ORIGINAL ARTICLE

LAND USE AND LAND COVER DYNAMICS: DRIVING FORCES AND IMPACTS IN LAY GAYINT WOREDA OF AMHARA NATIONAL REGIONAL STATE, ETHIOPIA

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ABSTRACT

The objective of this study is to assess the pattern and to identify the major driving forces of land use and land cover change as well as to analyze the consequences of these changes in Lay Gayint woreda. *The study used Landsat images of 1984 and 2004 to produce two layers of maps using Remote Sensing and GIS. The results showed that cultivation land and settlement increased by 51.8 % followed by increment in bare land by 19.1 % while communal grazing, forest cover, and shrub have reduced by 52.6 %; 79.6 % and 28.4 % respectively. Population growth, less hand holding related to traditional farming practices, and high fuel energy demand were the major driving forces for the observed changes. One of the major negative impacts of land use and land cover change in the* woreda *is land degradation, mainly in the form of erosion and the resulting loss of fertility. To curb this problem, the study recommends practising sustainable land management utilizing alternative energy sources, implementing expansive family planning, and creating awareness on the impacts of those changes.*

Keywords: GIS, remote sensing, land use and land cover changes, land degradation, soil fertility, soil erosion, sustainable land management practices.

INTRODUCTION

The question of what factors drive land use and land cover change has remained largely unanswered. Recently, human activities and social factors were recognized to have a paramount importance in land use and land cover change (Lambin, Geist & Lepers, 2003). The conceptual understanding of the proximate causes and underlying forces has a crucial importance in identifying the causes of land use and land cover changes (Meyer & Turner, 1994). Proximate (direct) causes are immediate actions of local people in order to fulfill their needs from the use of the land. These causes include agricultural expansion, wood extraction, infrastructure expansion and others that change the physical state of land cover. At the proximate level, land use and land cover change may be explained by multiple factors rather than by a single variable (Lambin, Geist & Lepers, 2003). Underlying (indirect or root) driving forces are fundamental processes that push proximate causes into immediate action on land use and land cover. Underlying driving forces such

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as demographic pressure, economic status, and technological and institutional factors, influence land use and land cover in combination rather than as single causations (Meyer & Turner, 1994).

Land use and land cover change play an important role in global environmental change. They are major factors affecting sustainable development. The scientific community has now come to recognize the diverse roles of land use and land cover change. Consequently, the need for understanding of land use and land cover change has been increasingly recognized in global environmental research (Lambin, Geist & Lepers, 2003). The degree and rate of change in land-cover and some land-uses are known to some extent. According to Turner et al. (1993), most of the earth's surface is already modified, except those areas that are peripheral in location or are fairly inaccessible. Of the total land surface, about 40% has been changed in the form of conversion into other uses. It is only about 25% of the land that remains nearly unchanged. In the case of Ethiopia, studies on land use and land cover change are few (Solomon, 1994). Those limited studies focused on the Northern Ethiopian highlands, areas early settled and relatively overpopulated (Belay Tegene, 2002).

One of the greatest historical challenges to the Ethiopian economy is linked with the problems of rural environment in general and that of the rural highlands in particular. Rural highland areas support about 88% of the human population, 95% of the cropland, more than 75% of the livestock and 90% of economic activities in the country (Mc Cann, 1995). This role as an economic powerhouse is related to the sufficient rainfall, moderate temperature and well-developed soil, which are characteristics to these highlands. Moreover, highlands in Ethiopia were historically the basis for the early development of agriculture and have been prior targets of settlement for the human population (Hürni, 1990).

More recently agriculture in the Ethiopian highlands has extended to more difficult terrains and to traditionally unexploited parts of the environment. The expansion of agricultural practices into terrains such as steeper slopes and swampy plains in many parts of the northwestern highlands of Ethiopia may indicate the presence of pressure on land, vegetation, and water resources. These parts of the country are amongst the most degraded and those with high rate of nutrient depletion in sub-Saharan Africa. As stated in the Ethiopian Forestry Action Program (1994), cited in Muluneh (2003), depletion of soils and plant biodiversity are recognized to be the two most important forms of environmental degradation in rural Ethiopia.

