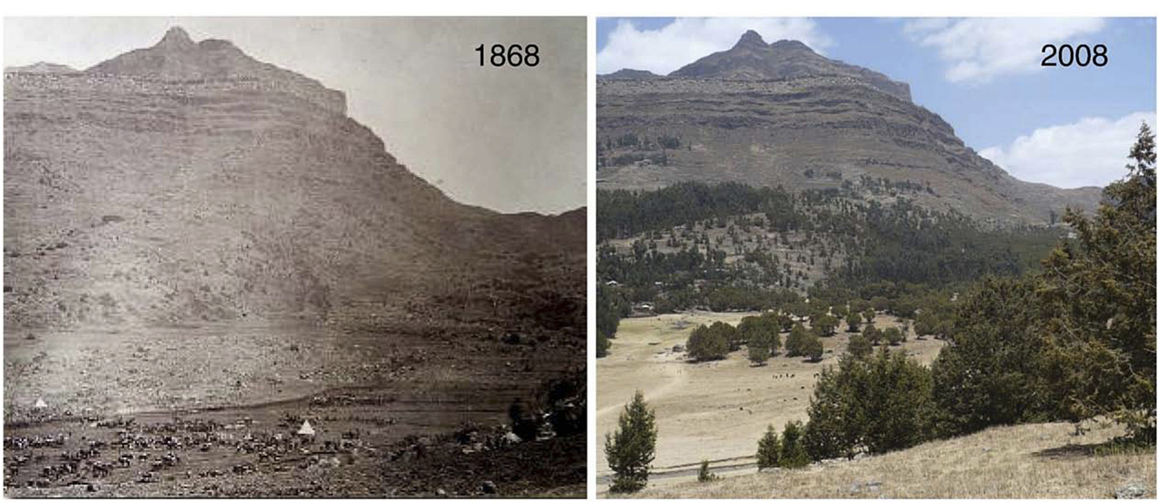

Fig. 4. *The Bolago valley, Tigray, showing bare landscape in 1868 and improved condition in 2008 (Source: Nyssen et al., 2009).*

According to the above two studies, using a similar method of repeated photography, the landscape from 1868 until 1975 was already highly degraded, indicating that the degradation from 1860s continued up to the 1970s. There are also other similar arguments that favour the above findings by narrating the deterioration of vegetation cover since the late 19th century in Ethiopia, especially in the northern part of the country, which was aggravated by the 1880s, and 1890s drought and famine (Pankhurst, cited in Dessie & Christiansson, 2008).

F. Alemayehu et al. (2009) used the aerial photo interpretation to research the upper Agula watershed, Tigray. The analysis compared land cover between the years 1965 and 1994. The study revealed the disappearance of vegetation, especially wood shrub, grassland and shrub lands at the expense of crop land expansion from 51% in 1965 to 55% in 1994. This claim was confirmed by interviews with farmers living in the area who said that the catchment had a better natural vegetation cover before the 1960s. The above three studies indicate continuous environmental degradation, particularly the loss of vegetation from 1868 to 1965 and which extended further than 1975.

Recent research by Gebresamuel et al. (2010) of two different watersheds in the highlands of Tigray came up with a different impression than what we have from other studies of the same area. According to their study, there was a decrease of cultivated land by 5% (Maileba watershed) and 9% (Gum Sellasa watershed) from 1964 to 1994 (Table 2). The likely reason suggested was area enclosures which are among the rehabilitation efforts that are being undertaken in the area by the government. The vegetation cover results are, however, in agreement with other studies mentioned above with a decline of forest cover, woodlands and shrublands (Table 2).

Results found using the Participatory Geographic Information System (PGIS) methods implemented in Begasheka watershed, Tigray, by Aynekulu et al. (2006) show similar results. The study indicated that for the last 50 years; 75% of forest land had been converted to arable land, which is in harmony with other studies in the region (Aynekulu et al., 2006).

Table 2. *Major land use and land cover changes in Gum Sellasa and Maileba, in the Tigray region (Source: Adapted from Gebresamuel et al., 2010).*

Land use/land cover	**Year**					
1. Gum Sellasa	**1964**		**1994**		**Change (1964–1994)**	
	ha	**%**	**ha**	**%**	**ha**	**%**
Cultivated land	1808	77	1650	70	-157	-9
Forest land	33	1.4	19	0.8	-14	-42
Shrublands	219	9	99	4	-120	-55
Woodland	53	2	0	0	-53	-100
2. Maileba	**1964**		**1994**		**Change (1964–1994)**	
	ha	**%**	**ha**	**%**	**ha**	**%**
Cultivated land	1313	76	1244	72	-69	-5
Forest land	2	0.1	2	0.06	-0.24	-14
Shrublands	33	2	22	1	-11	-33
Woodland	53	3.2	47	3	-6	-11

The studies of Nyssen et al. (2009) and Munro et al. (2008) analysed a series of paired ground photographs to investigate the past and present condition of vegetation cover. This method showed only a limited portion of the landscape, however, which can hardly indicate the overall change. Hence, it hardly covers the dynamics of landscape change that has happened during the past 140 years. However, further analysis of the situation using more diverse methods including the participatory local knowledge of elderly people and a series of matched aerial photographs and satellites images have provided a much wider view of the landscape than ground photographs and make the land use and land cover dynamics information more reliable.

4.2.2 North-eastern part of the Ethiopian highlands

The north-eastern part of Ethiopia, where cultivation has a long history, has had much publicized and recurrent droughts and famine in the past, particularly in the 1970s and 1980s. Deforestation, vegetation clearance and cultivation on steep slopes are being considered as the main driving forces for the problem (Admassie, 2000; Tegene, 2002). Wollo is a region that is particularly affected by heavy grazing and clearing of vegetation (Tekle, 1999).

Crummey (1998) studied landscape change in Tahuladare Woreda in Wollo using the methodology of matched pairs of photographs between 1937 and 1997. He found out that the Wollo environment is marked today by many more trees, and probably by considerably greater woody biomass, than it was in the 1930s. However, Crummey did not get a significant extension of the cultivated area from his photo analysis.

Later, Tekle & Hedlund (2000) studied land use and land cover changes in the north-eastern part of the Ethiopian highlands in the southern Wollo (Kalu District) by analysing two aerial photographs from 1958 and 1986. The study revealed the reduction of shrublands by 51% and of forests by 31% between 1958 and 1986 (Table 3). The increase in cultivated land was very insignificant (2% increase), which is in agreement with the findings of Crummey in a nearby

Table 3. *Major land use and land cover change in the north-eastern part of the Ethiopian highlands.*

Land use/land cover	**Year**					
1. Kalu District (Tekle & Hedlund, 2000)	**1957**		**1986**		**Change (1957–1986)**	
	ha	**%**	**ha**	**%**	**ha**	**%**
Cultivated land	5470	49.6	5600	50.8	130	2.4
Forests	860	7.8	590	5.4	-270	-31.4
Shrublands	3040	27.6	1490	13.5	-1550	51.0
2. Derekolli catchment (Tegene, 2002)						
Cultivated land	994.0	65.1	1064	69.7	70.2	7.1
Shrubland	251.2	16.4	105	6.9	145.8	-58.0
Grassland	24.4	1.6	71	4.7	46.6	191.0
Shrub-grassland	169.0	11.1	219	14.4	50.4	29.8

area. However, Tekle & Hedlund (2000) concluded that the small increase in cultivated areas may either have been because the areas left uncultivated were not suitable for cultivation or had been under protection. These suggestions are also in harmony with the conclusion made by Crummey, namely that almost all the currently cultivated land in Wollo might be used for cultivation back in the 1930s.

Another study by Tegene (2002) in the Derekolli Catchment, South Wollo area, showed that the shrubland declined by 58% between 1957 and 1986, with an increase in cultivated land of only 7%. This is in good agreement with the findings of Tekle and Hedlund (2000), who indicated an increase of only about 2% for the Kallu district, in the same period of 1957–1986. On the other hand, the increase in shrub grassland by 29.8% and grassland by 191% was presumably due to human intervention in modifying shrubland into shrub grassland and grassland by removing woody plants for fulfilling the domestic energy demand and as a means of earning income, in addition to overgrazing by livestock and subsequent bush encroachment (Tegene, 2002).

Generally, in the north-eastern highlands (Wollo), there was little expansion of cultivated land because of the lack of suitable land for cultivation. Although the review did not find an earlier study from the 19th century for the Wollo region it is very likely that Wollo had been degraded since early in the 19th century. However, a huge destruction of shrubs and forests was taking place from the 1930s to the 1980s.

4.2.3 North-western highlands of Ethiopia

The north-western highlands of Ethiopia comprise an area in the upper Blue Nile Basin, which is mainly known as the Abay Basin. Land use change induced by population increase in the upper Blue Nile catchment has contributed to century-old land degradation (Hurni, 1993).

Three land use and land cover change studies were found for this area. The first study was in the Chemoga watershed (Gojjam). It shows a remarkable decrease of woodlands by 46% and shrublands by 41% between 1957 and 1982 with 13% expansion of farmland (Beweket, 2002). The riverine trees were also among the most affected vegetation, indicating the continuous shrinking of the width of these strips of vegetation cover along the rivers from 458 ha in 1957 to 277 ha in 1982, which is a 40% decrease.

Furthermore, this claim gains support from a second study carried out a bit earlier but covering a similar period from 1957 to 1982 in the same region of the north-western highlands of Ethiopia. It is within the Dembecha area, Gojjam, and the study was done by Zeleke & Hurni (2001). The study illustrates the decline of the natural forest cover from 27% in 1957 to 2% in 1982 with an increase of cultivated land from 39% in 1957 to 70% in 1982, which is a 78% increment of cultivated land within only two and a half decades (Table 4).

