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Remote Sensing and GIS Stream**



**Integrating Remote Sensing and GIS for Land Degradation  
Assessment and its Socio-Economic Impact, A Case Study in  
Northeast of Alaba, SNNPR, Ethiopia**

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*(Remote Sensing and GIS Stream)*

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DEGRADATION ASSESSMENT AND ITS SOCIO-ECONOMIC  
IMPACT, A CASE STUDY IN NORTHEAST OF ALABA, SNNPR,  
ETHIOPIA**

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## **LIST OF ABVRIBATIONS**

DEM	Digital Elevation Model
DI	Degradation index
ERDAS	Earth Resources Data Analysis System
ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agricultural Organization
GIS	Geographic Information System
GPS	Global Positioning System
LULC	Land-use/Land-cover
LPC	Low Potential Cereal Crop
MSS	Multi Spectral Scanner
NDVI	Normalized Vegetation Index
SEI	Socio-economic Index
SI	Sensitivity index
SPSS	Statistical program for Social Science
SRTM	Shuttle Radar Topography Mission
USLE	Universal Soil Loss Equation

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## **ABSTRACT**

*Land degradation, caused by soil erosion and LULC changes, initiated by poor utilization of land resource beyond the carrying capacity to provide food and other related use has an effect on socio-economic status of the northeast of Alaba. Agriculture is the sole economy sector for people living in the region. The study guided with the main objectives of assessing the extent of land degradation and its socio-economic impact of the region. It also aimed to analyze socio-economic pattern, spatial and temporal variation of soil erosion and LULC of the region. Necessary data were collected through field observation and socio-economic survey. Landsat satellite imageries analyses of three periods (1973, 1986 and 2005) for LULC change detection, soil loss and socio-economic analysis were used. The result for LULC change detection depicted that major reduction in forestland was 42.98% during the period of 1973 to 1986. Increment observed in crop-land was 11.05% during the same period. The same phenomena observed during the period 1986 to 2005, when forest was reduced by 87.43% and crop-land was increased by 52.96%. This change brought a change in soil loss (land degradation) variation across the zones and at large to the whole study area between the period of 1986 to 2005. Accordingly the largest soil loss rate change exhibited in the zone two, which reached to 15.79% and the least went for zone one. In general, soil loss for the whole region changed by 35.43% during this period. The soil loss variations across the zones, which actually reflect the degradation status of the zones, influence socio-economic status of the local people. Zones which characterized higher degradation have lower socio-economic status like the case of zone two. To protect the land against further degradation and utilizing the land resource sustainably, the potential solution could be, introduce rural infrastructure for alternative livelihood of agrarian community and scale up the awareness of farmer about land degradation and possible management option.*

*Key words: land degradation, LULC change, northeast Alaba, socio-economic status*

# 1. Introduction

## 1.1 Background

Land degradation is one of the major socio-economic and environmental problems, affecting one billion people in 110 countries worldwide and is prevalent across about 40 percent of the earth's surface (UNEP, 1997). In Africa, it is estimated that about 320 million ha, or about one quarter of its dry lands, are affected by different types of soil erosion.

The utilization of a watershed area beyond its carrying capacity to provide food, fiber, and shelter for the exploding population has resulted in its deterioration in most part of the world (FAO, 1985). Such deterioration is more severe in developing countries like Ethiopia (Thapa and Weber, 1990). Ethiopia provides a well-known example of a severely degraded African environment with consequent implications for food insecurity and famine. Deforestation has reduced high forest cover to 2.7 per cent of surface area; 50-60 per cent of rainfall is lost as runoff, carrying an estimated 2-3 billion tones of topsoil away annually, and declining land/agricultural productivity is outstripped by population growth (the latter increasing at 2.6 to 2.9 per cent per annum) (Campbell, 1991). Proponents of soil and water conservation justify the urgency of their work by referring to the present state of environmental degradation in the highlands where extensive deforestation and wide scale soil erosion are associated with declining crop yields.

In Ethiopia, land (which includes soil, water and vegetation) is a vital resource, as agriculture is the most important economic sector. However, research has shown that this critical resource is in a state of serious degradation. The problem largely manifests itself in the form of soil and water degradation and loss of biodiversity. With high-intensity rainstorms and extensive steep slopes, the highlands in particular suffer high rates of soil erosion and nutrient loss. Although data on the extent of the problem are patchy and inconsistent, available estimates indicate that soil erosion averages nearly 10 times the rate of soil regeneration in the highlands, and the rate of soil nutrient depletion is the

highest in sub-Saharan Africa (FAO, 1993; Hurni, 1988; Hurni, 1993; Stoorvogel *et al.* 1993). Continuous cultivation with limited amendments and the widespread use of cattle-dung and crop residues for household energy have substantially contributed to the loss of soil organic matter.

Studies in the Ethiopian highlands have revealed that the Ethiopian highlands, which cover 44% the total land area of the country, are seriously threaten by soil and biological degradation. In extent of 27 million ha representing approximately 50% of the highland is already significantly degraded. Of this area, 14 million ha is badly eroded and if the present trend of soil degradation continues, per capita income in the highland will fall by 30% in 20 years (FAO, 1984 cited by kumela, 2007) and 54% of the remaining highlands are highly susceptible to erosion.

The implications of land degradation are extremely important, as the livelihoods of many Ethiopians are entwined with land resources. Degradation reduces the production potential of land, and thus makes it difficult to produce enough to feed the growing population. It also increases farmers' vulnerability to food shortages and becomes a threat to the mere survival of the people. The looming food insecurity in the country is mainly linked to the prevailing degradation problem (Sonneveld and Keyzer, 2003).

Being an integral part, the natural resources and socio-economic status of an area should be paid equal attention (Erickon, 1995). Unfortunately until now most of the people are confined only to the resource degradation, keeping the social factors aside.

## **1.2 Statement of the Problem**

For a sustainable land management, it is necessary to estimate soil loss and deposition even on large spatial and temporal scales. Land degradation is the major threat across the world due to human pressure and land-use changes, but the impact are more pronounced in the developing nations due to high population growth rate, poor farming system and the associated rapid depletion of natural resources. Land degradation in connection with socio-economic impacts have given due attention on a profound and ongoing research.

Land degradation in the form of soil erosion has influence the socio-economic status in many parts of Ethiopia. Land degradation (soil erosion) in the study area has been a major problem for soil resource, soil fertility and productivity. This could play an important role in the socio-economic status of the people in the study area. Therefore, assessment of current land degradation has a paramount role in identifying the correlation between land degradation and its socio-economic impacts in the region.

### **1.3 General Objective**

The main objective of this research is to assess the extent of land degradation and its impact on the socio-economic status of the local people in the area. It also aimed to analyze the spatial variations of soil erosion and temporal changes of land-use/land-cover and socio-economic patterns.

#### **1.3.1 Specific Objective**

- To quantify the changes in land-use land-cover of the study area
- To prepare soil erosion risk map and soil erosion zoning
- To describe the socio-economic status of the study area
- To prepare land-use\land-cover map of the study area
- To formulate empirical model for land degradation status estimation

### **1.4 Assumption**

- ❖ It has been used secondary data from different sources and this may introduce error and shall be considered as limitation of study.
- ❖ The study considered all local farmers have equal access and supply for agricultural input (fertilizer) and its application rate.
- ❖ The study ignore the contribution of wind erosion for land degradation

## **2. Literature Review**

### **2.1 Land Degradation Definitions**

The term land degradation refers “the aggregate diminution of the productive capacity of the land, including its major uses (rain fed, arable, irrigated range land, and forest), its farming systems (e.g. smallholder subsistence) and its value as an economic resource” (Stocking and Murnagham, 2001). This link between degradation (which is often caused by land-use practices) and its effect on land-use is central to nearly all published definitions of land degradation. The emphasis on land, rather than soil, broadens the focus to include natural resources such as climate, water, land forms and vegetation, the productivity of grass-land and forest resources in addition to that of crop-land, is embodied in this definition.

### **2.2 Extent and Forms of Land Degradation**

Land degradation due to water erosion is a serious threat for the quality of the soil, land, and water resources upon which man depends for his sustenance. A study by Bobe (2003) indicated that water erosion had accounted for about 55% of the 2 billion ha of the degraded soils in the world. There is no region of the globe where water erosion is not a threat to the long-term sustainability of mankind. Accelerated soil erosion is the one influenced by man through overgrazing, cultivation road construction and monocultures on steep land without conservation measures.

#### **2.2.1 Chemical Degradation of Soil**

Chemical degradation is mainly due to leaching and poor farming practices, which result in the loss of nutrients and a concomitant increase in exchangeable Al, and sometimes Mn. Chemical degradation can also be caused by poor farming systems which, “mine” the soil, i.e. where there is a steady removal of nutrients with no, or only minimal, nutrient replacements (Barber, 1984).

Soil nutrient depletion results when the inflows of nutrients to the soil through manure, chemical fertilizers, biological nitrogen fixation, addition of wastes or plant materials

from outside the system, atmospheric deposition, and sedimentation are less than outflows due to crop harvesting, removal of crop residues, erosion, leaching and gaseous losses (Stoorvoege *et al.*, 1993).

### **2.2.2 Physical Degradation of Soil**

Physical degradation results from many interrelated processes, including sealing, crusting, compaction, reduction in permeability and aeration, as well as from chemical and biological degradation processes. Many of these processes result in reduction of soil porosity, surface sealing and crusting of the soil surface to the impacts of raindrops. Some of these processes, which result in the exposure of the soil surface to rainfall, are closely related to sheet and rill erosion (Barber, 1984).

### **2.2.3 Biological Degradation of Soil**

Soil biological degradation refers to the decline of biological activity of the soil. It mainly occurs in areas where the natural vegetation cover of an ecologically balanced soil system is destroyed. Soil biological degradation is also a serious problem in most of the highland areas of Ethiopia. It results from misuse of land, in particular poorly adopted cropping and grazing systems.

The stability of soil aggregates is dependent on microbial biomass (Bezuayehu *et al.* 2002). Thus, elimination of soil micro organisms (by erosion, burring, etc) causes physical damage to soil ecosystem. These physical effects may in turn lead to increase erosion, organic matter depletion, and further reduction in microbial activity. All factors that favor the production and decomposition of organic matter will minimize the risk of biological degradation.

## **2.3 Causes of Land Degradation**

There is a general agreement on the direct causes of land degradation. These include production on steep slopes and fragile soils with inadequate investments in soil conservation or vegetative cover, erratic rainfall patterns, decline uses of fallow, limited recycle of dung and crop residues to the soil, limited application of external source of

plant nutrients, deforestation and overgrazing. Many factors underlie these proximate or direct causes including population pressure, poverty, high costs of inputs and limited access to agricultural inputs and credit, low profitability of agricultural production and many conservation practices, high risks facing farmers, fragmented land holdings and insecure land tenure, short time horizons of farmers and farmers' lack of information about appropriate alternative technologies (Lakew *et al.* 2000).

### **2.3.1 Natural Factors**

According to Barber (1994) the major physical agent for land degradation is soil erosion. Topography, rainfall, wind, lack of vegetation cover, soil properties, and land-use and management practices are the immediate cause of soil erosion.

Topography affect soil erosion rate through its morphological characteristics. The two variables, namely gradient and slope length are essential components in quantitative relationships for estimating soil loss (Wischmeier and Smith, 1978). On sloppy land, more than one half of the soil particle that are dislodging by raindrop during rainfall are carried downhill. Erosion increases dramatically because the increased angle facilitates water flow and soil movement. However data for assessing the effect of slope gradient and length on soil erosion are limited. Yet it is generally accepted that an increase in slope and slope length will increase erosion because they lead to an increase in overland flow volume and velocity. Thomas (1997) identified that slope shape together with ground/ field attributes a strong influence on the nature and extent of visible erosion damage.

Climate is the other variable that affects soil erosion through the two major components of rainfall and wind. Erosive process is set in motion by the energy transmitted from either rainfall or wind or a combination of these forces. Although the effects of erosion are not easily observed on a daily basis, water and wind are both capable of quickly damaging the soil. Sheet and rill erosion are by far the most widespread kinds of accelerated erosion with severe impacts in agricultural production more than other kinds of erosion. Soil erosion by rainfall and wind consists of two principal sequential events:

the detachment of soil particles from the soil mass and transportation of the detached particle (Young and Wiersma, 1973). Raindrops hit exposed soil particle and launching into the air. When rainfall is intense and rapid runoff occurs, gullies ranging from 1 to 100m deep may form and large volumes of water and soil may be swept away (Pimental *et al.* 1998). The force of rainfall to produce erosion is related to rainfall amount, intensity and distribution. Intensity of rainfall is more important than rainfall amount in causing erosion.

Soils vary in their resistance to erosion, partly based on texture and amount of organic matter. The resistance also depends on soil condition and depth. Soils high in silt and low in clay and sand are highly erodible (Nill *et al.*, 1996). The high erodibility of silt soils is explained by their weak structural stability. They rapidly form surface seals upon the impact of rain drops. Erosion is less on clayey soils due to better aggregation and on sandy soils due to the non-sealing surface. Organic matters in the soil improve soil structure, root penetration, water holding capacity and infiltration. Hence, with increasing organic matter, erodibility decreases (Wischmeire and Smith, 1978). However, soil with high sodium content results in dispersion influence on soil structure. The effect of this can cause for surface sealing and facilitate water erosion through decreasing of infiltration and also wind erosion.

Vegetation cover and land-cover have a direct impact on the amount of annual soil loss together with the other factors. Throughout the world, the lowest erosion rates, ranging from 0.004 to 0.5/ ha are found in undisturbed forests (Pimentel *et al.* 1998). However, once forest-land is converted to agriculture, erosion rates increase because of vegetation removal, overgrazing, and tilling. Vegetation cover reduces erosion. Living and dead plant biomass reduces soil erosion by intercepting and dissipating raindrops and wind energy. Above ground foliage slows the velocity of water running over the soil, decreasing the volume of water and soil loss in surface runoff. Plant roots physically bind particles, thus stabilizing the soil and increasing its resistance to erosion. Plant roots also enhance water conservation by creating pores in the soil surface that enable water to enter

easily into the soil matrix. The uptake of water by plant roots also deplete the soil water content and thereby further increases infiltration rates.

### **2.3.2 Socio-economic Factors**

Socio-economic factors affect land degradation through their impacts on farmers' decisions with respect to land-use and land management practices, such as ploughing, fallow, use of manure and other sources of organic matter, fertilizer use, and adoption of soil and water conservation measures. Factors influencing these decisions include population pressure, poverty the nature of farmers' perceptions and attitudes.