Historically, population was regarded as the most important and the only driving force behind global change. However, currently it is understood that environmental change has many driving forces that are closely interrelated, population being only one among them (Rindfuss & Adamo, 2004). In most developing countries, population growth has been a dominant cause of land use and land cover change (Kahsay Berhe, 2004). As a result, there is a significant statistical correlation between population growth and land cover

conversion in most African, Asian, and Latin American countries (Sege, 1994). Similarly, in Ethiopia, population pressure has been found to have negative effect on shrub land, communal grazing land and forests (Woldeamlak Bewket, 1993).

In the case of Ethiopia, views with regard to the relationship between population growth and land degradation are variable. For instance, the highland parts of the country have been severely degraded due to population growth coupled with early settlement, topographical features and geological history. Contrary to this, case studies in Sebat-bet Guraghe have highlighted a more positive impact of a high density of population. Similarly, in Konso, where population is relatively high and located at the margin land, degradation is less severe due to indigenous knowledge for soil conservation (Kahsay Berhe, 2004).

According to Turner et al. (1995), land use change is a common phenomenon associated with population growth, market development, institutional factors and policy action. The entire ecological infrastructure such as vegetation cover, soil characteristics, plant and animal population, and hydrological cycle has been strongly influenced by the conversion of land and forest resources. Understanding of the institutional causes (i.e. political, legal, economic, and traditional) and their interaction with individual decision making is important in explaining land use changes. Institutional causes need to be considered at micro and macro levels because the implementation of macro policies is practiced at the micro level. Land use and land cover changes are influenced significantly when macro policies undermine local policies in that the structure of local and national polices may determine local people's access to land, capital, technology and information (Lambin, Geist & Lepers, 2003).

The absence of applicable forest policy is cited as a contributing factor for deforestation in different parts of the world including Ethiopia. According to FAO (1999) the country's forest cover in 1989 was 12.9 percent. A decade later, in 1997, the forest cover was estimated to be only 4.2 percent (FAO, 2001). In addition, the lack of appropriate land use and forest policies as well as the absence of corresponding laws are responsible for the decline of forests in southwestern Ethiopia. The promotion of industrial crops with high return has encouraged the direct clearance of forests. The policy of food self-sufficiency based on surplus crop production has also been realized at the expense of forest degradation in southwestern Ethiopia (Million, 2002). Likewise, rapid expansion of crop cultivation at the expense of forests occurred due to the land reform policy changes of 1975 (Amare, 1994). Another obvious consequence of land use and land cover change, particularly of deforestation, is the shortage of fuel-wood to meet household energy consumption posed by high population pressure (Girma et al., 2002). As a result, land use change and resource degradation have been affected by land tenure system and government policies in Ethiopia.

Land use and land cover change can impact the socio-economic status of the rural population. Agricultural productivity, which may determine rural income, wealth and education, can be affected by the consequences of land use and land cover changes. Therefore, understanding of the complex interaction of these changes in their temporal and spatial patterns and processes is the baseline to formulate focused and targeted policy interventions in rural development and environmental management (Lambin, Geist & Lepers, 2003).

Land cover transformation in both tropical and temperate regions, by provoking intensified deforestation, has important implications in the dramatic loss of plant species in terms of density, diversity and community composition. Ethiopia, with the fifth largest flora in tropical Africa and with about 12% of its plant population being endemic, has been critically affected by the loss of plant biodiversity (Tewolde Berhan, 1991). Despite housing a large diversity of biological resources, biodiversity in Ethiopia is largely being affected by human activities (Kahsay Berhe, 2004). Assessments of this impact have indicated that forests have become depleted at a large scale as a result of expansion of agriculture and settlement areas. For instance, Ethiopia has about 60 million hectares of land for grazing. This figure has been reduced to less than 55 million hectares due to grassland conversion into other land uses and covers (Kebrom & Hedlund, 2000). On the other hand, an expansion of cultivated land at the expense of bush lands, natural pasture and forest, caused by increasing human population, has strongly affected the number of livestock and the quality of their products. This in turn induces overgrazing and soil erosion in different parts of the country. These local-level changes play a pivotal role in affecting the health of the ecosystem. Loss of biodiversity, soil degradation, and environmental deterioration are largely results of land use/cover change. An example of the negative effects of land use/cover change is that land productivity declines under continuous cultivation, overgrazing and soil erosion (Muluneh, 2003).