A recent study, which covered the same study period as the one by Zeleke & Hurni (2001) and Beweket (2002) came up with a similar trend of land use and land cover change. The study was done by Gebrehiwot, Taye & Bishop (2010) at Koga watershed at the headwaters of the Blue Nile Basin. The research found a striking forest decline of about 86% and a 40% expansion of cultivated land between the years 1957 and 1986 (Table 4). What has been seen from the above

Table 4. *Land use and land cover change in the North-western part of the Ethiopian highlands.*

Land use and land cover	Year					
1. Chemoga watershed (Beweket, 2002)	**1957**		**1982**		**Change (1957–1982)**	
	ha	**%**	**ha**	**%**	**ha**	**%**
Farmland/ settlements	22000	60.4	24832	68.2	2832	13
Forests	873	2.4	1041	2.9	168	19
Shrublands	1860	5.1	1099	3	-761	-41
Grassland/degraded land	3508	9.6	1766	4.9	-1742	-50
Riverine trees	458	1.3	277	0.8	-181	-40
Woodland	2449	6.7	1321	3.6	-1128	-46
Marshland	5252	14.4	6064	16.7	812	15
2. Demebecha Woreda (Zeleke & Hurni, 2001)						
Cultivated land	10692	39.5	19031	70.2	8338	78
Natural forest	7342	27.1	452	1.7	-6889	-94
Grassland	4901	18.1	3865	14.3	-1037	-21
Bushland	1349	5.0	1030	3.8	-319	-24
Shrubland	25	0.1	309	1.1	283	1132
Grass-and bushland	1691	6.2	1149	4.2	-542	-32
Bare land	17	0.1	69	0.3	53	312
3. Koga Watershed (Gebrehiwot et al., 2010)						
Cultivated land	12400	47	17300	65	4900	39.5
Forest land	4200	16	600	2	-3600	-85.7
Open bush land	1600	6	3300	13	1700	106.3
Scrub-wetland	7600	28	4100	15	-3500	-46.0

three studies carried out in the north-western highlands of Ethiopia is a very significant decline in forest cover and a proportional expansion of cultivated land.

4.2.4 Central highlands of Ethiopia

MacCann (1997) studied historical forest cover in the Ethiopian central highlands focusing around Ankober, the 19th century capital of one of the old kingdoms of Ethiopia, Shewa. MacCann mainly used European traveller's accounts for reconstructing the long term landscape condition. He states that "Ankober, and much of the central highland landscape has been devoid of trees and wood fuel for at least 150 years, and almost certainly much longer." (p. 142) More specifically, he indicated that deforestation in the central highlands of Ethiopia has long been going on since the late 19th century (MacCann, 1995), (Fig. 5).

In 1995, Wøien used aerial photo interpretation along with the Geographical Information System (GIS) in Northern Shewa province near the town of Debre Sina, covering an area of 150 km^2, to

Fig. 5. *19th century deforestation, wood to sell in Ankober, Ethiopian central highlands, 1880 (Source: McCann, 1995).*

study woody plant cover changes between 1957 and 1986. The result was somewhat surprising, showing an increase of woody plant cover from 4.4% in 1957 to 9.2% in 1986. According to Wøien (1995), the change in vegetation is most likely a result of afforestation and land rehabilitation programmes that were established in the region around 1981. According to the study, the gain in vegetation may be attributed to its easy accessibility that favoured the place to get more emphasis from a special afforestation programme (Robi Catchment Project) established in 1981. Wøien's focus seems to have been more on vegetation cover change than the cultivated land condition; he didn't mention land use change nor the condition of agricultural land in the area.

Another study was conducted in an adjacent area by Amsalu, Stroosnijder & Graaff (2007), using a similar method of aerial photographs analysis from the years 1957 and 1984 in the Beressa watershed, North Shewa. Progressive decline of natural vegetation cover was prevalent in this case, from 15% of the total land area under natural vegetation in 1957 to about 7% in 1984. A small increase in cultivated land (3%) was observed between 1957 and 1984. Generally, between the years 1957 and 1984, there was a reduction in natural vegetation and plantations by 55% and 35%, respectively (Table 5). According to the authors, the cleared natural forest area was converted into bare land (30%), cropland (21%) and grazing land (14%).

4.2.5 South-central Ethiopian highlands

This area covers most parts of the central and southern Central Rift Valley regions of the Ethiopian highlands. During the 19th century, most parts of the south Central Rift Valley was covered by remnants of high forests (Chaffey, 1979). However, starting from the late 19th century, the continuous change of socio-political, economic, and cultural conditions has affected the natural indigenous forest cover of southern Ethiopia, (McCann, 1999; McClellan, 2002).

Since the 1880s, noticeable land use change has taken place in the southern central Ethiopian highlands as a consequence of the introduction of new farming systems including the ox-plough

Table 5. *Land use and land cover change in the Beressa watershed (Amsalu et al., 2007).*

Land use and land cover	Year					
	1957		1984		Change (1957–1982)	
	ha	%	ha	%	ha	%
Cropland	11832	54.8	12171	56.6	339	3
Natural vegetation	3191	14.8	1451	6.8	-1740	-55
Plantations	386	1.8	252	1.2	-134	-35
Riparian vegetation	301	1.4	225	1.1	76	25
Bare land	3520	16.3	2769	12.8	-751	-21
Grazing land	1826	8.5	4032	18.7	2206	121

and cereal cropping, used on the former predominantly pastoral areas, because of the migration of more people from northern Ethiopia to the south following the 1882–1892 infamous famine in the northern part of the country (Maud, cited in Dessie & Christiansson, 2008).

Dessie & Christiansson (2008), using qualitative descriptions such as travellers' accounts drew the conclusion that from the late 1800s to around 1930 significant forest decline had been very likely in parts of the south Central Rift Valley region. The authors mentioned a combination of events for the forest decline, such as the introduction of coffee farming and land tenure arrangement that transferred the major part of the land to state ownership. Another study based on satellite image analysis in the Awassa watershed and the surroundings revealed that almost 82% of the forest cover was lost between 1972 and 2000 (Dessie & Kleman, 2007). This is a huge loss in terms of areal extent from 48,924 ha of forest cover in 1972 to 8,600 ha in 2000 (Table 6).

Table 6. *Forest cover change between 1972 and 2000 in the Awassa watershed (Dessie & Kleman, 2007).*

Forest area	1972	2000	Change (1972–2000)
ha	48924	8600	40324
%	16.0	2.8	82.4

Garedew et al. (2009) applied a combination of methods including satellite image analysis and Participatory Field Point Sampling (PFPS) to the Arsi Negele district, which is part of the Ethiopian Central Rift Valley, covering an area of 1400 km^2. The two methods showed the same trend of changes, particularly the change in the woodland, cropland and bare land categories (Table 7). The study divided the area into two peasant associations according to the government administrative structure, namely: the Gubeta-Arjo and the Keraru peasant associations (PAs). Similar trends for land use and land cover changes were shown for both study sites in the first category of the study period; from 1973–1986 with decreasing woodland cover and a corresponding increase in cropland area (Table 7).

Muzein (2006) used remote sensing and GIS to study the land use and land cover changes in the Central Rift Valley in the Zeway-Awassa basin, including the Arsi Ngele district and the

Table 7. Major land use and land cover change in Arsi Negele (Garedew et al., 2009).

Land use/land cover	Method	Year					
1. Keraru		**1973**		**1986**		**Change (1973–1986)**	
		ha	**%**	**ha**	**%**	**ha**	**%**
Cropland	Landsat	971	33	1426	49	455	46.9
	PFPS[1]	721	25	1298	44	577	80.0
Woodland	Landsat	1175	40	254	9	921	-78.4
	PFPS	1298	44	240	8	1058	-81.5
2. Gubeta-Arjo							
Cropland	Landsat	512	35	816	56	-304	59.4
	PFPS	408	28	639	44	-231	56.6
Woodland	Landsat	789	54	0	0	789	-100.0
	PFPS	843	58	0	0	843	-100.0

1: PFPS = Participatory Field Point Sampling

Awassa watershed. He focused on application of remote sensing and GIS for land cover and land use change detection. The study found a substantial forest cover loss at the expense of cultivated land expansion. In this case, about 152,000 ha of land that had been covered with forests and woodlands in 1973 had been reduced to nearly 112,000 ha in 1986, or about 27% of the woodland cover in just about one decade (Table 8). On the other hand, the extent of cultivated land increased from about 276,000 ha in 1973 to about 586,000 ha in 1986, which is a 113% expansion of cultivated land within a 13 year period (Table 8).

A closer investigation using aerial photo interpretation by Moges & Holden (2009) in the Umbulo catchment, the southern Ethiopian highlands, which is adjacent to the Awassa watershed, explored land cover change between 1965 and 1972. On a large tract of land they showed an increase of 137% for cultivated land at the expense of woodland and shrubland which shrank from 65% to 44% (Table 8).

Another study in the Abaya-Chamo sub-basin of the southern Ethiopian Rift Valley by Mengistu (2009) showed a significant rate of change from forest land into farmland. As indicated below in (Table 8) the farmland and settlement had increased by about 72% while the forest cover decreased by 17% within less than a decade. The rate of change amounted to 247 ha yr^{-1} over the 10 year period in this 2600 ha watershed.

4.2.6 Western and south-western Ethiopian highlands

Human intervention, both in conventional ways using traditional tools and in modern ways using sophisticated machinery, imposes threats to the environment of south-west Ethiopia. Construction of dams for irrigation purpose or for hydropower production is essential to fulfil the increasing demand for food and energy, particularly in developing countries like Ethiopia. However, the environmental impacts need to be thoroughly assessed before the construction

Table 8. *Results of land use and land cover change studies in southern central Ethiopian highlands.*

Land use and land cover	Year					
1. Ziway-Awassa Basin (Muzein, 2006)	**1973**		**1986**		**Change (1973–1986)**	
	ha	**%**	**ha**	**%**	**ha**	**%**
Agricultural land	275677	21.2	586135	45.1	310457	112.6
Closed low land forest	8642	0.7	6916	0.5	-1726	-19.9
Closed mountain forest	97989	7.5	69223	5.3	-28766	-29.4
Closed woodland	45692	3.5	35497	2.7	-10195	-22.3
Open woodland, shrubland or bushland	108680	8.4	66956	5.2	-41724	-38.4
2. Umbulo Catchment (Moges & Holden, 2009)	**1965**		**1972**		**Change (1965–1972)**	
	ha	**%**	**ha**	**%**	**ha**	**%**
Cropland/ Cultivated land	331	13	784	30	453	137
Forests/woodland	347	13	122	5	-225	-65
Shrublands	356	14	201	8	-156	-44
Grassland	610	24	631	25	21	3
Degraded land	555	22	589	23	33	6
Grassland with shrubs	173	7	37	1	-136	-79
3. Abaya-Chamo sub-basin (Mengistu, 2009)	**1967**		**1975**		**Change (1967–1975)**	
	ha	**%**	**ha**	**%**	**ha**	**%**
Farmland and settlement	2756	16.5	4728	28.3	1973	71.6
Forests	5757	34.4	4758	28.4	-999	-17.4
Wood lands/shrublands	2114	12.6	2305	13.8	191	9.0
Grass lands/pasture lands	3278	19.6	2843	17.0	-436	-13.3

of dams to avoid or minimize the adverse effects on the environment, particularly land use change.