Population growth increases the demand for land and contributes for even farming on steep and fragile soils, also leading to erosion problems. It increases the demand for biomass as a source of fuel, leading to deforestation and increased burning of cattle dung and crop residues, thus increasing the problems of erosion and nutrient depletion. Population growth increases demand for livestock products and therefore leads to increased livestock numbers, causing overgrazing and consumption of crop residues by animals. Poverty may be worsened by population growth as a result of resource constraints and decreasing returns to capital and labor in agriculture (Pender, 1998).

Deforestation and burning of dung and crop residues are increased by people's inability to afford or lack of access to alternative fuel sources. Poverty similarly limits farmers' ability to purchase feed for livestock, contributing to overgrazing, and their ability to purchase chemical fertilizer, contributing to soil nutrient depletion. Poverty tends to increase farmers' short-term perspective, limiting their interest in investing in soil and water conservation measures that yield benefits only in the longer term (Holden *et al* 1998; Pender, 1996). Lack of education or access to information associated with poverty may cause farmers to be less aware of land degradation problems, or to attribute such problems to causes beyond their control, and thus may reduce their efforts to address such problems (Ervin, 1982).

Farmers' perception and attitude can have a major bearing on land management. Although farmers are often more acutely aware of the condition of their land than is sometimes

assumed by experts, they may not be fully aware of severity of land degradation, its causes and consequences (Ervin, 1982). Soil degradation is often a very slow process and may be almost invisible. Farmers, may not observe ongoing erosion or nutrient depletion problems, or perceive them as immediate problems. While they do observe low or declining yields, farmers often attribute deterioration of crop yields to reduced rainfall. But, soil degradation may also have affected the water holding capacity and thereby reduced ability the soil to overcome situations of water stress, thus contributing to the decline of yields. As long as farmers do not perceive soil degradation as a major determinant of decreasing yields, this trend will certainly not be reversed.

## **2.4 Land Degradation in Ethiopia**

In Ethiopia, 85% of the population is directly supported by the agricultural economy. However, the productivity of that economy is being seriously eroded by unsustainable land management practices both in areas of food crops and in grazing lands. The occurrence of recurrent drought in the country has been attributed partly due to land degradation. Soil loss through water erosion is superabundant. Ethiopia loses an estimated 1.3 billion metric tons of fertile soil every year and the degradation of land through soil erosion is increasing at a tremendous rate (Berry, 2003).

According to the findings of the Soil Conservation Research Project Sites in different parts of Ethiopia, it is estimated that about 1500 million ton of soil is eroded from the highlands of Ethiopia every year. About 50% of the rural population is affected to some degree, and 1 – 2% of the country's agricultural production is lost due to this problem (Hurni 1998). Adugna *et al.* (1996) reported a 72% yield reduction of barley in west Hararghe as result of soil erosion over 15-year period. Annual productivity losses on croplands in the Ethiopia highlands due to erosion are estimated to be from 0.12 – 2% (kappel, 1996).

The direct cost of loss of soil and essential nutrients due to unsustainable land management is estimated to be about three percent of agricultural GDP or \$106 million. Other modeling work suggests that the loss of agricultural value from 2000- 2010 will be

around \$7 billion USD. None of these estimates takes account of the indirect impacts of land degradation in Ethiopia.

Several studies were made on land degradation issues at the national level in Ethiopia. As listed in Berry (2003), these include the Highlands Reclamation Study; which concluded that in the mid 1980's, 27 million ha or almost 50% of the highland area was significantly eroded, 14 million ha seriously eroded and over 2 million ha eroded beyond reclamation possibility. Soil erosion rates were estimated at 130tons/ha/yr for cropland and 35tons/ha/yr for all type of land in the highland. Forests in general have shrunk from 65% of the covering of the country and 90% of the highlands to 2.2% and 5.6% respectively.

## **2.5 Causes for Land-use/Land-cover Dynamics**

The force for LULC change could be natural and/or anthropogenic such as construction of human settlements, government policies, climate change or other biophysical drivers (Riebsame *et al.*, 1994; Lambin *et al.*, 2000). But the degree of influence as compared to the two factors anthropogenic is more influential as compared to the natural one for LULC change in a given region. Increased demands for food production and associated agricultural intensification also cause loss of natural components from agricultural areas thereby influencing LULC (Lambin *et al.*, 2000; Foley *et al.*, 2005; Ningal *et al.*, 2007). Hence studying the LULC change will give as an opportunity to understand the trend of change and causal factors for change.

In Ethiopia, inappropriate agricultural practices, deforestation and overgrazing are affecting crop and livestock productivity of the rural poor and hence their livelihoods. These alterations of ecosystem services, due to changes in LULC, negatively affect the ability of the biological systems to support human needs. These changes also determine, in part, the vulnerability of places and people to climatic, economic or socio-political perturbations. Ethiopia is one of the top six food aid recipient countries in the world (McClelland, 1998).

## **2.6 Crop Production and Land Degradation**

Soil degradation in Ethiopia can be seen as a direct result of the past and present agricultural practices on the highlands. The dissected terrain, the extensive areas with slopes above 16 percent, and the high intensity of rainfall lead to accelerated soil erosion once removal of vegetation occurs. Some of the farming practices within the highlands encourage erosion. These include cultivation of cereal crops such as tef (*Eragrotis tef*) and wheat (*Triticum* spp.), which require the preparation of a fine-tillth seedbed.

The estimated average erosion rate on currently unproductive cropland are 70ton/ha/yr and the average erosion rate from currently used cropland (planted to annual crops) are 42ton/ha/yr or 4mm of soil depth, which is sufficient enough to wear away the total soil profile within 100-150 years (assuming average soil depth is 60cm in the highlands) (Hurni, 1986). But it may also reach up to 300ton/ha/yr in individual fields, Hurni, (1993), this by far exceeds the natural rate of regeneration, while erosion is average 8ton/ha/yr on land planted to perennial crops and 5ton/ha/yr or less for all other land-cover type.

Further research has shown that soil erosion is greatest on cultivated lands, where almost half of the loss of soil comes from, even though they cover only 13 percent of the country (Hurni, 1990). Excessive land degradation, along with other climatic factors such unreliability and high intensity of rainfall could lead to reduced average crop yields per unit area (FAO, 2000). As a result of continuous low crop yields, the total produce of most farming families is not sufficient to cover their annual consumption.

## **2.7 Livestock and Land Degradation**

The Ethiopian highland experiences a severe deficit of animal feed due to the fact that supports a large livestock population. Hurni (1988) forecasted that all pastureland will be fully utilized by the year 2005 as the demand for cropland has come into increasing competition with that for grazing land. This has; however, not been proven to be totally true, even though reduction in size of the natural pasture land is inevitable. Still most of livestock feed in Ethiopia is derived mainly from grasses, crop residue and fodders.

Shortage of livestock feed supply is highest during both the dry and wet seasons. This is because crops occupy the land and large areas of permanent pastures on the lowlands become waterlogged. An important factor contributing to the decline in fodder resources is the ever increasing human population, which resulted in an increase in cropland at the expense of traditional grazing areas such as bush-lands, natural pasture and forests (Hoekstra *et al.*, 1990). This has aggravated in recent years. The simultaneous upward surge in both human and livestock populations would, therefore, bring about the depletion of the biological resources. This in turn would force livestock to move mainly to the upper slopes in search of feed or to concentrate on the small natural pasturelands or on to the roadsides. This has induced overgrazing and soil erosion, which eventually led to land degradation. Cow dung, which could have been used to enrich soil fertility, is consistently collected to fulfill energy requirements of the household.

## **2.8 Forest Resource and Land Degradation**

In Ethiopia, population pressure is inducing, the clearing of forests for agriculture and other purposes, and the accelerated soil erosion, is gradually destroying the soil resource (Hurni, 1990). This is because natural forests are the main sources of wood for fuel, construction and industry, even though plantation forestry is also increasingly becoming important.

The annual loss of natural forest cover has been estimated to be 150,000 to 200,000 ha/yr and in 1989 forest cover was estimated at only 2.7% of the Ethiopian land mass (EFAP, 1993). Today, little of the natural vegetation of the highlands remains, except for the southern and southwestern parts of the country. Consequently, large extent of forest of the country is now exposed to heavy soil erosion resulting in a massive environmental degradation and serious threat to sustainable agriculture and forestry.

## **2.9 Cost of Land Degradation**

Land degradation represents a loss of natural capital, the value to society of land, water, plant, and animal resources. The value includes:

- The direct contribution to primary production in crop agriculture, livestock rearing and fishing. Indicators include reduced yield, change in land-use, and change in crops, abandonment of fields, and altered livestock mixes and patterns of grazing.
- The quality of environmental services indicated by such processes as changes in stream flow, silting of dams, reliability of irrigation water flow and decline in quality of drinking water.

These losses also result in costs related to changes in rural society due to processes such as migration and associated loss of human capital and break up of communities, social costs of poverty, and reduced ability to invest in anti-degradation activities. Most current evaluations of the costs of land degradation have focused on the loss of soil from farm plots and the loss of nutrients resulting in decreased productivity or the need for increased inputs to maintain productivity.

A pilot studies was made in seven different countries around the world. According to the study land degradation plays a paramount effect on national GDP and related effects (Leonard B *et al.*, 2003). Then they summarize the cost and extent of land degradation as follow in Table 2.1.

Table 2.1: Cost of land degradation in different countries

Country	Extent of Land Degradation	Cost of Land Degradation, USD
China	Widespread, especially North & West	\$7.76 Direct \$ 31 billion Indirect & 4% GD
Ethiopia	Highlands and Drier Areas, 50% highlands	4% GDP Direct, Acute poverty
Mexico	65% of land area	\$3.5 billion, Migration
Uganda	Varied 60% land area	4% GNP?
Rwanda	Extreme especially SW	3.5% Ag GDP Direct, acute poverty
Chile	Widespread	50% on wheat & 23% goat
Indonesia	Varied	0-4% crop value

## **3. Materials & Methods**

Primary and secondary data sets have been obtained from different sources. Materials used for the study, methods followed and the software's used during the study for the analysis of land degradation and socio-economic of the study area are being discussed below.

### **3.1 Phase of Activity**

This section explains the various activities that have been included in the study. The general working plans were as follows.

#### **3.1.1 Pre-field work**

- Organizing the literature review so as to substantiate this study.
- Preparation of questionnaire for socio-economic survey.
- Geo-referencing, digitizing and mosaicking part of the scanned topographic sheet in order to delineate the study area.
- Digitizing of rivers and roads from the 1:50,000 scale topographical map sheets.
- Acquire Landsat image from different institutions.
- 2005 ETM+ Landsat Image processing and making unsupervised classification.

#### **3.1.2 Field work**

- Conducting Socio-economic survey based on the prepared questionnaire.
- Recording ground truth using Garmin GPS.

#### **3.1.3 Post- field work**

- Summarized socio-economic data.
- Supervised classification based on the ground truth.
- Making change detection between 1973, 1986 and 2005 satellite imageries.
- Estimating parameters of USLE based on the previous research in Ethiopian highlands.
- Preparation soil loss risk map.
- Preparation degradation model.

### 3.2 Data Collection

Table 3.1: Data type and source

No	Type of data	Source
1	Topographic map	EMA(Ethiopia Map Agency)
2	Soil type	FAO soil map of Ethiopia
3	Socio-economic data	Study area
4	Annual mean rain fall	NMSA(national metrological system agency)
5	Satellite imagery(land sat, ETM+ of (1986 & 2005) and Landsat MSS of year 1973 with ground resolution of 30m	Colleague
6	GPS reading of study area	Study area
7	Soil data, land holding size, livestock population and major crops productivity(Qt\ha)	Alaba Wereda Bureau Agriculture and Rural Development

### 3.3 Socio-Economic Data Source and Sampling Procedure

Both primary and secondary data were used for this study. The primary data was obtained through household survey on people, who were directly or indirectly influenced by the land resource of the area. The secondary data source included published and unpublished materials, books, journals and reports. As mentioned earlier, the study focused on the communities directly attached to the land resource of the area. Hence, the sampling procedure was made by categorizing the total study area in to three categories. It was assumed that the communities within each categorized zone were homogenous with this research context (i.e. they all depend on natural resource and sustain their life on agriculture). A list of households obtained from the Woreda Administration and sample household was drawn randomly.

A structured survey questionnaire was administered to 60 farm households randomly selected from the three zones. Interviews were made to the heads of the households to obtain data on household characteristics, farming and farm resources, perceptions of crop and livestock production and constraints. Information on growth and yields of the major crops grown and productivity, livestock population and land holding size per household in the area were obtained from the Alaba Woreda Bureau of Agriculture and Rural Development.

### **3.4 Methods**

An integrated approach of GIS and digital image processing of satellite imagery combined with land-use and land-cover dynamics and soil erosion loss estimation were carried out for land degradation assessment. The USLE model was used to estimate amount of annual soil loss from the region. Hence assessment of soil loss rate was made cell by cell multiplication of six USLE parameters in ArcGIS environment using raster calculator.

For the analysis of degradation index (DI), the difference between average values of soil properties for each of the three zones and the values of the corresponding soil properties of the forest region were synthesized and expressed as a percentage. The percentage changes were summed across all soil properties to compute the soil DI for each zone, which was used as an index of soil degradation or improvement.

Household survey was conducted through well structured questionnaire for the socio-economic status assessment. The analysis for socio-economic survey was carried out using qualitative description and descriptive statistics. In this case, both methods of analyses were used. The survey data was analyzed employing descriptive statistic using SPSS.

The socio-economic status index encompasses different socio-economic factors. Among those factors few were considered for this study that can address the socio-economic condition of the region. Hence comparison was made between zones. Each of the variables was further categorized in to whether the variables have positive or negative

impact upon resource. Therefore, negative or positive values were given according to the influence to the resource.

