Journal of Sustainable Development in Africa (Volume 13, No.1, 2011)
*ISSN: 1520-5509*
*Clarion University of Pennsylvania, Clarion, Pennsylvania*

# EVALUATING THE LAND USE AND LAND COVER DYNAMICS IN BORENA WOREDA OF SOUTH WOLLO HIGHLANDS, ETHIOPIA

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**ABSTRACT**
This paper describes the land use and land cover dynamics in Borena Woreda of South Wollo Highlands of Ethiopia and its implication by using the framework DPSIR - Driving Forces-Pressures-State-Impact-Response in a Geographical Information System (GIS) context. The integration of satellite remote sensing and GIS was an effective approach for analyzing the direction, rate, and spatial pattern of land use change. Three land use and land cover maps were produced by analyzing multi temporal remotely sensed images of three dates from Landsat satellite imageries. The result shows five major land use and land cover types. These include forest, shrub or bush, grass, agricultural, and bare land. In between (1972 to 1985), there was a dramatic expansion of agricultural land followed by bare land however, shrub land, forest land and grass land shows a reduction in aerial coverage. On the other hand in between 1985 to 2003, the same is true for agricultural land, bare land, shrub land and forest land but grass land shows a slight expansion in the aerial coverage due to the conversion of forest and shrub land to grass land. The major driving forces for these changes were natural factors such as steep slope, drought and Climate change. The human driving factors include Population growth and density, over intensification of land use, farm size, land tenure status, and policies on land use. These factors results in various forces and strong effect to change the quantity and quality of land use .The implication of this study includes ecosystems and biodiversity loss, central ownership of natural resources, the breakdown of traditional structures and consequent difficulties in the form of insecurity in individual use of fallow lands, open access to grasslands, inability to protect and manage land resources, inappropriate development strategies, and lake of land use planning.
**Keywords:** Land Use/Land Cover Dynamics; DPSIR Model; Remote Sensing; Ethiopia

## INTRODUCTION

The land use and land cover pattern of a region is an outcome of natural and socio – economic factors and their utilization by man in time and space (Zubair, 2006). Driving forces which also referred to as factors, can be categorized as natural and human induced were recognized in the study area. The natural factors in the study area include high intensity of rainfall and steep relief (Lakew, Menale, Benin and Pender, 2000) and soil types as well as Climate change are also driving forces for land use/land cover change. Among the straightforward identified human causative factors includes Population growth and density, over intensification of land use, Farm size, Land tenure status and Lake of Policies on land use.

A change in land use and land cover is increasingly rapid, and can have adverse impacts and implications at local, regional, and global environments (Brandon, 1998). As rightly noted by Reid, Kruska, Muthui, Taye, Wotton, Wilson and Mulatu (2000), land use and land cover is an endlessly changing process taking place on the surface of the earth. Furthermore, Richards (1990) argues that the modern world has been facing massive changes in its land use patterns in the past few centuries. Williams (1990) clearly stated that in the last few decades' conversion of grassland, woodland and forest into cropland and pasture has risen dramatically in the tropics.

It is taken as a serious problem in changing the environment. The change is due to human activities and atural processes (Meyer & Turnnor, 1994). Moreover, this change could be the result of complicated interactions of socio economic and biophysical situations like economic diversification, technological advancement, demographic pressure and many other related conditions (Reid *et al*., 2000).

Major land cover changes have also occurred at the local level for all land types. For instance, a significant increase in cultivated land at the expense of forestland was found to have occurred between 1957 and 1995 in the Dembecha area, northwest Ethiopia (Zeleke, 2000). Kebrom and Hedlund (2000) reported increases in open area settlements at the expense of shrub lands and forests between 1958 and 1986 in the Kalu area, northcentral Ethiopia. On the other hand, deforestation trend was reduced through appropriate interventions by promoting planting of local tree species in the Chemoga Watershed, Blue Nile basin, Ethiopia (Bewket, 2003) between 1957 and 1998. Similarly, Amsalu (2006) concluded that in the Beressa watershed (central Ethiopia), there were substantial land use changes in the area during the second half of the 20$^{th}$ century. The most important changes were destruction of the natural vegetation, increased plantations, and expansion of grazing land. Cropland increased slightly in the 43 years period. Moreover, Bezuayehu and Geert (2008) reported that the decline of natural forests and grazing lands was due to the conversion to croplands between 1957 and 2001. In this respective period, crop lands increased from 403km$^2$ in 1957 to 607 km$^2$ in 2001- a net increase of 51% in Fincha'a watershed. In addition, in Chirokella Micro-watershed of South Eastern Ethiopia, the dense forest covered decreased by over 80%, the moderately forested land was completely transformed into other land use and land cover systems, cultivated and settlement lands increased by 62.8% and bushes and degraded land cover categories showed increasing patterns of 49.9% and 100%, respectively between 1966 and 1996 (Assen & Nigussie, 2009).

Such local-level dynamics is very important in determining the status of land and ecosystem health. Hence, information on land use, land cover, and possibilities for their optimal use is essential for the selection, planning, and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population (Moshen, 1999). Studies of rates, extents, patterns, causes, and implications of land use and land cover dynamics at local level can help to design appropriate land management practices, strategies and policies. Evaluation of land use and land cover dynamics at this level is rare in Ethiopia in general and the highlands of Wollo in particular. The specific objectives of this study are to evaluate the extent and rate of land use and land cover dynamics over a time and to assess the cause-effect relationships between interacting components of social, economic, and environmental systems with land use/land cover change and implications of these changes in Borena Woreda of South Wollo Highlands of Ethiopia.

**DESCRIPTION OF THE STUDY AREA**

The study is carried out in Borena Woreda which is located in the north-central highlands of Ethiopia (Figure 1). The area is located within South Wollo administrative zone of the Amhara Regional State. It lies between $10^0$ 34'N to $10^0$ 53'N and $38^0$ 28' E to $38^0$ 54'E. The Woreda covers a total area of $937km^2$ and is inhabited by about 158,920 people (CSA, 2008). It is characterized by diverse topographic conditions consisting of four agro-climatic zones ranging from 1000 to 4000 meters above sea level Ministry of Natural Resources Development and Environmental Protection- Watershed Development and Land Use Department (MONRDEP-WDLUD, 1995). These are Kolla(Tropical) refers to lowlands between 500 and 1,500 meters, Woina Dega (Subtropical) refers to highlands between 1,500 and 2,300 meters, Dega(Temperate) refers to highlands between 2,300 and 3,200 meters and Wurch (Alpine) refers to highlands between 3,200 and 3,700meters. A mountainous and highly dissected terrain with steep slopes characterizes the upstream part of streams whereas ups and downs topography and relatively gentile slopes characterized the downstream part of streams in the Woreda.