The Fincha hydropower dam was constructed in 1973 within the Fincha watershed, which is a tributary to the Blue Nile. Land use change in the Fincha watershed, western Ethiopia, was studied by Tefera and Sterk (2008), mainly focusing on hydropower-induced land use change from the Fincha hydropower dam. According to their study forest cover declined by 51.6% between 1957 and 1980 with a corresponding expansion of cropland by 18.7% and decreased grazing land by 50.8%.

A case study of south-western Ethiopia at Gibe Valley (Reid et al., 2000) showed cultivated land had expanded from 21% in 1957 to 25% in 1973. Subsequently, there was a reduction of cropland to 13% in 1987 (Table 9). The wooded grassland showed a small decline of around 7% from 1957 to 1973, but it increased nearly by 18% between 1973 and 1987. On the other hand, the riparian woodland increased by 21% between 1957 and 1973 and decreased by 12% between 1973 and 1987 (Table 9). Therefore, the wooded grassland and riparian woodland seems not to follow any specific pattern of change between the years 1957 and 1987.

Table 9. Land use and land cover change in the Gibe Valley and the Fincha watershed.

Land use and land cover	Year									
1. Gibe valley (Reid et al., 2000)	**1957**		**1973**		**Change (1957–1973)**		**1986**		**Change (1973–1987)**	
	ha	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
Small holder cultivation	9630	21.0	11510	25.1	1880	19.5	6330	13.8	-5180	45.0
Wooded grassland	33750	73.7	31300	68.4	-2450	-7.2	36880	80.5	5580	17.8
Riparian woodland	2420	5.3	2940	6.4	520	21.6	2590	5.6	-350	-12.1

Land use and land cover	Year					
2. Fincha watershed (Tefera & Sterk, 2008)	**1957**		**1980**		**Change (1957–1980)**	
	ha	**%**	**ha**	**%**	**ha**	**%**
Cropland	40330	30.6	47880	36.3	7550	19
Forest	7050	5.4	3410	2.6	-3640	-52
Grazing land	55520	42.1	27290	20.7	-28230	-51

4.3 Changes in land use and land cover, 1980s–2000s

In this section, more recent changes are discussed than in section 4.2.

After the drought and subsequent famine of the 1970s and ‘80s in Ethiopia, land degradation was addressed more seriously by promoting massive afforestation and conservation programmes (Bewket & Stroosnijder, 2003; Tadesse, 2001; Wøien, 1995). It was at this time that research programmes were also established to provide technical and scientific support for the conservation programmes. The Ethiopian Soil Conservation Research Programme (SCRP) was established in 1981 jointly with the Ethiopian and Swiss governments (SCRP, 1982). Since the early 1980s reforestation, mainly on private agricultural land, has occurred in many places in the Ethiopian highlands (Hurni, Tato & Zeleke, 2005)

There have been several studies to document the status of land cover change and the results of natural resource management efforts implemented over the past several decades.

There were impressive quantitative results obtained in afforestation and conservation programmes; however the overall achievement was evaluated as unsatisfactory, especially compared to the extent of the problem (Hurni, 1990; Bekele, 1997; Admassie, 2000; Bishaw, 2001; Taddese, 2001).

4.3.1 Northern Ethiopian highlands

Nyssen et al. (2009), in their photo-monitoring analysis, praised “the remarkable” recovery of vegetation cover in 2008 in the northern part of the Ethiopian highlands as compared to the condition back in 1868. Figures 4 and 6 give a good testimony of improved vegetation in 2008 and 2006, respectively. The study demonstrated the possibility of reversing environmental degradation in semi-arid areas where active, farmer-centred soil and water conservation (SWC) policies are in place. This demonstration can go along with the Millennium Ecosystem

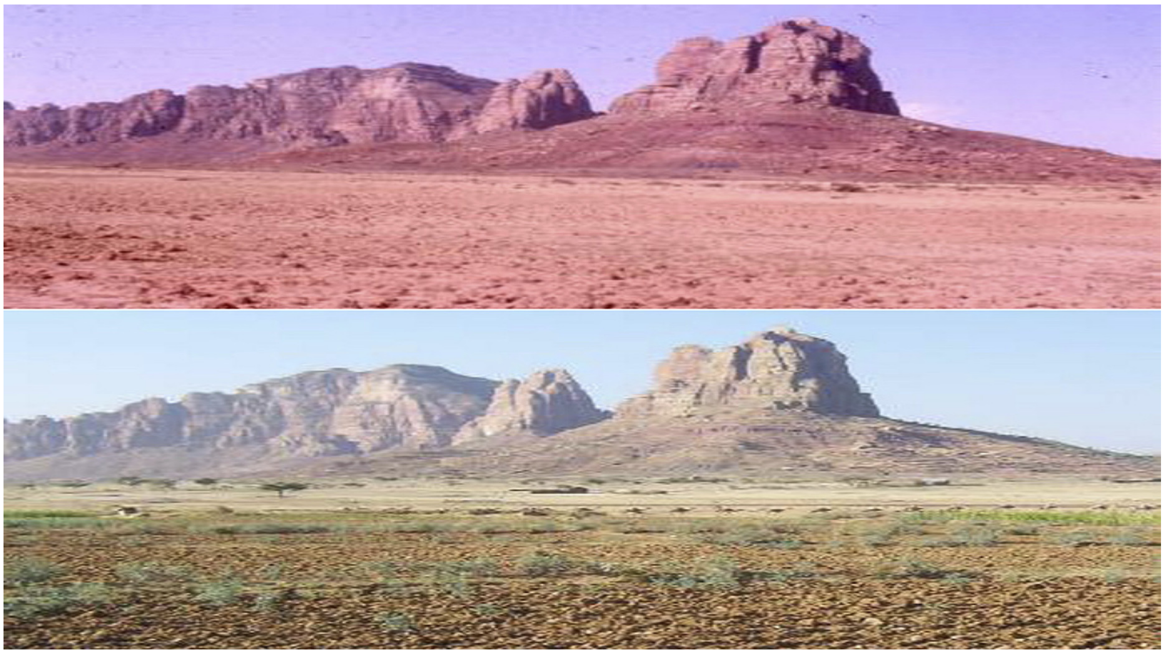

Fig. 6. *Illustrating improved landscape 2006 (bottom) in contrast with degraded land in 1975 (top) (Source: Munro et al., 2008).*

Assessment (2005) that stated people living in dry lands and their land management systems have a proven resilience and the capability of preventing land degradation.

A study by Munro et al. (2008) was carried out to quantify the variation in land cover and erosion between 1975 and 2006 in the same region as was studied by Nyssen et al. (2009). The study showed that the state of natural resources has improved recently as a result of improved vegetation cover and physical conservation structures. Thanks to the continuous and strong rehabilitation effort of governmental, local and foreign NGOs ‘‘the situation of natural resources has improved (and locally strongly improved) since 1974’’ (Munro et al., 2008, p. 55). This was supported by quantifying the current average soil loss which was found to be 68% of what it was in 1975 using the Universal Soil Loss Equation (USLE) assessment method.

F. Alemayehu et al. (2009) described positive achievements in eastern Tigray after implementation of integrated watershed management since 1987. The improvements were expressed in terms of better vegetation cover, reduced soil erosion, increased soil moisture availability and subsequent crop production increment, with reduced sedimentation and runoff in the lower catchment. The authors also reported a small reduction of cultivated land between the years 1994 and 2005 from 55% to 52%, respectively. The study involved local farmers in the assessment, who have witnessed the remarkable achievement, particularly the improvement of vegetation cover resulting from the establishment of enclosures and plantation of riparian trees between the years 1994 and 2005.

In the case of the Maileba and the Gum-Selassa watersheds, there has been no specific trend of land use and land cover change from the beginning until the last study period. The situation in these two catchments is explained below in Table 10. There was an expansion of cultivated land in Gum-Sellasa and a reduced area of cultivated land in the Maileba watershed between 1994

Table 10. Major land use and land cover changes in the Gum Sellasa and the Maileba watersheds, Tigray (Gebresamuel et al., 2010).

Land use and land cover	**Year**					
1. Gum Sellasa	**1994***		**2006**		**Change (1994–2006)**	
	ha	**%**	**ha**	**%**	**ha**	**%**
Cultivated land	1650	70.4	1877	79.8	227	13.8
Forest land	19	0.8	0	0	-19.0	-100
Shrublands	99	4.2	35.5	1.5	-63.6	64.2
2. Maileba	**1957***		**1986**		**Change (1957–1986)**	
	ha	**%**	**ha**	**%**	**ha**	**%**
Cultivated land	1244	71.8	1083	62.7	-159.9	-12.9
Forest land	1.5	0.06	0	0	-1.5	-100
Shrublands	22	1.3	49.2	2.8	27.0	122.2
Woodland	47	2.7	0	0	-47.1	-100

* Only the major land use types are included here, hence % does not add up to 100%

and 2006 (Gebresamuel et al., 2010). But the forest land in both watersheds vanished between 1994 and 2006. Therefore, the rehabilitation success was not clearly visible in these watersheds.

4.3.2 North-eastern part of the Ethiopian highlands

The north-eastern part of the Ethiopian highlands (Wollo) was one of the regions in Ethiopia that received early attention from land rehabilitation programmes (Tekle, 1999) since the area was the hardest hit by drought and famine in 1973 which was associated mainly with deforestation (Admassie, 2000). However, little success in terms of reversing poor land condition has been registered in the area (Tekle, 1999, 2001; Tekle and Hedlund, 2000).

Crummey (1998) in his study of matched pairs of ground photographs has argued that in Wollo there is an apparent increase of woody biomass in 1997 as compared to 1937. He noted also that the increase of vegetation was mainly from the planting of eucalyptus trees.

Another investigation carried out in the Derekolli catchment of the southern Wollo by Tegene (2002) explained a continuous decreasing trend of shrublands and forest cover. The rate of shrubland contraction was faster between 1986 and 2000 than during an earlier period between 1957 and 1986.

Tegene (2002) further reported that shrubland shrank by 63.2% between 1986 and 2000, while the shrub-grassland and grassland expanded by 29.8 and 191%, respectively. Tegene explained how overgrazing by livestock and subsequent bush encroachment may have led to a drastic decline of the shrubland and a subsequent gain of the shrub-grassland and grassland. The expansion of cultivated land further decreased from 7% from 1958 to 1986 to 1.5% between 1986 and 2000. According to the author, there was no more land available suitable for cropping; even some of the previously cultivated areas were taken out of crop production primarily because of the rugged terrain, steep slopes and shallow soils.