### **3.4.1 Image Enhancement**

Image enhancement is a procedure applied to image data in order to more effectively display or record the data for subsequent visual interpretation. Normally, image enhancement involves techniques for increasing the visual distinction between features in a scene. Such preprocessing of satellite images prior to image classification and change detection is essential. Preprocessing functions involve those operations that are normally required prior to the main data analysis and extraction of information. Selecting appropriate satellite imagery is the first task in image data processing. The selection is often limited to the resources that are available. In this study, the imagery Landsat MSS of path181 and row 55 of year the 1973, Landsat TM path 168 raw 55 of year the 1986 and Landsat ETM + path168 raw55 of year 2005 were used for the analysis, which were already orthorectified. The down loaded satellite images were in tiff format and were not stacked it to single layer and it was stacked in ERDAS 9.1 with Moduler main icon and developing function in it to stack each layer to produce one single layer composing each band. Then from the stacked band the study area sub-set with the help of area of interest in ERDAS 9.1 environment.

#### **3.4.1.1 Pansharping**

Panchromatic image of the study area and Landsat ETM+ images were merged in order to gain high resolution of panchromatic (15m) over the Landsat ETM+. This process was performed in the ERDAS IMAGINE environment in the tool of merging. The logic behind this tool was to change low spatial resolution image with high resolution image. Hence, merging panchromatic image with that of Landsat ETM+ gave an advantage of high spatial resolution of panchromatic and high spectral resolution of LandSat ETM+ image. After this process the final images were high spectral resolution, which was gained from ETM+ and high spatial resolution (15m), which was gained from panchromatic image. This was made visual interpretation easier for feature identification and for further analysis.

### **3.4.1.2 PCA**

PCA, one of multi-spectral image manipulation techniques, is used for natural resource monitoring and management application. The technique makes us to reduce the dimensionality of the data, to compact the redundant information. The purpose of these procedures was to compress all of the information contained in an original n-band data set into fewer than n “new bands”. The new bands were then used for further classification analysis.

For the purpose of distinguishing different LULC types in the region it was found that the first three principal components (PC-1, PC-2 and PC-3) were enough. The first three principal components consisted about 99% of the information in the original image. Hence, the resulting output (image) was used additional input for classification image in to different land-use and land-cover classes.

### **3.4.1.3 Linear Stretching**

Linear Stretch, one of the Contrast Stretching techniques, is the uniform expansion of limited image levels range to fill the range of display values (0-255). Subtle variations in input image data values were now displayed in output tones that would be more readily distinguished by the interpreter. Light tone areas were appeared lighter and dark areas were appeared darker.

In general, the schematic data analysis is represented in the Fig 3.1.

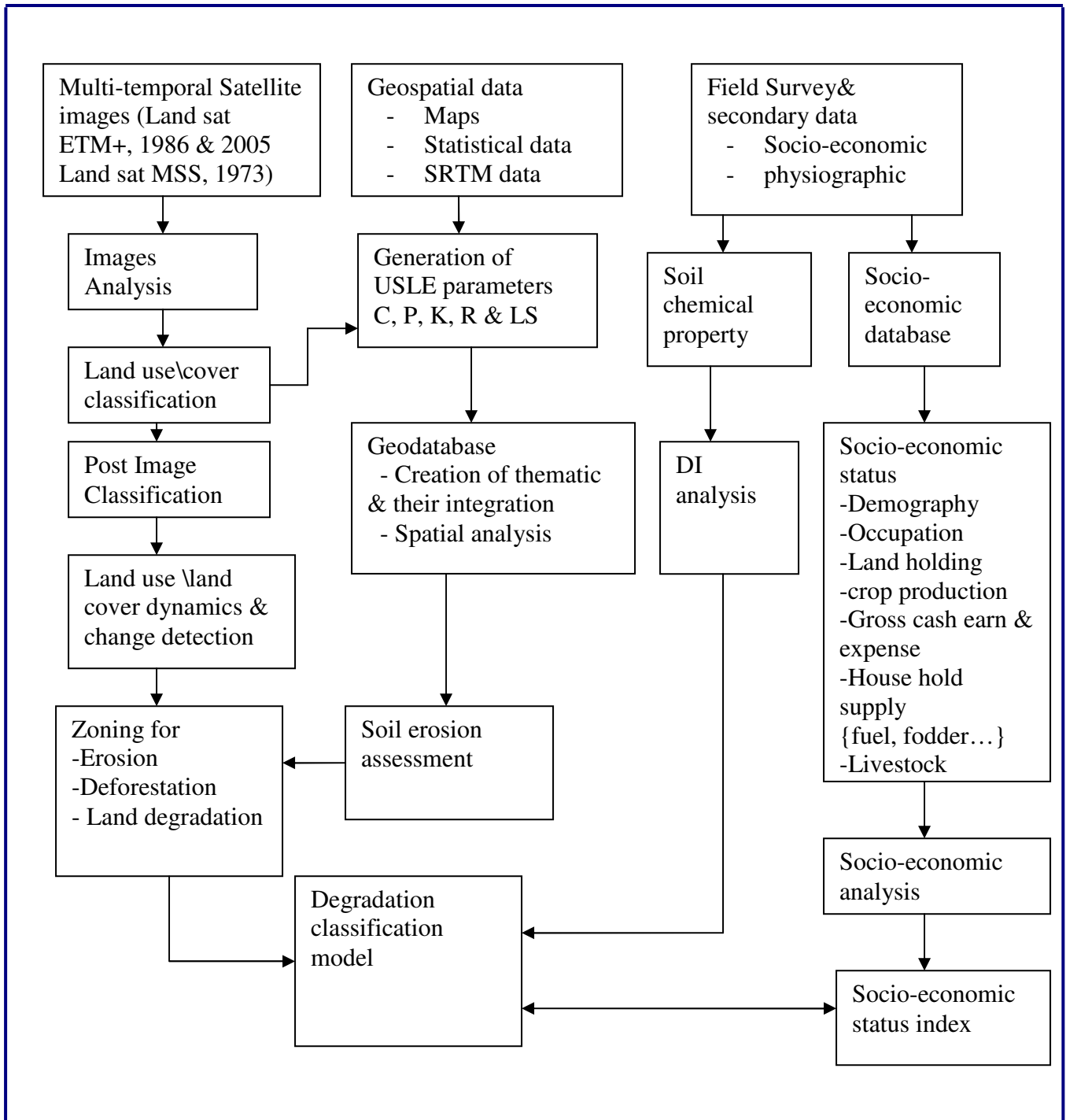


Fig 3.1. Flow Chart of the general methodology

## 4. General Description of the Study Area

### 4.1 Study Area

The study area is located in the southern part of Ethiopia, which is administratively situated to SNNRP regional Government. The area lies between 7°29' north latitude and 7°19' south's of latitude and 38°19'40" Of east longitude and 38°11'30" of west longitude Fig 4.1. The area is around 315km away south of Addis Ababa.

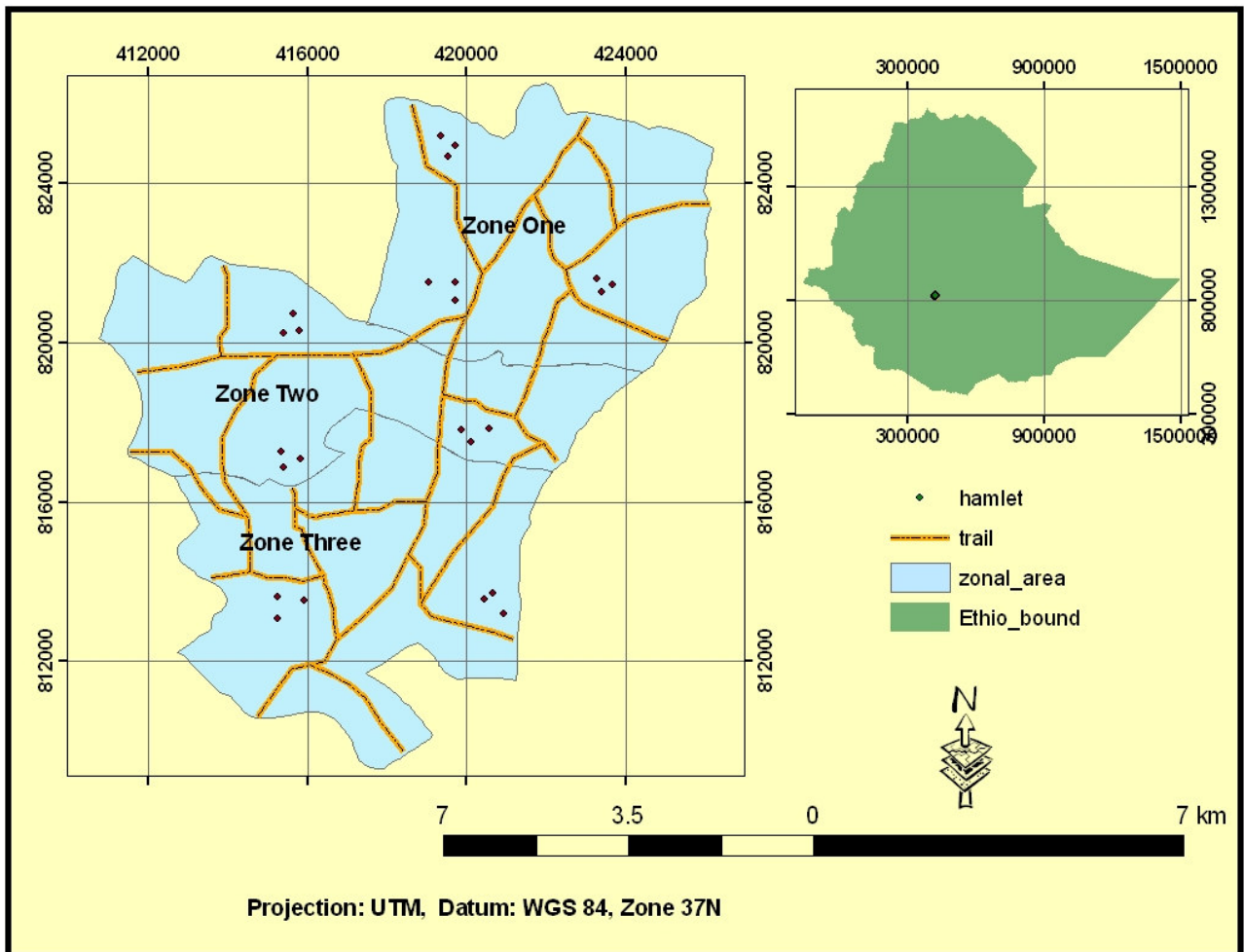


Fig 4.1: Location map of study area

### 4.2 Agro-Climatic Zone

The Ethiopian Rift valley is characterized by its semi-arid climate with a long summer season (late June - mid September) bringing heavy rains from the Indian and Atlantic Oceans, a dry season (October – February) and a short rainy season (March - May)

bringing moisture from the Indian Ocean and the Red Sea (Ayenew, 2004 as cited by Bedru, 2007).

The altitude of the study area falls within the range of 1700 – 2200m a.s.l. It mainly falls in Woina Dega agro climatic zone. The mean annual rainfall ranges between 759mm - 1241 over the last eleven years. And the mean maximum and minimum temperature ranges for the last eleven years 24.9°C - 29.9°C and 6.7°C - 13.8°C respectively.

### **4.3 Farming systems**

The farming system in the region is mixed type, where crop production and livestock rearing goes hand in hand. Accordingly, crops such as *Teff* and Haricot bean are abundantly produced. Cattle are the predominant livestock type. Intensification of cultivation is higher in *teff* /Haricot bean / livestock farming system and hence lands are covered with crops leaving very small plots for grazing land.

### **4.4 Geology**

As described in SNNPR regional map ( Water Action 2001), the study area is geologically part of the magdala shield group of Cenozoic era of tertiary volcanic predominate by acidic rocks including acid tuffs, mostly ignimbrites, pentelleritic rhyolites and trachytes. These rocks are bedded with lava and agglomerates of basaltic composition. The volume of acidic rocks tends to decrease away from the rift valley.

### **3.5 Local Economy**

Almost all people in the study area are subsistence farmers with an average land holding of less than 2.5 hectares. Their source of income is crop and livestock production. Therefore, agriculture is the sole economic sector in the region.

## **5. Analysis**

### **5.1 Image Classification Analysis**

The overall objective of image classification procedures is to automatically categorize all pixels in an image into land-cover class or theme (Lillisand and Kieffer, 2000). Normally, multi-spectral data were used to perform the classification and, indeed, the spectral pattern present within the data for each pixel was used as the numerical basis for categorization. There were two primary methods of image classification methods utilized by image analysts, unsupervised and supervised classification. The classification methods used in by this paper are all those two techniques mentioned earlier. Hence each of the classification technique was utilized whenever necessary. Supervised image classification was a method in which the analyst defines small training sites on the image, which were representative of each desired land-cover category. The delineation of training areas representative of a cover type was most effective when an image analyst has knowledge of the geography of a region and experience with the spectral properties of the cover classes. However the unsupervised classification technique is performed when there was little or no knowledge to the geography of the region where classification is under taken.

#### **5.1.1 Unsupervised classification**

Imagery information will be categorized in to different land-use land-cover categories based on their spectral signature. However such classification was sometimes difficult when there was little knowledge to the geography of the region. In such cases unsupervised classification method become appropriate and easier to the analyst to categorize the spectral signature based on their similarities in to different class.

Unlike supervised classifiers, unsupervised ones do not utilize training data as the basis for classification. These classifiers try to aggregate reflectance value of pixels in the feature space into well separated clusters. Clusters were considered as classes. Once the spectral grouping was made, the obtained classes to some form of reference data. There were numerous clustering algorithms that were used to determine the natural spectral clusters present in the image. The most common algorithm is “K-means”. In this approach

user has to define the number of clusters or classes to be located in the image (Lillesand and Kieffer, 2000). The algorithm automatically locates the centre means of various clusters present in the image and each pixel in the image is then assigned to the cluster whose mean was closest. After all pixels have been classified, revised mean vectors for each of the cluster was computed. The whole process was repeated again until there was no further change in the location of class means vectors. Finally, classifying land-cover maps required ground truth of the region in order to label each cluster with its equivalent in the real world.

### **5.1.2 Supervised classification**

Supervised classifications require a priori knowledge of the scene area in order to provide the computer with unique material groups or what are called "training classes". Regions containing a material of interest within a scene were delineated graphically and stored for use in the supervised classification algorithm. It was the job of the user to define the original pixels that contained similar spectral classes representing certain land-cover class. The supervised classification techniques are the Maximum Likelihood classifier for parametric input data and Parallelepiped classifier for non-parametric data. Maximum Likelihood Classifier (MLC) assumes that a pixel has a certain probability of belonging to a particular class. These probabilities were equal for all classes and the input data in each band follows the gaussian (normal) distribution function (Lillesand *et al.*, 2000). Maximum Likelihood Classifier functions by using the band means and standard deviations from field collected data in order to project land-cover classes as centroids in feature space. These centroids of each land-cover classes were circumscribed by probability contours. The probability density function assumes that the sample values for each class were normally distributed. The unclassified pixels were plotted in the same feature space and get a posteriori probability. The pixels were then assigned to the class for which they have highest membership probability. But it was possible to soften the maximum likelihood classification by using the posteriori membership probability values as indices of class membership.

