SINET: Ethiop. J. Sci., 33(2): 75–88, 2010

ISSN: 0379–2897

PATTERNS OF LAND USE/COVER DYNAMICS IN THE MOUNTAIN LANDSCAPE OF TARA GEDAM AND ADJACENT AGRO-ECOSYSTEM, NORTHWEST ETHIOPIA

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ABSTRACT: This study analyzed land use/cover dynamics in the mountain landscape of Tara Gedam and adjacent agro-ecosystem of northwest Ethiopia over a period of 46 years (1957–2003). The changes were measured through interpretation of aerial photographs taken in 1957 and 1980, and Land-sat satellite image of 2003 using Arc GIS 9.2 software, supported by focal group discussions and field visits. Three separate maps (for years 1957, 1980 and 2003) of the study area were produced and six major land use/cover classes were identified: dense forest, woodland, shrub land, grassland, riverine vegetation and cultivated and settlement land. The results indicated that the main land trajectory was from natural vegetation cover to settlement and cultivated land. The cultivated and settlement land coverage increased by 90.60% between 1957 and 2003. However, woodland, dense forest, riverine vegetation, shrub and grasslands coverage declined by 97.87, 71.04, 37.00, 9.02 and 3.03%, respectively. These could be mainly attributed to anthropogenic factors. Increasing demands of more land for cultivation and settlement, overgrazing, deforestation for fuel wood and construction have resulted in a dramatic shrinkage of the area under natural vegetation. The 1975 national land reform proclamation of the country had also contributed to the expansion of cultivated and settlement land. The implications of these changes are increased land degradation and loss of biodiversity affecting the livelihood of the community. It is suggested that the study area needs an immediate intervention for developing sustainable land use practices and to manage the remaining natural vegetation and to rehabilitate the degraded lands.

Keywords/phrases: Anthropogenic factors, deforestation, land degradation, remote sensing, Northwest Ethiopia

INTRODUCTION

The largest sources of change on the earth's surface are caused by human transformation of ecosystems and land systems. It has been recognized that changes in land use are important drivers of environmental change on spatial and temporal scales (Turner *et al.*, 1994). The major consequences of these land use changes are reflected on the status of natural resources such as soil and water quality, global climatic system and biodiversity (Houghton, 1994; Turner *et al.*, 1995). The amount, rate and intensity of land use/cover changes are particularly considerable in developing countries (Rao and Pant, 2001). In most parts of the world, major changes largely involve transformation of forests to agricultural and settlement land.

In Ethiopia, change in land use mainly through the conversion of natural forests to agricultural land and settlement is the most widely distributed activity. Existing sources indicate that about 40% of the country's land area was covered with dense forests at the turn of the 20th century (Breitenbach, 1961; EFAP, 1993). The presence of old remnant forests around old churches and protected areas are indicators of the types of forests which covered the country in the past. However, the forest coverage has reached a low level of 3.56% (WBISPP, 2004). Deforestation in Ethiopia seems to have a long history and started to occur relatively earlier than in the other east African countries (Bonnefille and Hamilton, 1986). Available evidence indicates that major deforestation in the northern highlands of Ethiopia took place at least 2000 years ago (Eshetu Yirdaw, 2002). According to FAO (2001), deforestation in Ethiopia was estimated to be 0.80%, while expansion of plantation forest was about 0.18% per year, thus aggravating the loss of natural forests.

Land use/cover changes incurring deforestation are particularly related to population increase which demands more crop and grazing land and forest resource consumption for diverse purposes (Verburg *et al*., 1999). These human-induced factors are advancing at a faster rate in Ethiopia and are playing an important role in the conversion of indigenous forests into crop and grazing lands (Paulos Dubale, 2001). Such land use change is significant especially on the highlands of the country where there is dense population whose livelihoods directly depend on the exploitation of natural resources (Kebrom Tekele and Hedlund, 2000).

Government policies in land tenure system have also contributed much towards the major land use/cover changes in the country (Gete Zeleke, 2000). For instance, following the 1975 Land Reform Proclamation, the socialist government (1974–1991) of Ethiopia established a system of state farms, cooperatives and small-holder farms (Omiti *et al.*, 1999), which accelerated the conversion of much of the forested lands into agriculture and other land use categories. The socio-political instability in some parts of the country was another factor which furthered the heavy deforestation rate (Eshetu Yirdaw, 2002). Recently, the few remnant forests are also threatened by pressure from investors who are converting the evergreen forests into other land use systems such as coffee and tea plantations (Million Bekele, 2001).

In Ethiopia, specific local factors could be related to land use changes and associated impacts. This was verified by few studies that quantify land use/cover changes in different localities of the country (Kebrom Tekle and Hedlund, 2000; Gete Zeleke and Hurni, 2001; Woldeamlak Bewket, 2002; Selamyihun Kidanu and Tekalign Mamo, 2003; Mohammed Assen, 2006, Mohammed Assen and Tasew Nigussie, 2009). These studies indicated the occurrence of rapid land use/cover changes and its implications on natural resource degradation. It is evident that these studies have been insufficient for the large topographic and agro-climatic diversity of the country. This demands more studies to quantify the influences of land use/cover changes in different parts of the country. In this study attempt is made to quantify changes in land use/cover in the mountain landscape of Tara Gedam and adjacent agro-ecosystem of north-western Ethiopia. In this area most of the natural vegetation has been destroyed and transformed to different land uses due to long-term human activity. Thus, a thorough understanding of the patterns of historical land use changes in this area will undoubtedly enhance our capability to devise more effective and sustainable land management strategies that best fit to local conditions.

In the present study, analysis of available remote sensing (RS) data such as aerial photographs and satellite images in conjunction with geographical information system (GIS) tools has become a valuable set and an alternative approach to conventional methods of field survey for assessing the extent of land use/cover changes (Armenteras *et al*., 2003). Information gathered through repeated analysis of aerial photographs and satellite images are useful for visual assessment of natural resources present at a particular time and space and for quantitative evaluation of land use/cover changes (Kebrom Tekle and Hedlund, 2000). RS and GIS-based change detection studies can, therefore, be utilized to provide information on the amount of place and type of land use/cover changes that have occurred (Mwavu and Witkowski, 2008). Therefore, the objective of the present study is to investigate land use/cover changes at the mountain landscape of the Tara Gedam locality and adjacent agro-ecosystem on the north-western highlands of Ethiopia using the analysis of available panchromatic aerial photographs and satellite images.

MATERIALS AND METHODS

Description of the study area

The study locality, the Tara Gedam mountain landscape and the surrounding agro-ecosystem (12° 08'–12° 15' N and 37° 40'–37° 49' E), is situated on the north-western highlands of Ethiopia on the northeast of Lake Tana (Fig. 1). It is found in the Kemkem District of South Gonder Zone, Amhara National Regional State (ANRS) at a distance of 650 km from Addis Ababa. The altitude in the locality varies between 1900 and 2800 meters above sea level (masl). The area is characterized by rugged topography with hills and mountains and dissected side slopes (2–33%). Such a topographic setting makes it the source of many streams and small rivers that drain southwards to Lake Tana.