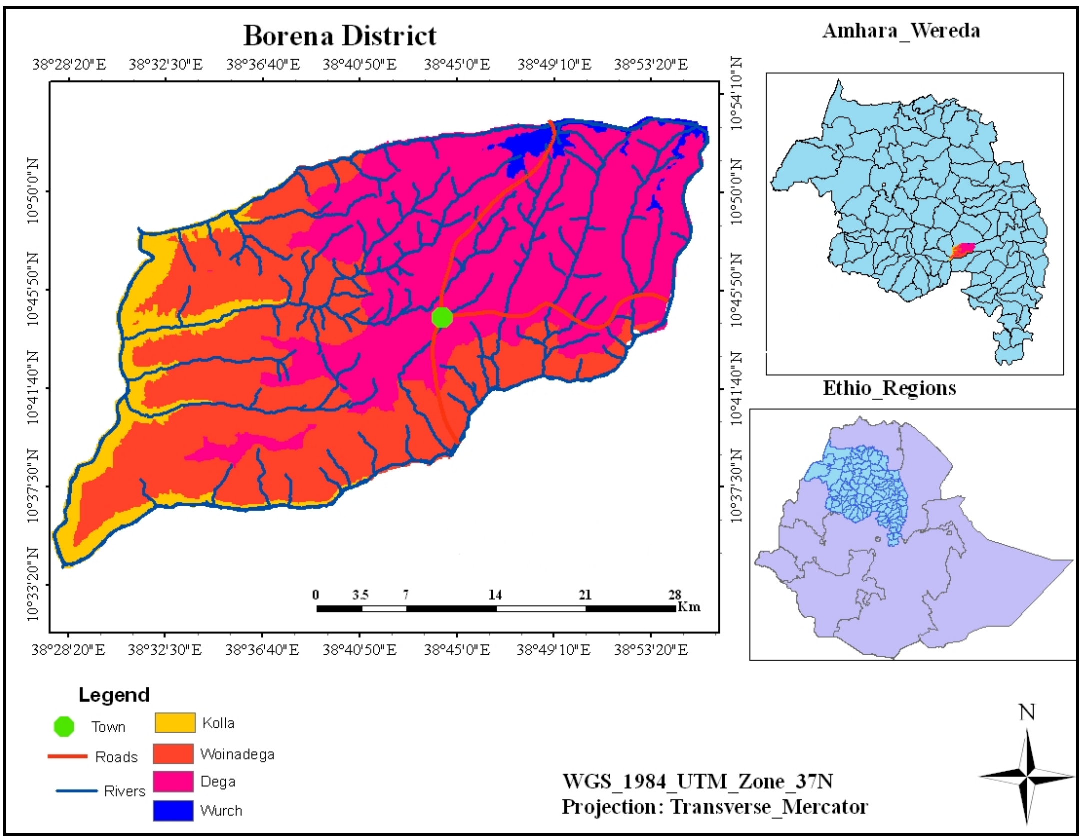



Figure 1: Location map of Borena Woreda made by the writer, 2010

The total annual rainfall varies from 889mm to 1500 mm per year. The highest rainfall falls during summer, which starts in June and ends in September and short rainy season is in spring which encompass March, April, and May. The mean annual temperature of the region varies from $14^0$c to $19^0$c. The absolute maximum temperature occurs from March to May and the absolute minimum temperature occurs in December, July, and August. The upper North Western part of the Woreda is known for its minimum temperature which results in the prevalence of Wurch type of climate while the South Western part of the Woreda, has the highest temperature, characterized by Kolla climate.

## MATERIALS AND METHODS

### The Description of DPSIR model for land use and land cover evaluation

Land use and land cover data play important roles in evaluating landscape state, change, pressures, and potential management responses. The model assumes cause-effect relationships between interacting components of social, economic, and environmental systems, which are:

- **D**riving forces of land use/land cove change
- **P**ressures on the land use/land cover
- **S**tate of the land due to the changing situations
- **I**mpacts on population, economy, ecosystems, and/or environment
- **R**esponse of the society

The DPSIR model (Figure 2) shows how human activity (also known as a driver or driving force) exerts pressure on the land resources and, as a result, changes the state of the environment or land. The state of the environment or land can have impacts on people's health, ecosystems, and natural resources. These impacts can result in responses in the form of management approaches, policies, or actions that alter the driving forces, pressures, and, ultimately, the state of the environment. Changes in impacts over time can result in people modifying their response to those impacts (European Environment Agency, 2003).

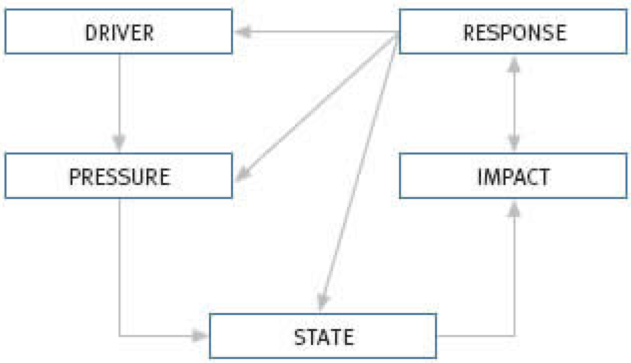



Figure 2: DPSIR model (**Source**: Adapted from Smeets & Weterings, 1999.)

**Table 1: Description of DPSIR indicators**

| **Indicator type** | **Description of indicator type** |
|---|---|
| Driving force (driver) | Describes social, demographic, and economic developments. Primary driving forces are population growth and changes in people's needs and activities. These change lifestyles and overall levels of production and consumption, which in turn exert pressures on the land. |
| Pressure | Tracks people's use of natural resources and land, and production of waste and emissions (for example, greenhouse gases and particulates into the air). These pressures can change environmental conditions. |
| State | Describes the quantity and quality of the environment and natural resources (for example, water quality, air quality, or land cover). |
| Impact | Describes the effects that land use/land cover changes have on environmental or human health (for example, land productivity decline). |
| Response | Describes responses by government, organizations, or the community to prevent, compensate, ameliorate, or adapt to changes in the environment (for example, the introduction of regulations such as national environmental standards and legislative initiatives to protect native vegetation and biodiversity). |

Source: Adapted from European Environment Agency, 2003.

According to Lillesand, T.M., Kiefer, R.W., and Chipman, J.W. (2006), change detection involves the use of multi-temporal datasets to discriminate areas of land cover change between dates of imaging. Thus, the materials used to create spatio-temporal database needed for this study were three sets of satellite imageries. To analyze and quantify the spatial-temporal LU/LC dynamics the GIS and Remote sensing technologies were used. This is because of the fact that Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates, the synoptic analyses of Earth system function, patterning, and changes at local, regional and global scales over time and space, provide an important link between rigorous, localized ecological research and regional, national and international conservation and management of biological diversity (Wilkie & Finn, 1996).

To meet the objectives of the research, multi-temporal satellite imagery and global positioning system, as well as topographical maps of scale 1:50,000 for ground verification were used and summarized (Table 2).

