



Analyses of land cover changes and major driving forces assessment in middle highland Tigray, Ethiopia: the case of areas around Laelay-Koraro

Thadiparthi Byragi Reddy, Mekonen Aregai Gebreselassie *

Department of Environmental Science, Andhra University, Visakhapatnam 530003, Andhra Pradesh, India

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Abstract

Analyzing the land cover changes and understanding the subsequent trends of change contribute to present complex dynamics of land cover and is important for policy making, planning and implementing of natural resource management. In this study, the land cover changes in a 64512 ha, in areas around Laelay-Koraro middle highland Tigray, Ethiopia has been investigated. Aerial photos from 1964 and 1994 and satellite imagery for the year 2007 were used to appraise the land cover changes and Geographic Information System (GIS) were employed to interpret maps and ground truth checking. Changes have also been detected using semi-structured questionnaire from a randomly selected 400 households on socioeconomic factors driving land cover changes. The aggregate of change through time tested using the combined techniques revealed that, the rates of conversion of land cover types were observed between 1964 and 1994 and this were during the second period in forest cover, degraded and bare land areas. The size of forest cover increased by 10.5% between 1994 and 2007 contributed to a remarkable increment in irrigable land from -0.3% to 3.4% of the total area. Interviewed households revealed that increasing population aggravated the rates of conversion of cultivated land and built up areas at the expense of vegetation cover caused high rates of soil erosion, runoff, excessive sedimentation, reduced infiltration rates and soil moisture. Finally, this study validates the reversibility of natural resource as the result of extensive management practices and community participation.

*Corresponding Author: Mekonen Aregai Gebreselassie ✉ mekonen2001@gmail.com

Introduction

Determining the effects of land-use and land-cover change on the Earth system depends on an understanding of past land-use practices, current land-use and land-cover patterns, and projections of future land use and cover, as affected by human distribution, economic development, technology and other factors (Tom, 2003). The land cover change, in many parts of the world has become a global issue, as a result contributed to the present complete transformation of land cover types. Natural disasters such as droughts, floods caused by climatic change, as suggested in many literatures is not a commonly occurring phenomenon, human interventions are, however cause dramatic changes in a society. FAO (1983) suggested that, such human induced processes are advancing at much faster rate. The most potent forces affecting natural vegetation arises from the direct effect on an expanding human population (Grime, 1997).

In Ethiopia, soil degradation is a direct consequence of land cover changes and farming practices being carried out in the past. Approximately, 150,000 to 200,000ha of forest are lost each year mainly for the expansion of rain fed agriculture and also for fuel wood and through over grazing (EFAP, 1994). FAO (2001) has been pointed out, deforestation occur when forest is converted to another land cover or when tree canopy cover fall below minimum percentage threshold-10%. Vegetation has a considerable effect on water recycling in an ecological land system (McCulloch and Robinson, 1993).

The long term effect of resource degradation coupled with erratic rainfall, recurrent drought and the ecological imbalance in the highlands of Ethiopia become a root cause for the emergence of resource conservation (Nyssen *et al.*, 2009). Munro *et al* (2008) proved, environmental recovery programs were initiated by the government in the early 1980s, with collective terracing and reforestation program. As a consequence, conservation practices

significantly make an impact on the quantum of water resources and land degradation. Keeping other factors being constant, many of the farm households in the study area continue to perceive the reversibility of natural resource upon in situ conservation and the management activities in practices. In the uplands of Ethiopia, Nyssen *et al.* (2007) proved that, stone bunds reduce soil loss on average to 32% by measuring 202 field parcels. The magnitude of land cover change reflected was basically due to an increase in the population density coupled with an increase in the size of crop land at the expense of vegetation cover, regressed the process of maintaining the health of the ecosystem. The existing situation of natural resource is demanding the development of an integrated approach for sustainable natural resource management. Hence, this study has aimed at exploring the status of land cover change and major driving forces assessment based on remotely sensed data in middle highland Tigray, Ethiopia.