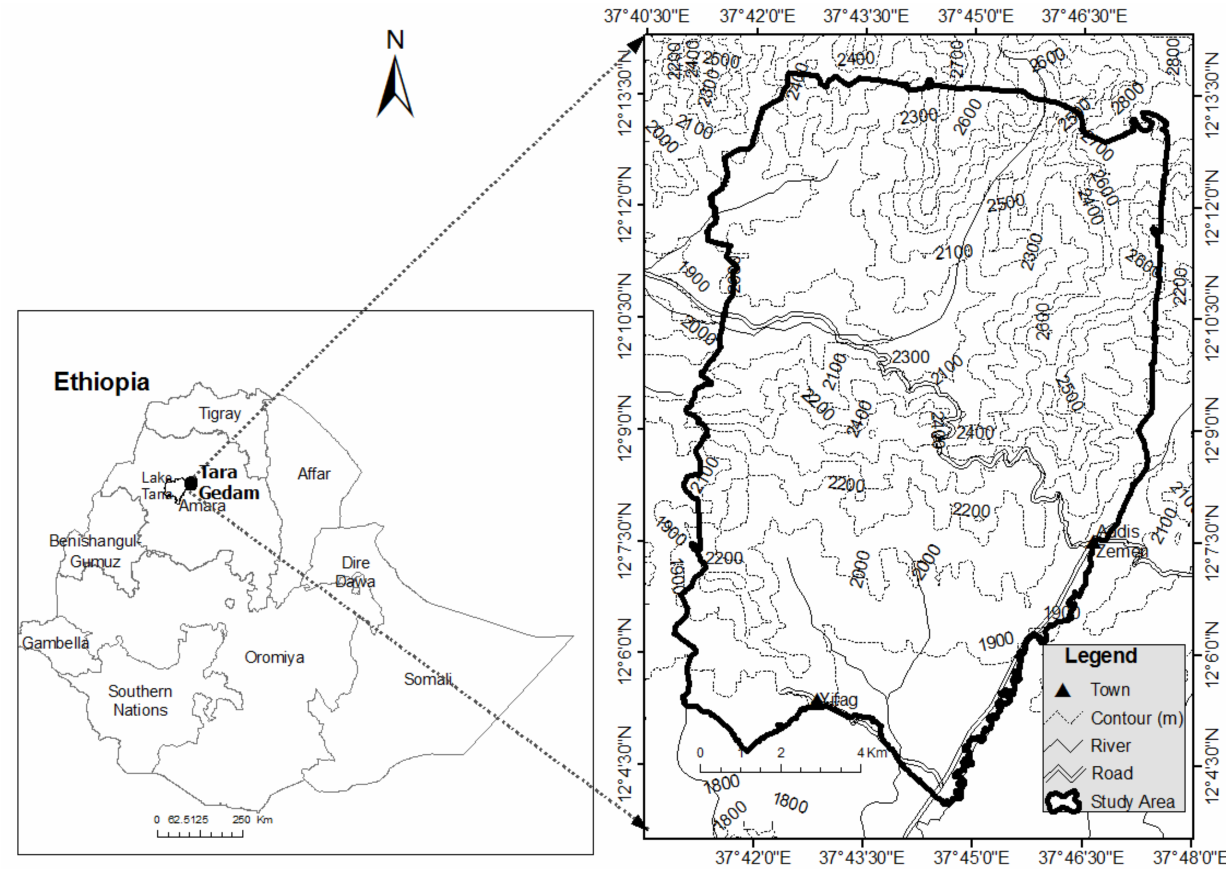

Fig 1. Location map of the Tara Gedam mountain landscape and adjacent agro-ecosystem.

Geologically, the area is made up of volcanic rocks that belong to the Trap series of cenozoic age and is similar to most parts of central Ethiopian highlands (Mohr, 1971). According to the FAO/UNESCO (1990) classification legend, the soils of the study area are mainly Leptosols, Luvisols and Cambisols occurring on the steep slopes and mountain regions and Vertisols in the valley bottoms.

Following the Ethiopian traditional agro-climatic zonation, the study area falls in the *weyna dega* (Tepid to cool moist mid-highland) zone. A twenty six year (1981–2006) climatic data from a nearby meteorological centre (Addis Zemen, 1950 masl; 12° 07' N and 37° 47' E) recorded an average annual precipitation of 1,135 mm with more than 80% of the rain occurring between June and September. The mean monthly temperature is 19.8°C ranging between 11.5°C in July and August and 28.5°C in March and April (Fig. 2).

The study area covers 16,156.67 ha of land with a population size of 10,391 in 1984 (OPHCC, 1990) and 18,863 in 2007 (BoPED, 2008) (Table 1). Due to a long term human activity, most of the natural vegetation of the study area has been destroyed. Some of the existing remnant forests are mainly confined to the mountain ridges and steep slopes, around monasteries, churches and burial grounds. The dominant tree species of the natural forest are *Olea europaea* L. subsp cuspidata, *Cordia africana* Lam., *Acacia abyssinica* Hochst., *Croton macrostachyus* Del., *Millettina ferruginea* Hochst. Ex. Benth, and the shrub species such as *Vernonia amygdalina* Del., *Calpurnea aurea, Carissa edulis,* and *Bersama abyssinica.* Adjacent to the natural forest of the Tara Gedam monastery, there is a substantial tract of planted exotic tree forest dominated by species of *Pinus, Cupressus* and *Eucalyptus.*

The livelihood of the local people depends on subsistence farming relying on rain-fed agriculture and livestock husbandry. The principal cultivated crops are mainly *tef (Eragrostis tef)*, sorghum *(Sorghum bicolor)*, barley *(Hordeum vulgare L)*, horse beans *(Vicia faba L)*, potato *(Solanum tubersoum* L.*)* and maize *(Zea mays* L*).*

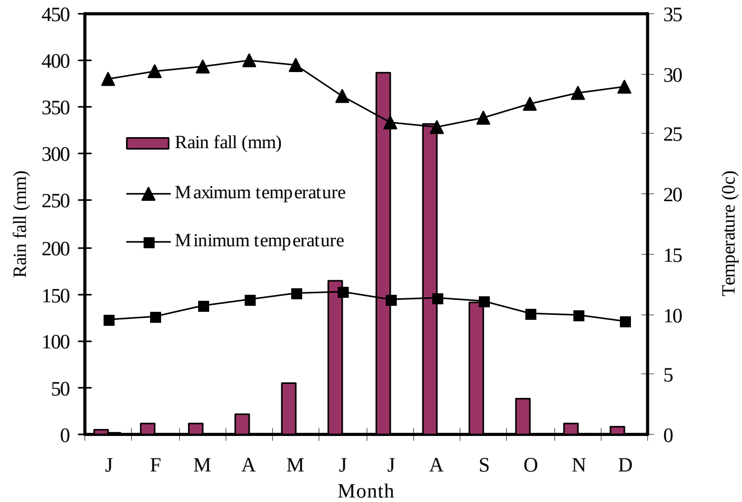

Fig. 2. Mean monthly rainfall (RF), maximum and minimum temperatures (Temp) of the mountain landscape of Tara Gedam and adjacent agro-ecosystem (1981–2006). (Data from Ethiopian National Meteorological Service Agency).