4.3.3 North-western highlands of Ethiopia

In the densely populated Demecha area in Gojjam, which had a long history of land degradation, 99% of the natural forest cover was lost between 1957 and 1995. This was a loss of 7259 ha of forest land out of a 27103 ha total study area with a subsequent reduction from 27% in 1957 to 2% in 1982 and 0.3% in 1995 (Zeleke & Hurni, 2001). Similarly, the bushland has shown a persistent decline from 5% in 1957 to 3.8 % in 1982 and to 0.4% in 1995. On the other hand, the forest cover increased to 2% from 1982 to 1995. This increase was mainly attributed to tree plantation by a government afforestation programme. Along with diminishing of the natural forest, increased cultivation took place mainly between the years 1957 to 1982 with a 78% increase, with only 10% occurring from 1982 to 1995. The shrinking of the expansion rate of cultivated land was because of the unavailability of potential area for cultivation. This also explains why the expansion of cultivated land from 1982 to 1995 was extended to steep slopes of up to a 30% gradient, which was supposed to be used either for perennial crops or kept under forest cover rather than for cultivation (Zeleke & Hurni, 2001). The same trend of reducing the cultivated land expansion rate through time has been discussed above for the Derekolli catchment at the southern Wollo. The figure below (Fig. 7) shows examples of cultivation of steep slopes and the consequences of such practices.

Fig. 7. *Steep slopes (>45° slope) used for cultivation, making the soil susceptible to erosion (Pictures from: Gete Zeleke & Eva Ludi).*

In the Chemoga watershed, there was a general improvement between the years 1982 and 1997 in forest cover, woodland and shrublands by 27%, 86% and 8%, respectively (Bewket, 2002). Based on the researcher's observation, the improvement in forest cover was predominantly from planting of trees at the household level. There was a slight reduction of cultivated land (by only 2%) between the years 1982 and 1997.

In another study by Gebrehiwot et al. (2010) at the Koga watershed, the forest cover remained similar (1%) between the years 1986 and 2001. However, there was a small reduction in cultivated land from 68% in 1986 to 67% in 2001.

4.3.4 Central highlands of Ethiopia

Wøien (1995), in his study of the Debre Sina area using aerial photo interpretation, observed improved vegetation cover in 1986 compared to the 1950s. He also noted that eucalyptus plantations increased in extent from 1.1% of the landscape in 1957 to 4.6% in 1986.

At the Beressa watershed, Amsalu et al. (2007) indicated a progressive decline of natural vegetation cover from 6.8% in 1984 to 2.4% in 2000. However, a very large area has been covered with plantations through government afforestation programmes, which was 252 ha (1.2%) of the total area in 1984 but increased to 2295 ha (10.6%) in 2000. The cultivated land had increased from 57% in 1984 to 61% in 2000.

4.3.5 Southern Ethiopian highlands

Dessie & Kleman (2007) conducted a study in the south Central Rift Valley region of Ethiopia covering an area of 3060 km^2. They found that 16% of the total study area was covered with forests in 1972, but this cover diminished to only 2.8% in 2000, losing about 82% forest cover within 28 years. The main causes of the land cover change are thought to be the increasing expansion of small-scale farming, as has been the case in most other studies discussed above.

Another study at the Umbulo catchment came up with a similar trend of land cover change that reveals the loss of 100% of high vegetation between 1986 and 2000 (Moges & Holden, 2009). The study also pointed out a slight increase in vegetation (10%) by the year 2000, which is attributed to recently introduced ''Enset'' perennial crop production in the area.

Table 11 shows results for the Arsi Negele area, using both satellite image analysis and Participatory Field Point Sampling (PFPS) methods. The results indicate the increasing trend of cultivated land and further shrinking of woodland from 1986 to 2000 (Garedew et al., 2009).

Another study by Dwivedi et al. (2005) was carried out in areas between Chencha Wareda and Gamo Awraja which are part of the southern Ethiopian highlands. Based on their satellite image analysis, an estimated cropland area of 4688 ha in 1994 increased to 5717 ha during 1997. This is a remarkable crop land expansion within a three-year period.

Table 11. *Major land use and land cover change in Arsi Negele (Garedew et al., 2009).*

Land cover	Method	Year					
1. Keraru		**1986***		**2000**		**Change (1986–2000)**	
		ha	**%**	**ha**	**%**	**ha**	**%**
Cropland	Landsat	1426	49	1750	60	324	22.7
	PFPS	1298	44	1586	54	288	22.2
Woodland	Landsat	254	9	156	5	-98	-38.6
	PFPS	240	8	192	6	-48	-20
2. Gubeta-Arjo							
Cropland	Landsat	816	56	889	61	73	8.9
	PFPS	639	44	817	56	178	27.9
Woodland	Landsat	0	0	0	0	–	–
	PFPS	0	0	0	0	–	–

* Only the major land use types are included here, hence % does not add up to 100%

4.3.6 Western and south-western Ethiopian highlands

In the western highlands, the Fincha watershed cropland was continuously expanding from relatively flat areas in 1957 and 1980 to steep lands in 2001 at the expense of grazing land and forest (Tefera & Sterk, 2008). Based on the study, the trend shows a rapid forest reduction from 1957 to 1980, but a slight increase of forest cover from 1980 to 2001, likely to be due to re-afforestation activities carried out since the 1980s (Tefera & Sterk, 2008).

5. THE MAIN EFFECTS OF LAND USE AND LAND COVER CHANGE ON LAND DEGRADTION

5.1 The effects of land use and land cover change on the hydrological flow regime of the watershed

Land use and land cover change modifies the hydrological cycle of a watershed area by altering both the balance between rainfall and evaporation and the runoff response of the area and subsequently affects water resources (Mengistu, 2009; Sahin & Hall, 1996). Hence, vegetation removal results in an increase in surface runoff and a decrease in evapotranspiration that may also in turn lead to lower rainfall in semi-arid areas (Savenije, 1995; Sahin & Hall, 1996). Use of experimental catchments for studying the hydrological impacts of land cover changes provide ample evidence for increased water yield as a result of land cover change in a catchment (Brown, Zhang, McMahon, Western & Vertessy, 2005; Bosch & Hewlett, 1982; Sahin & Hill, 1996). A study conducted by Hurni et al. (2005) in the Ethiopian and Eritrean highlands assumed about 5–30 times higher runoff in spread agriculture than the originally forested land.

There are a number of studies of the Ethiopian highlands which show that forest clearing up-stream causes an increase in water yield down-stream by creating a temporary water reserve. During a land use and land cover change study in the Umbulo catchment, Moges & Holden,

(2009) explained that vegetation removal in the upper steep slope by the year 1972 started to generate larger amounts of runoff that drained to the flat lower slope of the catchment and accumulated as a small temporary water reservoir (<5ha). This temporary water reservoir (lake) emerged late in the 1980s but disappeared in 2002 (Moges & Holden, 2009). As the land cover change study of the catchment indicates, the formation of the lake corresponds to the time when there was 100% vegetation cover loss.

By the same reasoning, a land cover change study by Bewket (2002) in the Chemoga watershed reported the sudden appearance of a pond in 1998, using satellite image analysis, presumably created by the increased water yield due to a decrease in vegetation high up in the area. In the above two studies at Umbulo and Chemoga watersheds, the clearing of forests was assumed to bring high surface runoff and less evaporation that leads to higher water yield induced by land cover change and later creates a temporary water reservoir/pond. The appearance of temporary water ponds in the above two watershed studies was correlated with the decline of vegetation cover, clearly indicating the land cover change effect on the hydrological flow of the watershed.

A study focused on land use changes and their impacts on soil degradation and surface runoff by Gebresamuel et al. (2010) was carried out in northern Ethiopia for two catchments, Gum-Selassa and Maileba using an empirical Soil Conservation Service (SCS) model curve number. The simulation results of the model showed 2.7 mm y^{-1} and 2.3 mm y^{-1} direct surface runoff increment annually from 1964 to 2006 from Gum-Sellassa and Maileba catchments, respectively, which is in accordance with the land use and land cover change. Similarly, the model resulted in a decreasing water retention capacity coinciding with vegetation cover reduction from 1964 to 2006.

A study in the eastern Tigray by F. Alemayehu et al. (2009) also reported the disappearance of wetland area of 198.4 ha between 1965 and 1994. This was a period when wooded shrub grassland and shrub grassland have vanished, probably contributing to reduced infiltration and high runoff rates that contributed to the loss of the wetland. Later, in 2005, the wetland reappeared in response to the improvement of vegetation cover and the intensive soil conservation measures undertaken in the upper watershed.

Similarly, studies have reported the drying of Lake Cheleleka as a result of long term land use changes and subsequent sediment deposition in the lake (Ayenew, 2004; Dessie & Kleman, 2007; Gebreegziabher, 2005; WWDSE, 2001). This disappearance of the lake directly correlates with the deforestation record of the Awassa watershed with a 16% forest cover in 1972 reduced to 2.8% of the study area in 2000 (Dessie & Kleman, 2007). As a result $44 \cdot 10^6$ m^3 of sediment load was deposited in the lake within 35 years (WWDSE, 2001). According to Ayenew (2004), the surface area of Lake Cheleleka was about 12 km^2 in 1972, with a storage volume of about $60 * 10^6$ m^3. Currently the lake no longer has any open water surface area, but has been reduced instead to a grass covered swampy area. Lake Awassa and the swampy area of Cheleleka are hydrologically connected through the Tikur Wuha River, which delivers runoff and sediment from Lake Cheleleka and the surrounding catchment to Lake Awassa. Therefore, the likely causes for drying up of the lake are: reduced stream flow related to deforestation and water extraction for irrigation from streams feeding the lake (Dessie & Kleman, 2007), sediment deposition in the lake resulting from land use and land cover change (WWDSE, 2001), and climatic factors (Geremew, 2000).

A similar case has been found in the eastern Ethiopian highlands where Lake Haramaya reportedly disappeared, due to water abstraction, deforestation and clearing of land for farming on its watershed. The expansion of farming around the lake catchment resulted in increased siltation of the lake that decreased the lake's volume and surface albedo, which in turn increased the rate of evaporation (T. Alemayehu, Furi & Legesse, 2007). Studies have also indicated the albedo effect in such a way that when dark tropical rainforest trees are cleared and replaced with crop growing, darker soils will increase the average temperature of the area up to 3°C year-round (Dickinson & Kennedy, 1992).