In Ethiopia, only a few land use and land cover change studies have been conducted in different parts of the country. As a result, land use and land cover change, and its driving forces and impacts are hardly documented. This study aims to contribute to the knowledge on land use and land cover change, its driving forces and consequences with an empirical study in Lay Gayint *woreda*. The target *woreda* is taken as a representative area for the northwestern part of the country in terms of topography, climate, vegetation and socioeconomic conditions. The pattern of land use and land cover is one of the indicators of sustainability of resource utilization and management, which provides a basis for conservation planning. Hence, this study is significant to understand the rate of land-cover and land-use change, to identify the causes and impacts of these changes and, finally, to find solutions for sustainable use of land and other resources. The study analyzes the rate of land use and land cover change over the past 20 years, identifying the major driving forces and impacts in these processes.

STUDY AREA

Lay Gayint is one of the ten *woreda*s of South Gondar zone in Amhara regional state. It is bordered by the districts of Ebnat on the north, Tach Gaint and Simada on the south, Misrak Estie on the southwest, Farta on the west, and Meket on the east (North Wollo zone). The absolute location of the *woreda* is 11°32'-12° 16' N Latitude and 38° 12'- 38° 20'E Longitude. The administrative center is Nefas Mewcha, located on the Woreta-Woldia highway, which is 237 km (North Gondar Trade and Transportation Department, 2011) away from Gondar city and 175 km away from the regional capital Bahir Dar. Other towns in the same *woreda* include Gob Gob, Sali and Checheho. The administrative town is located at 11°44'N Latitude and 38° 28'E Longitude.

The physiographic of the *woreda* is very rugged and dissected. The elevation ranges approximately from 1200 m above the sea level in the Tekeze lowland to 4235 m above the sea level on the Guna Mountain. The topography of the district is characterized by 11.97 % plain, 5% mountain, 8% valley, 75% plateau and 0.03% covered with water. According to Lay Gayint Woreda Office of Agriculture (2012), the *woreda* is covered by red soil (15%), brown soil (55%), black soil (15%), grey soil (10%) and others (5%).