Table 1. Population growth in three villages in the study area between 1984 and 2007.

Village	Population size			Population growth rate between 1984–2007
	1984[a]	1994[b]	2007[b]	
Tara Gedam	3400	5252	6489	3089
Bankiso Sendyo	3907	5498	6180	2273
Ginaza Silkesa	3084	5285	6194	3110
Total	10391	16035	18863	8472

[a] Source: OPHCC (1990), [b] Source: (BoPED, 2008).

Data source and analysis

To detect changes of land use/cover, at least two time-period data sets are required (Jenson, 1986). In this study land use/cover changes were monitored at three period intervals. Data required for the study were generated from systematic analysis of two sets of 1:50,000 panchromatic aerial photographs (taken in December, 1957 and November, 1980) and a multispectral Land-sat satellite image (Land sat-ETM; December, 2003). The use of satellite image for the year 2003 was crucial due to the absence of recent aerial photographs for the study site. The boundary of the study area was delineated on a 1:50,000 topographic map (EMA, 1988).

Before interpretation of the aerial photographs and satellite images, a reconnaissance survey was carried out in November and December 2008 to obtain general understanding of the land use/cover pattern of the study area. Then, identification and classification of the land use/cover on the aerial photographs were monitored through intensive use of stereoscopic magnifying lenses for visual verification. Six land use/cover categories were identified (Table 2). Owing to the fact that the scale of analysis made it difficult to separate plantation forest from natural forest and rural dwellings from cultivated land, these were grouped into dense forest and cultivated and settlement land cover categories, respectively. Similarly, grassland was made to include grazing area and bare lands with little or no vegetation cover. The grouping of the two together was necessary because it was difficult to differentiate one from the other as they had the same tone on the images. The aerial photographs were scanned with 1200 dots per inch scanner and saved in a Tagged Image File (TIF) format. The scanned aerial photographs were georeferenced according to Universal Transverse Mercator (UTM) system using Arc GIS 9.2 software and digitized manually as polygon coverage. In the process of geo-referencing the photo mosaics, distinctive features such as roads, rivers and stream confluences that were clearly visible on the aerial photographs were used as control points.

Table 2. Description of land use/cover classes identified in the mountain landscape of Tara Gedam and the adjacent agro-ecosystem.

Land use/cover	Description
Dense forest	Areas that are covered with dense growth of trees with closed canopies. It includes a virgin forest dominated by indigenous tree species and plantation forest dominated by exotic tree species
Cultivated and Settlement land	Areas used for rain fed crop cultivation and scattered rural settlements usually associated with cultivated lands.
Woodland	Land covered by scattered trees mixed with grasses, bushes and with some open areas.
Shrub land	Land covered by bushes and shrubs and sometimes with scattered small trees mixed with grasses.
Grassland	This includes communal and\or private grazing lands including bare lands with little or no vegetation cover.
Riverine vegetation	Represents areas covered by scattered trees and shrubs grown in response to the wet microenvironments along the courses of rivers and streams in the study area.

The land use/cover classes from the 2003 land sat image (Land sat-ETM) were produced by supervised digital image classification method in ENVI (Environment for Visualizing Images) 4.3 software using training area taken on the basis of false colour composite (reflectance characteristics) of each land use/cover classes. Then, using the line objects on a 50,000 scale topographic sheet, the images were adjusted and clipped to the frame that covers the study area. The arc GIS 9.2 software made it possible to link the polygon lines to label the specific land use/cover classification and calculate the spatial statistics of each polygon. Finally, three land use/cover maps were produced corresponding to the three years (1957, 1980 and 2003). A few focus group discussions and interviews were also conducted with randomly selected elderly farmers in the three major villages of the study area to obtain additional information on historical and current changes in land use/cover types including both the causes and effects. These discussions were undertaken during field surveys and after the interpretation of the aerial photographs and satellite images.

RESULTS AND DISCUSSION

Land use/cover dynamics

Dense forest land

The dense forest cover was found to be declining over the period (1957–2003) (Fig. 3, 4 and 5) for which the data were analyzed. In 1957, 9.99% (1,614.57 ha) of the study area was covered by dense forest, but it diminished to 2.06% (332.53 ha) in 1980. In 2003 the forest cover was increased by 134.99 ha of land and the total coverage was 2.89% (467.52 ha) (Table 3). However, within 46 years time the overall pattern was a decline by 71.04% (1147.05 ha) at a 1.54% (24.94 ha) annual rate of deforestation (Table 4). The land use/cover transformation between 1957 and 2003 indicated that much of the dense forest covered land was shifted to cultivated and settlement land, shrub land, woodland and grassland. However, a small proportion of land was transformed to dense forests during the entire study period (Table 5).

Table 3. Land use/cover types and areas covered by the respective land use type in the Tara Gedam mountain landscape and adjacent agro-ecosystem in three different periods (1957, 1980 and 2003).

Land use/land cover type	Area covered by respective land use/cover type					
	1957		1980		2003	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Dense forest	1,614.57	9.99	332.53	2.06	467.52	2.89
Woodland	4,016.11	24.86	1,146.78	7.09	85.59	0.53
Shrub land	3,312.50	20.50	2,444.46	15.13	3,013.71	18.65
Grassland	977.46	6.05	1,721.12	10.65	947.85	5.87
Riverine vegetation	186.96	1.16	178.75	1.11	112.30	0.70
Cultivated and Settlement land	6,049.07	37.42	10,333.03	63.96	11,529.63	71.36
Total	16,156. 67	100.00	16,156.67	100.00	16,156.70	100.00

Table 4. Land use/cover changes in the mountain landscape of Tara Gedam and the adjacent agro-ecosystem between 1957 and 2003.

Land use/land cover type	Change in land use area (ha and %) coverage; gain (+) or loss (-)					
	1957–1980		1980–2003		1957–2003	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Dense forest	-1282.04	-79.40	+134.99	+40.59	-1147.05	-71.04
Woodland	-2869.33	-71.45	-1061.19	-92.54	-3930.52	-97.87
Shrub land	-868.04	-26.20	+569.25	+23.29	-298.79	-9.02
Grassland	+743.66	+76.08	-773.27	-44.93	-29.61	-3.03
Riverine vegetation	-8.21	-4.39	-66.38	-37.14	-74.59	-37.00
Cultivated land and Settlement	+4283.96	+70.82	+1196.60	+11.58	+5480.56	+90.60
Total	0		0		0	

Table 5. Land use/cover transformation proportions in the Tara Gedam mountain landscape and adjacent agro-ecosystem for the periods from 1957–1980 and 1980–2003.