## 5.2 Land-use and Land-covers Classification

The different classification techniques were performed on the three periods of Landsat imageries. There were no sole classification technique, which was used to classify the imageries. Rather it combined with one another to produce a better land-use/ land-cover map. It was found that the enhanced image was quite useful for visual interpretation through the technique of geo-link. Moreover, the addition of NDVI layer helped to distinguish the area occupied by vegetation.

The land-use and land-cover types in the study area were categorized into six types, namely forest, degraded forest, bush, grass, crop and bare land. The rural settlements, which were located in the plain areas, were encircled by farms. Hence, it was difficult to define specific land-cover type for each. The descriptions of these land-cover types are given in Table 5.1.

Table 5.1: Land-use and Land-covers description of the study area.

No	Land-use/land-cover type	Descriptions
1	Cropland	Areas used for cultivation, both annuals and perennials, and the scattered rural settlements that were closely associated with the cultivated fields.
2	Forestland	Areas covered with dense growth of trees that formed nearly closed canopies.
3	Degraded forest - Land	Areas with sparse trees mixed with bushes, grasses and open areas; less dense than the forest.
4	Bush-land	Areas covered with shrubs, bushes and small trees, with only sparse woody trees, mixed with some grasses.
5	Grass-Land	Grassy areas used for communal grazing, as well as closed pasture land and grass mixed with very sparse shrubs
6	Bare-Land	Land that has very little or no grass cover including exposed rocks

### 5.2.1 Land-Use and Land-Cover of 1973

Main land-use/ land-covers in the year of 1973 were forest, degraded forest, bush, crop and bare-land. Large area was covered by crop-land, to extent of 5834ha, which constituted 40.69% of the total study area. The next LULC type was bush land. It covered 3096ha of land, which was 21.58% of the total area. The third LULC type was the forest-land, which contributed for 2154ha (14.91%) out of the total land mass. The fourth land-cover type was grass-land, which contributed for 1430ha of land (9.99%). The area also characterized with degraded forest land which accounted for 1350ha of land (9.43%) of the region. The smallest area coverage identified was bare land. It reached 492ha of land (3.39%). Table 5.2 and Fig 5.1 display the spatial distribution and area coverage of Land-use/land-cover for the year 1973.

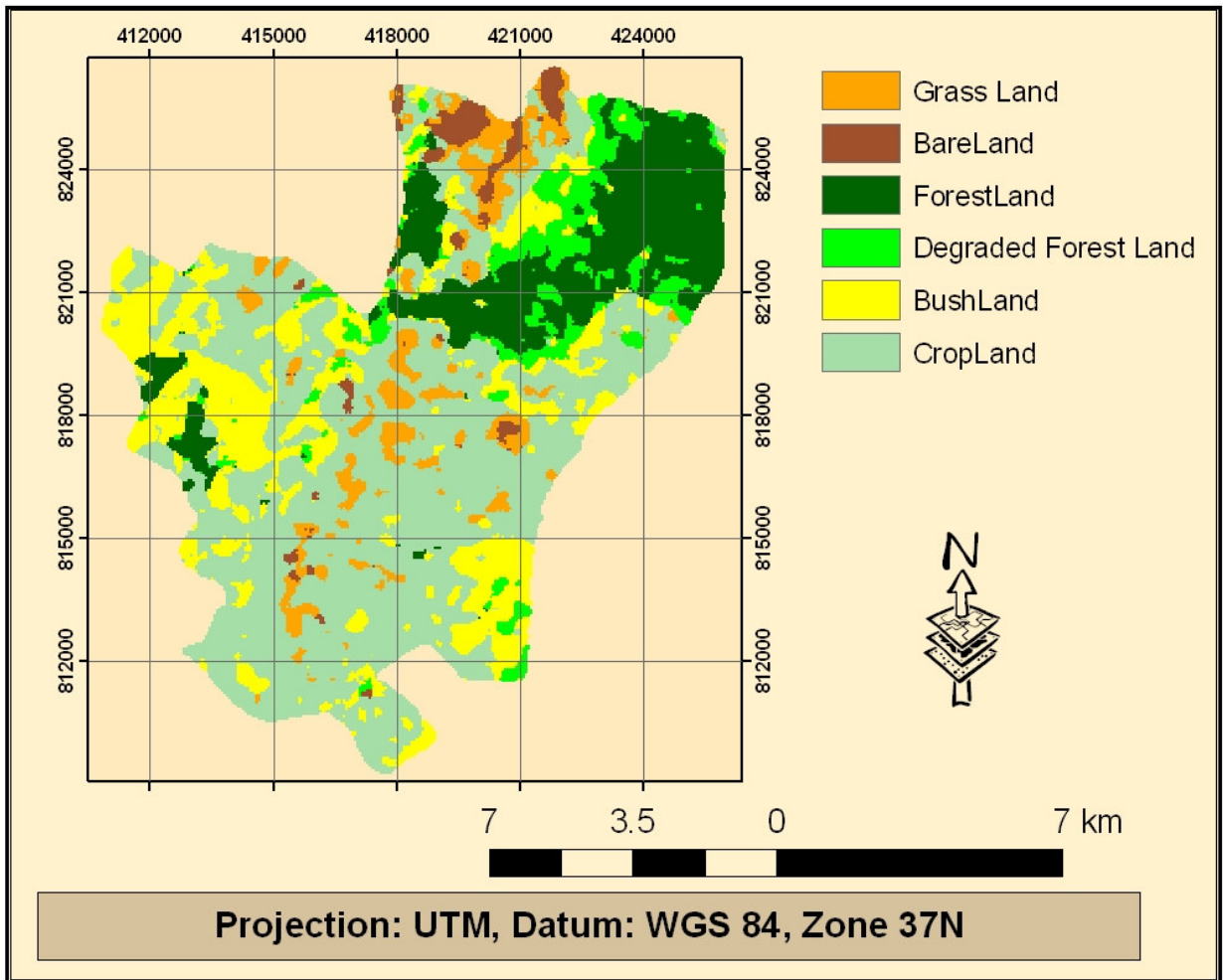


Fig 5.1: Land-use and land-cover of the study area in 1973.

Table 5.2: Land-Use and Land-Covers distribution of the study area for the year 1973

<b>Land-Use/Land-Cover Type</b>	<b>Area coverage in (ha)</b>	<b>Percent area coverage (%)</b>
Forestland	2154	14.91
Degraded Forest Land	1350	9.43
Bush-land	3096	18.45
Grass-land	1430	9.99
Crop-land	5834	40.69
Bare-land	492	3.39

### 5.2.2 Land-use and Land-cover 1986

Main land-use/ land-covers in the year of 1986 were forest, degraded forest, bush, crop and bare land. A total of 6451ha was covered by crop-land, which was 45.18% of the total study area. The next largest extent was bush-land, which accounted for 3053ha of land (21.38%). The third largest LULC was the grass-land which contributed for 1557ha of land (9.25%). The degraded forest land covered 1334ha of land (9.34%). The area also had forest-land which constituted for 1214ha of land (8.5%). The smallest area covered in 1986 was bare-land. Which accounted for 668ha of land, (4.68%) of the total area. Table 5.3 and Fig 5.2 display the spatial distribution and area coverage of Land-use\land-covers analysis for the year 1986.

Table 5.3: Land-Use and Land-Covers distribution of the study area for the year 1986

<b>Land-use\Land-cover Type</b>	<b>Area coverage in (ha)</b>	<b>Percent area coverage (%)</b>
Forest-land	1214	8.5
Degraded Forest Land	1334	9.34
Bush Land	3053	21.38
Grass Land	1557	10.9
Crop-land	6451	45.18
Bare Land	668	4.68

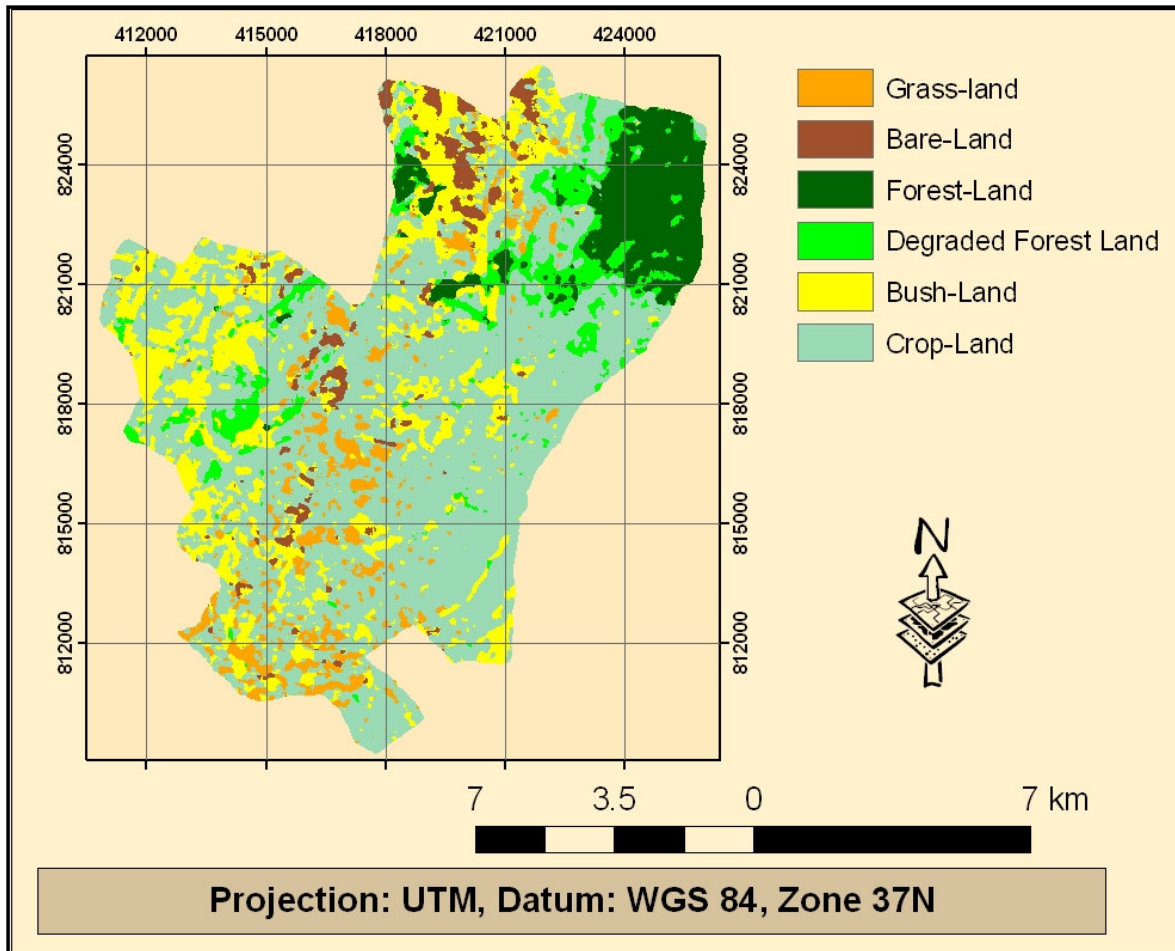


Fig 5.2: Land-use and land-cover of study area in 1986

### 5.2.3 Land-Use /Land-Cover 2005

Main land-use/ land-covers types in the year of 2005 were forest, degraded forest, bush crop and cultivated bare land. A total of 9868ha of land area was covered by crop-land (69.12%). The next LULC type was degraded forest land. It covered 1250ha of land (8.75%). The third LULC type was grass-land, which was covered 1227ha of land (8.59%). Next to this bush-land and bare-land shared significant size of land. Hence bush-land covered 998.4ha of land (6.99%), whereas bare-land covered 781ha of land (5.5%). The smallest area was covered by forest-land. It reached 152.6ha of land (1.07%). Table 5.4 and Fig 5.3 display the spatial distribution and area coverage of Land-use/land-covers for the year 2005.

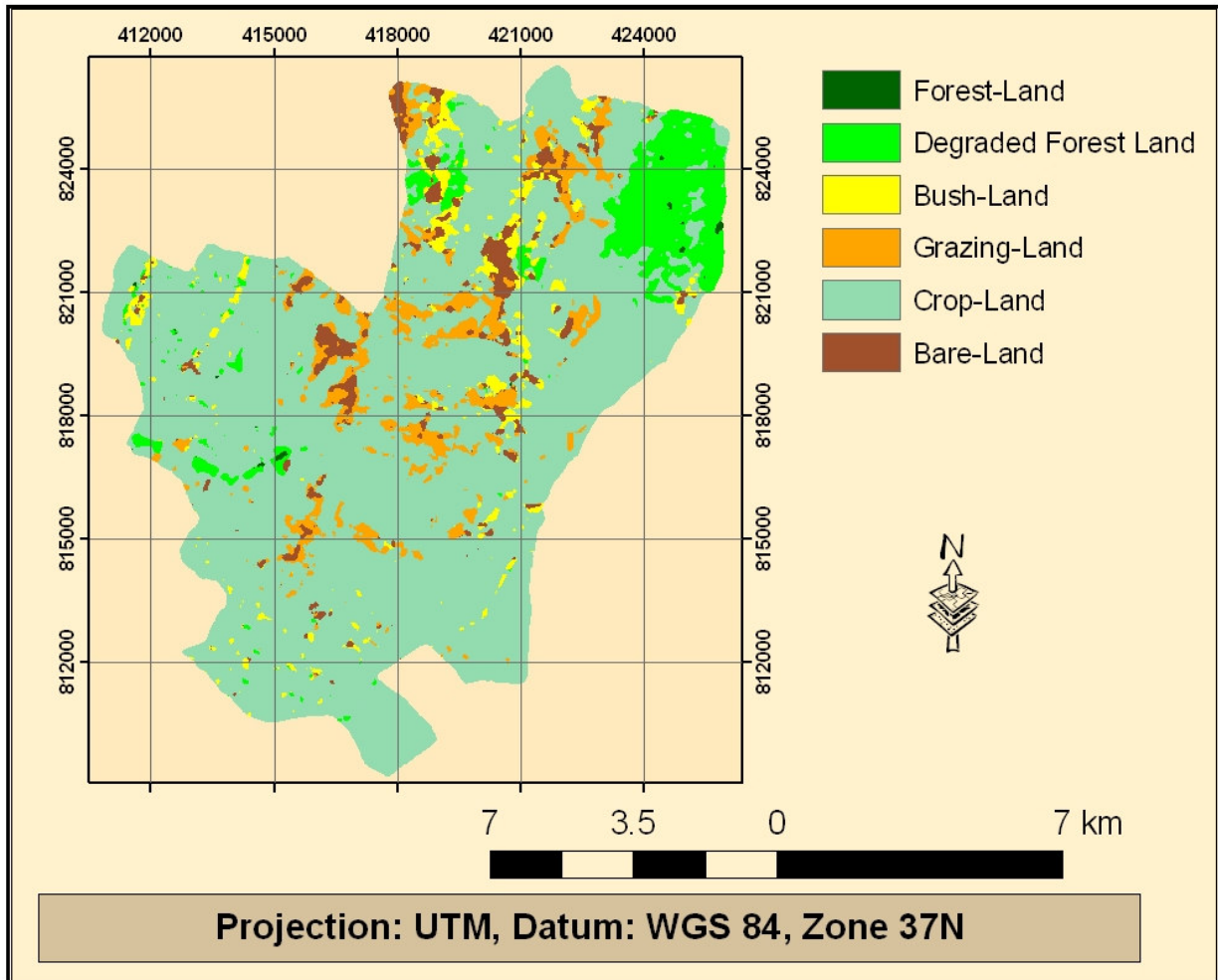


Fig 5.3: Land-use and land-cover of the study area in 2005.