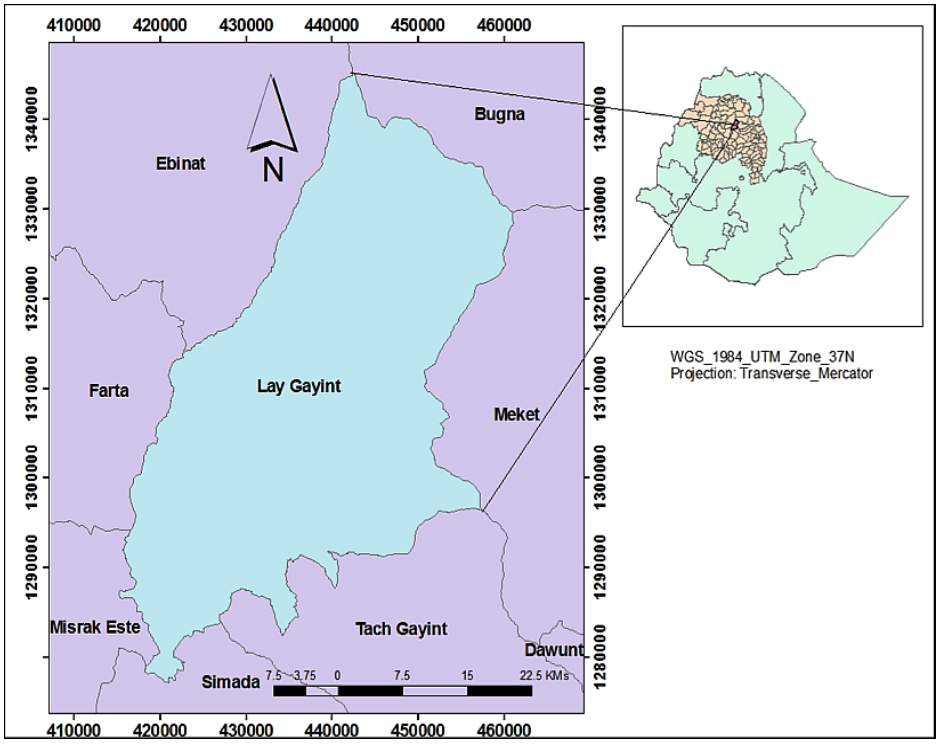

Figure 1: *Location Map of Lay Gayint* woreda

The maximum and minimum mean annual temperature of the *woreda* is 20° C and 8°C respectively. The annual rainfall of the *woreda* is between 600 mm and 1200 mm (Lay Gayint Woreda Office of Agriculture, 2012). The nature of the rainfall is erratic, short in duration, late onset and early offset as well as poorly distributed temporally and spatially. The livelihood of farmers is endangered by seasonality of rainfall, recurrent drought and variability of rainfall. The annual mean rainfall of the district for the last 27 years was 1053.61 mm. The small rainy season (*belg*), occurs between March and May and the long rainy season (*keremt*), occurs between June and September. Therefore, summer rainfall is the main rainy season for crop production.

According to Central Statistical Authority (2007) this *woreda* has a total population of 206,499 (104,401 male and 102,098 female). Out of these, 22,825 (11.05%) are urban dwellers and 183,674 (88.95%) rural dwellers with a total household (HHs) number of 39,638. Concerning the population distribution, 41% live in *dega*, 31% live in *woyna dega*, and 28% live in *kolla* agro ecology (Lay Gayint Woreda Office of Agriculture, 2012; Mesfin Wolde-Mariam, 1991). About 88.95% of the population depend on agriculture and the average land holding size of a household in the woreda is 0.75 hectare (Lay Gayint Woreda Office of Agriculture, 2012). Small-scale mixed agriculture is the dominant source of livelihood to the local people.

METHODS

Geo-referenced satellite images (Landsat TM) of 1984 and 2004 of Lay Gayint

Table 1: *Lay Gayint* woreda *land use classification*

Land use type	Area coverage (ha)	%
Cultivated land (annual crops)	68,649	44.33
Communal grazing land	22,160	14.31
Forest cover	1,023	0.66
Shrub land	8,150	5.26
Infrastructure and settlement	2,344	1.51
Bare land	52,540	33.93
Total	154,866	100.0

Source: Lay Gayint Woreda Office of Agriculture, 2012.

woreda, was downloaded freely from Global land cover facility (www.earthexplorer.usgs.gov). The *woreda*'s office have been doing land use and land cover classification in six major classes, namely: cultivated land, grazing land, forest cover, bush and shrubs land, infrastructure and settlement and bare land. Due to the difficulty to identify cultivated land from settlement and infrastructure, these two are merged and called cultivated land and settlement. Therefore, the classification is reduced to five, i.e. cultivated land and settlement, communal grazing land, forest cover, shrub land and bare land. Finally, a supervised classification was made to establish

the land use and land cover types of the two satellite images of 1984 and 2004, and was analyzed in percentages.

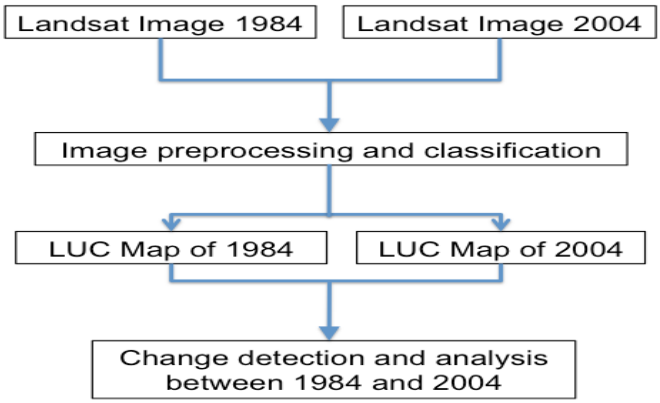

Figure 2: *Flow chart showing the general methodology of land use/land cover evaluation*

RESULTS AND DISCUSSION

As indicated in Table 2, the land use and land cover types in the study area are defined into five types, namely: cultivated land and settlement, communal grazing land, forest land, shrub land and bare land. The separation of cultivated land and settlement was not possible due to their intermingled pattern. For example, usually, rural settlements are encircled by farm plots. Because of this it was difficult to define specific land cover type for each. Therefore, cultivated land and settlement are classified as one class.