According to the study, the current status of Lake Haramaya is a dried lake surface area with dry bare soil, and the surrounding catchment is seen with few trees, some of which died as a consequence of the drying up of the lake. Figure 8 clearly indicates the total disappearance of the lake within about two decades. The level of the lake had been constantly decreasing until its extinction (Fig. 9).

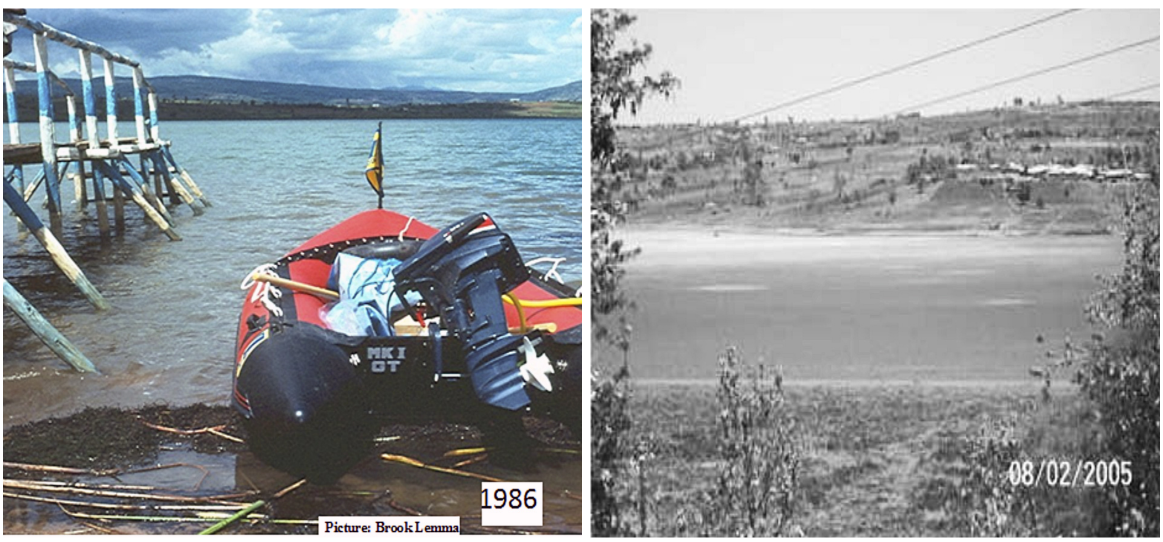

Fig. 8. Lake Haramaya as seen in a better condition during 1986 and dried up since 2005 (Source: T. Alemayehu et al., 2007).

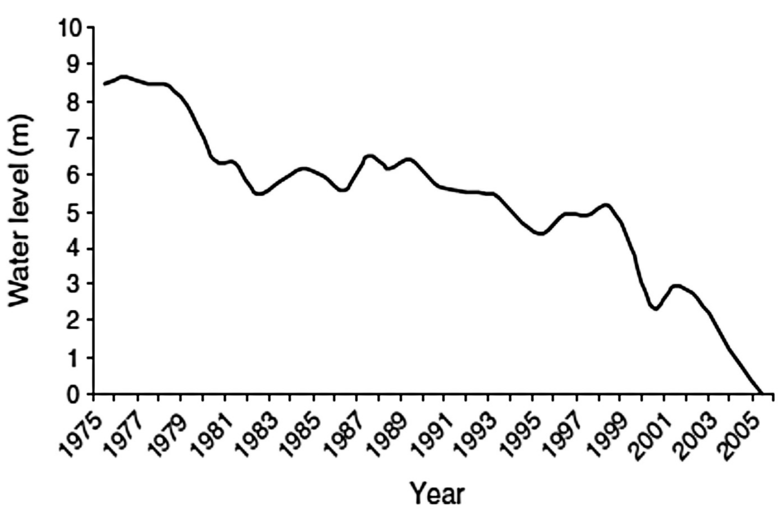

Fig. 9. Haromaya lake level fluctuations since 1975, which finally dried in 2005 (Source: T. Alemayehu et al., 2007).

5.2 The effects of land use and land cover change on soil erosion

Since land cover determines the rate of soil loss, the removal of vegetation by conversion of land to cultivation reduces the protection of soil cover, minimizes the regrowth capacity of vegetation, and speeds up sheet and gully erosion (Zerihun & Mesfin, 1990).

Based on the estimates of the severity and extent of erosion in the mid-1980s, FAO (1986) concluded that about half (about 27 million hectares) of the highlands' land area of Ethiopia was "significantly eroded" and over one-fourth (14 million hectares) was "seriously eroded". It also concluded that over 2 million hectares of farm lands had reached the "point of no return" in the sense that they are unlikely to sustain economic crop production in the future.

Soil erosion estimates that were conducted three decades ago by the Ethiopian Highland Reclamation Study (EHRS) revealed that 20,000–30,000 hectares of cropland in the highlands were being abandoned annually by soil erosion and about 2 million hectares of land had been severely degraded to the extent of reaching "point of no return" for crop production (FAO, 1986). Generally, about half of the highlands´ land area, close to 27 million hectares, was significantly eroded, and over one-fourth nearly or 14 million hectares of arable land was seriously eroded (FAO, 1986).

The formation and advancement of gully erosion are common effects of soil erosion. Gully development in the Umbulo catchment was extended from upslope to the middle and lower slopes at the same pace as the rate of forest reduction from the catchment, indicating the influence of land cover change for the formation of soil erosion, since vegetation was providing soil protection (Moges & Holden, 2009). The farmers in Arsi Negele that participated in interviews during land use and land cover research reasoned that the cause of continued declining crop productivity was soil degradation due to the destruction of woodland (Garedew et al., 2009). Land cover change, especially deforestation, not only facilitates the physical removal of soil but also accelerates the deterioration of the basic soil properties (Gebresamuel et al., 2010).

Bewket (2002) described cultivated fields and part of the grassland and degraded land as the most susceptible land use types to erosion threats because of lack of vegetation cover in the Chemoga watershed.

Zeleke & Hurni (2001) extended the concern of drastic land use and land cover change effect in the Ethiopian highlands into regional implications, since it will affect countries downstream because of the water and sediment carried by the Blue Nile from Ethiopia.

6. POPULATION GROWTH AS THE MAIN DRIVING FORCE FOR LAND USE AND LAND COVER CHANGE

The population of Ethiopia has increased from an assumed 16 million around 1950 to about 65 million at the turn of the 20th century (Zeleke & Hurni, 2001) and almost 85 million today (CIA, 2010). According to Haile (2004) unsustainable population growth, particularly the Ethiopian highlands which is the most densely populated area (Fig. 10), contributed significantly to environmental degradation.

Therefore, in the context of the Ethiopian highlands, most studies pinpoint population pressure as one of the major drivers of land use and land cover change through destruction of the vegetation cover, mainly for agricultural expansion (Amsalu et al., 2007; Bewket, 2002; Gebresamuel et al., 2010; Zeleke & Hurni, 2001).

The growing population is one of the most critical drivers of the observed land cover dynamics because the livelihood of almost the entire rural population is dependent on a mixed farming system of crop production and livestock. At the same time, the growing demand for cultivated land and settlement and trees for fuel and construction purposes aggravates the change (Bewket, 2002; Gebresamuel et al., 2010). Population growth coupled with lack of migration for non-farm employment options makes young adults remain in rural areas, either unemployed or sharing the land with someone else. This leads to further fragmentation of land and intensification of land use and subsequent reduction of fallowing practice or abandonment of fallow periods, ultimately expansion of cultivated land into forests, grazing lands and other marginal lands, which is most common in the western highlands (Gebreselassie, 2006; Zeleke & Hurni, 2001). Practical examples have also been mentioned in case study areas such as Arsi-Negele in the Central Rift Valley where the population drastically increased in only 3 decades (1975–2004) by 114% in Keraru and 408% in Gubeta-Arjo and, correspondingly, the woodland areas decreased by 85% and 100%, respectively, whereas the cropland area expanded by about 126% in both PAs (Garedew et al., 2009).

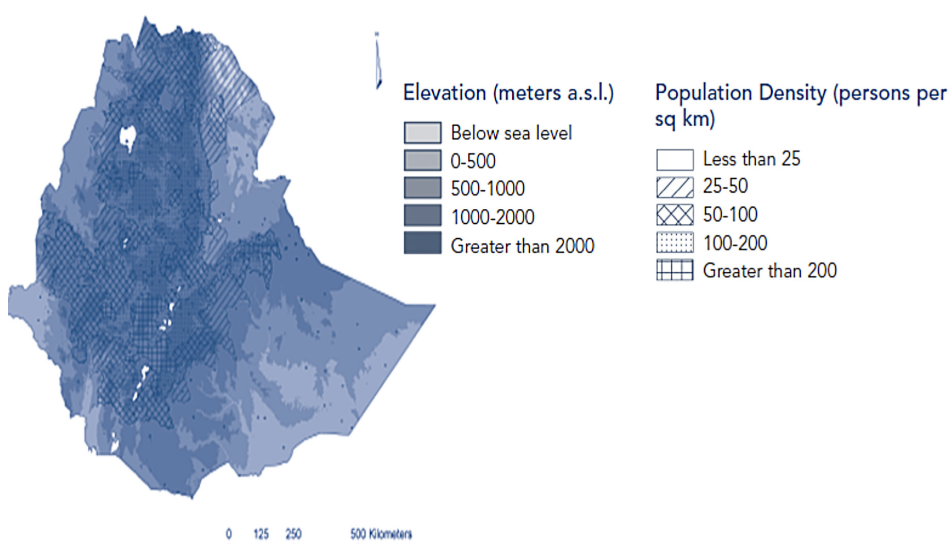

Fig. 10. *Elevation and population density in Ethiopia (Source: Haile, 2004).*

7. DISCUSSION

The studies reviewed above represent almost the entire Ethiopian highlands. The studies were based on diverse methodologies ranging from ground photographs to remotely sensed aerial photographs and satellite images, participatory GIS, models and community participation methods.

The inference from this review is that there is a clear trend of land use and land cover change in terms of declining forest cover and expansion of cultivated land in the Ethiopian highlands from the 1860s to the 1980s. In the northern part of the Ethiopian highlands the studies using methodologies of ground rephotography, the Participatory Geographic Information System (PGIS) and aerial photography showed that the Northern Ethiopian highland, Tigray, was much more degraded before the 1980s. These studies have also explained a progressive improvement of the situation from 1990s onwards, such as vegetation cover improvement, a decreasing rate of cultivated land expansion and even to the extent of reduction in a few cases. Generally, in this region many of the studies ascertained a good improvement of the vegetation cover and reduction of further degradation around 2000.