Materials and methods

Study area

The study was carried out in areas around Laelay-Koraro in North-Western part of Tigray regional state of Ethiopia. It lies between latitudes 14° 10' 21" N and longitudes 38° 24' 12" to 38° 24' 36" E (Fig. 1). The total area of the study site is 64512 ha. The area lies in the semi-arid agro-climatic zone with diverse topographic conditions characterized with undulating terrain having steep and gentle slopes. The altitude of the study area ranges from 750M to 2300M above sea level.

The mean annual air temperature is 28°C, the maximum temperature reaches its pick during the month of April and May, and an annual precipitation ranges from 600mm to 900mm (Ethiopia Metrological service). The rainfall season is three to four months from June to September; and more than 80% of the total precipitation rains within these months. The rainfall is erratic in nature which impose early, mid or late season droughts. Soils are

predominantly dark brown in the middle highland area and light brown and grayish color in the low land area.

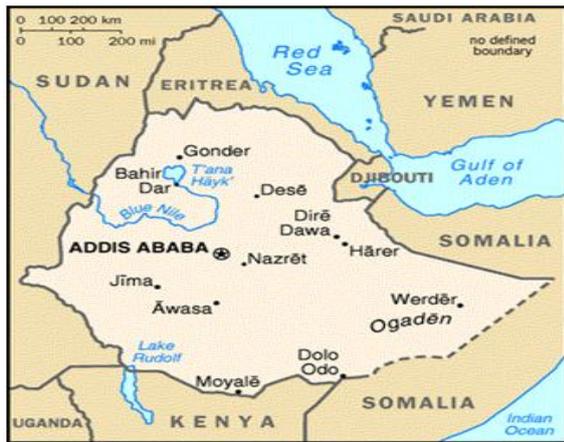


Fig.1. Location of the study area.

Table 1. Description of the land cover types of the study area.

Category	Description
Forest cover	densely covered area with different species of forest trees on mountains. Canopies cover >70%.
Wood land	an area with tree crown and height with more than 70% and about 5M height tree respectively.
Shrub land	an area with scattered small trees not exceeding 3M in height. Bushes, shrubs mixed with grass.
Cultivated land	agricultural rain fed cultivated land with scattered trees.
Scattered trees	
Top land	rain fed crop land with less than 30% tree cover.
Irrigated land	land with annual and perennial crops.
Grass land	grass dominated land
Wooded grass land	land covered with trees 40-70% crown not less than 5% height.
Stony land	land composed of stones and soils.
Degraded land	land with observable frequent gullies.
Settled up areas	residences, land used for small industries and other trade enterprises.

Data analysis

In order to analyze the land cover changes, a geo-information modeling approach was employed, taking the base map from survey of Ethiopia top sheets on 1:50,000 scale. In the present study, remote sensing techniques have been applied to identify and quantify the land cover changes using to sets of aerial photographs taken in 1964 and 1994, and land sat imagery taken in 2007. The two sets of aerial photographs were obtained from Ethiopian

Mapping Agency (EMA) having an approximately base scale of 1:50,000.

To detect changes, database establishment has been done through the following steps: a) the data sources involved obtained from aerial photographs were scanned in TIFF format using high resolution scanner. b) the geo-referenced photo mosaics were rectified according to the Universal Transverse Mercator (UTM) using datum Adindan Ethiopia. Polynomial function algorithm and spherical Clark 1880 were also inputs used for geo-referencing. Processing images was carried out using Arc GIS software. c) aerial photo interpretation of each land cover type was classified from aerial photo (1964 and 1994) using stereo-scope; whereas land sat images were produced from visual interpretation. Cutting and delineating of the survey area from topographic maps and digitized on screen using ILWIS GIS software. Erdas Imagine 9.1 was also used to analyze the data base created. Finally, to assess the temporal changes in land cover, the land cover maps for three years were produced for the above referenced years. Thus, for the purpose of this study, land cover features were categorized in to eleven broad types (Table 1) prior to aerial photo and spot image interpretation coupled with field check with help of GPS to confirm the land use units. In addition to data collected from aerial photos and image processing, semi-structured questionnaire were used for gathering data on socio-economic factors causing land use change. A systemic random sampling method was employed to select a total of 400 farm households above the age of 56 years to detect the underlying causes of land cover change, such as demographic changes, farming systems and causes of disturbance to the different land cover type.