As indicated in Figures 3 and 4, the second greatest share of land use/land cover next to bare land is communal grazing land, which covers an area of 42,643.60 hectares (28%). Cultivated land and shrub land covers an aerial of

Table 2: *Types of land use and land cover in Lay Gayint* woreda

Land use and land cover class	Description
Cultivated land and settlement	Areas allotted to rain fed crop cultivation including annuals and perennials, mostly of cereals in subsistence farming and the scattered rural settlements included within the cultivated fields.
Forests cover	Areas covered by trees forming closed or nearly closed canopies; forest; plantation forest.
Shrub land	Land covered by small trees, bushes, and shrubs, in some cases mixed with grasses; less dense than forests.
Grazing land	Areas of land where small grasses are the predominant natural vegetation. It also includes land with scattered or patches of trees and it is used for grazing and browsing.
Bare land	Parts of the land surface which are mainly covered by bare soil and exposed rocks.

35,451.30 hectares (23%) and 14,083.40 hectares (9%) respectively. The least aerial coverage is forest, which accounts for only 3,610.61 hectares (3%).

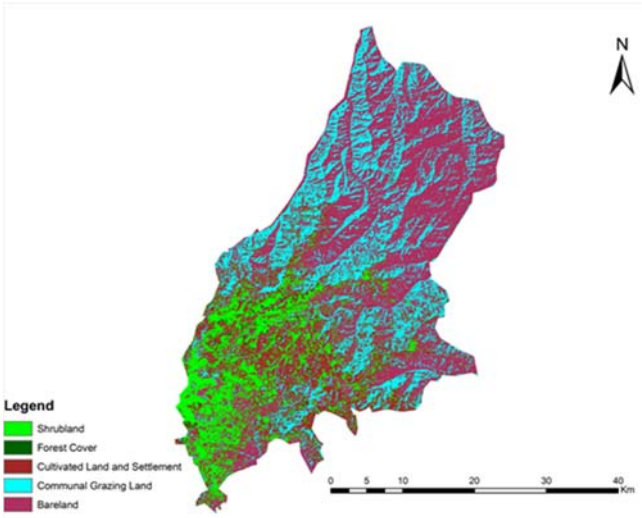

Figure 3: *Land use and land cover map of Lay Gayint* woreda *in 1984*

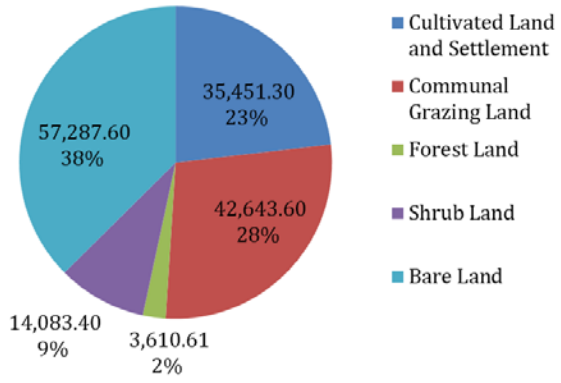

Figure 4: *Aerial coverage (in hectares) and percentage of Lay Gayint* woreda *in 1984*

As indicated in Figures 5 and 6, the greatest share of land use and land cover from all classes, except the bare land, is cultivated land, which covers an area of 53,816.00 hectares (35%). Communal grazing land and shrub land cover an area of 20,209.90.30 hectares (13%) and 10,085.80 hectares (7%), respectively. The least aerial coverage is forest, which accounts for only 735.80 hectares (0.48%).