**Table 2: Materials and their Sources used in the study**

| No | Image | Sensor | Resolution or Scale | Date of acquisition | Source |
|---|---|---|---|---|---|
| 1 | Landsat1 | MSS | 57x79m | 12/12/1972 | GLCF |
| 2 | Landsat5 | TM | 30x30m | 1/1/1985 | GLCF |
| 3 | Landsat7 | ETM + | 30 x30m | 12/2/2003 | GLCF |
| 4 | Top Sheet | | 1:50,000 | | EMA |

GIS and remote sensing method allow spatial monitoring and analyses where the knowledge of the stakeholders can be integrated. As a result to analyze and quantify the spatial-temporal land use and land cover dynamics the GIS and Remote Sensing technologies were used.

Data from Landsat imageries was processed by ERDAS EMAGINE 9.1 software and spatial analysis, interpolation and other calculations by ArcGIS 9.2. For change detection the ENVI 4.3 software was utilized and MS office Visio 2007 was used to create charts and graphs. Supervised digital image classification technique was employed and complemented with field surveys that provided on-the-ground information about the types of land use and land-cover classes.

The methods for Land Use and Land Cover dynamics analysis with spatio-temporal changes were monitored by analyzing multi-temporal remotely sensed images of three dates of Landsat satellite imageries. A blend of steps and procedures were developed to interpret, analyze, map, and quantify the available data sets (Figure 3).

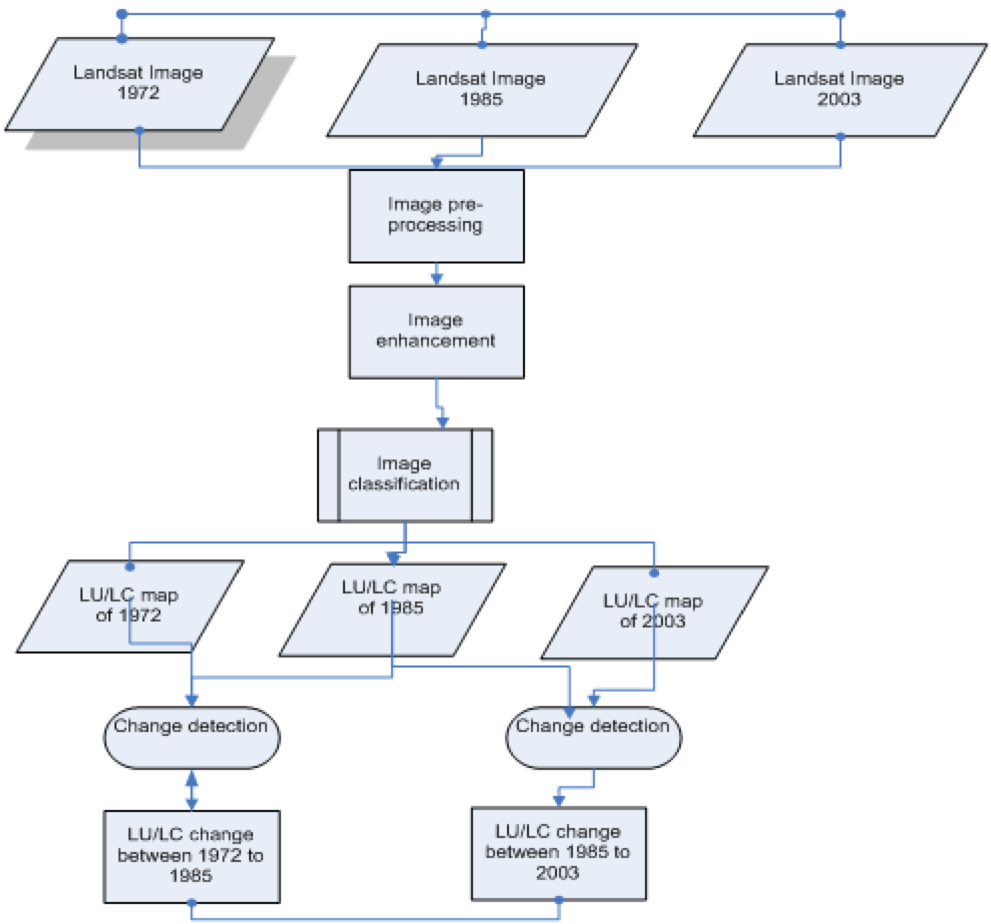



Figure 3: Flow chart showing the general methodology of land use/land cover evaluation.

Local geodetic datum of Adindan, reference ellipsoid of Clark1880(Modified) and projection type of UTM Zone 37 North are the spatial reference coordinate systems applied to rectify and resample both the three imageries using Arc GIS software. For the land cover classification 30 (10 from agricultural land, 10 from forest cover, and 10 from shrub land) ground control points were collected by global positioning system (GPS) and assisted with topographic maps of 1:50,000 as bas map to register the data sets with RMS error of less than 0.85. In the mean time, Geo-database was created and all spatial data sets were stored within a geo-database environment to facilitate further analysis. Finally, three land use/land cover maps were produced corresponding to the three reference years and temporal changes in land use/land cover were determined. A few focus group interviews and observation were also conducted in six villages in the study area to obtain additional information on the long year experience of land use and land cover practices of the Woreda. "The informal, in-depth interviews along with intensive discussions including 12 of the elder household heads, 3 of which were female, showed their long year land use system of the people in the study area".

The investigated households for this study were selected based on multistage sampling technique. Firstly, the existing households were stratified spatially into *Dega*, *Woinadega and Qolla* agro-climatic zones. Then, the sample households were proportionally selected from each agro-climatic zone based on systematic sampling technique. Hence, 80 sample households were selected for this study. Given the relative homogeneity of the subsistence farms in the three agro-climatic zones in terms of physical environmental factors and resource endowments, the sample size of each agro-climatic zone would be reasonably representative of the population it stood for. Moreover, knowledgeable key informants were included into the study through purposive sampling technique.

## RESULTS AND DISCUSSION

### Dynamics in Land use and land cover types in the Study Woreda

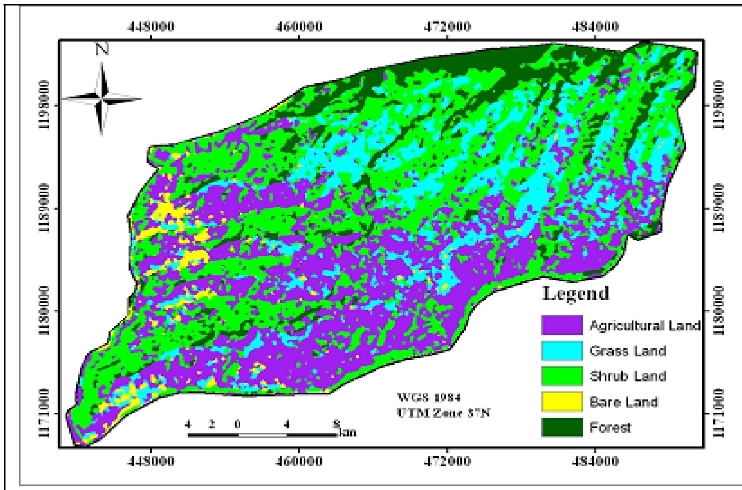
Using the application of image classification methods, five major land uses and land cover types were identified in Borena district. These include forest, shrub or bush, grass, agricultural and bare land, based on the characteristics of Landsat satellite images of the year 1972, 1985, and 2003.