Table 5.4: Land-Use and Land-covers distribution of the study area for the year 2005.

No	Land-Use\Land-Cover Type	Area coverage (ha)	Percent of area (%)
1	Forest-land	152.6	1.07
2	Degraded Forest Land	1250	8.75
3	Bush Land	998.4	6.99
4	Grass Land	1227	8.59
5	Crop-land	9868	69.12
6	Bare Land	781	5.5

### 5.3 Accuracy Assessment

Land-cover maps derived from remote sensing always contain some sort of errors due to several factors which range from classification technique to method of satellite data capture. In order to wisely use the land-cover maps which are derived from remote sensing and the accompanying land resource statistics, the errors must be quantitatively explained in terms of classification accuracy.

The ground truths collected during the field survey for each land-use/ land-cover were utilized as independent data set from which the classification accuracy was compared. The accuracy assessment indicates that how much the classified image approach to the actual land-use/land-cover class. An overall accuracy of 90.00% was achieved with a Kappa coefficient of 0.8148 for Landsat ETM+ 1986, while that of 2005 image was 85% with Kappa coefficient of 0.7849 and that of 1973 image was 80.00% with 0.7337Kappa coefficients. Table 5.5 given summarizes the accuracy assessment of classification.

Table 5.5: Classification accuracy assessment report

<b>Accuracy Assessment</b>	<b>1973</b>	<b>1986</b>	<b>2005</b>
Overall Classification Accuracy	80.00%	90.00%	85.00%
Overall Kappa Statistics	0.7337	0.8148	0.7849

### 5.4 USLE Factors Determination

Soil loss is one and major forms of land degradation. Based on this fact, the level of land degradation can be explained with the amount of soil loss from the given area in a given period of time. Hence estimation of soil loss provides us an opportunity to determine level of land degradation in a given locality. It was used a model for quantification of soil loss. The most widely used model for quantification of soil loss is the universal soil loss equation (USLE). The equation only estimates sheet and rill erosion, when forest management and agricultural activities expose the soil surface to rainfall impact and runoff. It couldn't estimate gully, landslide or soil creep erosion (Krauer, 1988). As its name indicate that it was designed to be geographically universal in its applicability. But

later on it was found to be modified based on the prevailing local condition. Accordingly the model was modified and adapted to Ethiopian conditions based on recommendations of the Soil Conservation Research Project (SCRCP) by (Hurni, 1985). The six parameters of the USLE were estimated for each land mapping unit using the land resources data as an input. The equation was validated by comparison with the plot measurement in Ethiopia and showed a high correlation of 0.90, explaining 80% of the measured sample (Hurni, 1986). It is this latter version, which employed in this work.

It computes soil loss as a product of six major factors, rainfall erosivity **R** factor; soil erodibility **K** factor, slope gradient **S** factor; slope length **L** factor, land-cover **C** factor and land management **P** factor. To predict the mean annual soil loss (**A**) [tons/ ha/year] of an area the parameters incorporated in the following USLE model.

$$A = R * K * L * S * C * P$$

#### 5.4.1 Derivation of Land-Use/Land-Covers (C) Factor

The C factor measured the combined effect of all the interrelated cover and management variables (Wischmeir *et al.*, 1978). USLE was developed to estimate soil loss in agricultural areas, but later it was adapted for non-agricultural lands by relating the land-use/land-cover situation with the agricultural land.

Based on classified image as it was described in the above land-use/land-cover classification secessions the area had six land-use\land-cover classes. Their corresponding C factor values have been assigned according to Hurni (1985). However, in this study it temporal variation of LULC was taken account. This temporal variation of LULC created spatial difference in the values of C-factor. Accordingly the C-factor values assigned for each land-use type for the period of 1986 and 2005. Fig 5.4 explains the effect of temporal variation on spatial difference of C-factor.

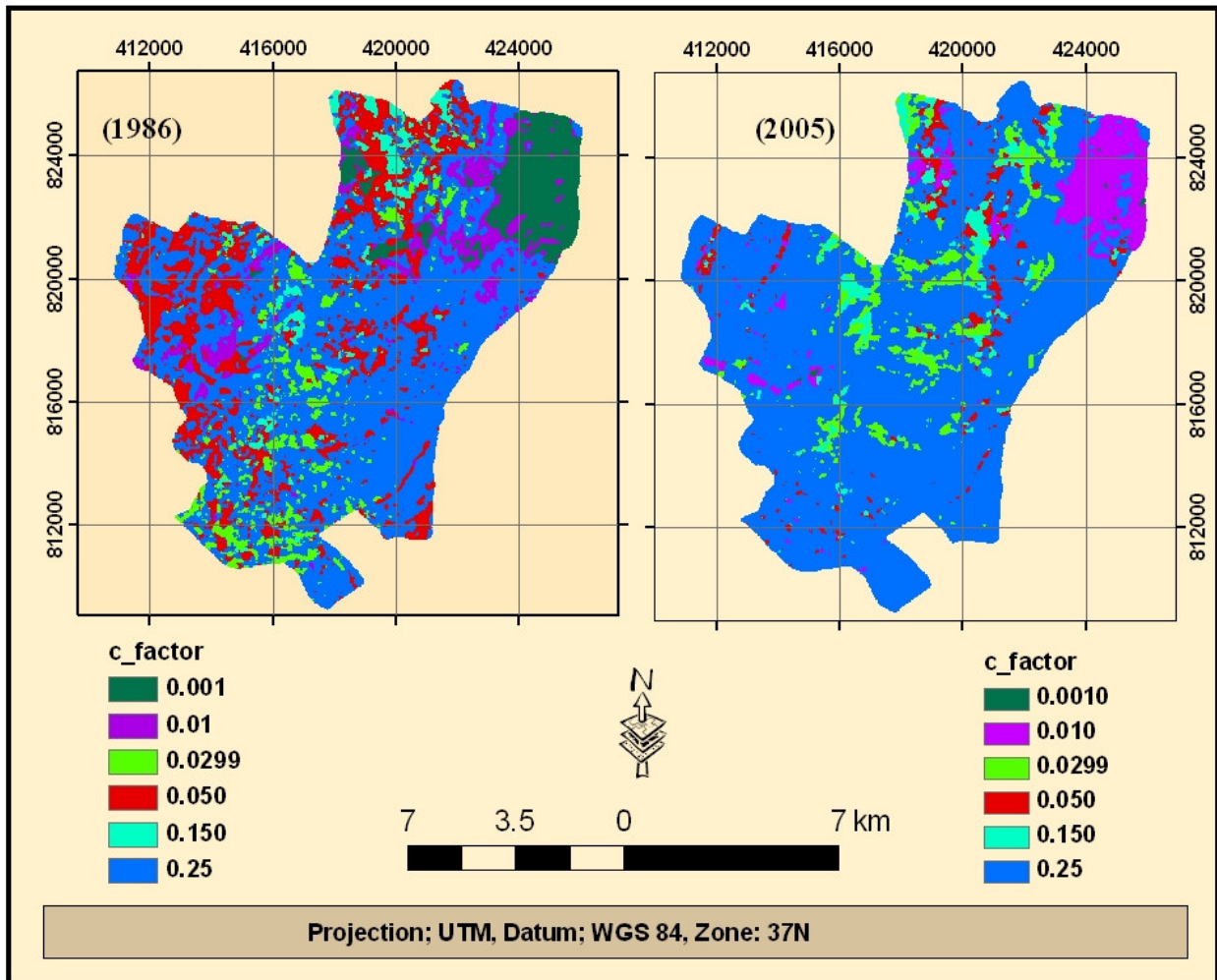


Fig 5.4: Cover factors(C) maps of study area for the year 1986 & 2005

#### 5.4.2. Soil Erodibility (K) Factor

The major soil types found in the study area are Chromic Luvisol and vertic Andosol and Luvic Phaeozems. According OESPO (1999) different soil types respond differently to erosion process. Soils vary in their resistance to erosion, which called to be erodibility, partly based on texture and amount of organic matter (Buzuayehu *et al.*, 2002). Soil erodibility defines the inherent resistance of the soil to both detachment and transport. The soil erodibility factor is a measure of the susceptibility of soil particles to detachment and transport of rainfall and runoff.

K-factor or what we call soil erodibility is a quantitative value, which experimentally determined by analysis of soil texture, structure, organic content and permeability (Wishmeier and Smith, 1978). Values range from 1.0 (most eroded) to 0.01 (almost non-eroded). Soils high in silt and very fine sand are more easily eroded than other soils. Organic matter, larger structural aggregates and rapid soil permeability all lessen the soil K factor (Raymond W. Miller and Roy L. Donahue, 1997). Hence soil type identified in the area reclassified and assigned their K value based on Hurni (1985) for Ethiopian condition and found the following layer (Fig 5.5).

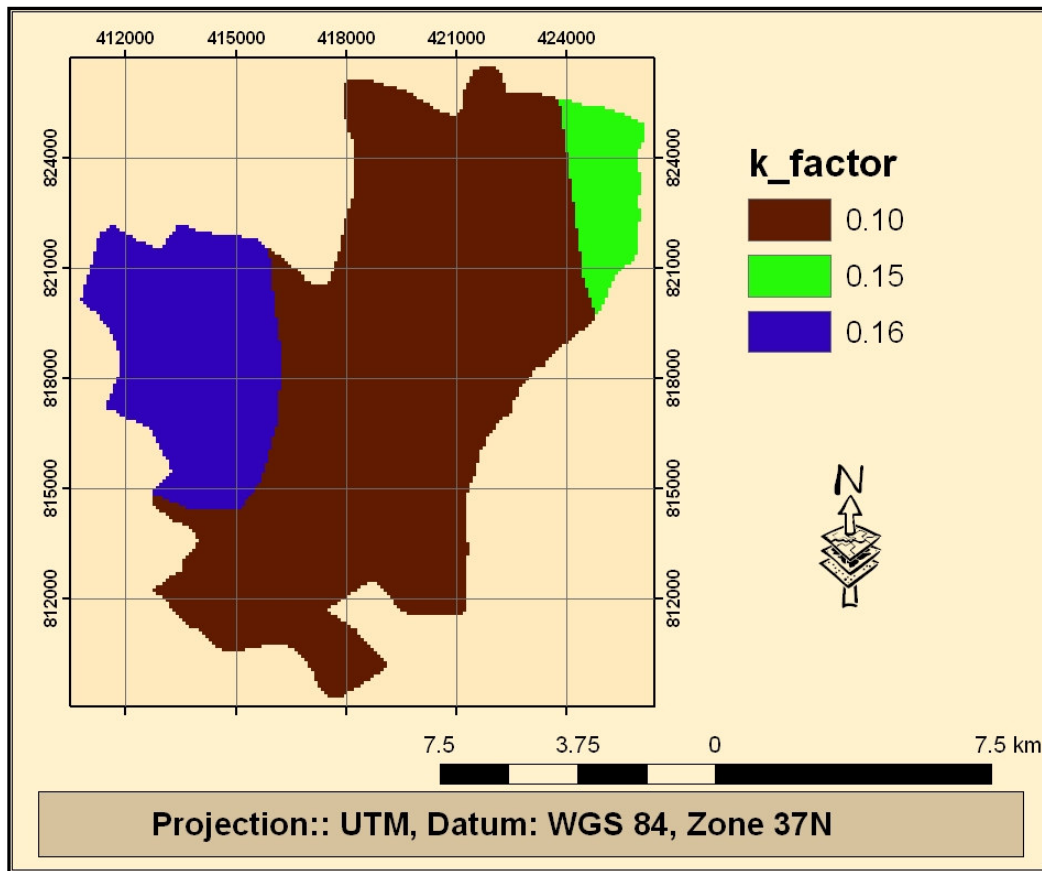


Fig 5.5: soil erodibility factor (K) maps of the study area.