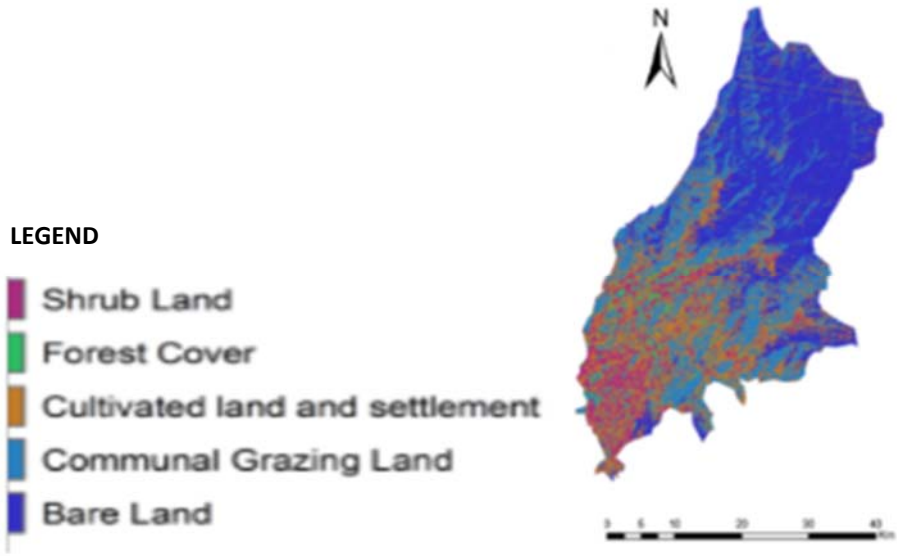

Figure 5: *Land use and land cover map of Lay Gayint* woreda *in 2004*

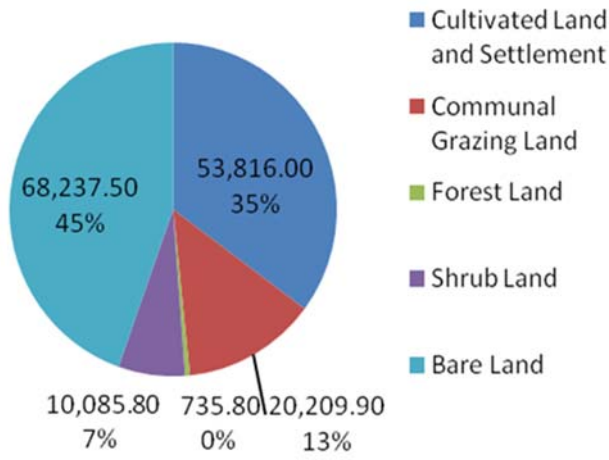

Figure 6: *Aerial coverage (in hectares) and percentage of Lay Gayint* woreda *in 2004*

An important aspect of change detection is to determine what is actually changing to what category of land use and land cover type, i.e. which land use class is changing to another type of land use class. This information will also serve as a vital tool in management decisions. This process involves a pixel-to-pixel comparison of the study year images through overlay analysis.

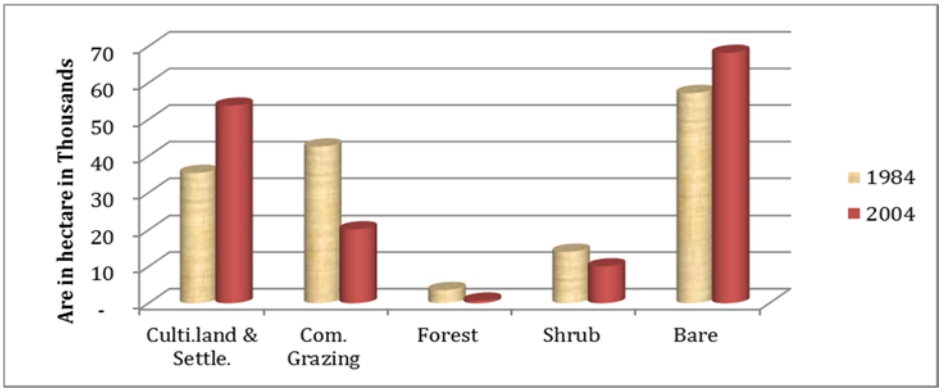

Figure 7: *Land use land cover types and trends in 1984 and 2004*

Pattern and areal extent of land use and land cover change

The change for cultivated land and settlement showed very high increase between 1984 and 2004. In 1984, the area under cultivated land and settlement coverage was 35,451.30 hectares (23.16%), which was escalated to 53,816.00 hectares (35.15%) in 2004. An additional 18,364.70 hectares of land was incorporated into this land use type. This is at the expense of forestland, communal grazing land and shrub land. The original land use increased by 51.80%.