**Table 3: shows description of each land use land cover type in the study area.**

| **Land use and Land cover classes** | **Description of each land use class** |
|---|---|
| Crop Land | Areas allotted to rain fed crop cultivation both annuals and perennials, mostly of cereals in subsistence farming and the scattered rural settlements included within the cultivated fields. |
| Forests | Areas covered by trees forming closed or nearly closed canopies; Forest; Plantation forest; Dense (50-80% crown cover) predominant species like Juniperus procera. |
| Shrub land | Land covered by small trees, bushes, and shrubs, in some cases mixed with grasses; less dense than forests |
| Grass 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 | Are parts of the land surface which is mainly covered by bare soil and exposed rocks. |

### Land cover mapping

The major land use and land cover types shown by the maps of 1972, 1985, and 2003 include cultivated land, grassland, shrub or bush land, forest, and bare land. As indicated in (Figures 4 and 5), the greatest share of land use and land cover from all classes is shrub land, which covers an area of 36,239 hectares (ha), contributes 35% of the total area. Agricultural land and grass land cover an aerial size of 32,750 ha (31 %) and 16,535 ha (16 %) respectively, whereas the aerial coverage of forest and bare land is 13,599 ha (13%) and 4790 ha (5%) from the total area of the Woreda. This shows that 64% of the total area of the district was covered by shrub, forest and grass land in 1972 and the remaining 36% was covered by agricultural and bare land, which indicates that much of the area was covered by green vegetation in 1972.



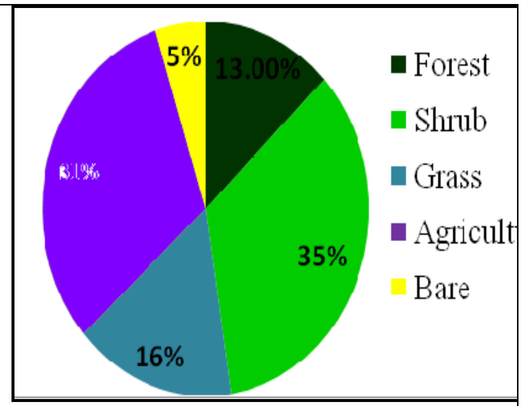
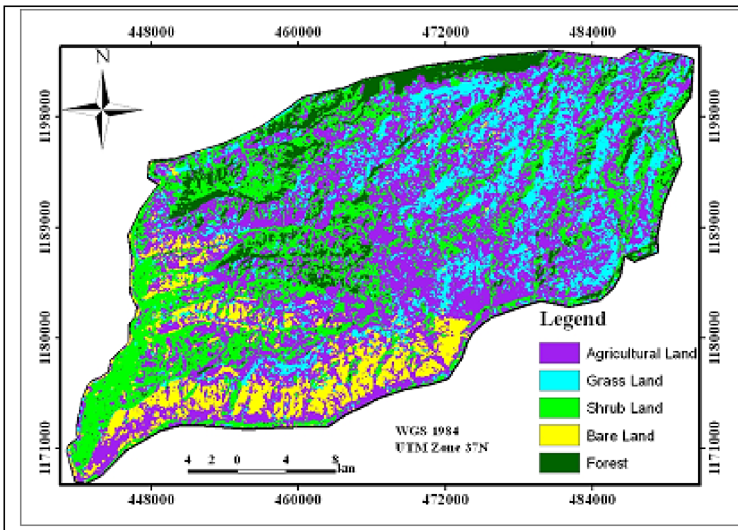




Figure 4: Land use and land cover map of the Woreda in 1972.

Figure 5: Aerial coverage and percentage of land use and land cover types in 1972.

As indicated in (Figures 6 and 7) the greatest share of land use/land cover from all classes is cultivated land, which covers an area of 45,735 ha (44 %). Shrub or bush land and grass land cover an aerial size of 25020ha (24 %) and 15,580 ha (15 %) respectively. The least aerial coverage is still forest and bare land, which accounts for only 9,795 ha (10 %) and 8,117 ha (8%) respectively from the total area of the Woreda. The fast growth of agriculture up to 44% was due to the conversion of forest, shrub, and grass land to agricultural land because of rapid population growth in the study area. In addition to this there was an expansion of bare land from 5% in 1972 to 8% in 1985 due to a severity of a drought in Wollo area.



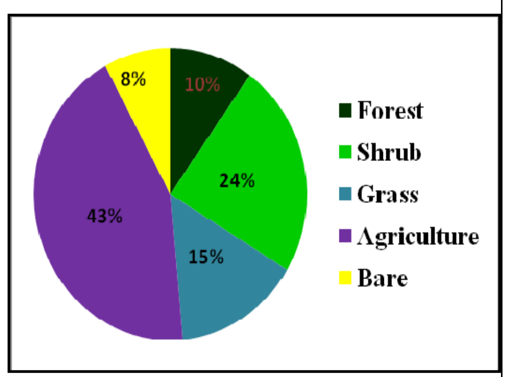




Figure 6: Land use and land cover map of the Woreda in 1985.

Figure 7: Aerial coverage and percentage of land use and land cover types in 1985.

As indicated in (Figure 8 and 9) the greatest share of land use/land cover from all classes is cultivated land, which covers 51,842 ha (49 %) almost half of the total area of the district. Shrub or bush land and grass land covers 18,186 ha (17 %) and

19,604 ha (19 %) respectively. The least area is covered by forest and bare land, which is 6,087 ha (6%) and 9,076 ha (9%) from the total size of the Woreda. Agriculture still covered the largest area in 2003, which depicts conversion of other land cover classes to cultivated land.

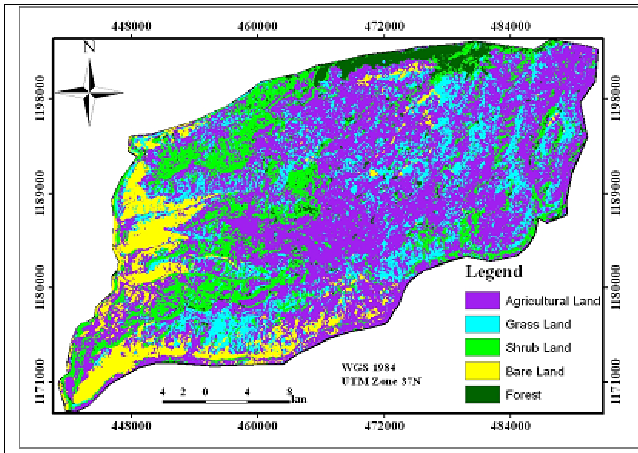



Figure 8: Land Use and Land Cover Map of the Woreda in 2003.