### 5.4.3 Slope Length (L) Factor

According to the conventional approach of the USLE, the slope length is the determining variable of the SL factor. Slope length factor is the ratio of soil loss from the field slope length to soil loss from a 22.1m length under identical conditions (Wishmeier and Smith, 1978). Slope length was defined as the distance from the point of origin of overland flow to the point where either

the slope gradient decreases enough that deposition begins or the runoff water enters a well-defined channel that may be part of a drainage network. Hence, soil erosion increases with increases in slope gradient and slope length resulting from respective increases in velocity and volume of surface run-off water. In the case of raster image analysis, it is being recommended to calculate the flow accumulation for each pixel of the surface (Hallden, 1987). Each pixel value then represents an approximation of the total water run-off length, which can be described as the catchments area for an individual raster cell. Then, the SL factor was calculated for each pixel using the following equation and map of slope length factor was produced (Fig 5.6).

$$SL = 0.799 + 0.0101 * \text{slope length}$$

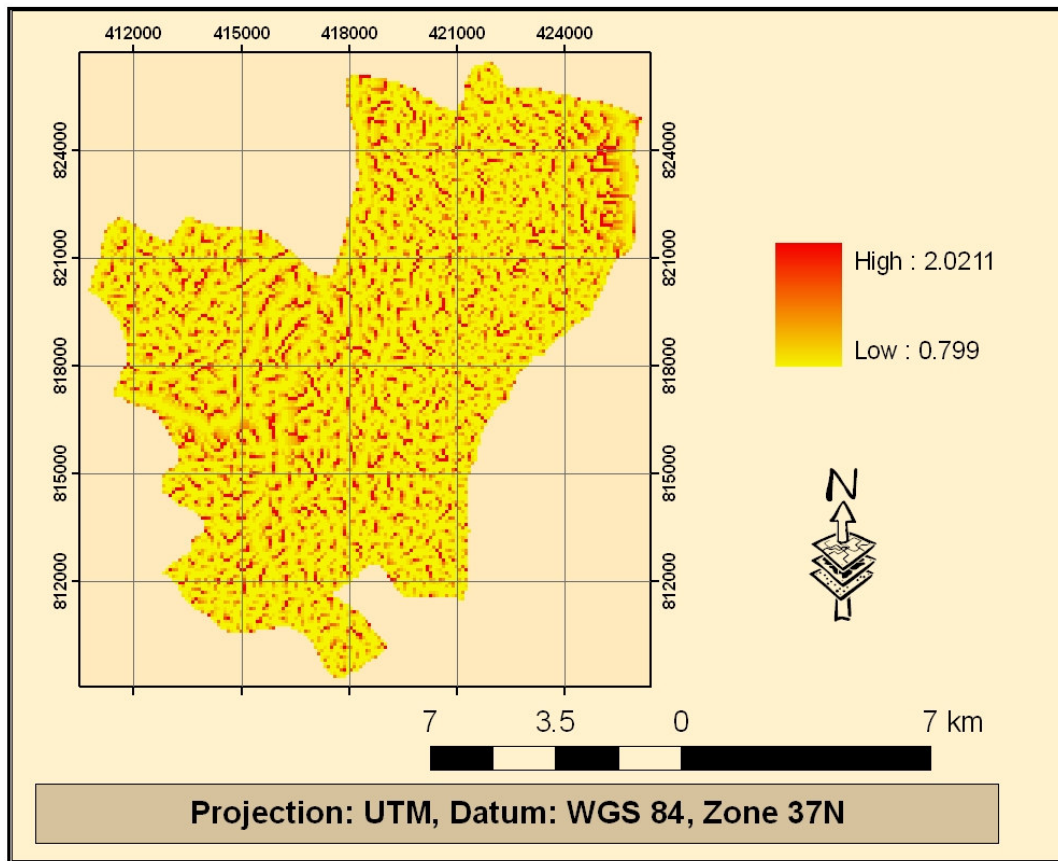


Fig 5.6: slope length factor (L) maps of the study area.

#### 5.4.4 Rainfall Erosivity (R) Factor

Soil loss is closely related to rainfall partly through the detaching power of raindrops striking the soil surface and partly through the contribution of rain to run-off. Rainfall erosivity factor is a property of rainfall and can be used to quantify the potential capacity of

rain to cause erosion in given circumstances. It measures the combined effect of rainfall and its associated runoff. The measurement performed through interpolating of rainfall data. There are many interpolating techniques which can be used to create continuous raster surface. Here again there are also different types of stochastic methods and among those kriging was selected and suitable to produce rainfall layer.

#### **5.4.4.1 Geo-statistical (Stochastic) Methods**

Geo-statistical method of interpolators assumes that some of the spatial variation of natural phenomena like rainfall of different stations may be modeled by random processes with spatial autocorrelation. Hence, the interpolator consist geo-statistical methods, which are based on statistical models that include autocorrelation (statistical relationships among the measured points). Among the different Geo-statistical methods kringing has been selected for synthesise of rainfall data to erosivity map.

#### **5.4.4.2 Kriging**

Kriging is an explicitly geo-statistical form of interpolation that uses the local spatial structure of a variable to predict values for nearby locations. The weights used to predict neighboring values are based on a fitted semi-variance plot. Semi-variance is a measure of the degree of spatial dependence between samples. The magnitude of the semi-variance between points depends on the distance between the points. A smaller distance yields a smaller semi-variance and a larger distance results in a larger semi-variance. Having this fact into consideration the annual rainfall distribution interpolated and produced a raster layer of 30m cell size. The raster layer has been sub-setted by study area for farther analysis (Fig 5.7).

Annual rainfall map has been subjected for erosivity analysis. According to Hurni (1985), the rainfall erosivity calculation for Ethiopian condition is performed based the formula given below.

$$\mathbf{R = -8.12 + (0.562 * P)}$$

Where : R.....is rainfall erosivity factor

P.....is the mean annual pericipitation(mm)

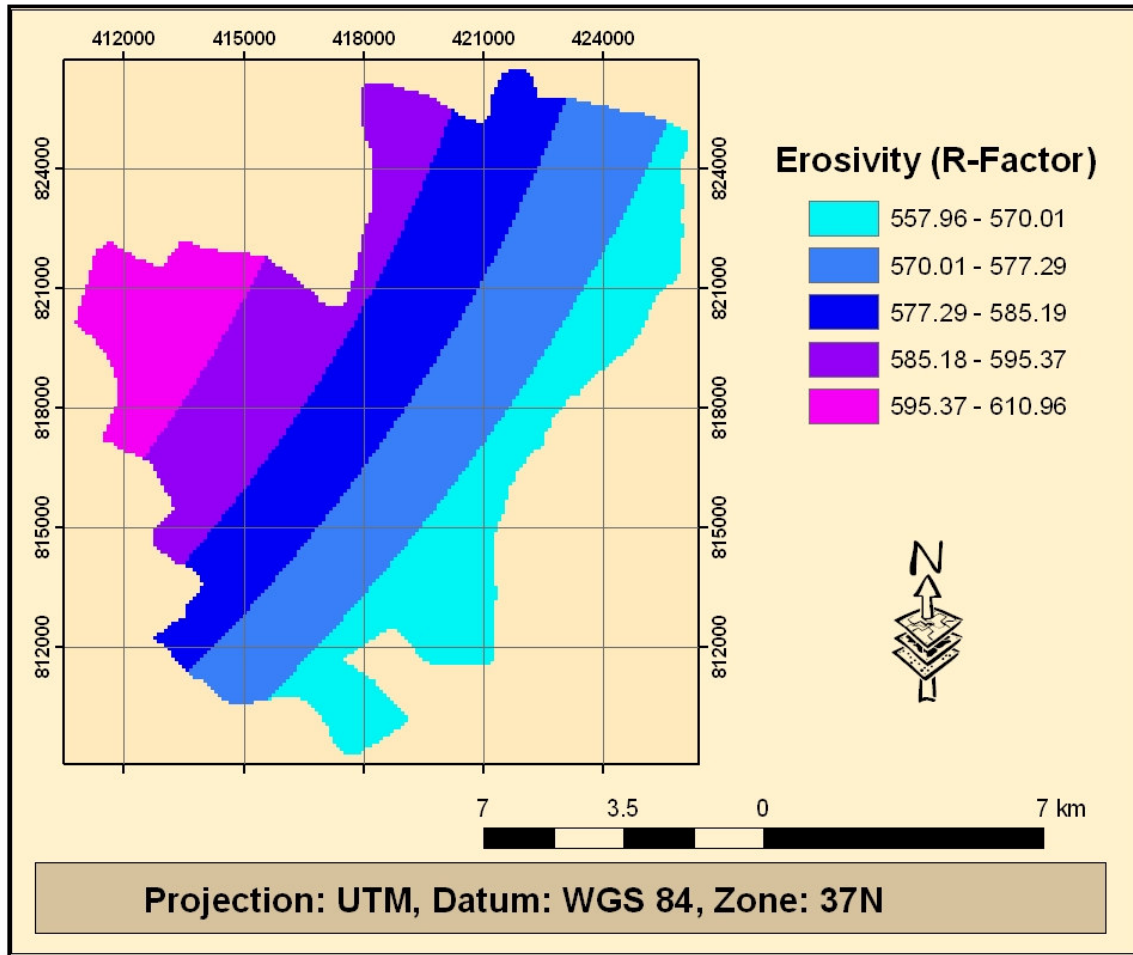


Fig 5.7: Rainfall erosivity factors(C) maps of the study area.

### 5.4.5 Slope Gradient (S) Factors

Among the six variables that are used to model soil erosion in a given area is slope. The slope again subdivides in to two components. These two components are slope length and gradient, which affect amount of soil loss according to their dominance in the area. As a general principle soil erosion will increase as slope gradient increases. Hence, the erosive capacity of runoff to detach and transport soil material also be get increase. Therefore, keeping other factors as constant, changing the slope gradient factors change soil loss.

The slope gradient was derived from the DEM by calculating the maximum rate of change in value around each pixel to its neighbors. After having a continuous slope gradient surface (Fig. 5.8) the following equation has been used to derive slope gradient factor (S) (Hallden, 1987).

$$\text{Gradient factor(S)} = 0.344 + 0.0798 * \text{slope gradient (\%)}$$

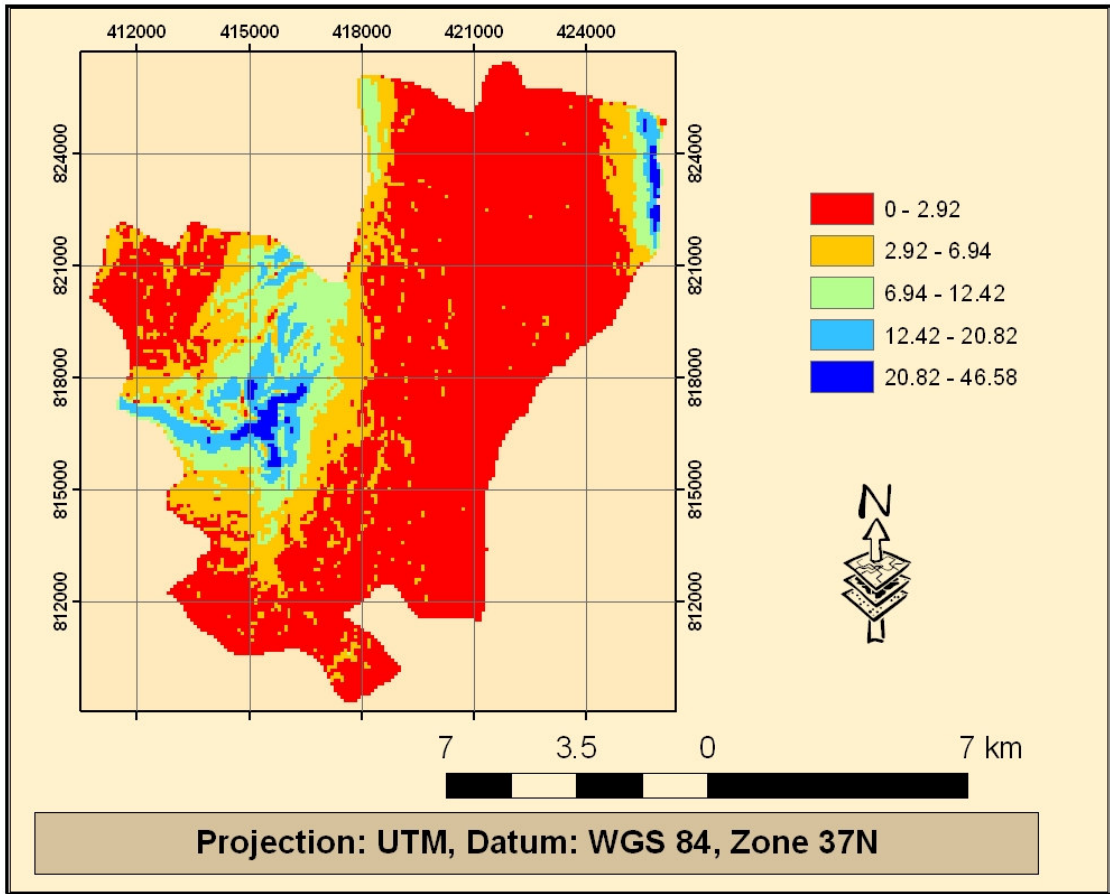


Fig 5.8: slope gradient factors(S) maps of study area

**5.4.6 Derivation of Support Practice (P) Factor**

P-factors demonstrate the effects of practice that will reduce the amount and the rate of water runoff that causes the amount of erosion to reduce. The P-factor represents the ratio of soil loss by a support practice to that of straight –row farming up and down the slope. The conservation practices principally affect erosion by modifying the flow pattern or direction of surface run-off. The most commonly used supporting cropland practices are cross slope cultivation, contour farming and strip cropping.

The P Values for the erosion control practice factor are obtained from tables of the ratio of soil loss where the practice is applied to the soil loss where it is not. With no erosion control practice, P is equal to one. This means the P value indicates reduced erosion potential, with a range between 0 to 1 because of farming practices or soil and water

conservation measures. The only farming practices increasing erosion instead of reducing is ploughing in the direction of up and down slope. Studies conducted by Hurni (1985) have found P values for various support practices and land-use cover.

As it indicated in the Figure 5.9, this study took into account temporal variation of LULC of the study area. Hence this temporal variation of LULC created spatial difference in the values of P- factor. Accordingly the P-factor values assigned for each land-use type for the period of 1986 and 2005.