The change for communal grazing land decreased highly between 1984 and 2004. In 1984, the area under communal grazing land coverage was 42,643.60 hectares (27.86%), which was reduced to 20,209.90 hectares (13.20%) in 2004. Of the total communal grazing land cover in 1984, 52.61% was converted into other forms of land use. Only 47.39% of the original area remained in the same category. An attempt to plant forage for livestock to reduce the pressure on communal grazing land and exercise zero grazing was not working as expected.

The pattern of change for forest cover showed a decrease between 1984 and 2004. In 1984, the area under forest cover was 3,610.61 hectares (2.36%), which declined to 735.80 hectares (0.48%) in 2004. Of the total forest cover in 1984, 51.80% was converted into other forms of land use. Only 20.8% of the original area remained in the same category. A large proportion of the forest, i.e. 79.62% land was transformed into other land categories. An attempt to recover the lost forest cover through afforestation program was never successful in the area.

The pattern of change for shrub land also showed a decrease between 1984 and 2004. In 1984, the area covered by shrubs and bushes was 14,083.40 hectares (9.2%), which was reduced to 10,085.80 hectares (6.59%) in 2004. Of the total shrub land in 1984, 28.39 % was converted into other forms of land use. 71.62% of the original area remained in the same category. The land cover/land use change in shrub is relatively less. This might be due to planting of eucalyptus trees on the highland parts of the *woreda*, as a result of which some of the forest covers in 1984 changed into shrub land.

The change for bare land showed a very high increase between 1984 and 2004. In 1984, the bare land was 57,287.60 hectares (37.42%), which was raised to 68,237.00 hectares (44.57%) in 2004. An additional 10,949.90 hectares of land was incorporated into this land use type.

Major drivers of land use and land cover changes

In the case of our study area, the total population increased by 40% between the years 1984 and 2004, i.e. from 123,900 in 1984 to 206,499 in 2004 (Lay Gayint Woreda Office of Agriculture, 2012). This implies the rural population who earn their livelihood from agriculture has increased. From this data we can induce that population growth in the study area was possibly a crucial factor that caused change in land use and land cover.

Land holdings

As is the case in most of north-central highlands of Ethiopia, the farm size of households for the study *woreda* was small. In the study area, the unit of measurement of land is *timad*: 4 *timad* is equivalent to 1 hectare and conversion was made on this basis. The average land holding size for a household was more than 1.5 hectares in the base year, whereas in 2004 this figure was reduced to 0.75 hectare (Lay Gayint Woreda Office of Agriculture, 2012). This shows that the land holding for a household was reduced by half when compared with the reference year. Hence, landholding is an important factor that caused land use and land cover change.

Livestock production

Livestock play a very important role for which agriculture is the major source of livelihood (Befekadu Degefe & Berhanu Nega, 2000). There was a significant increase in the livestock population of the study area, especially on small ruminants: sheep and goat (Lay Gayint Woreda Office of Agriculture, 2012). This shows that the number of animals is increasing while the size of the grazing land is decreasing. This in turn will result in over grazing, erosion, and land degradation.

Sources of energy

In Ethiopia, the most important sources of energy are fuel wood, charcoal, cow dung and crop residues; of which fuel wood covers about 85% of the energy source (Ethiopian Forestry Action Program, 1994). Similarly farmers in the study area use similar sources to satisfy their energy demand (Lay Gayint Woreda Office of Agriculture, 2012). This will have an impact on the change in land use/land cover of the area.