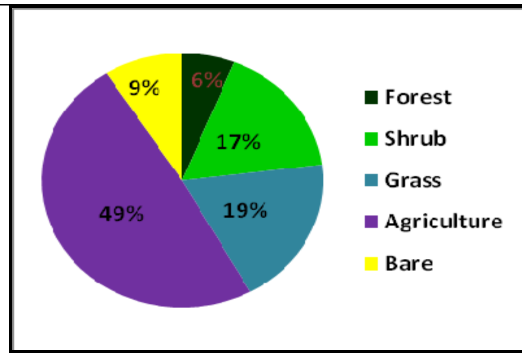



Figure 9: Aerial coverage and percentage of land use and land cover types in 2003.

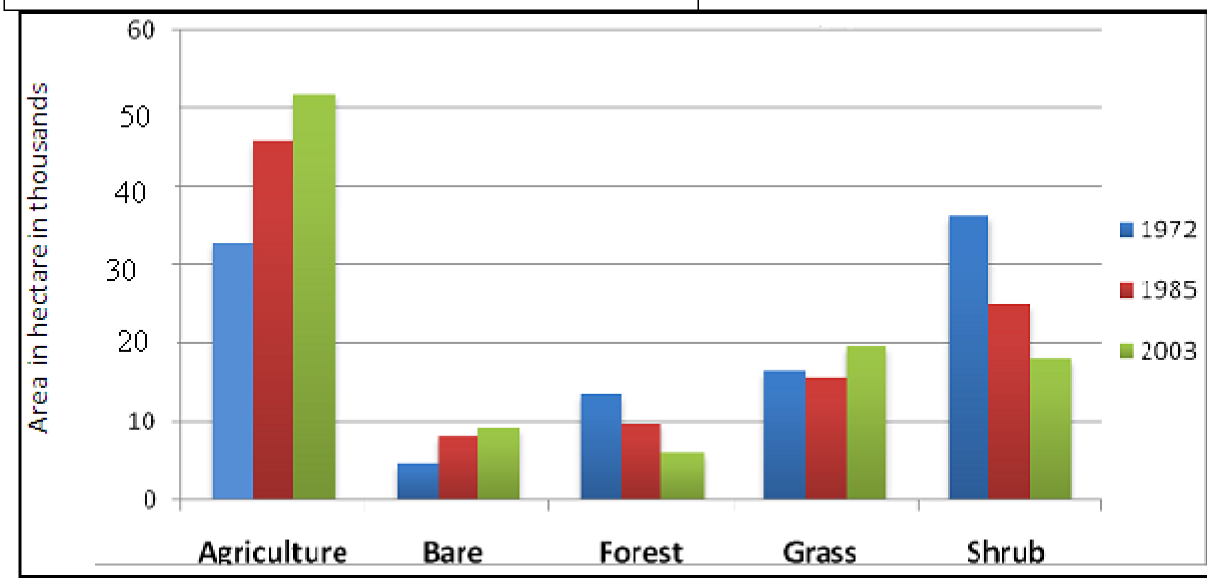



Figure 10: Land use land cover types and trends of 1972, 1985, and 2003

**The extent of Land use and Land covers change in the Woreda**

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 the other 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. The land use land cover change matrix depicts the direction of change and the land use type that remains as it is at the end of the day. For the land, use land cover change matrix shown in (Table 4 and 5). The rows and columns represent land use and land cover categories they represent.

**Table 4: Land use land cover change matrix between 1972 and 1985**

| Land use land cover type of 1985 \ Land use land cover type of 1972 | Agricultural land | Forest | Bare Land | Shrub Land | Grass Land | Class Total |
|---|---|---|---|---|---|---|
| Agricultural land | **27953** | 1221 | 0 | 11432 | 5205 | 45811 |
| Forest | 0 | **7665** | 0 | 2130 | 0 | 9795 |
| Bare Land | 4797 | 0 | **4747** | 11 | 3359 | 8117 |
| Shrub land | 0 | 4562 | 0 | **20458** | 0 | 25020 |
| Grass Land | 0 | 151 | 43 | 5352 | **7971** | 15517 |
| Class Total | 32750 | 13599 | 4790 | 36239 | 16535 | 0 |

**Table 5: Land use land cover change matrix between 1985 to 2003.**

| Land use land cover type of 2003 \ Land use land cover type of 1985 | Agricultural land | Forest | Bare Land | Shrub land | Grass Land | Class Total |
|---|---|---|---|---|---|---|
| Agricultural Land | **40711** | 2688 | 0 | 7896 | 547 | 51842 |
| Forest | 0 | **5399** | 0 | 688 | 0 | 6087 |
| Bare Land | 2500 | 0 | **6576** | 0 | 0 | 9076 |
| Shrub Land | 1017 | 1247 | 141 | **15082** | 699 | 18186 |
| Grass Land | 1507 | 461 | 1400 | 1354 | **14882** | 19604 |
| Class Total | 45735 | 9795 | 8117 | 25020 | 15580 | 0 |

As shown in (Figure 11) between (1972 to 1985), there was a dramatic expansion of agricultural land followed by bare land but shrub land, forest land and grass land showed a reduction in aerial coverage.

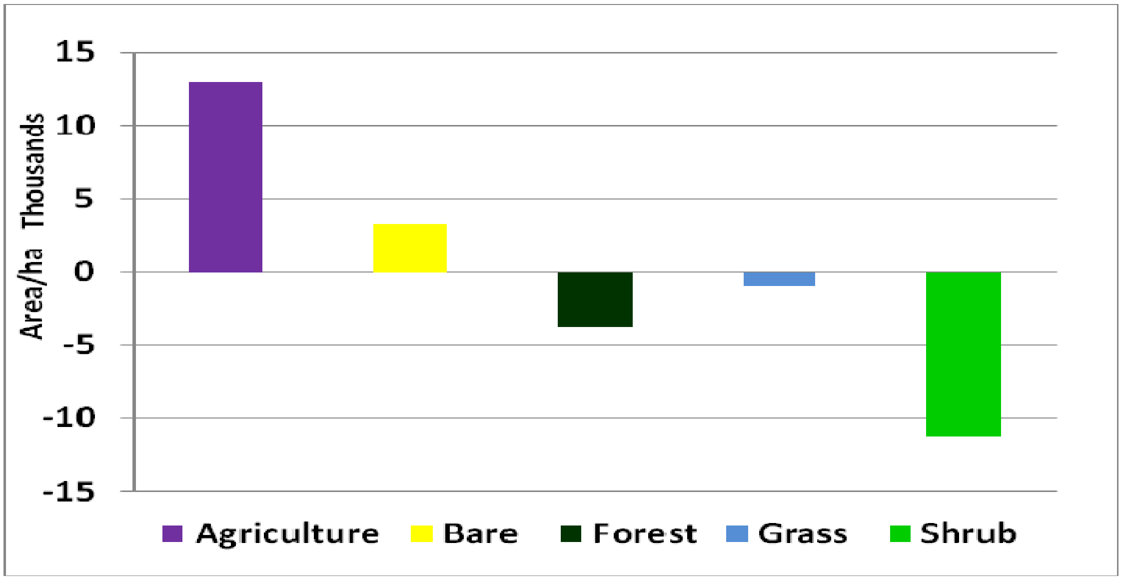



Figure 11: Land Use/Land Cover change difference from 1972 to 1985

On the other hand, from 1985 to 2003, the same is true for agricultural land, bare land, shrub land, and forest land. Grass land however, shows a slight expansion in the aerial coverage due to the conversion of forest and shrub land to grass land, and it is clearly shown in (Figure 12) agricultural land increases at the expense of other lands and leading to use marginal lands and accelerate land degradation as indicated that bare lands expanded.