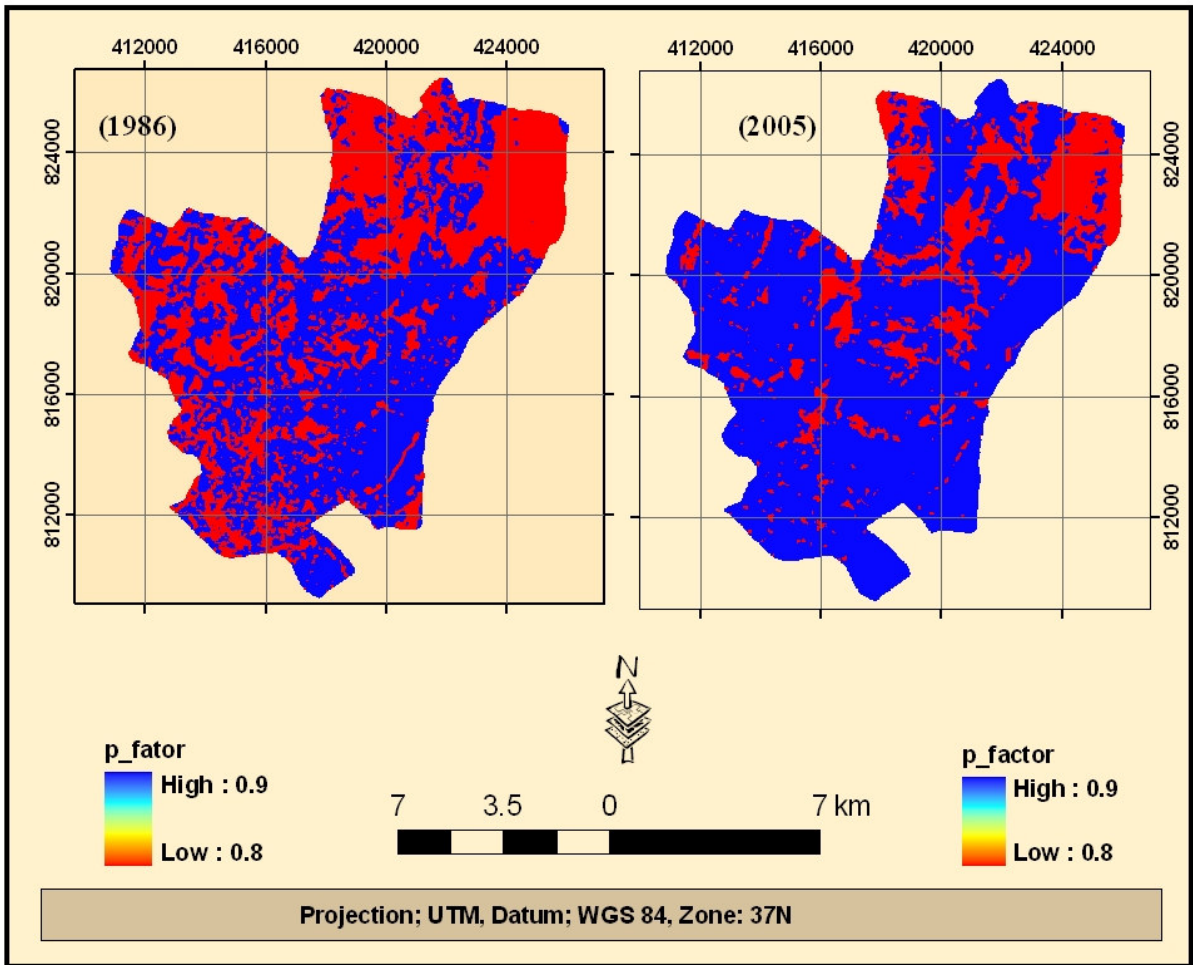


Fig 5.9: Management factors (P) maps of study area for the year 1986 & 2005

## 5.5 Socio-Economic Analysis

The socio-economic analysis encompasses the analysis of farming system and major constraint, household characteristics, and socio-economic status index analysis. For

synthesizing of these it has been used the methods of qualitative and descriptive statistics data analysis were used. This helped us to understand respondent view and understanding on land resource status.

Crop productivity data, land-holding size and livestock population data were collected from the Woreda bureau of agriculture and rural development for each Kebele and summarized for the average productivity for each crop type and zone and land holding size. However, constraints for crop production and livestock were collected using the prepared questionnaire and summarized in percentage relative to the total sample of respondents. The other socio-economic data collected through direct questionnaire survey were household age structure, sex composition, educational status and gross income and expenditure pattern. The same activities have performed for the analysis of these data like the analysis mentioned earlier.

After collecting the socio-economic status indicators of the households in each zone the index analysis have been carried out. For this study, parameters considered as socio-economic status indicators were crop productivity, income, expenditure, occupation, livestock size, household size, fuel wood consumption, source of fodder to their livestock and educational status. These data's summarized for each zone and for the total study area. Finally, the socio-economic status index calculated using the following empirical formula:

$$\text{Socio-economic Status Index} = \sum_{1}^n \pm (X \setminus Y)$$

Where, X = zonal socio-economic indicator index

Y= total study area socio-economic index

± = the negative and positive impact of indicator upon resource.

## 6. Result and Discussion

### 6.1 Land-use and Land-covers Change Detection

The use of spatial analysis enhances the understanding of the processes and causal factors of LULCC that may be useful for decision making at different levels of administration.

#### 6.1.1 Land-use and Land-cover Change between “1973 - 1986”

Table 6.1 and Figure 6.1 give land-use/land-cover pattern and change in LULC for the period between 1973 and 1986. As it is observed in the Table 6.1, the total forest cover between the years 1973 to 1986 was shrunken due to clearance of forest-land for the new expansion of crop-land and the use of wood as construction material and household energy purpose. As a result of this 940ha of land, which was forest in 1973, was changed to other LULC types by 1986. This implies that 43.6% of the total forest was deforested for the purpose mentioned earlier. In a similar manner, the area coverage of degraded forest land between the years 1973 to 1986 was reduced in its size by 16ha and transformed to other LULC types.

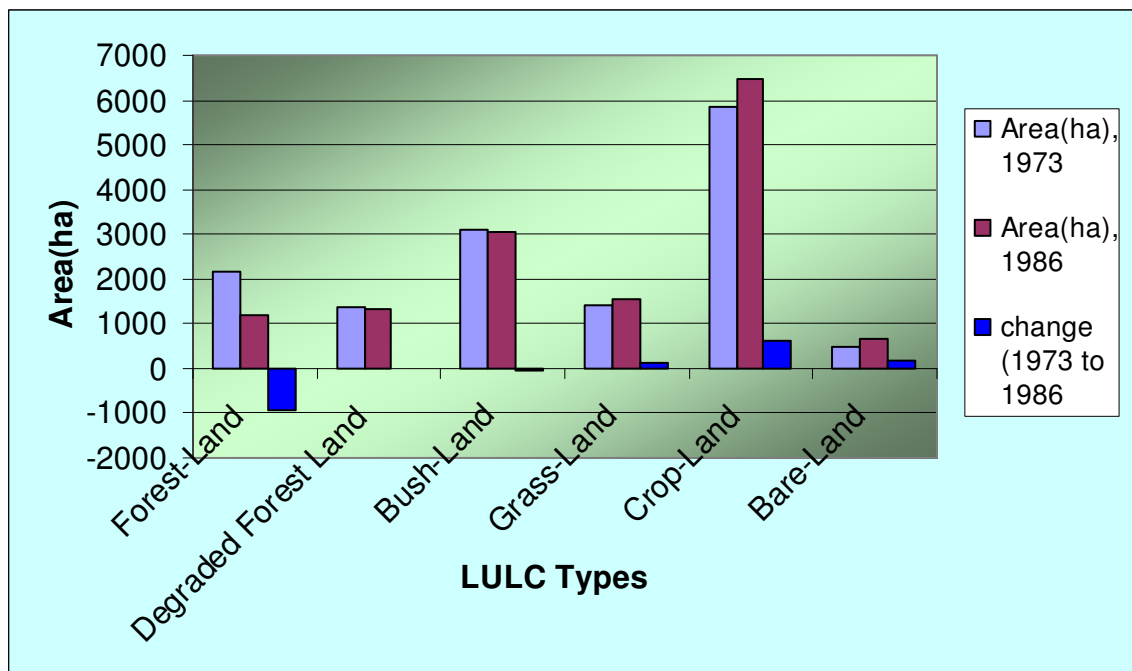


Fig.6.1: Graphical presentation of LULC change between year 1986 and 1973

The other land-use/land-cover type, which characterizes similar land-use/land-cover change, was bush-land. During 1973 to 1986, a total of 43ha bush-land , which was 1.3% original bush land, was transferred to other LULC type.

Table 6.1: Area coverage of LULC in 1973 & 1986 and change in coverage

LULC	1973		1986		Change (1973 – 1986)	
	coverage in (ha)	% cover	coverage in (ha)	% cover	Area (ha)	Area (%)
Forest-land	2154	14.91	1214	8.5	-(940)	-(43.6)
Degraded Forest Land	1350	9.43	1334	9.34	-(16)	-(1.1)
Bush Land	3096	21.58	3053	21.38	-(43)	-(1.3)
Grass Land	1430	9.99	1557	10.9	127	8.8
Crop-land	5834	40.69	6451	45.18	617	10.5
Bare Land	492	3.39	668	4.68	176	36.0

On the other hand, the change in crop-land, bare-land and grass-land were different to that of LULC types. During the period 1973 to 1986, the total area devoted for crop-land was increased and made it the largest LULC types in the region. An extent of 617ha of land, which was not initially crop-land, was added to the crop-land. It was estimated 10.5% of the initial crop-land size. The bare-land expansion was the second largest expansion during this period, although the total area coverage in both years smaller as compared to the other LULC types. As a result of this 176ha of land was added as bare land during this period which was not in 1973. This was estimated to be 36% of the initial bare land size. The grass-land was also expanded during this period. The expansion of grass-land made it the third largest expansion in the region. During the period 1973 to 1986 the grass-land increased considerable size of land. The estimated size of the land added to this LULC types was 127ha, which was estimated 8.8% of the initial land area

### 6.1.2 Land-Use and Land-Cover Change between “1986 - 2005”

Table 6.2 and Figure 6.2 give land-use/land-cover pattern and change in LULC for the period between 1986 and 2005. As it was observed in Table 6.1, the total forest cover between the years 1986 to 2005 was kept shrinking due to clearance of forest-land for the new expansion of crop-land and the use of wood as construction material and for household energy. As a result of this 1061.4ha of land, which was forested in 1986, was changed to other LULC types by 2005. This implies that 87.43% of the total forest was deforested for the purpose mentioned earlier. In a similar manner, the area coverage of bush-land was reduced significantly and made it the second most reduced land-cover type. During the period 1986 to 2005 it was reduced in its size by 2054.6ha, which was 67.29% of the same land-cover in 1986, to other LULC types.

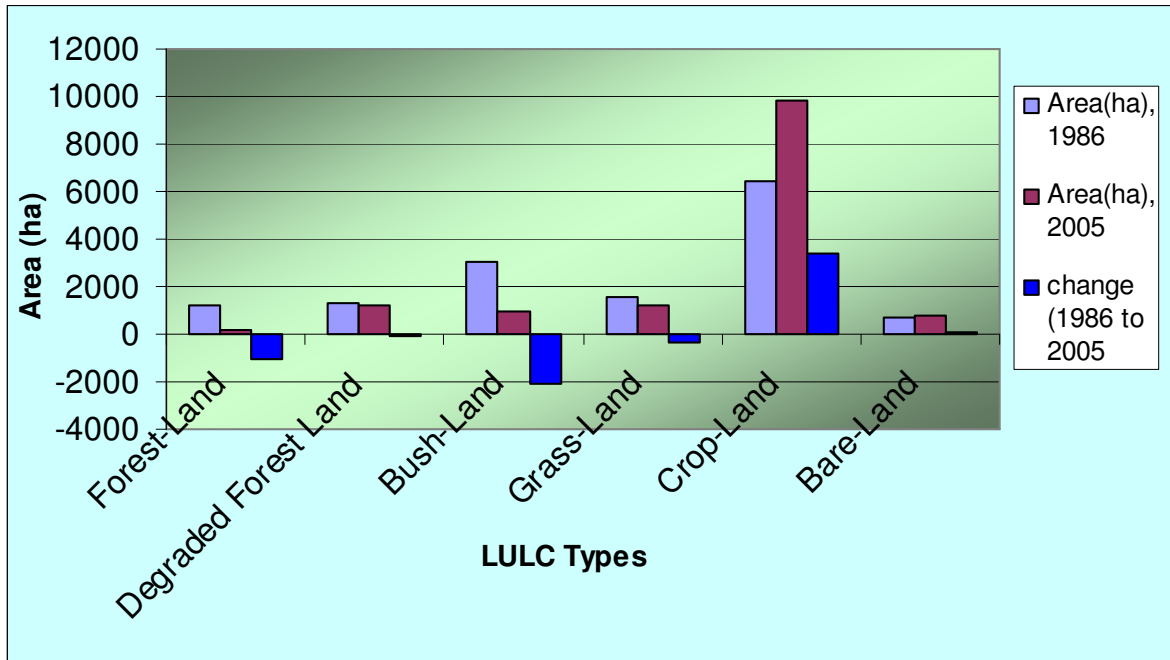


Fig 6.2: Graphical presentation of LULC change between year 1986 and 2005.

The third land-use/land-cover type, which characterizes similar land-use/land-cover change, was grass-land. The grass-land during this period reduced its size by 330ha. it was counted 21.19% of the land, which was under bush-land, transformed into other LULC types. The smallest land size reduction was exhibited on the degraded forest land-cover

during this period. Only 84ha of land was converted in to other LULC types from this cover type.

Table 6.2: Area coverage of LULC in 1986 & 2005 and change in coverage.

LULC	1986		2005		Change (1986 – 2005)	
	coverage in (ha)	% cover	coverage in (ha)	% cover	Area (ha)	Area (%)
Forest-land	1214	8.5	152.6	1.07	-1061.4	-87.43
Degraded Forest Land	1334	9.34	1250	8.75	-84	-6.29
Bush Land	3053	21.38	998.4	6.99	-2054.6	-67.29
Grass Land	1557	10.9	1227	8.59	-330	-21.19
Crop-land	6451	45.18	9868	69.12	3417	52.96
Bare Land	668	4.68	781	5.5	113	17

On the other hand the change on crop-land and bare-land were different to that of LULC types discussed earlier. In between the year 1986 to 2005 the total area devoted for crop-land was kept increasing and made it the largest LULC types in the region. As it was the leading land-use type in the year 1986 it extended its dominance in the year 2005. Hence 3417ha of land, which was not initially crop-land, has been added to the crop-land. It was estimated to be 52.96% of the initial crop-land size. The bare-land expansion was the second largest expansion during this period, although the total area coverage in both years smaller as compared to the other LULC types except in 2005. As a result, of this 113ha of land was added as bare land during this period which was not in 1986. And this estimated that 17 % of the initial bare land size.