Result

Land cover change analysis (1964-2007)

Observed changes over the study period

Land cover maps from aerial photos and spot- image were produced and trend analysis was carried out to compare the land cover type (Table 2 and Fig. 2). The

various land cover type's forest cover, wood land, mixed tree cropland, grassland, bare land, and degraded land (Table 2) shown almost a similar trend with dramatic decline in an area. Regardless of the proportion of changes in size of the cover types, significant changes have been observed between 1964 and 2007. Household irrigation schemes completely disappeared during this season. In relative terms, the size of degraded and bare lands was much pronounced during this period. Meanwhile, important changes have been observed between 1994 and 2007. A vital change in land cover was observed in almost all vegetation cover. In the first season of the study period, the irrigated land constituted a very small portion, only 0.3% of the total area (64512ha), which only comprises 190ha., later completely disappeared in the second season, but conversely a remarkable increment have been observed during 2007 to 2210ha of the total area, though bare and degraded lands failed to accomplish a complete rehabilitation through time.

Drivers of land cover change

Identifying the cause of land use change requires understanding how people make land use decisions. (Lambint and Gesit, 2007). Fluctuations and human activities are causes of land cover changes. However, changes attributed due to human activities are factors distinguished globally. The global nature of change emanates from various perspectives of human alteration of the environment which degrades the natural base. Among the major causes, demographic factors, especially an increase in local population play a significant role in land cover change (Lambint, E and J. Gesit.H, 2007). Hence, emphasis has been made on explicating the arguments about drivers of land covers change between the years and to that of the initial year to address the key questions. Population growth is the most important of human factors in Ethiopia (Hurni, 1993).The general trends of the land cover were identified in the aerial photos and satellite image of the respective years in the study area. To further understand the land cover change, data's on

population dynamics, rate of disturbance of the land cover and the changes in farming systems of the past decades and recent developments has also been gathered. Population growth rate in the study area increased from 15, 850, 19,520, and 24,536 and to 32,732 at the growth rate of 2.0, 2.3 and 2.9% respectively (Table 3).

Table 3. Population growth in the study area between 1974 and 2007.

<u>Population characteristics</u>			
<u>Season</u>	<u>Population size</u>	<u>Density no. /Km²</u>	<u>Growth rate. %^a</u>
1974	15,850	25	
1984	19,520	30	2.0
1994	24,536	38	2.3
2007	32,732	51	2.9

^aThe rates of growth were calculated based on the assumption of exponential growth: $N(t) = N(o)ert$. Data source: Ethiopian Central Statistics Agency (ECSA).

There was a common agreement between the interviewed households that increasing population was one of the major causes of land cover change in the study area. The total population size of the study area changing significantly at increasing rate. In the period between 1974 and 2007, the population of the study area increased from 15,850 to 32,732 at the rate of 2.0%-2.9%. The estimated population growth of Ethiopia is about 3.202% (CSA, 2010). Hence, population growth scenarios indicate that there is an increase in per-capita size of cultivated land, settlement and an increased demand for fuel wood and construction. Here we should note that, there are several arguments that agriculture will continue to be one of the major economic and institutional forces of the country which determine the livelihood of the vast majority. Much of the concern about population increase in developing countries reflects fears of insufficiency in local food production (Lee et al., 1988). On the other hand is the argument by Boeserup (1965) that population pressure might drive farmers to innovate new land use practices and mitigate resource degradation. Despite a thorough investigation, the rehabilitation of vegetation and catchment areas in the study area has been widely observed at present.