Land use/land cover type	Changed to	1957–1980		1980–2003	
		Area (ha)	Area (%)	Area (ha)	Area (%)
Dense forest	Cultivated & settlement land	834.31	51.67	53.91	16.21
	Grassland	104.36	6.46	6.57	1.97
	Shrub land	211.32	13.09	19.21	5.78
	Woodland	171.07	10.60	2.85	0.86
	Unchanged	293.51	18.18	249.99	75.18
Woodland	Cultivated & settlement land	1,746.56	43.49	554.78	48.38
	Grassland	421.28	10.49	21.28	1.86
	Shrub land	862.97	21.49	469.09	40.90
	Dense forest	10.53	0.26	25.13	2.19
	Unchanged	974.77	24.27	76.5	6.67
Shrub land	Cultivated & settlement land	1561.86	47.15	250.06	10.23
	Grassland	442.07	13.35	29.39	1.20
	Dense forest	4.50	0.14	33.94	1.39
	Woodland	0.94	0.03	6.24	0.26
	Riverine vegetation	18.86	0.57	4.21	0.17
	Unchanged	1284.44	38.78	2120.62	86.75
Grassland	Cultivated & settlement land	318.81	32.62	663.68	38.56
	Shrub land	6.17	0.63	218.83	12.71
	Dense forest	5.02	0.51	14.55	0.85
	Unchanged	647.46	66.24	824.06	47.88
	Grassland	10.35	5.54	0.00	0.00
Riverine vegetation	Shrub land	4.21	2.25	0.00	0.00
	Dense forest	12.51	6.69	70.66	39.53
	Unchanged	159.89	85.52	108.09	60.47
Cultivated and settlement land	Grassland	95.6	1.58	66.55	0.64
	Shrub land	75.52	1.25	185.96	1.80
	Dense forest	6.46	0.11	73.25	0.71
	Unchanged	5871.49	97.06	10007.27	96.85
Total		16,156.67		16,156.67	

The intensification and diversification of this change could be attributed to high demand for cultivable land which is associated with high population growth (Table 1) and to the 1975 land tenure policy of the Military Government (*Derg*) of Ethiopia that distributed much of the land held by few land-lords to the vast majority of small-holder farmers. The 1975 land reform proclamation allowed many new farmers to own plots within traditionally protected forests and grazing lands and land that was privately owned and protected (Tsehai Berhane Selassie, 1994).

Thus, the land tenure policy which did not put restrictions on the use of protected and fragile lands, and the mechanism of its implementation were the major factors that encouraged the unsustainable use of dense forests (Gete Zeleke, 2002). Collection of timber for construction and fire wood through selective and constant thinning has also contributed to the transformation of dense forests to shrublands and woodlands. During the discussions, the inhabitants of the study area also expressed their concern emphasizing on poverty-driven activities and land shortage that resulted from population pressure as the major factors for the wide deforestation in the area. Most of the farmers were involved in illegal preparation of firewood and charcoal from natural forests for sale to the nearby towns. This was a common practice that supplemented their insufficient income from agricultural outputs.

However, in contrast to the first period (1957–1980), dense forest increased by 134.99 ha (40.59%) during the second period (1980–2003) (Table 4). This happened following the attempts by the then government to conserve the remnant natural forests through increased tree planting as part of the afforestation program implemented throughout the country in the 1980's (Poschen-Eiche, 1987). During this period, fast growing exotic tree species have been established for the rehabilitation of degraded lands and to provide forest products (Pohjonen and Pukkala, 1990). This program encouraged the inhabitants of the study area to establish small private plantations around their homesteads and to participate in community forestry development activities. The practice of developing and managing plantation trees, mainly exotics, provided timber for construction and fuel wood, thereby easing the expansion pressure to the natural forests during the second period (1980–2003).

The private plantations and some of the patches of community plantation forests that are currently seen in the study area are the result of the massive afforestation program of the 1980s. Although the intervention was promising, this program could compensate only 8.36% (134.99 ha) of the dense forest that was present in 1957. This proportion was less than the magnitude of deforestation. As a result, only 2.89% (467.52 ha) of the study area was covered by fragmented remnant dense forests in 2003 (Table 3). The recent field survey indicated that these dense forests are mainly found on steeper slopes, around churches, monasteries and homesteads. Some of these have been preserved by the Bureau of Agriculture and Rural Development of ANRS as state forests and others by monks in the monasteries who controlled illegal tree cutting and encroachment. In particular forests found in the premises of churches and monasteries remained protected due to the Orthodox Church's faith that considers cutting trees from a church compound as a curse. The significant decline in forest and its conversion to other land uses indicate that deforestation has been a continuous trend in the study area as has also been reported in different parts of Ethiopia (Kebrom Tekle and Hedlund, 2000; Gete Zeleke and Hurni, 2001; Woldeamlak Bewket, 2002; Selamyihun Kidanu and Tekalign Mamo, 2003; Mohammed Assen, 2006; Mohammed Assen and Tasew Nigussie, 2009).

Woodland

Results from this study revealed that the woodland cover decreased substantially over the 46-year period for which the data were analysed. Woodland was the second largest land cover in 1957 (Table 3 and Fig. 3) occupying 24.86% (4016.11 ha) of the study area, but it shrunk to 7.10% (1,146.78 ha) in 1980 and to 0.53% (85.59 ha) in 2003 (Table 3, Fig. 4 and 5). The total woodland cleared and transformed to other land use categories throughout the study period was 97.87% (3930.52 ha) (Table 3), with annual rate of change of 2.13% (85.45 ha). On the other hand, only a small percentage of the shrubland and dense forest were transformed into woodland (Table 5). This dramatic change could be attributed to the expansion of grazing land, cultivated and settlement land, and to the increased demand for fire wood and construction materials. Analysis of the aerial photographs and satellite images and discussions with the local communities and key informants revealed that the lower and gentle slope areas, that are at present cultivated for annual crops and used for settlement, were once covered by *Acacia* woodlands. The scattered *Acacia* trees currently found standing alone in the cultivated fields and around homesteads are apparent indicators of the extent of *Acacia* woodland coverage in the past. Thus, the gentle slopes and deep soil of this part of the study area have contributed to its subsequent transformation into grazing land, and cultivated and settlement land uses.