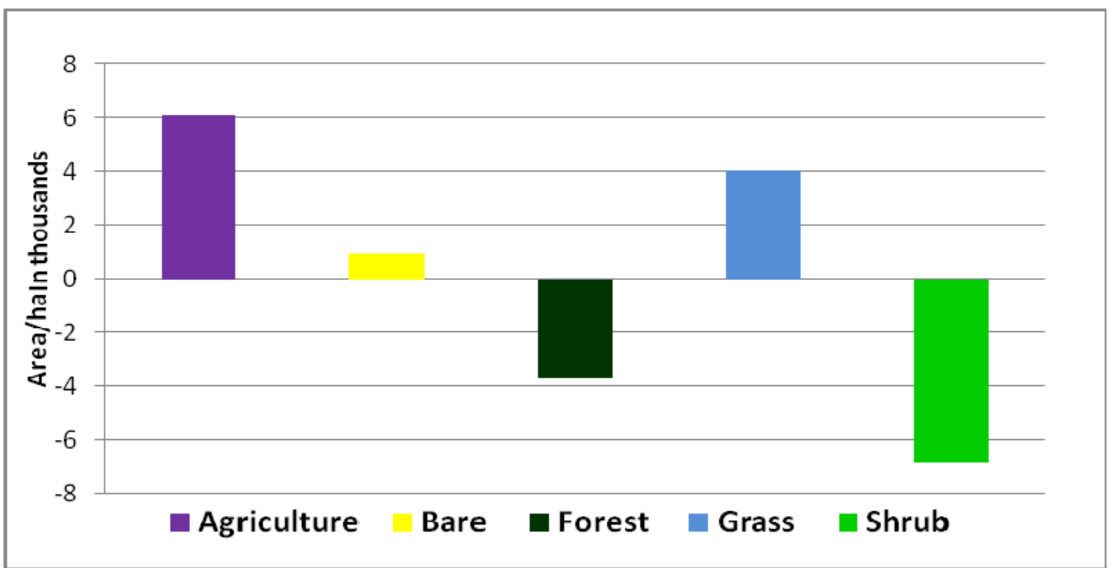



Figure 12: Land Use/Land Cover change differences from 1985 to 2003

**Accuracy Assessment**

To assess the classification accuracy, confusion matrix was used. Confusion matrix indicates the nature of the classification error and used in many other research works. As it is shown (Table 6) the overall accuracy and kappa coefficient is 86.11% and 0.8312 respectively. This shows 86.11% of the land use/ land cover classes are correctly classified.

**Table 6: Confusion matrix of 2003 land use land cover classification.**

| Land Use Type | Bare Land | Forest | Shrub Land | Grass Land | Agriculture |
|---|---|---|---|---|---|
| Bare Land | 95.9 | 0.08 | 2.05 | 4 | 6.24 |
| Forest | 0 | 94.91 | 5.96 | 0.69 | 0 |
| Shrub Land | 0.57 | 2.31 | 80.43 | 8.09 | 6.55 |
| Grass Land | 1.4 | 2.57 | 8.11 | 80.22 | 8.12 |
| Agriculture | 3.58 | 0.13 | 3.45 | 7 | 79.09 |
| Total | 100 | 100 | 100 | 100 | 100 |

Overall Accuracy = 86.11% with a Kappa Coefficient of = 0.8312

**Rate of land use and land cover changes in the study Woreda**

The rate of change was calculated for each land use and land cover using the following formula:

Rate of change (ha/year) = (A-B)/C Where A = Recent area of land use/ cover in ha.

B = Previous area of land use/ cover in ha. C = Time interval between A and B in years

**Table 7: Land use land cover classes and rate of change in between 1972 through 2003**

| **Land use land cover** | **Years** | | | **Rate of change** | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1972 | 1985 | 2003 | 1972 to1985 (ha/yr) | %◆ | 1985 to 2003 (ha/yr) | %◆ | 1972 to 2003 (ha/yr) | %◆ |
| Agricultural land | 32750 | 45735 | 51842 | 998.85 | 3.1 | 339.28 | 1.57 | 50.66 | 0.88 |
| Forest | 13599 | 9795 | 6087 | -292.62 | -0.91 | -206 | -0.95 | 14.32 | 0.25 |
| Bare Land | 4790 | 8117 | 9076 | 255.92 | 0.79 | 53.28 | 0.25 | 6o.63 | 1.06 |
| Shrub land | 36239 | 25020 | 18186 | -863 | -2.67 | -379.67 | -1.76 | 16.06 | 0.28 |
| Grassland | 16535 | 15580 | 19604 | -73.46 | -0.23 | 223.56 | 1.03 | 37.94 | 0.65 |
| Total* | 103913 | 104247 | 104795 | 2483.85 | | 1201.79 | | 179.61 | |

◆ Rate of change in percent is calculated as change in between the two study years per total change of these years divided by the time interval times 100.

*Note. Stream beds are not included in the classification due to resolution problem of the image (30meter) that is why some hectares vary in the total area.

Between 1972 and 1985, agricultural land increased with a rate of 927.5 ha/year and further increased in 2003 with accelerated rate of change 339 ha/ year. The expansion of agricultural land was by the outflow of bush/shrub land, forest land and grass land as it is explained in the change matrix of (Table 7 and 8). From (1972 to 1985) 1221, 11432, and 5205 ha of forest, shrub and grass land had been changed to agricultural land respectively. Between 1985 to 2003, 2688, 7896, and 547 ha of forest, shrub and grass land had been changed to agricultural land respectively. This shows that there was a dramatic expansion of agricultural land within the specified time period because of population pressure and poor land administration. The expansion of agricultural land between 1972 and 2003 in the district in general, could be directly related to rapid population growth.

On the contrary, shrub or bush land and forest land had decreased from 1972 to 1985 with 863 and 293 ha/year rate of change and further decreased in 2003 with rate of 380 and 206ha/year. The change was induced by the transfer of shrub and forest land to agricultural land in between 1972 to 1985 and to grass land and agricultural land in between 1985 to 2003. The massive reduction of vegetation particularly in between 1972 to 1985 was because of lack of administration especially during the transition period and land redistribution.