Fig. 2. Land cover changes in areas around Laelay-Koraro middle highland Tigray, Ethiopi 1964-2007.

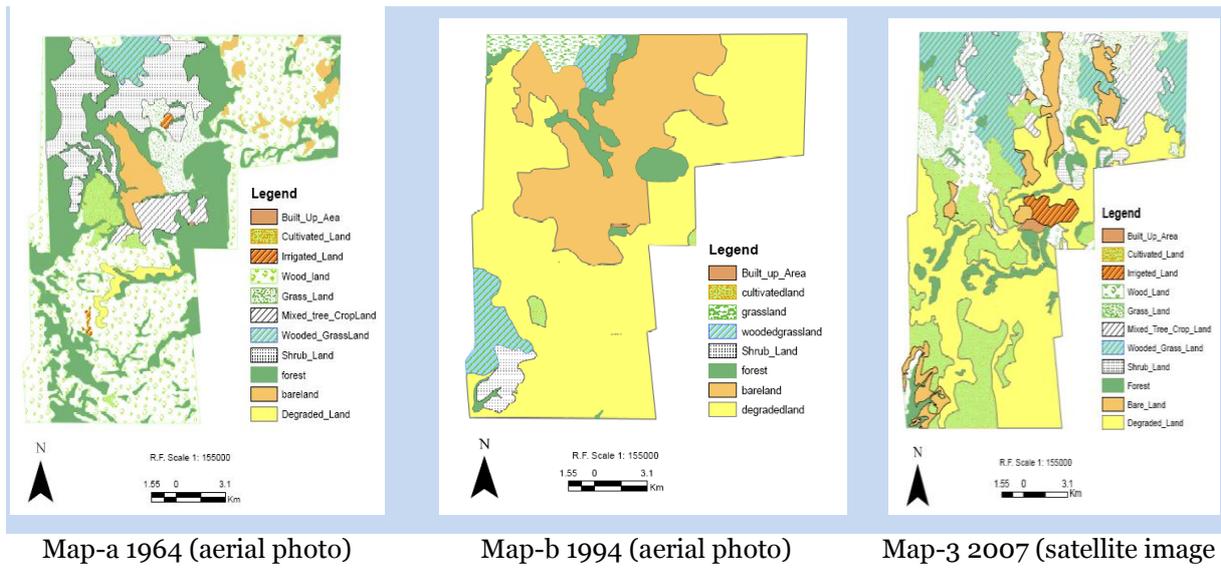


Fig. 3. Partial view of conservation efforts in the study area, GTZ-SUN project Tigray, Ethiopia, 2007.



Fig. 4. Partial view of the present land feature in some part of the study area, 2011.



Table 2. Land cover change; 1964 – 2007 in areas around Laelay-Koraro in middle highland Tigray, Ethiopia.

Land cover categories	Trends of land cover change							
	Area - 1964		Area - 1994		Area - 2007		Change between 1964 and 1994 (%)	Change between 1994 and 2007(%)
	ha	%	ha	%	ha	%		
Forest cover	9725	15.1	2249	3.5	9053	14	-11.6	+10.5
Wood land	7917	12.2	-	-	4081	6.3	-12.2	+6.3
Shrub land	8060	12.5	9369	14.58	9697	15	+2.08	+4.2
Cultivated land	10110	15.75	12203	18.98	14175	21.9	+3.23	+2.98
Mixed tree cropland	5630	8.7	-	-	2312	3.5	-8.7	+3.5
Irrigated land	190	0.3	-	-	2210	3.4	-0.3	+3.4
Grassland	7850	12.2	1959	3.0	1130	1.8	-9.2	-1.2
Wooded grassland	8032	12.4	2375	3.7	3703	5.7	-8.7	+2
Bare land	3625	5.6	14763	22.8	8320	12.9	-17.2	-9.9
Degraded land	3017	4.7	2098	32.5	9355	14.5	-27.8	-18
			2					
Built up area	356	0.55	606	0.94	1254	1.9	+0.39	0.96
Total	64512	100	64512	100	64512	100	-	-