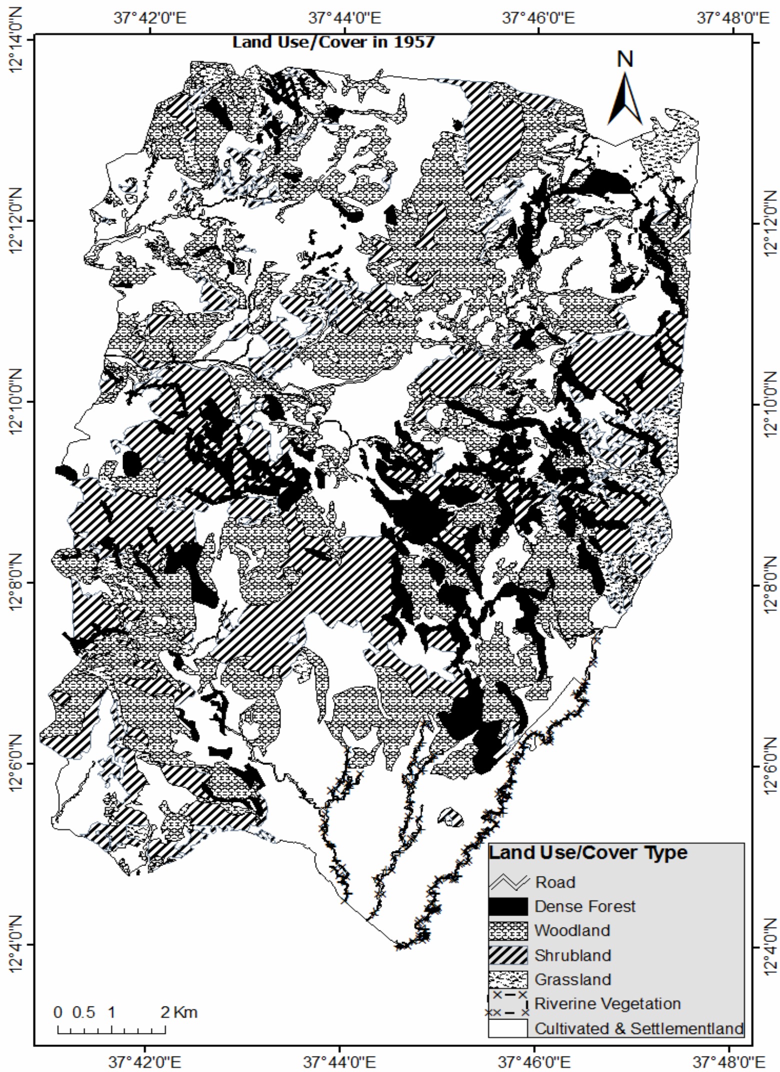

Fig. 3. Land use/cover map in the mountain landscape of Tara Gedam and adjacent agro-ecosystem in 1957.

Shrub land

The patterns of change of shrub covered land showed a decrease by 26.20% during the first period (1957–1980), and then an increase during the second period (1980–2003) by 23.29%. However, the overall trend showed a decline by 9.02% (298.79 ha) throughout the study period (Table 3 and 4). The scenario of change during the first period could be due to the expansion of grazing land, and cultivation and settlement onto this land cover. On the other hand, the increase during the second period suggests that there was a slight shift from other land uses/cover onto shrub lands that could be explained by the following reasons. The first reason could be the abandonment of some of the intensively-cropped lands as fallow period due to the loss of their fertility and the subsequent regeneration of bushes and shrubs on to these lands. The second reason could be associated with selective thinning of dense forests and woodlands. For instance, during this period 5.78% of the dense forest and 40.90% of the woodland areas were transformed to shrub lands (Table 5). Some isolated trees standing alone also indicate the transformation of forests and woodlands to shrub land. This practice arose from increased demand for fire wood and construction materials for subsistence and commercial purposes. The intervention of the government in the early 1980s to rehabilitate degraded lands through soil conservation and afforestation programs with the prohibition of further deforestation and cultivation of the remnant natural vegetation cover (Poschen-Eiche, 1987) could have also contributed to the increase of shrub land that was observed in the second period.

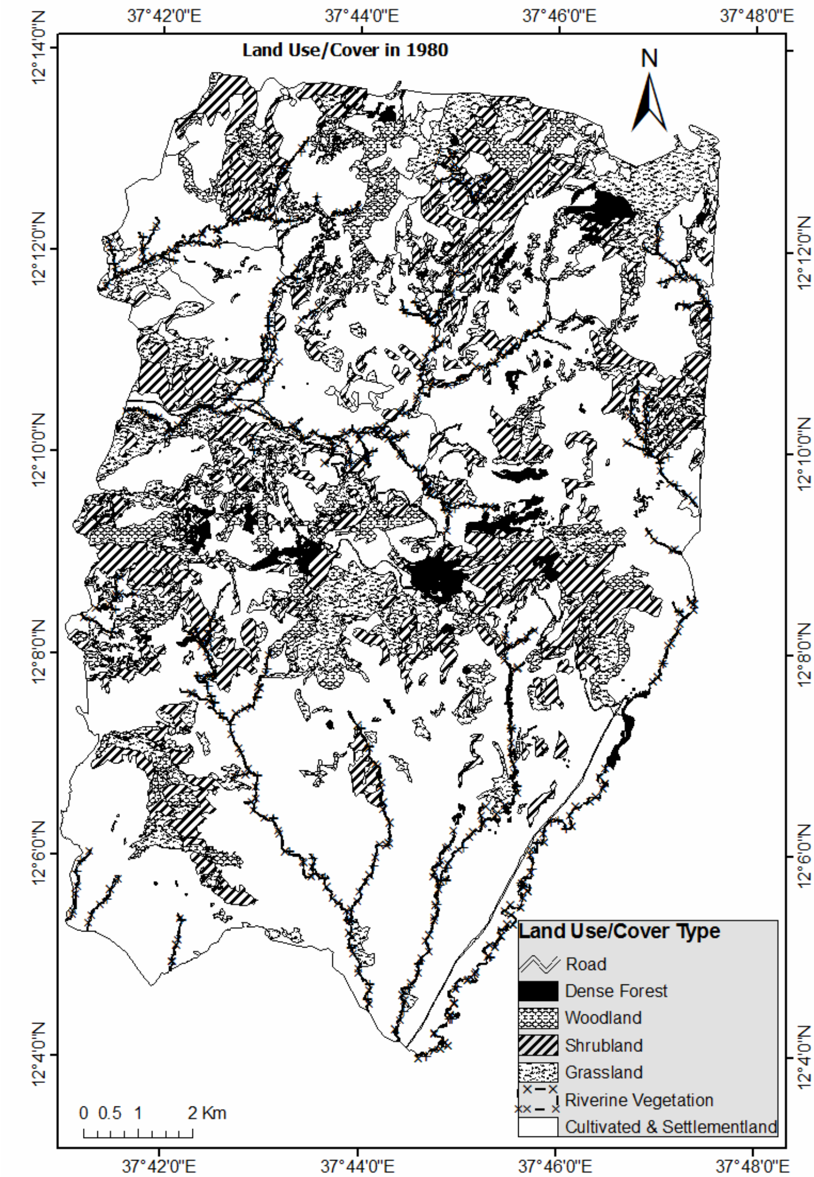

Fig. 4. Land use/cover map in mountain landscape of Tara Gedam and adjacent agro-ecosystems in 1980.

Grassland

The area under grassland cover increased from 6.05% (977.46 ha) in 1957 to 10.65% (1,721.09 ha) in 1980, but subsequently regressed to 5.87% (947.85 ha) in 2003 (Table 3; Figs 3, 4 and 5). Land use/cover change analysis indicted that 32% to 39% of the grassland cover was transformed into cultivated and settlement land resulting in its decline by 3.03% over the entire study period (Tables 4 and 5). As the elder local people indicated, the increase in grassland cover during the first period of the analysis could primarily be attributed to a considerable shift of vegetation-covered lands to grazing land, as livestock rearing was equally important to crop production in the area. On the other hand, abandonment of some earlier cultivated and deteriorated lands as fallow, and their subsequent transformation into bare and grazing lands could have also caused an increase in the coverage of grasslands. On the contrary, an important factor for the regression of this land use type in the second period (1980–2003) could be related to rapid human population growth (Table 1) which caused the transformation of grasslands into cultivated land and settlement areas. This phenomenon is especially common in the north-western parts of Ethiopia where grazing lands are increasingly being transformed to settlement and cultivated lands due to population pressure (Lakew Desta *et al.*, 2000; Woldeamlak Bewket, 2002).