Similarly, grass land was reduced in size between 1972 and 1985 with a rate of 73 ha/year. But it increased between 1985 and 2003 with a rate of 223 ha/year. This is because of the degraded forest and shrub lands especially during the drought years and the transition to grasslands. Whereas bare land was continuously increased between 1972 and 1985 with a rate of 256 ha/year and then further increased with a rate of 53 ha/year. The rate of expansion was very high between 1972 and 1985 because of the severity of the 1985 drought in the Wollo area which killed thousands of animal and human life and a huge of loss of vegetation biomass. Now, only 9% of the study area is covered by bare land particularly areas which are found at the south western part of the Woreda around Blue Nile river.

**Assessment of DPSIR indicators in relation to Land use and Land cover in the study area**

Indicators are variables, parameters, or measures which provide evidence of a condition in change of quality, or change in state of something valued (Dumanski and Pieri, 1996). Land quality indicators, for instance, include statistics that report on the condition and quality of the land resource itself. They may also reflect the cause-effect relationships that may result in changes in land use/land cover, and on the responses to these changes by society. Indicators should allow the determination and analysis of the cause-effect relationships involved and identifies trends of land use/land cover in order to take remedial action. Land use change is therefore often modeled as a function of a selection of socio-economic and biophysical variables that act as the so-called ‘driving forces’ of land use change (Turner, Ross and Skole , 1993). Accordingly the land use/land cover indicators in the study area were modeled as follows (Figure 13).

**Driving forces of land use and land cover change in the study Woreda**

The total population of the study area was 125,126 in 1994 Central Statistical Authority (CSA, 1994) and it increases up to 158,920 in 2007 (CSA, 2008) with the rate of 1.84% ($r=1/n L_n (p_t/p_o)$) which implies it will double within 38 years ($DT=Ln2/r$). Thus population growth was certainly the greatest driving force in the observed land use/land cover dynamics. This is because the demand of land for cultivation and settlement, forests for fuel, and construction purposes was greater. As Population pressure is often considered to be an important driver of deforestation (Pahari & Marai, 1999). In economic models of land use change, demand and supply functions are the driving forces of land use change. There has been little adjustment of family size since children are considered an asset in the struggle for survival, as well as a security in old age. Environmental consequences of population growth thus have been a reduction in fallow periods and soil exhaustion, cultivation of shallow soils and steep slopes followed by accelerating erosion, over-exploitation of forest and range areas, consequent denudation and erosion, and worsening prospects for future agricultural growth.

The system of land tenure in Ethiopia in general and the study area in particular is uncertain about farmers' security of rights to the land which in turn led for short-term needs than long-term yield. This resulted in ecological damage, inappropriate or over-intensive land use and poor land management practices that accelerate land use/land cover change. Agricultural growth is still based on area expansion, and intensification through new technology, cash inputs, or adjustments in farming systems. The failure of agriculture to keep pace with population growth when the nonfarm sector can only absorb a fraction of the added labor force has resulted in decreased per capita resources of land and livestock. Livestock grazing in high densities and with static grazing patterns may alter floristic composition, reduce biodiversity, increase soil compaction, and in extreme cases eliminate vegetation cover altogether (White, Tunstall, & Henniger, 2002).

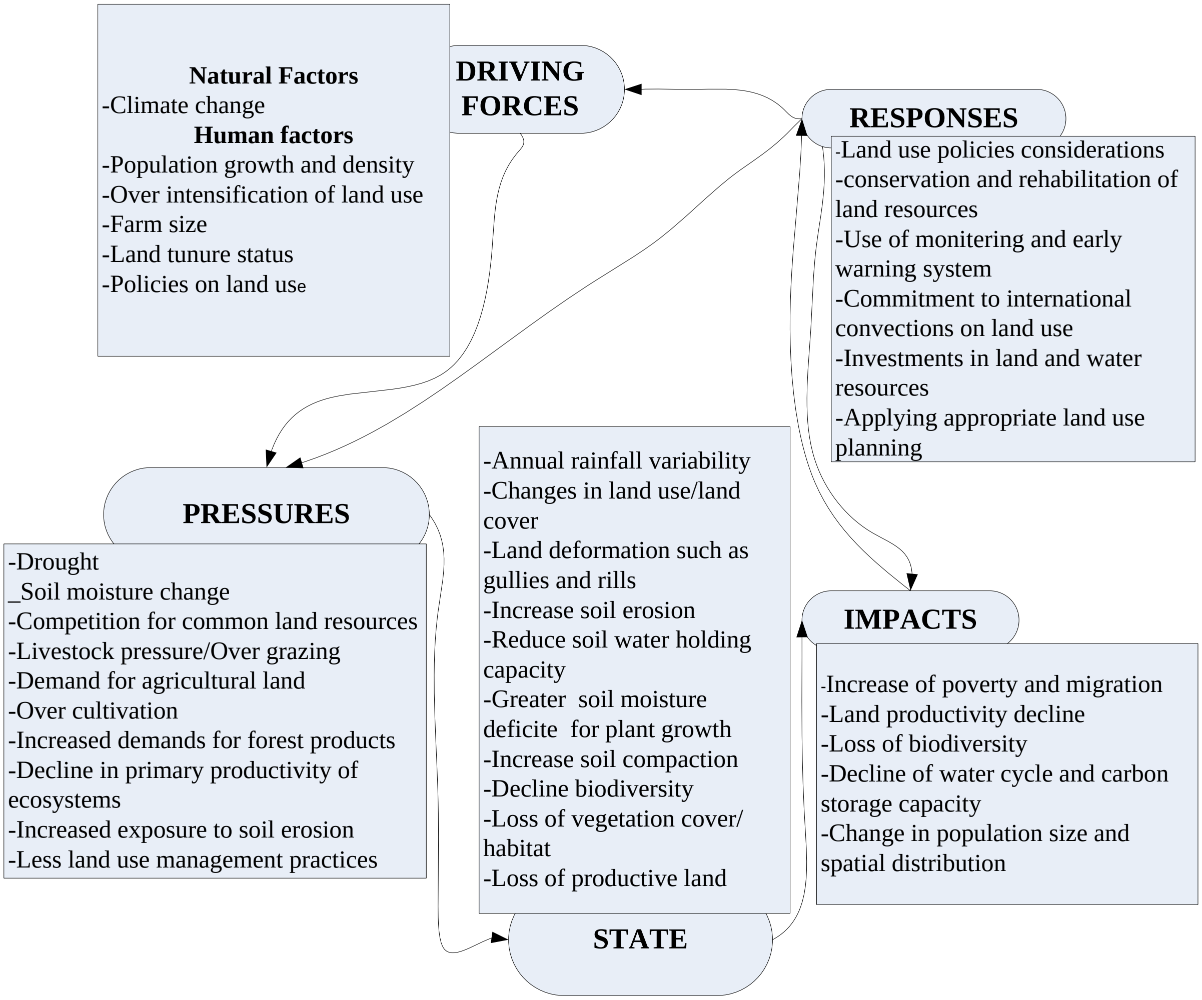



Figure 13: Major types of DPSIR indicators with their description in the study area (adapted from FAO, 2004)