In the north-eastern part of the Ethiopian highlands, particularly in Wollo, studies conducted by ground photography, aerial photographs and satellite images indicated that the decline of shrublands, woody vegetation and forest cover continued from the 1930s up to the 2000s even at a faster rate, apparently with very little farm land expansion. The main reason for the drastic decline in shrubland and the gain in shrub-grassland and grassland was overgrazing by livestock and subsequent bush encroachment (Tegene, 2002). In the Wollo area, visible success stories have not been recorded with the exception of one in terms of vegetation cover improvement.

Tekle (2001), in his studies of natural regeneration of degraded hill slopes, argued that the ‘‘successes registered in the land rehabilitation programmes were short-lived and most of the shrubs and small trees that regenerated under the hillside closure programmes in the early 1970s and late 1980s were destroyed in 1991, during government transition.’’ (p. 280).

One can ask the question as to why a success story in the Tigray region does not apply to the Wollo area, which is operating under similar policy premises and has a more or less similar agro-climatic zone and biophysical conditions? One thing also looks obvious from the studies of both regions: in Tigray the positive results were attributed to active, farmer-centred soil and water conservation practices while in Wollo the lack of active participation of the local community emphasized the failure. Therefore, local community participation seems necessary for the success of rehabilitation efforts. This claim is supported by similar success stories achieved through empowerment of village communities that have been reported in other African dry land areas like soil and water conservation in Niger and forest resources management in Tanzania (Reij & Steeds, 2003).

The three studies in the north-western highlands of Ethiopia, which are located at the headwaters of the Blue Nile, share similar biophysical and socio-economic landscape features. All showed an increasing expansion of cultivated land between the 1950s and 1980s at the expense of woodlands, shrublands and natural forest cover. However, during the second period (1980s–2000s), there was a trend to increasing cultivated land at a slow pace, even to the extent of using steep slopes and shallow soils that are vulnerable to degradation for cultivation in Dembecha. There has been a small reduction in the extent of cultivated land in the Chemoga and the Koga watersheds. Generally speaking, in the south-western highlands, particularly in Gojjam, the rate of change of cultivated land has slowed drastically.

Plantation of eucalyptus has clearly been seen both in Dembecha and Chemoga, with a remarkable increase of vegetation cover of forests, woodlands and shrublands in Chemoga.

No major change either in vegetation cover or cultivated land was seen in the case of the Koga watershed between 1986 and 2001.

In the central Ethiopian highlands, particularly northern Shewa, in almost the same period of study, two contrasting results were obtained, one with a progressive decline of natural vegetation cover between 1957 and 1984 and the other where there was an increase of woody plant cover from 1957 to 1986, and this trend was further extended to at least the early 2000s. However, both studies explained the results in terms of a trend of planting trees in this area since the second half of the 20th century. In the Beressa watershed a small but continuous increase of cultivated land has been observed from the 1950s until the 2000s.

On the other hand, the findings of Nyssen et al. (2009) and MacCann (1997) in their respective studies of the northern and central Ethiopian highlands, showed that since the late 19th century and even earlier, the northern and central parts of the Ethiopian highlands were less vegetated and in much poorer condition than is the case today. But, this is contrary to the notion that at the turn of the 19th century the forest and vegetation cover of Ethiopia was abundant to the extent of covering about 40% of the total land (Mengistu, 1987; Markos, 1990; Girma, 1992). However, little evidence supports these claims that 40% of Ethiopia was covered at the turn of the century (Wøien, 1995; McCann, 1997; Crummey, 1998).

All the studies carried out in the south-central Ethiopian highlands, the area covering most parts of the central and southern Central Rift Valley regions of the Ethiopian highlands, described a drastic decline in forest cover and a corresponding increase in cultivated land from the 1960s up to the 1980s and extended further at the same rate to the second period until the early 2000s with a corresponding increase in cultivated land (Fig. 11).

The two studies conducted in the western and south-western Ethiopian highlands showed a declining trend of the wooded grassland and forest cover during the 1950s to the 1970s, while there was expansion of cultivated land. After the 1970s the two watersheds behaved differently in such a way that in the Fincha watershed cropland was continuously expanding until the 2000s whereas there was a reduction in cropland from the 1970s to the 1980s in Gibe valley. In Fincha there was a slight increment of forest cover from 1980 to 2001 attributed to re-afforestation activities.

The land use and land cover change from the 1980s–2000s showed a parallel trend of continued reduction of shrublands and forest cover in some areas and improvement in terms of vegetation cover mainly attributed to re-afforestation programmes, predominantly eucalyptus, in many areas. On the other hand, the expansion of cultivated land continues encroach up very steep slopes and

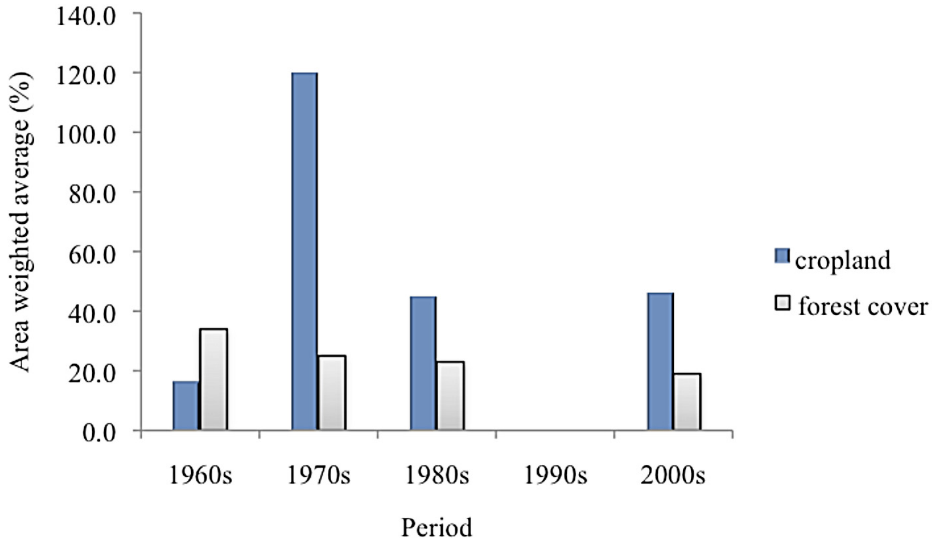

Fig. 11. *Forest cover and cultivated land changes of southern central Ethiopian highlands. Weighted average values from the studies revised in the paper for this area.*

onto marginal lands with a very low rate of conversion. The slow and small decreasing trend of deforestation and cultivated land expansion is thought to be because of the unavailability of forest to be cleared and less land available to be converted in to crop land.

The effects of land use and land cover change on the hydrological flow regime of the watershed, such as increasing surface runoff, decreasing water retention capacity, decrease of stream flow, loss of wetland, and drying of lakes has been clearly described by many land use and land cover change case studies in the Ethiopian highlands. Forest clearing upstream causes an increase in water yield downstream by creating a temporary water reservoir. The previous studies in the Umbulo Wacho and Chemoga watersheds witnessed the emergence of temporary ponds on the down slopes of the watersheds corresponding to the deforestation in the upper slopes of the watersheds. A study carried out in northern Ethiopia for two catchments, Gum Selassa and Maileba using an empirical model, observed a direct surface runoff increment in accordance with the land use and land cover change. The drying of the Haramoya and Cheleleka lakes has directly implicated the direct adverse effect of land cover change on surface water quantity to the extent of leading to a total extinction of lake water.

According to Zerihun & Mesfin (1990) land cover determines the rate of soil loss since the removal of vegetation reduces the protection cover of soil and speeds up sheet and gully erosion. The formation and advancement of gully erosion, the high erosion susceptibility of areas devoid of vegetation resulting from land cover change has been documented in studies under this review. Furthermore, the concern of drastic land use and land cover change effects in the Ethiopian highlands has regional implications, since it will affect countries downstream because of the water and sediment carried by rivers such as the Blue Nile (Zeleke & Hurni, 2001).

8. SUMMARY

Generally, this review overwhelmingly, though with a few exceptions, indicates expansion of cultivated land at the expense of woodland, shrublands and forest cover. Figure 12 was made only from studies that used aerial photography and satellite image analysis for land use and land cover change, but there are other studies that used other methodologies which were not included in this graph because of their qualitative nature. The graph indicates clearly the general trend of cropland increment and reduction of shrubs and forests.

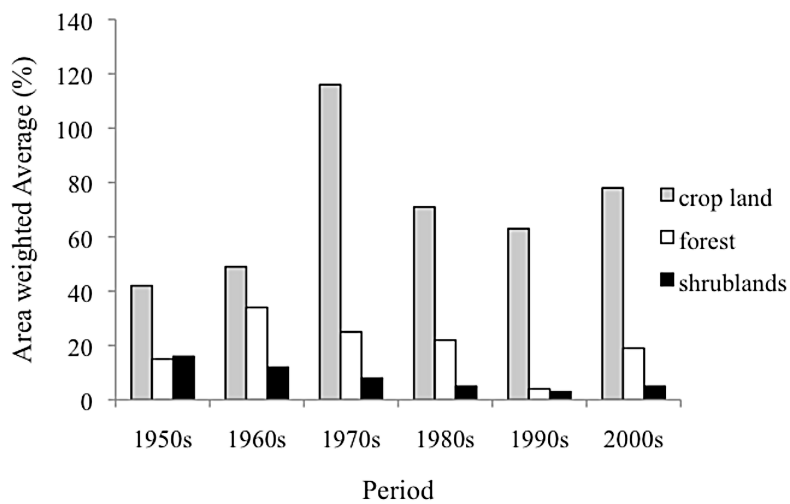

Fig. 12. *Land use and land cover change of the Ethiopian highlands. Weighted average values for all studies investigated under this review that used aerial photography and satellite image analysis for land use and land cover change examination.*

An earlier narrative from the Ethiopian Forestry Action Program (EFAP, 1993) confirms this trend of land cover change, stating that accelerated deforestation has been taking place in Ethiopia since the beginning of the 20th century.

Another study by Reusing (2000) also showed the same trend of vegetation cover change seen in this review, which is a continuous reduction of forest cover since the early 1970s (Fig. 13).