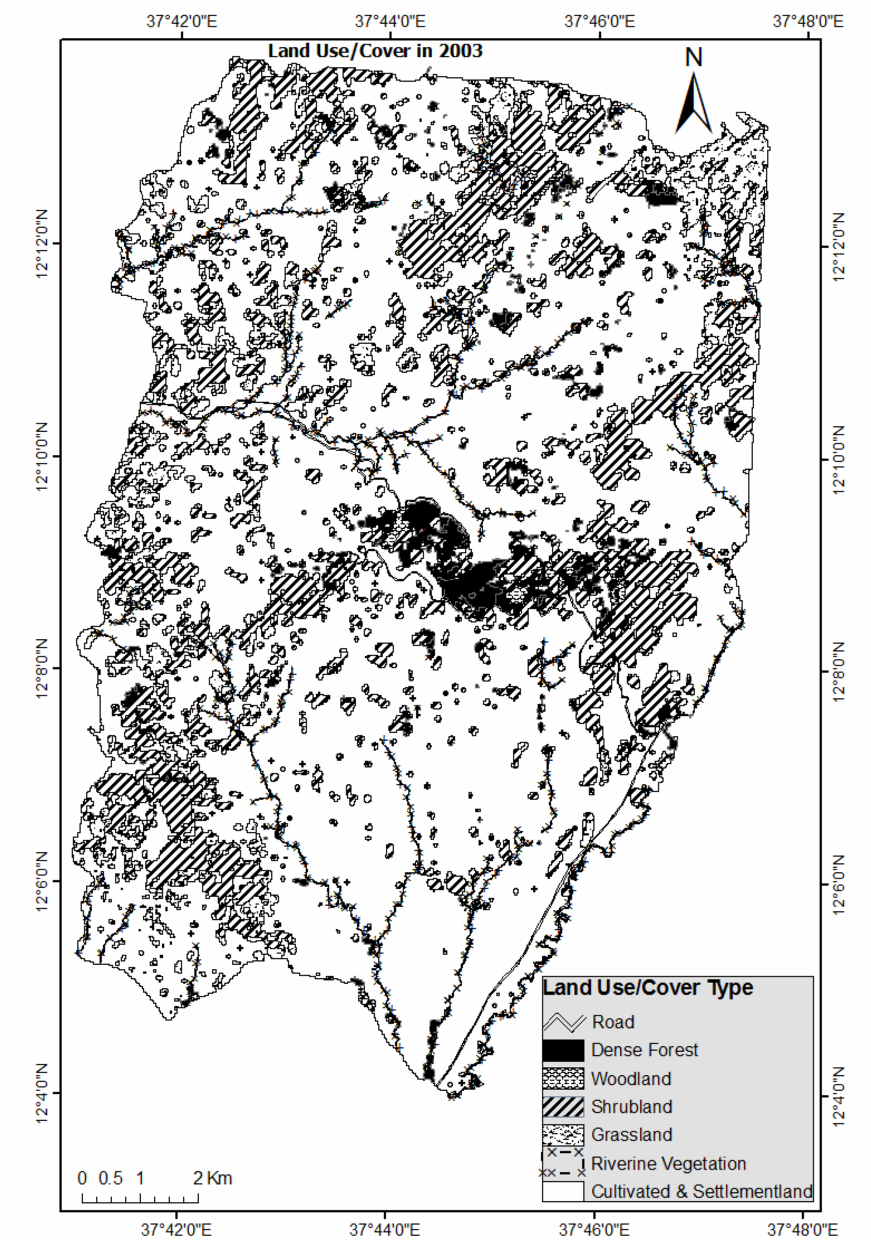

Fig. 5. Land use/cover map in the mountain landscape of Tara Gedam and adjacent agro-ecosystems in 2003.

Riverine vegetation

Land cover by riverine vegetation shrunk continuously throughout the study period. The area covered by this vegetation in 1957 was 186.96 ha (1.16%); it was consistently reduced to 178.75 ha (1.11%) in 1980 and to 112.3 ha (0.70%) in 2003 which constituted a 37% decline in 46 years (Table 3 and 4). This decline is attributed to the increased use of much of the riverine vegetation for fire wood, construction and grazing. The analysis of change revealed that a large part of the land area under riverine vegetation cover was replaced by dense forest (6.69%) followed by grassland (5.54%) and shrub land (2.25%) during the first period. During the second period, about 39.53% of the riverine vegetation was transformed mainly to dense forest cover (Table 5). This was observed during the field visits in 2008 and 2009 where small tracts of privately owned Eucalyptus tree forests have been planted along river and stream banks, replacing the natural riverine vegetation. One possibility is that much of the riverine vegetation has been replaced by plantation forest due to their proximity water source.

Cultivated and settlement land

Cultivated and settlement land was found to be the largest land use/cover practiced throughout the study period with fields scattered in almost all parts of the landscape (Fig. 3, 4 and 5). This land use had an expansion of 70.82% (4,283.96 ha) between 1957 and 1980 and 11.58% (1196.6 ha) between 1980 and 2003. This accounts for an overall increase of 90.60% (5,480.56 ha) in 46 years (1957–2003), with an average annual rate of expansion of 1.97 % (119.14 ha) (Table 3 and 4).

The land use change detection analysis revealed that the substantial expansion in cultivated and settlement land observed in the study area took place at the expense of reduction of areas under dense forest, shrub land, woodland, and grassland covers. For instance, during the first period, 51.67% of the dense forest, 47.15% of the shrub land, 43.49% of the woodland and 32.62% of the grassland areas were transformed into cultivated and settlement land. Similar trends were observed during the second period. On the other hand, only 2.94% of the cultivated and settlement land during the first period (1957–1980) and 3.15% during the second period (1980–2003) were transformed to grassland, shrub land and dense forest (Table 5).

The local communities made it clear that high cost and limited access to agricultural inputs, fragmented land holdings, and insecure land tenure together with the subsequent desire to get fertile lands for more crop production resulted in the expansion of cultivated land. Thus, instead of maximizing production through sustainable soil and land management, abandonment of earlier cultivated and deteriorated fields was a common practice. This increased the need to convert large areas under natural vegetation cover into cultivated land for additional crop production. The significant increase in cultivated and settlement land during the first period could also be partly attributed to the 1975 land reform proclamation. The land reform gave the chance to numerous landless farmers to have their own land, but was not accompanied by certification of ownership (Gete Zeleke, 2002). In a similar move, in 1997 and 1998 the regional government (ANRS) implemented a major land redistribution program in the region. It is argued that land redistribution erodes tenure security and that under this situation farmers will not undertake land improving investments because they may not be able to fully claim the return of their investment (Benin and Pender, 2001; Lakew Desta *et al.*, 2000). This leads to the expansion of cultivated fields and settlement by smallholder farmers, mainly through deforestation, irrespective of the potentials of the land. Therefore, the overall trend was the reduction in natural vegetation covered area and the increase in cultivated and settlement land.