Impacts of land use and land cover changes

Land degradation has been the major negative impact of land use and land cover change in Lay Gayint *woreda*. The most common form of degradation is produced by sheet erosion (Lay Gayint Woreda Office of Agriculture, 2012). As our image analysis demonstrated, the area of bare land increased by about 10,949 hectares: 19% increase between 1984 and 2004. As a result, production that was obtained from this area was lost. Moreover, soil fertility

is reduced due to over utilization and improper use of the soil (Lay Gayint Woreda Office of Agriculture, 2012); this has critically increased the total use of fertilizer to counteract this decline in production. Due to this and other interrelated factors, a significant number of people in the *woreda*, about 80,000, have been facing food shortage and have been given food aid by the NGOs and GO's such as USAID (Lay Gayint Woreda Office of Agriculture, 2012) .

CONCLUSIONS

Finer-scale land use and land cover assessments generally involve the use of higher resolution spatial and field data (such as, data on vegetation structure, plant species type, etc), statistics or measures that relate to a condition, change or quality, or change in state of environment and socio-economic conditions. The analysis of this data allows knowing land use and land cover changes that have occurred in Lay Gayint *woreda* during the last 20 years, from 1984 to 2004. The methods this study used were remote sensing integrated into a Geographical Information Systems (GIS) environment, which provided an ability to characterize large assessment areas and establish reference conditions. Generally the situations of land use and land cover dynamics have a depressing effect on the local scale and on others because its consequences do not have clear boundaries. Therefore, there is an urgent need for local land use planning and design with conservation practices in the study area. In this area, forest land decreased by 79.62% between 1984 and 2004. An increasing demand for farming land, rural settlement and grazing land was the cause for change of forest land (Lay Gayint Woreda Office of Agriculture, 2012). Shrub land also declined from 14,083.40 hectares (9%) to 10,085.80 hectares during the last 20 years in the study area. This is due to high household energy demand of the peoples of the *woreda*. The lesser reduction of shrub land might be due to the fact that some forest lands are converted into this form of land cover.

The expansion of cultivated land at the expense of other land cover types resulted a decrease in the amount of fodder and the number of cattle. This has lead to shortage of animals required for plowing and other economical purposes. Small numbers of livestock also have an impact on the use of cow dung for manure. Moreover, the expansion of cultivated land into marginal land leads to more severe land degradation.

There has been a change in land cover during the past twenty years of the study period (1984 to 2004) in the *woreda*. For instance, forest land, communal grazing land and shrub land cover types declined during the study period, whereas cultivated land and bare land increased at the expense of forest land and shrub land. These changes have not taken place without negative consequences.

RECOMMENDATIONS

The study suggests a series of measures in order to improve the land use and land cover status of the *woreda* and thus safeguard the livelihood of the local communities.

Forest protection and recovery
Soil and water conservation measures through afforestation program are an immediate requirement. The lack of national forest policies or guidelines on utilization, protection and property right of forest land and an ever increasing demand of farming land exacerbated the rate of deforestation. Moreover, the lack of a single afforestation program to be used as a model and to be organized by either the government or non-governmental organizations has an influence in hindering actions of forest protection and recovery processes in the study area. Therefore, an attempt should be made to show a model afforestation practice on degraded lands.

Population policy
Changes in land use and land cover in the study areas are mainly caused by increasing population. The current household family size and its annual crop production are not proportional. Moreover, farmers were unable to improve the amount of production with the existing conventional farming practice. Therefore, enhancement of households' knowledge regarding the impact of population growth on their living situation, through family planning programs and sex education, has a paramount importance.

Alternative energy sources
Fuel wood is the main source of energy in the study area. To this effect, farmers should be encouraged to plant trees on their homesteads, hillsides and degraded lands instead of cutting trees from the existing forest. Rural electrification program, introduction of modern energy sources like kerosene, and introduction of fuel saving stoves, instead of using fuel wood in traditional three stone stoves has to be given priority consideration.

Improving literacy level of the community
In the study area, the level of illiteracy is high, despite the fact that the contribution of educated manpower is unquestionable. Farmers, therefore, should be encouraged to send their children to school. Moreover, school drop -out rate should be reduced by changing the attitudes of family heads through education. Under the present population pressure in the study area, intensification of agriculture (increasing productivity per unit area) is recommended. The contribution of literate farmers in the intensification of agriculture will be greater than that of illiterate ones. Therefore, both the government and the society should take an immediate action to increase the number of students and their enrolment in schools.

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