**Pressures on the land use and land cover in the study Woreda**

Causes are the direct agents that promote change resulting in a given state of land use and land cover. Causes are the direct pressures exerted on land resources under which the onset of degradation or deterioration processes occur. These pressures are, in turn, caused by driving forces of a variety of origins (i.e. economic, social, political, etc.), which can be understood as indirect causes of land use and land cover change. The problem of land degradation in Ethiopia stems largely from poor land-use practices and population pressure (especially in the highlands) as explained by United Nations Convention to Combat Desertification (UNCCD, 2008). The pressures in the study area include drought, soil moisture change, competition for common land resources, livestock pressure/over grazing, demand for agricultural land, over cultivation, increased demands for forest products, decline in primary productivity of ecosystems, increased exposure to soil erosion and less land use management practices (Figure 13). Inappropriate farming practices, overgrazing, deforestation, the use of crop residues, and dung for fuel in rural households are among the main causes. Very high population pressure, particularly in the highland farming areas has led to a decline in arable area. Combined with increasing land degradation and recurrent droughts, this has contributed to declining crop productivity. Increased human and livestock populations have led to agricultural encroachment on to marginal areas as well, have, and significantly reduced the already dwindling forest and woodland resources of the highlands.

**States of the land due to the land use and land cover changing situations in the Study Woreda**

The important current conditions observed in the study area include: annual rainfall variability, land deformation, such as gullies and rills, increase soil erosion, reduced soil water holding capacity, greater soil moisture deficit for plant growth, increased soil compaction, declined biodiversity, loss of vegetation cover/habitat, and loss of productive land.

**Impacts of land use and land cover change on population, economy, ecosystems and/or environment in the Study Woreda**

According to FAO (2004) Impacts in the Land Degradation Assessment in Dry lands (LADA) framework refers to land use/land cover changes on the different aspects of people's livelihoods imposed by the state of land degradation and its causes. Examples of impacts of land degradation which are caused by land use/land cover changes in the study are: increase of poverty and migration, land productivity decline, loss of biodiversity, decline of water cycle and carbon storage capacity, change in population size, and spatial distribution (Figure 13). One of the immediate impacts of the thinning and destruction of the shrub land is shortage of fuel wood and construction materials for the farming community. This condition forces farmers not only to travel very long distances to collect wood, but also to increasingly burn crop residues and organic manure for cooking and heating. The latter has momentous consequences for the fertility and productivity of the cropland as the action leads to depletion of the organic matter in the cultivated soils. The shortage of land has compelled farmers to practice continuous cropping and completely abandon even seasonal fallowing. Such continuous cultivation in a situation where little organic matter returns to the soils, it leads to severe soil erosion and land degradation (Belay, 2002).

The decrease of land quality brings a decrease in land productivity and has an effect on the livelihoods of people in terms of food insecurity, poverty, and migration. The reduction of habitat for living species, both, macro and micro flora and fauna, and the likely increase on Greenhouse Gases (GHG) emissions, for example, the increase in carbon emissions through the oxidizing of organic matter induced by tillage are the impacts of land use and land cover dynamics. The ecosystem functions and landscape processes such as water and nutrient cycles which in turn affect water availability and primary productivity of ecosystems and their services to populations as well as the decline in land productivity are directly related to land use and land cover dynamics.

**Response of the stakeholders to reduce the effects of land use and land cover change in the study Woreda**

Responses are understood in the LADA framework as the direct or indirect actions are taken by land users and managers to the impacts on their livelihood caused by the state of land degradation, the pressures on the land causing such a state, and the driving forces causing such pressures. Such responses may manifest themselves as possible remediation actions. The experience of land users themselves, who run informal "experiments" with nature through their responses in their particular lands, accrue knowledge, and experience (i.e. "indigenous" or traditional knowledge) about remediation actions. The response of stakeholders for the changing land use/land cover is very limited. The inconvenience for such weak responses includes the needs of the local people for: cultivation, grazing land, hunting, and forest products. The activities have suffered from several efforts, the major ones have been (a) a lack of tenure security for the farmers; (b) political instability; (c) repeated famines (d) paid (food) labor-both on communal and cultivated land, by individual farmers-to alleviate the famines; (e) farmers not involved in planning and implementation of the work on their land; (f) the soil conservation extension not integrated into the agricultural extension; and (g) ineffective agricultural extension.

Therefore, there is a need for land use policy considerations, conservation and rehabilitation of land resources, use of monitoring and early warning system, commitment to international convections on land use, investments in land and water resources, and applying appropriate land use planning (Figure 13).

**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. This study shows land use and land cover changes that have occurred in Borena Woreda in the last 31 years and considers as well as relates different components responsible for the change with the implications on increase in biodiversity loss, soil erosion, and inappropriate land management. The methods developed as an outcome of this study have been employed for their capability to assess the spatial and temporal changes in land use and land cover at a landscape scale and to subsequently determine an effective means to measure landscape stability over large assessment areas such as Woreda. Specifically, remote sensing integrated into a GIS environment provides 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 as well as beyond that because its consequences do not have clear boundaries. There is, therefore, a need for local land use planning and design with conservation practices of the study area.

**Implications of land use and land cover dynamics in the study Woreda**

This study clearly shows the under-mentioned policy implications:

- ✓ Changes in land use/land cover affect land-based ecosystems and biodiversity
- ✓ Changes in land use/land  affect soil health (that is, soil quality) or soil intactness (the ability of soils to stay in place), and have flow-on effects for water quality in rivers, lakes, and increase the risk of erosion and flooding
- ✓ Insufficient government attention to land degradation, agricultural development and peasant farming, and to family planning;
- ✓ Lack of economic incentives for producers and marketing difficulties caused by public interference;
- ✓ Insufficient adaptation of recommendations to the large agro-ecological variability over time and deficiencies in proven technology, extension, input distribution, and credit, outside more high potential situations;
- ✓ Inefficiencies arising from institutional weaknesses, particularly the over-emphasis of the public sector and central decision making, and the consequent need to promote privatizing and local initiatives;

- ✓ Central ownership of natural resources, the breakdown of traditional structures and consequent difficulties in the form of insecurity in individual use of fallow lands; open access to grasslands; inability to protect and manage public forests and parks;
- ✓ Inappropriate development strategies and lake of land use planning.

**Acknolodgements**

*I thank K.N.SING (*Associate Professor in the Department of Geography and Environmental Studies at Addis Ababa University and my advisor) and I also thank Alelign Desalew for technical assistant in the interpretation of the remote sensing images and Addis Ababa University School of Graduate Studies for the meager financial support for the study.

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