On the other hand, the decrease from 70.82% to 11.58% in the expansion of cultivated land and settlement in the second period could be related to the implementation of the soil conservation program in the 1980s in most parts of the country and the study area (Poschen-Eiche, 1987). Some of the factors that contributed to the decline in the expansion of cultivated and settlement lands between 1980 and 2003 in many parts of the area include: intensification of crop production through the use of agricultural inputs (*e.g.*, fertilizers), short fallow periods, total abandonment of frequently cultivated lands (due to loss in soil fertility and its transformation to shrub land and grazing lands). Although the expansion of this land use seems to slow down in the second period, with increasing population growth and shortage of land for crop production, it is likely that some of the remnant strips of land that are found adjacent to the forest cover could also be converted into cultivated and settlement lands.

Implications of land use changes on land degradation

An ecologically balanced ecosystem is one which is in a state of dynamic equilibrium mainly composed of forest land, grassland and wetland that are considered essential components of the environment. These land cover types are ecological assets that are crucial to land protection, biodiversity, and hydrological and geochemical cycles (Turner *et al.*, 2000). However, inappropriate land use changes affect their natural ecological functions and lead to a decline in land productivity and loss of biodiversity (Shahid *et al.*, 1999). Land degradation could be partly explained in terms of removal of land cover through deforestation and overgrazing. This process leads to soil erosion and land degradation and to the loss of biodiversity as explained in many parts of the world (Hurni, 1988; Houghton, 1994; Rao and Pant, 2001; Gete Zeleke and Hurni, 2001; Gete Zeleke, 2002).

On the highlands of Ethiopia, land degradation by soil erosion is the most vital environmental problem for the food security of the population and future development prospects of the country (Hurni, 1988). This study demonstrated that continuous removal of natural land cover (*i.e.*, vegetation) has occurred in the mountain landscape of Tara Gedam and adjacent agro-ecosystem over a period of 46 years. As a result, more than 70% of the forest and woodland and significant proportions of shrub land and riverine vegetation cover were removed during the same period exposing large areas of the landscape to land degradation. All these were driven by human-induced factors such as population pressure and expansion of agricultural activities, land tenure insecurity and frequent land redistribution. A combination of these factors reduced activities such as fallowing, planting and investing on conservation structures causing the expansion of cultivated and grazing areas to steep slopes and fragile lands. As a result large areas of the study site were exposed to the processes of soil erosion and immense loss of biodiversity. At present, this area with shallow soil depth and with no soil conservation measures, is regularly cultivated causing more land degradation and accelerated soil erosion. Although not quantified in the present study, gullies observed during the field visits of 2008 and 2009 mainly in the deforested and cultivated lands; testify the presence of accelerated soil erosion and land degradation. The impacts of all these negative changes in the land use history are shallow soil depth, loss of soil fertility and a decline in crop productivity affecting the livelihood of the community. In addition to this, some of the important indigenous tree species such as *Juniperus procera, Podocarpus falcatus, Olea eroupea* sub spp. *cuspidata* and existing wild animals such as Menilik bush buck (*Tragelaphus seriptus* meneliki), Red fronted gazelle (*Gazzela rufifrons*), and others are on the verge of extinction, contributing to further loss of biodiversity.

CONCLUSIONS

The quantitative evidence obtained through interpretation of aerial photographs and satellite images revealed the occurrence of significant land use/cover changes in the mountain landscape of Tara Gedam and the surrounding agro-ecosystem between 1957 and 2003. The temporal trend over the 46-year period indicated that the area covered by dense forest, woodland, shrub land, riverine vegetation and grassland decreased while cultivated and settlement land increased substantially. The main cause of the dramatic land use/cover changes was the expansion of cultivated and settlement land to meet the demands of food and fibre for the alarmingly growing population. The study clearly showed that the interactions of different factors including expansion of cultivated and settlement land, insecure land tenure and the 1975 land reform program, lack of alternative sources of energy and construction materials, shortage of agricultural inputs and technologies, the fragile biophysical conditions of the area and lack of early awareness of farmers about soil erosion and soil fertility are obviously responsible for the major land use/cover changes in the area. All these factors have collectively contributed to the loss of natural vegetation and land resource degradation. Therefore, efforts are needed to devise and implement appropriate land use management strategies with full involvement of the local communities through identifying areas to be protected, farmed, grazed and used for settlements so as to sustainably utilize and conserve the natural resource of the area. The land use policy should also be reconsidered such that it could provide a long term and lasting tenure security for the farmer. In this regard, the rural land certification program initiated by the regional government a few years ago should be strengthened and implemented in a faster way so that farmers will be more concerned about their land and thus become more responsible in protecting and conserving the natural resources. In addition, responsible regional government and non-government institutions have to conduct awareness raising campaigns on easing the population pressure by putting into practice the national population policy of the country.

Among the positive steps taken so far, the afforestation and soil conservation programs of the 1980s to counter balance the deforestation scenario were of great importance. In particular, the practice of *Eucalyptus* tree plantation around homesteads between 1980 and 2003 have eased the expansion pressure to the natural vegetation for collecting wood for fire and for construction. This practice should be encouraged especially by providing the community with ecologically-friendly fast-growing tree species. Land-use intensification strategies, including the application of manure, various intercropping patterns, and on-farm soil conservation approaches with full involvement of the local community will certainly help in minimizing land degradation. Extension workers should play an active role in disseminating information on the usefulness of all these practices and convince farmers to conserve the remnant vegetation cover and to rehabilitate the degraded lands. The results of the present study provide useful base line information to better understand the magnitude and implications of land use/cover changes, thus serving as a tool for future integrated natural resources conservation planning and possible management scenarios in the study area and in other similar biophysical settings.

ACKNOWLEDGEMENTS

The authors are grateful to Development Innovation Fund (DIF) project for the financial support of granted through Haramaya University. We also acknowledge Bahir Dar University and the Environment Protection, Land Administration and Use Authority of the ANRS for their logistic support during field survey. Sincere thanks are extended to Abebe Mohammed for his technical assistance in the interpretation of remotely sensed images. We also thank the local residents of the study area who participated in the interviews and group discussions. Anonymous reviewers of *SINET* are also thanked for their constructive ideas and opinions.