Land cover changes, as perceived by farmers Interviews with elders illustrate that they have a clear understanding of deforestation and the change in population density caused to an increase in rates of conversion of forests to cropland. Further discussion with the farm households also revealed that, a decline in land cover, particularly a failure in land resource management has been source of erosion in farm lands and as a consequence a decline in crop productivity has been apparent. Changes in farming system, expansion of infrastructures and built up areas were the most observable changes during the study period. Rigorous efforts in conservation on the other hand, have also proved the performance of conservation technologies to reduce the extent of disturbance on different land cover types.

Discussion

Repercussions of land cover changes

A significant change has been observed in land cover type between 1964 and 1994. As it can be detected from Table- 2, wood land, mixed tree crop land and irrigated land are completely transformed to other land cover types. Land cover changes are caused by a number of natural and human driving forces (Meyer and Turner II, 1994). Surprisingly, after such extensive transformation, the aerial photo interpretation reveals the rate of transformation was in an expansion of bare and degraded land, the GIS and Remote sensing data also indicate that there was a great decline of forests and vegetation cover in the study area during the 30 years period. From the point of resource conservation, degraded and bare lands are most seemed have less soil cover for crop production. The population of the study area has increased from 15,850 to 32,732 between 1974 and 2007 (Table-3). Both population and the decline in vegetation increased bi-laterally, even policy makers

were late to perceive that the problem has been deep rooted. The major observed changes, especially during the first three decades were strikingly alarming. Erratic rainfall, drought, and low agricultural productivity initiated policy makers involve in conservation practices. Today conservation practices continue over a large region (Nyssen et al., 2007). A rapid change in land cover of the study area has been observed at present as a result of the intervention in resource conservation and management practices (Fig.-3).

Observed changes on ground and surface water

As shown in Table-2, there was a rapid land cover change in the study area throughout the period. The observed changes at the end of the study period, i.e., the improvements on vegetation cover has positively influenced the water retention capacity of soils and increase in an infiltration rates, since then improved the ground and surface water potential which enhanced irrigation system of the study area. According to interviewees, the combined efforts being made towards resource management and the practical involvement on soil and water conservation practices showed the potential in reducing surface runoff and erosion. But features of land degradation are still visible captured during the field visit in areas around Laelay- Koraro. Various indicators of the ground condition clearly illustrate that the area is still with inadequate soil water and excessive soil erosion where rain fed agriculture being the main stay of the household economy. The escarpments are still bare demanding intensive conservation efforts to improve the hydrological cycle and ecological succession of the community. According to the interviewees, the mission to scaling up irrigated lands solely depends in the ability to maintain ground and surface water potential, were the existing size of irrigated land can undergo remarkable changes through an intensive resource management.

Conclusion

The impact of land cover change has been significantly affected the natural resource base of the study area over the past four decades. The conversion

of forest land and steep slopes to cropland which has been aggressively pulled by population increase resulted in an increased flooding and runoff upon intensively cultivated croplands led to a serious decline of soil moisture and cropland productivity. The land cover change of the study area demonstrates the dramatic change in population and higher rates of transformation of land cover types and computation among different categories. The general trend significantly illustrates, poorly managed resources, caused by changing the environment through destruction of vegetation, and subsequently resulted in the detachment and excessive removal of soil by erosion and losses of soil moisture. Mean while, after intervention, the rehabilitation program on improving vegetation and the wildly introduced conservation practices enable to improve the natural resource base. Therefore, there is a need for an integrated approach for sustainable use of natural resource management to achieve the foreseen environmental management programs. To this end, participatory resource management practices in collaboration with government, society and Non-Governmental Organization's (NGO's) keeping intact with the existing programs on climate change can reduce the pressure on natural resources through identifying broad based interventions at community level.

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