Furthermore, the trend of land use and land cover change in the Ethiopian highlands has shown the same trend of land use and land cover change as is observed globally. The global trend of agricultural expansion during the late 19th century, specifically expansion of croplands since the 1850s, is estimated to have converted about 6 million km^2 of forests/woodlands and 4.7 million km^2 of savannahs/grasslands/steppes (Lambin et al., 2001). Similarly, an assessment by the United Nations Environment Programme (UNEP) concluded that 70% of total deforested areas were converted to permanent agricultural systems during the 1990s (UNEP, 2002). It seems that human beings have been putting accelerated pressure on natural resources globally since the late 19th century.

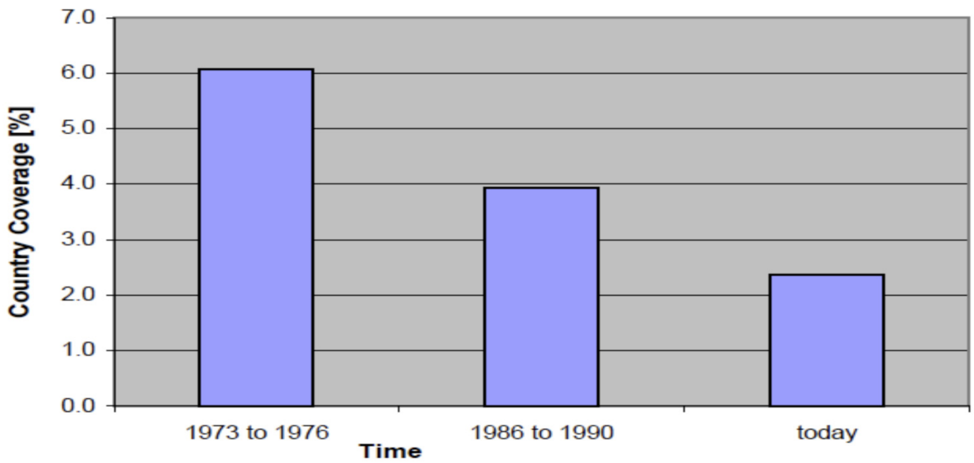

Fig. 13. *Forest degradation in Ethiopia between 1973 and 1990 (Source: Reusing, 2000).*

Population growth in Ethiopia, particularly in the densely populated Ethiopian highlands, is one of the most critical drivers of the observed land cover dynamics because the livelihood of almost the entire rural population is dependent on agriculture. Especially, lack of non-farm employment options worsen the situation since young adults remain in rural areas by sharing the land, which leads to further fragmentation of land.

Generally, land expansion has reached the upper limit to the extent of moving up to marginal lands in the Ethiopian highlands. Therefore, the livelihood requirements of the growing population, particularly in rural areas, can only be met by increasing land productivity through intensification of agriculture and by diversifying the sources of income such as by creating off-farm job opportunities.

Community participation at the grass roots level has clearly indicated success in restoring degraded lands.

REFERENCES

Admassie, Y. (2000). *Twenty Years to Nowhere: Property Rights, Land Management and Conservation in Ethiopia.* Lawrenceville, Georgia: Red Sea Press.

Alemayehu, F., Taha, N., Nyssen, J., Girma, A., Zenebe, A., Behailu, M., Deckers, S. & Poesen, J. (2009). The impacts of watershed management on land use and land cover dynamics in Eastern Tigray (Ethiopia). *Resources, Conservation and Recycling, 53,* 192–198.

Alemayehu, T., Furi, W. & Legesse, D. (2007). Impact of water overexploitation on highland lakes of eastern Ethiopia. *Environmental Geology, 52*, 147–154.

Amsalu, A., Stroosnijder, L. & Graaff, J. d. (2007). Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highlands of Ethiopia. *Journal of Environmental Management, 83*, 448–459.

Awulachew, S., Erkossa, T., Smakhtin, V. & Fernando, A. (2009, February). *Improved Water and Land Management in the Ethiopian Highlands: Its Impact on Downstream Stakeholders Dependent on the Blue Nile*.Intermediate Results Dissemination Workshop, Addis Ababa, Ethiopia.

Ayenew, T. (2004). Environmental implications of changes in the levels of lakes in the Ethiopian Rift since 1970. *Regional Environmental change, 4,* 192–204.

Aynekulu, E., Wubneh, W., Birhane, E. & Begashaw, N. (2006). Monitoring and Evaluating Land Use/Land Cover Change Using Participatory Geographic Information System (PGIS) Tools: A Case Study of Begasheka Watershed, Tigray, Ethiopia. *The Electronic Journal of Information Systems in Developing Countries, 25*, 1–10.

Bekele, A. (1997). A participatory agroforestry approach for soil and water conservation in Ethiopia. *Tropical Resource Management Papers,* No. 17, Wageningen Agricultural University, Wageningen.

Bewket, W. (2002). Land cover dynamics since the 1950s in Chemoga watershed, Blue Nile basin, Ethiopia. M*ountain Research and Development, 22*, 263–269.

Bewket, W. & Sterk, G. (2005). Dynamics in land cover and its effect on stream flow in the Chemoga watershed, Blue Nile basin, Ethiopia. *Hydrological Processes, 19*, 445–458.

Bewket, W. & Stroosnijder, L. (2003). Effects of agroecological land use succession on soil properties in Chemoga watershed, Blue Nile basin, Ethiopia. *Geoderma, 111*, 85–98.

Bishaw, B. (2001). Deforestation and Land Degradation in the Ethiopian Highlands. *Northeast African Studies, 8*, 7–26.

Bosch, J. & Hewlett, J. (1982). A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. *Journal of Hydrology, 55*, 3–23.

Brown, A. E., Zhang, L., McMahon, T. A., Western, A. W. & Vertessy, R. A. (2005). A review of paired catchment studies for determining changes in water yield resulting from alterations in vegetation. *Journal of Hydrology, 310*, 28–61.

Chaffey, D. R. (1979). *South-west Ethiopia forest inventory project*. An inventory of forest at Munessa and Shashemane Project Report 29. Land Resources Division, Ministry of Overseas Development. UK.

Chase, T. N., Pielke, R.A., Kittel, T.G.F., Nemani, R.R. & Running, S.W. (1999). Simulated impacts of historical land cover changes on global climate in northern winter. *Climate Dynamics, 16*, 93–105.

CIA. (2010). The World FactBook. Retrieved September 27, 2010 from https://www.cia.gov/library/publications/the-world-factbook/geos/et.html

Crummey, D. (1998). Deforestation in Wällo: Process or illusion? *Journal of Ethiopian Studies*, *31*, 1–42.

Crummey, D. (2009). Exploring landscape change in Ethiopia: Evidence from imaging and its interpretation. In S. Ege, H. Aspen, B. Teferra & S. Bekele (Eds.), *Ethiopian Studies* (pp. 173–184). Proceedings of the 16th International Conference of Ethiopian Studies, Norway, Trondheim, 2009.

de Sherbinin, A. 2002. *Land-Use and Land-Cover Change*. A CIESIN Thematic Guide, Palisades, NY. Center for International Earth Science Information Network of Columbia University. Retrieved July 27,2010 from http://sedac.ciesin.columbia.edu/tg/guide_main.jsp

Dessie, G. & Christiansson, C. (2008). Forest decline and its causes in the south-central Rift Valley of Ethiopia: Human impact over a one hundred year perspective. *Ambio, 37*, 263–271.

Dessie, G. & Kleman, J. (2007). Pattern and magnitude of deforestation in the South Central Rift Valley region of Ethiopia. *Mountain research and development, 27*, 162–168.

Dickinson, R. E. & Kennedy, P. J. (1992). Impacts on regional climate of Amazon deforestation. *Geophysical research letters, 19*, 1947–1950.

Dwivedi, R. S., Sreenivas, K. & Ramana, K. V. (2005). Cover: Land-use/land-cover change analysis in part of Ethiopia using Landsat Thematic Mapper data. *International Journal of Remote Sensing, 26*, 1285–1287.

EFAP. (1993). *Ethiopian Forestry Action Programme*. Final Report, Ministry of Natural Resource Development and Environmental Protection, Addis Ababa, Ethiopia.

El-Swaify, S. & Hurni, H. (1996). Transboundary effects of soil erosion and conservation in the Nile Basin. *Land Husbandry, 1*, 6–21.

Ellis, E. & Pontius, R. (2007). Land use and land cover change. In C. J. Cleveland (Ed.), *Encyclopedia of Earth*. Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment. Retrieved July 29, 2010 from http://www.eoearth.org/article/land-use_and_land-cover_change

FAO (1986). *Ethiopian highland reclamation study*. Final Report, Vol. 1. FAO, Rome.

FAO (2001). *Global Forest Resources Assessment 2000: main report*. FAO forestry paper 140. Rome: FAO.

Garedew, E., Sandewall, M., Söderberg, U. & Campbell, B. M. (2009). Land-use and land-cover dynamics in the Central Rift Valley of Ethiopia. *Environmental Management, 44*, 683–694.

Gebreegziabher, Y. (2005). *Assessment of the water balance of Lake Awassa Catchment, Ethiopia* (Unpublished MSc Thesis). ITC, Enschede, The Netherlands.

Gebrehiwot, S., Taye, A. & Bishop, K. (2010). Forest cover and stream flow in a headwater of the Blue Nile: Complementing observational data analysis with community perception. *Ambio, 39*, 284–294.

Gebresamuel, G., Singh, B. R. & Dick, Ø. (2010). Land-use changes and their impacts on soil degradation and surface runoff of two catchments of Northern Ethiopia. *Acta Agriculturae Scandinavica, Section B – Plant Soil Science, 60*, 211–226.

Gebreselassie, S. (2006). Land, land policy and smallholder agriculture in Ethiopia: Options and Scenarios. Institute of Development Studies, Paper prepared for the Future Agricultures Consortium meeting at the Institute of Development Studies.Brighton, UK. 20–22 March 2006. Retrieved August 15,2010 from http://www.future-agricultures.org/pdf%20files/SG_paper_2.pdf

Geremew, Z. (2000). *Engineering geological investigation and lake level changes in the Awassa basin*. MSc thesis, Department of Geology and Geophysics, Addis Ababa University, Addis Ababa, Ethiopia.

Getahun, A. (1988, November). An overview of the Ethiopian highlands: *The need for agroforestry* *research and development for national survival*. IAR/ICRAF national agroforestry workshop. Awasa, Ethiopia.

Girma, K. (1992). *The state and development in Ethiopia.* London: Humanities press.