REFERENCES

1. Armenteras, D., Gast, F. and Villarel, H. (2003). Andean forest fragmentation and the representativeness of protected nature areas in the eastern Andes, Colombia. *Biological Conservation* **113**:245–256.
2. Benin, S. and Pender, J. (2001). Impacts of land distribution on land management and productivity in the Ethiopian highlands. *Land Degradation and Development* **12**:555–568.
3. BOPED (2008). Population size by sex and age in the Amhara Region 1994–2007 (in Amharic, unpublished report). BOPED, (Bureau of Planning and Economic Development), Bahir Dar, Ethiopia. pp 12–27.
4. Bonnefille, R. and Hamilton, A. (1986). Quaternary and late territory history of Ethiopian vegetation. **In**: *Research on the Ethiopian Flora .Proceedings of the First Ethiopian Flora Symposium*, pp. 48–55, (Hedberg, I., ed.), May 22–26, 1984. Uppsala.
5. Breitenbach, F.V. (1961). Forest and woodlands of Ethiopia: a geo-botanical contribution to the knowledge of the principal plant communities of Ethiopia, with special regard to forestry. *Ethiopian Forestry Review* **1**:5–16.
6. EFAP (1993). *Ethiopian Forestry Action Program: The Challenge for Development* (Vol. II). Ethiopian Forestry Action Plan, Ministry of Natural Resource Development and Environmental Protection. Addis Ababa. Ethiopia, pp 27–63.
7. EMA (1988). Map series ETH 4 Sheet 1237 D3 and 1237 D4. EMA, Ethiopian Mapping Agency, Addis Ababa, Ethiopia.
8. Eshetu Yirdaw (2002). Restoration of the native woody-species diversity, using plantation species as Foster Trees, in the degraded highlands of Ethiopia. PhD Thesis, University of Helsinki, Helsinki, pp 10–15.
9. FAO /UNESCO (1990). *Soil Map of the World: Revised Legend.* World Soil Resource Report 60. Food and Agriculture Organization, Rome, Italy, pp 97–119.
10. FAO (2001). *Global Forest Resource Assessment* 2000. Forestry Paper No. 140. Food and Agriculture Organization, Rome, Italy. pp 21–24.
11. Gete Zeleke (2000). *Landscape Dynamics and Soil Erosion Process Modelling in the North-western Ethiopian Highlands.* African Studies Series A16. Geographica Bernensia, Berne, Switzerland. pp 1–8.
12. Gete Zeleke and Hurni, H. (2001). Implications of land use and land cover dynamics for mountain resources degradation in the north-western Ethiopian highlands. *Mountain Research and Development* **21**:184–191.
13. Gete Zeleke (2002). Resource use and poverty in the Ethiopian highlands. **In**: *Natural Resources Degradation and Environmental Concerns in the Amhara National Regional State: Impact on Food Security*, pp 51–62, (Tilahun Amede, ed.). Proceedings of the Natural Resource Management Conference, July 24–26, 2002. Bahir Dar, Ethiopia.
14. Houghton, R.A. (1994). The world wide of extent of land-use change. *Bioscience* **44**:305–313.
15. Hurni, H. (1988). Degradation and conservation of the resources in the Ethiopian highlands. *Mountain Research and Development* **8**:122–130.
16. Jenson, J.R. (1986). *Introductory Digital Image Processing*. Prentice Hall: New Jersey. pp 316–325.
17. Kebrom Tekele and Hedlund, L. (2000). Land cover change between 1958 and 1986 in Kalu district, southern Wello, Ethiopia. *Mountain Research and Development* **20**:42–51.
18. Lakew Desta, Minale Kassie, Benin, S. and Pender, J. (2000). *Land Degradation and Strategies for Sustainable Development in the Ethiopian Highlands:* Amhara region socioeconomic and policy research working paper 32. ILRI (International Livestock Research Institute), Nairobi, Kenya. pp 8–19.
19. Million Bekele (2001). Forestry outlook studies in Africa (FOSA). Ethiopia. http//www.fao.org-|DOCREP|004|AB582E|AB582E07.htm.#3573, pp 1–28 (Accessed on March 5, 2009).

20. Mohammed Assen (2006). Land use/cover dynamics over a period of three decades in the Jelo micro-mountain landscape, Chercher highlands, Ethiopia. *Ethiopian Journal of Natural Resources* **8**:39–56.
21. Mohammed Assen and Tasew Nigussie (2009). Land use/cover changes between 1966 and 1996 in Chirokella Micro-watershed, south-eastern Ethiopia. *East African Journal of Sciences* **3**:1–8.
22. Mohr, P.A. (1971). *The Geology of Ethiopia*. Haile Sellassie I University Press. Addis Ababa, Ethiopia.
23. Mwavu, E.N. and Witkowski, E.T.F. (2008). Land use and cover changes (1988–2002) around Budongo forest reserve, NW Uganda: Implications for forest and woodland sustainability. *Land Degradation and Development* **19**:606–622.
24. Naeem, S., Chapin III, C.F.S., Costanza, R., Ehrlich, P.R., Golley, F.B., Hooper, D.U., Lawton, J.H., O'Neill, R.V., Mooney, H.A., Sala, O.E., Symstad, A.J. and Tilman, D. (1999). Biodiversity and ecosystem functions: Maintaining natural life support processes. *Issues in Ecology* **4**:1–14.
25. Omiti, J.M., Parton, K.A., Sinden, J.A. and Ehui, S.K. (1999). Monitoring changes in land use practices following agrarian decollectivization in Ethiopia. *Agriculture, Ecosystem and Environment* **72**:111–118.
26. OPHCC (1990). Population and Housing Census 1984. Analytical Report on Gondar Region. Office of Population and Housing Census Commission, Addis Ababa, Ethiopia.
27. Paulos Dubale (2001). Soil and water resources degradation. Factors affecting productivity in Ethiopian highland agro-ecosystems. *Northern East Africa Studies* **8**:27–51.
28. Pohjonen, V. and Pukkala, T. (1990). *Eucalyptus globules* in Ethiopian forestry. *Forest Ecology and Management* **36**:19–31.
29. Poschen-Eiche, S.B. (1987). The Application of Farming Systems in Research to Community Forestry: A Case Study in the Harargae Highlands, Eastern Ethiopia. *Tropical Agriculture* Vol. **1**, pp. 5–110, Weikensheim, Germany.
30. Rao, K.S. and Pant, H. (2001). Land use dynamics and landscape change pattern in a typical micro watershed in the middle elevation zone of central Himalaya, India. *Agriculture, Ecosystem and Environment* **86**:113–123.
31. Selamyihun Kidanu and Tekalign Mamo (2003). Land use changes and erosion on some highland soils of Ethiopia. *Ethiopian Journal of Natural Resources* **5**:215–231.
32. Tsehai Berhane Selassie (1994). *Social Survey of the Soil Conservation Areas, Dizi, Anjeni and Gununo (Ethiopia).* University of Berne, Switzerland in association with the Ministry of Natural Resources Development and Environment protection, Ethiopia and UN University. pp 1–55.
33. Turner, B.L., Meyer, B. and Skole, D.L. (1994). Global land use/land cover: towards an integrated study. *Ambio* **23**:91–95.
34. Turner, D.P., Koerper, G.J., Harmon, M.E. and Lee, J.J. (1995). A carbon budget for forests of the conterminous United States. *Ecological Applications* **5**:421–436.
35. Turner, R.K., Van der Berg, J.C., Soderquist, A., Barendregt, A., Vander, J.S., Maltby, J. and Ireland, V.E. (2000). Ecological economic analysis of wetlands: scientific integration management and policy. *Ecological Economics* **35:**7–23.
36. Verburg, P.H., Veldkamp, A. and Bouma, J. (1999). Land use change under conditions of high population pressure: The case of Java. *Global Environmental Change* **9**:303–312.
37. WBISPP (2004). Woody Biomass Inventory and Strategic Planning Project. Ministry of Agriculture. Addis Ababa, Ethiopia. 118 pp.
38. Woldeamlak Bewket (2002). Land cover dynamics since the 1950s in the Chemoga watershed, Blue Nile Basin, Ethiopia. *Mountain Research and Development* **22**:263–269.