Gryseels, G. & Anderson, F. (1983). *Research on farm and livestock productivity in the central Ethiopian highlands: Initial results, 1977–1980*. Research Report no. 4. International Livestock Centre for Africa, Addis Ababa: ILRI (aka ILCA and ILRAD).

Haile, S. (2004). *Population, Development, and Environment in Ethiopia*. Special report. Retrieved from http://www.wilsoncenter.org/sites/default/files/ecspr10_specialreport.pdf

Hailu, G. (2000). Environmental Law of Ethiopia. International Encyclopaedia of Laws, Kulwer Law International. Leuven, Belgium.

Hassan, R., Scholes, R. & Ash, N. (2005). *Ecosystems and human well-being: Current state and trends.* Findings of the Condition and Trends Working Group of the Millennium Ecosystem Assessment. Washington, DC: Island Press.

Hawando, T. (1997). Desertification in Ethiopian Highlands. In O. Arnalds & S. Archer (Eds.), *Case studies of Rangeland Desertification. Proceedings from an International Workshop in Iceland*. RALA report No. 200 (pp. 75–86). Reykjavik: Agricultural Research Institute.

Houghton, R. A. (1995). Land-use change and the carbon cycle. *Global Change Biology, 1*, 275–287.

Hurni, H. (1982). Climate and the dynamics of altitudinal belts from the last cold period to the present day: Semen Mountains, Ethiopia. G13, Vol. 2. University of Berne, Berne, Switzerland.

Hurni, H. (1990). Degradation and conservation of the resources in the Ethiopian highlands. *Mountain Research and Development, 8*, 123–130.

Hurni, H. (1993). Land degradation, famine, and land resource scenarios in Ethiopia. In D. Pimentel (Ed.), *World Soil Erosion and Conservation* (pp. 27–61). Cambridge: Cambridge University Press.

Hurni, H., Tato, K. & Zeleke, G. (2005). The implications of changes in population, land use, and land management for surface runoff in the upper Nile Basin Area of Ethiopia. *Mountain Research and Development, 25*, 147–154.

Kloos, H. & Adugna, A. (1989). The Ethiopian population: Growth and distribution. *Geographical Journal, 155*, 33–51.

Lambin, E., Geist, H. & Lepers, E. (2003). Dynamics of land-use and land-cover change in tropical regions. *Annual Review of Environment and Resources, 28*, 205–241.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., … Xu, J. (2001). The causes of land-use and land-cover change: Moving beyond the myths. *Global Environmental Change, 11*, 261–269.

Markos, E. (1990). Population issues in rural development. In S. Pausewang, F. Cheru, S. Brune & E. Chole (Ed.), *Ethiopia. Rural development options*. London: Zed Books.

McCann, J. C. (1995). *People of the plow: an agricultural history of Ethiopia 1800–1990*. Madison: University of Wisconsin Press.

McCann, J. C. (1997). The plow and the forest: Narratives of deforestation in Ethiopia, 1840–1992. *Environmental history, 2*, 138–159.

McCann, J. C. (1999). *Green Land, Brown Land, Black Land: An Environmental History of Africa, 1800–1990.* Oxford: James Currey.

McClellan, W. C. (2002). Coffee in centre-periphery relations: Gedeo in early twentieth century. In *The Southern Marches of Imperial Ethiopia* (pp. 175–195). Ohio: Ohio University Press.

McGinley, M. (2008). ''Ethiopian montane moorlands." In C. J. Cleveland (Ed.), *Encyclopedia of Earth*. Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment. Retrieved August 20, 2010 from http://www.eoearth.org/article/Ethiopian_montane_moorlands

Mekuria, W., Veldkamp, E., Haile, M., Nyssen, J., Muys, B. & Gebrehiwot, K. (2007). Effectiveness of exclosures to restore degraded soils as a result of overgrazing in Tigray, Ethiopia. *Journal of Arid Environments, 69*, 270–284.

Mengistu, K. T. (2009). *Watershed Hydrological Responses to Changes in Land Use and Land Cover, and Management Practices at Hare Watershed, Ethiopia*. Dissertation, Universität Siegen Fakultät Bauingenieurwesen, Research Institute for water and Environment, Germany.

Mengistu, W. (1987). *The Geography of Hunger: Some Aspects of the Causes and Impacts of Hunger*. Department of Social and Economic Geography, University of Uppsala, Uppsala, Sweden.

Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being: Synthesis*. Washington, DC: Island Press.

Moges, A. & Holden, N. M. (2009). Land cover change and gully development between 1965 and 2000 in Umbulo Catchment, Ethiopia. *Mountain Research and Development, 29*, 265–276.

Munro, R. N., Deckers, J., Haile, M., Grove, A. T., Poesen, J. & Nyssen, J. (2008). Soil landscapes, land cover change and erosion features of the Central Plateau region of Tigrai, Ethiopia: Photo-monitoring with an interval of 30 years. *CATENA*, *75*, 55–64.

Muzein, B. (2006). *Remote Sensing & GIS for Land Cover/ Land Use Change Detection and Analysis in the Semi-Natural Ecosystems and Agriculture Landscapes of the Central Ethiopian Rift Valley.* PhD thesis, Technische Universität Dresden, Germany.

Nyssen, J., Haile, M., Naudts, J., Munro, N., Poesen, J., Moeyersons, J., Frankl, A., Deckers, J. & Pankhurst, R. (2009). Desertification? Northern Ethiopia re-photographed after 140 years. *Science of the Total Environment, 407*, 2749–2755.

Nyssen, J., Poesen, J., Moeyersons, J., Deckers, J., Haile, M. & Lang, A. (2004). Human impact on the environment in the Ethiopian and Eritrean highlands – A state of the art. *Earth-Science Reviews, 64*, 273–320.

Omiti, J. M., Parton, K. A., Sinden, J. A. & Ehui, S. K. (1999). Monitoring changes in land-use practices following agrarian de-collectivisation in Ethiopia. *Agriculture, Ecosystems & Environment, 72*, 111–118.

Pender, J., Place, F. & Ehui, S. (2006). S*trategies for sustainable land management in the East African highlands.* Washington DC: International Food Policy Research Insitute.

Popay, J., Roberts, H., Sowden, A., Petticrew, M., Arai, L., Rodgers, M., … Duffy, S. (2006). Guidance on the conduct of narrative synthesis in systematic reviews. A product from the ESRC Methods Programme. *Retrieved July 20, 2010, from* http://www.ersc.ac.uk

Reid, R. S., Kruska, R. L., Muthui, N., Taye, A., Wotton, S., Wilson, C. J. & Mulatu, W. (2000). Land-use and land-cover dynamics in response to changes in climatic, biological and socio-political forces: The case of southwestern Ethiopia*. Landscape Ecology, 15*, 339–355.

Reij, C. & Steeds, D. (2003). Success stories in Africa's drylands: Supporting advocates and answering skeptics. Global Mechanism of the Convention to Combat Desertification, Rome.

Reusing, M. (2000). Change detection of natural high forests in Ethiopia using remote sensing and

GIS techniques. *International Archives of Photogrammetry and Remote Sensin*g 33 (B7/3; Part 7): 1253–1258.

Sahin, V. & Hall, M. J. (1996). The effects of afforestation and deforestation on water yields. *Journal of Hydrology, 178*, 293–309.

Sandewall, M., Ohlsson, B. & Sawathvong, S. (2001). Assessment of historical land-use changes for purposes of strategic planning – A case study in Laos. *Ambio, 30*, 55–61.

Savenije, H. H. G. (1995). New definitions for moisture recycling and the relationship with land-use changes in the Sahel. *Journal of Hydrology, 167*, 57–78.

Soil Conservation Research Programme (SCRP). (1982). *Inception Report*. Berne, Switzerland: University of Berne in association with United Nations University.

Soil Conservation Research Programme (SCRP). (1996). *Data base report (1982–1993)*, Series II: Gununo Research Unit, University of Berne, Berne.

Sissay, L. (2003). Biodiversity potentials and threats to the southern Rift Valley lakes of Ethiopia. In Abebe, Y. D. & Geheb, K. (Eds.), *Wetlands of Ethiopia. Proceedings of a seminar on the resources and status of Ethiopia's wetlands* (pp. 18–24). *Addis Ababa, Ethiopia:* IUCN 2003.

Taddese, G. (2001). Land degradation: A challenge to Ethiopia. *Environmental Management 27*, 815–824.

Tefera, B. & Sterk, G. (2008). Hydropower-induced land use change in Fincha'a watershed, western Ethiopia: Analysis and impacts. *Mountain Research and Development, 28*, 72–80.

Tegene, B. (2002). Land-cover/land-use changes in the Derekolli catchment of the South Welo zone of Amhara region, Ethiopia. *Eastern Africa Social Science Research Review, 18*, 1–20.

Teketay, D. (2001). Deforestation, Wood Famine, and Environmental Degradation in Ethiopia's Highland Ecosystems. *Northeast African Studies, 8,* 53–76.

Tekle, K. (1999). Land degradation problems and their implications for food shortage in South Wollo, Ethiopia. *Environmental Management, 23*, 419–427.

Tekle, K. (2001). Natural regeneration of degraded hillslopes in Southern Wello, Ethiopia: A study based on permanent plots. *Applied Geography, 21,* 275–300.

Tekle, K. & Hedlund, L. (2000). Land cover changes between 1958 and 1986 in Kalu District, southern Wello, Ethiopia. *Mountain Research and Development, 20*, 42–51.

UNEP. (2002). *Earthscan, Global environmental outlook 3. Past, present and future perspectives*. London: Earthscan Publications.

WWDSE. (2001). *The Study of Lake Awassa Level Rise* (Main Report, Vol II). Unpublished report of the Water Works Design and Supervision Enterprise, Addis Ababa, Ethiopia, 291 pp.

Wøien, H. (1995). Deforestation, information and citations. *GeoJournal 37*, 501–511.

Yirdaw, E. (1996). Deforestation and forest plantations in Ethiopia. In P.M. Palo & G. Merry (Eds.), *Sustainable forestry challenges for developing countries* (pp. 327–342). Dordrecht, the Netherlands: Kluwer Academic Publishers.

Zeleke, G. & Hurni, H. (2001). Implications of land use and land cover dynamics for mountain resource degradation in the northwestern Ethiopian highlands. *Mountain Research and Development, 21*, 184–191.

Zerihun, W. & Mesfin, T. (1990). The status of the vegetation in the Lake Region of Rift Valley of Ethiopia and the possibilities of its recovery. Sinet: *Ethiopian Journal of Scienc*e, 13, 97–120.