The expansion of crop-land together with bare land in the region was increasing from time to time. The crop-land expansion was in expense of other LULC types to satisfy food demand for the ever increasing human population. This alteration of LULC type coupled with poor land management practice in the region resulted in exposing of land for erosion hazard, which was later turned to accelerated land degradation. This was evident in session 6.2.3 as the soil loss rate was significantly changed in relation to the as the

alteration of LULC of the region. Similar studies pointed out that there were changing of LULC type in most highlands of Ethiopia. Most of these studies identified that deforestation and expansion of cultivation land in to marginal areas were the principal cause of land degradation in the region (Zeleeke and Hurni 2000).

### 6.1.3 Land-use and Land-cover Dynamics

As long as there is an increase in population size in an area there is a need to change the LULC type of for the satisfaction of food demand, energy, and grazing land. Similar phenomena were observed in the study area after generating LULC change matrix on the basis of 1973, 1986 and 2005 classified images. Table 6.3 and Table 6.4 explain how each land-use/land-cover classes shared portion of study area and have underwent transformation from one type to another or being remained intact for longer time.

- ❖ Key points for analyzing land-use/land-cover change matrix:
  - Each column values represents land-use and land-cover percentage of initial state class (the initial stage)
  - Each row values gives land-use/land-cover percentage of the final state of class ( the final stage)
  - The diagonal represents where no change has occurred

The dynamicity of LULC in the study area was clearly revealed in the Table 6.3. From the matrix displayed in the above table, it can be seen that the extent of land-use/land-cover converted to other form or remain the same. The crop-land expanded in the study area at the expense of all other land-use/land-cover types. Hence crop-land gained the major share of each land-use/land-cover types during the period of 1973 to 1986. Accordingly, 52.676%, 42.799%, 42.850%, 28.449%, and 17.916% of bush-land, grass-land, degraded forest land, bare-land and forest-land converted to crop-land respectively. Although the change in total bare-land size was larger as compared to other land-use/land-cover types, the size of the land took from each land-use/land-cover types was minimum. For instance 1.010%, 0.770%, 2.015%, 4.299%, and 13.040% forest-land, degraded forest land, bush-land, crop-land and grass-land converted to bare land

respectively. Whereas the bolded diagonal values represent the unchanged land-use / land-cover types that maintained from initial stage to the final stage.

Table 6.3: Land-use and land-cover dynamics for the period 1973 to 1986.

	<b>Initial stage</b>						
	<b>Land-use\Land-cover 1973</b>						
<b>Final stage</b>	Class	Forest-land	Degraded forest-land	Bush-land	Crop-land	Grass land	Bare land
<b>L and Use/cover 1986</b>	Forest-land	<b>47.338</b>	11.314	0.955	0.256	0.023	0.000
	Degraded forest-land	18.594	<b>22.388</b>	11.220	4.366	1.499	0.660
	Bush-land	12.728	14.035	<b>22.471</b>	22.321	28.964	34.983
	Crop-land	17.916	42.850	52.676	<b>53.264</b>	42.799	28.449
	Grass land	1.930	8.089	9.824	14.959	<b>13.130</b>	6.865
	Bare land	1.010	0.770	2.015	4.299	13.040	<b>27.921</b>
	Image difference	-43.432	-1.420	-1.32	10.50	8.8	36.040

From the matrix displayed (Table 6.4), it can be seen that the size of the land-use\ land-cover converted to other form or remain intact. It is clear, crop-land expanded in the study area in the expense of all other land-use\land-cover types. Hence, crop-land gained the major share of each land-use\land-cover types during the period of 1986 to 2005. Accordingly 84.807%, 72.573%, 63.308%, 50.407%, and 23.159% of grass-land, degraded forest land, bush-land, bare-land and forest-land converted to crop-land respectively. On the contrary forest-land took the smallest portion of size from each land-use\land-cover types. For instance 1.029%, 1.354%, 0.808%, 0.616%, and 0.377% of degraded forest-land, bush-land, crop-land, grass-land and bare-land converted to forest-land respectively. Whereas the bolded diagonal values represent the unchanged land-use / land-cover types that maintained from initial stage to the final stage.

Table 6.4: Land-use and land-cover dynamics for the period of 1986 to 2005

		<b>Initial stage</b>					
		<b>Land-use\Land-cover 1986</b>					
<b>Final stage</b>	Class	Forest land	Degraded forest-land	Bush-land	Crop-land	Grass-land	Bare land
<b>L and use\ cover 2005</b>	Forest-land	<b>2.743</b>	1.029	1.354	0.808	0.616	0.377
	Degraded forest-land	64.366	<b>8.716</b>	5.033	2.468	1.346	2.810
	Bush-land	3.913	6.154	<b>10.689</b>	5.998	4.716	12.298
	Crop-land	23.159	72.573	63.308	<b>77.944</b>	84.807	50.407
	Grass-land	3.111	6.835	11.782	8.588	<b>6.083</b>	13.368
	Bare land	2.709	4.693	7.834	4.193	2.431	<b>20.740</b>
	Image difference	-87.43	-6.29	-67.29	52.96	-21.20	17.042

Significant LULC change was observed during 1973 to 1986 and 1986 to 2005. In both situations the largest positive change was observed in cultivated (crop) land and followed by bare land (Table 6.4 and Table 6.3). This implies that i) land that was in relatively permanent cover has either become bare or under minimum cover, providing little protection from erosive rain, ii) the soil erosion problem was likely to be aggravated as this cover change took place in the steep-slope hilly areas of the region. That is why the threat of land degradation increased in the region that is caused by erosion.

## 6.2 Soil Loss Estimation

### 6.2.1 Soil Erosion in 1986

Based on the spatial difference of the six USLE parameters the influence for soil loss varies accordingly. Fig 6.3 the spatial variation of soil loss rate in a region as evident for spatial distribution of all erosion governing factors.

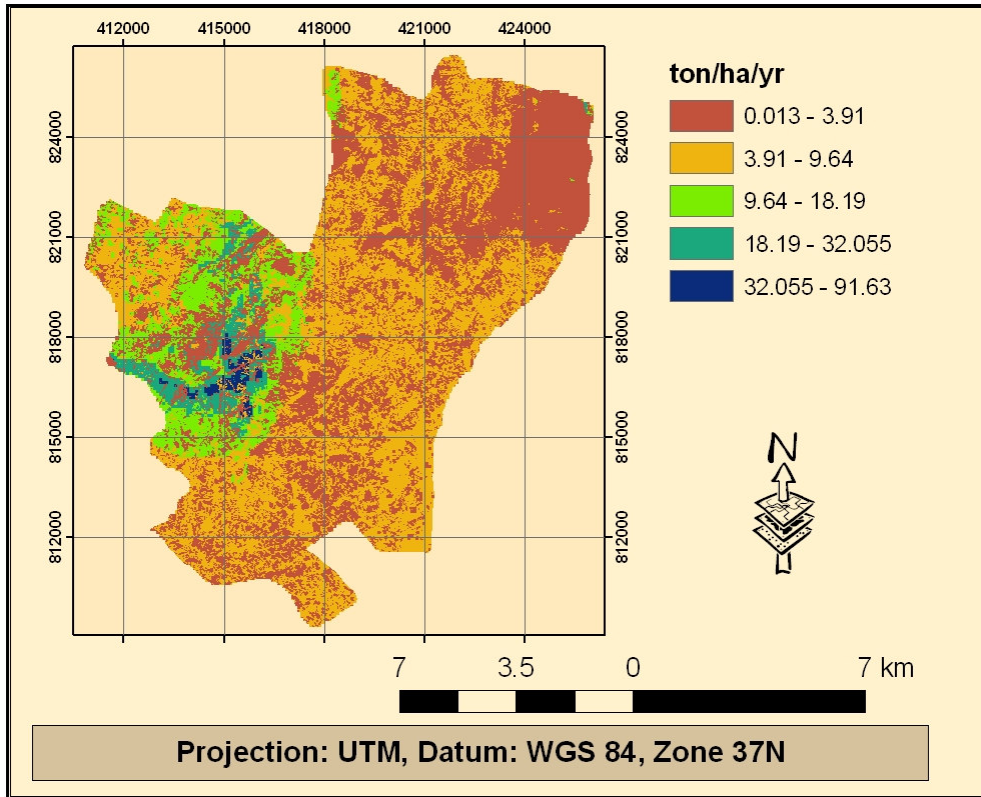


Fig 6.3: Soil erosion rate for year 1986

As given in the Table 6.5, the study area experienced soil loss rate range from 0.013 to 91.63ton/ha/year and the mean erosion rate was 6.2ton/ha/year. However, there was spatial variation in soil loss rate in the region. Accordingly, 82.64% of the study area experience low to medium soil loss rate. 12.07% of the region was under the moderately to high soil loss rate condition. The remaining 5.29% of the study area was in state of high to very high soil loss rate condition.

Table 6.5: Soil erosion rate and its area coverage

Range	Soil loss rate (ton/ha/yr)	Area covered (ha)	% covered
1	0.013 – 3.91	5852.25	41.64
2	3.39 – 9.64	5761.8	41
3	9.64 – 18.19	1696.14	12.07
4	18.19 – 32.055	562.68	4
5	32.055 – 91.63	180.63	1.29
Mean	6.2		

## 6.2.2 Soil Erosion in 2005

According to the spatial differences of the six USLE parameters that influence soil loss, the study area exhibited spatial variation of soil loss. Fig 6.4 depicted the spatial variation of soil loss rate in a region as evident for spatial distribution of all erosion governing factors.

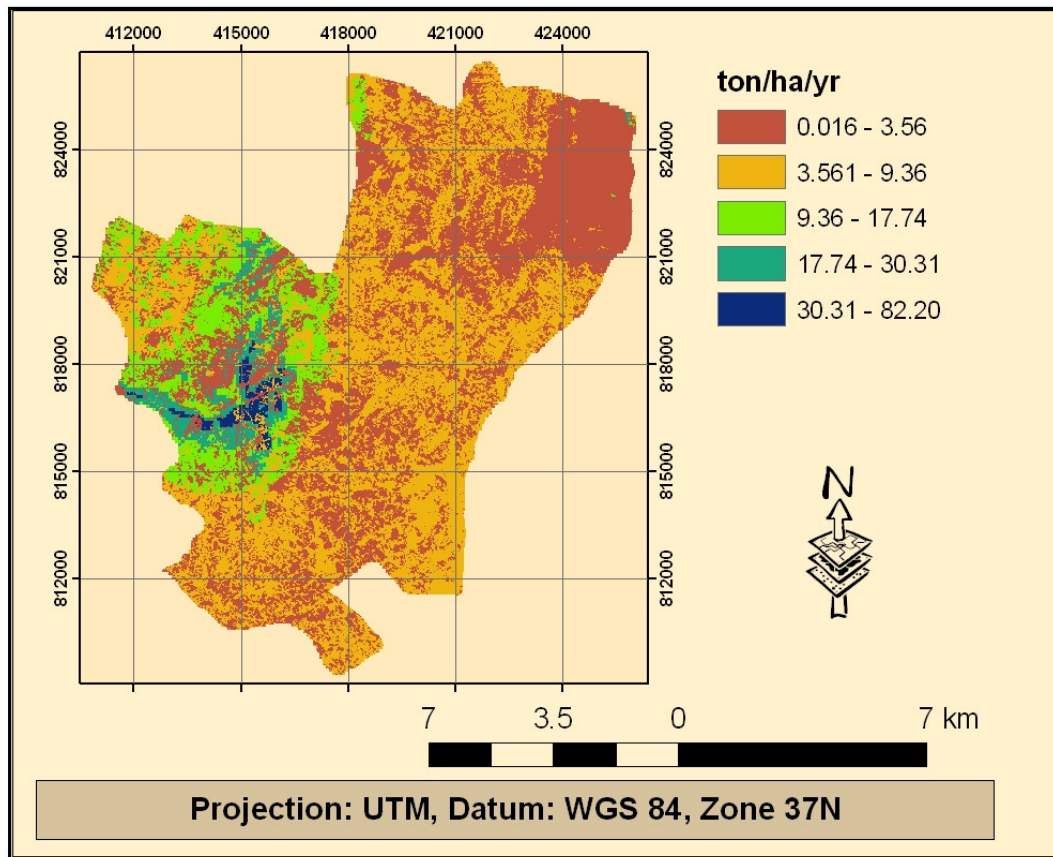


Fig 6.4: Soil erosion rate for year 2005.

Table 6.6: Soil erosion rate and its area coverage.

Class	Soil loss rate (ton/ha/yr)	Area covered (ha)	% covered
1	0.016 – 3.56	2766.51	19.76
2	3.56 – 9.36	7162.47	51.15
3	9.36 – 17.74	2827.44	20.19
4	17.74 – 30.31	949.77	6.78
5	30 – 82.20	296.1	2.11
Mean	8.43		

As it presented in the Table 6.6 the study area experienced soil loss rate range from 0.016 to 82.2ton/ha/year and the mean erosion rate was 8.43ton/ha/year. However, there was spatial variation in soil loss rate in the region. Accordingly 70.91% of the study area was covered with low to medium soil loss rate. An extent of 20.19% of the region was under the moderately to high soil loss rate condition. The remaining 8.89% of the study area was in the state of high to very high soil loss rate condition.

### 6.2.3 Soil Loss from Different Land-Use and Land-Cover in 1986 and 2005

As shown in the Table 6.7 there was variation of the amount and rate of soil loss in both cases. However this variation was resulted by the area coverage of each land-use/land-cover type, which was true for the rate and total amount of soil loss.

Table 6.7: Soil loss pattern in different LULC type and period (1986 – 2005)

Land-use/land-cover	1986		2005		% contribution to total soil loss		Change (%)
	soil loss (ton\ha)	Mean soil loss (t\ha\yr)	soil loss (ton\ha)	Mean soil loss (t\ha\yr)	1986	2005	
Crop-land	77840	10.04	112731.4	10.4	89.35	95.55	44.82
Bare Land	2805.8	5.57	2913.12	5.60	3.22	2.47	3.82
Grass-land	895.23	1.02	1004.7	1.05	1.03	0.85	12.23
Bush-land	5111	1.89	774.2	1.46	5.87	0.66	-84.85
Degraded Forest-land	409.15	0.41	552.5	0.5	0.47	0.47	35.04
Forest-land	54.9	0.044	1.7	0.098	0.063	0.0014	-96.9
Total	87116.049	6.2	117977.63	8.43	100	100	35.43

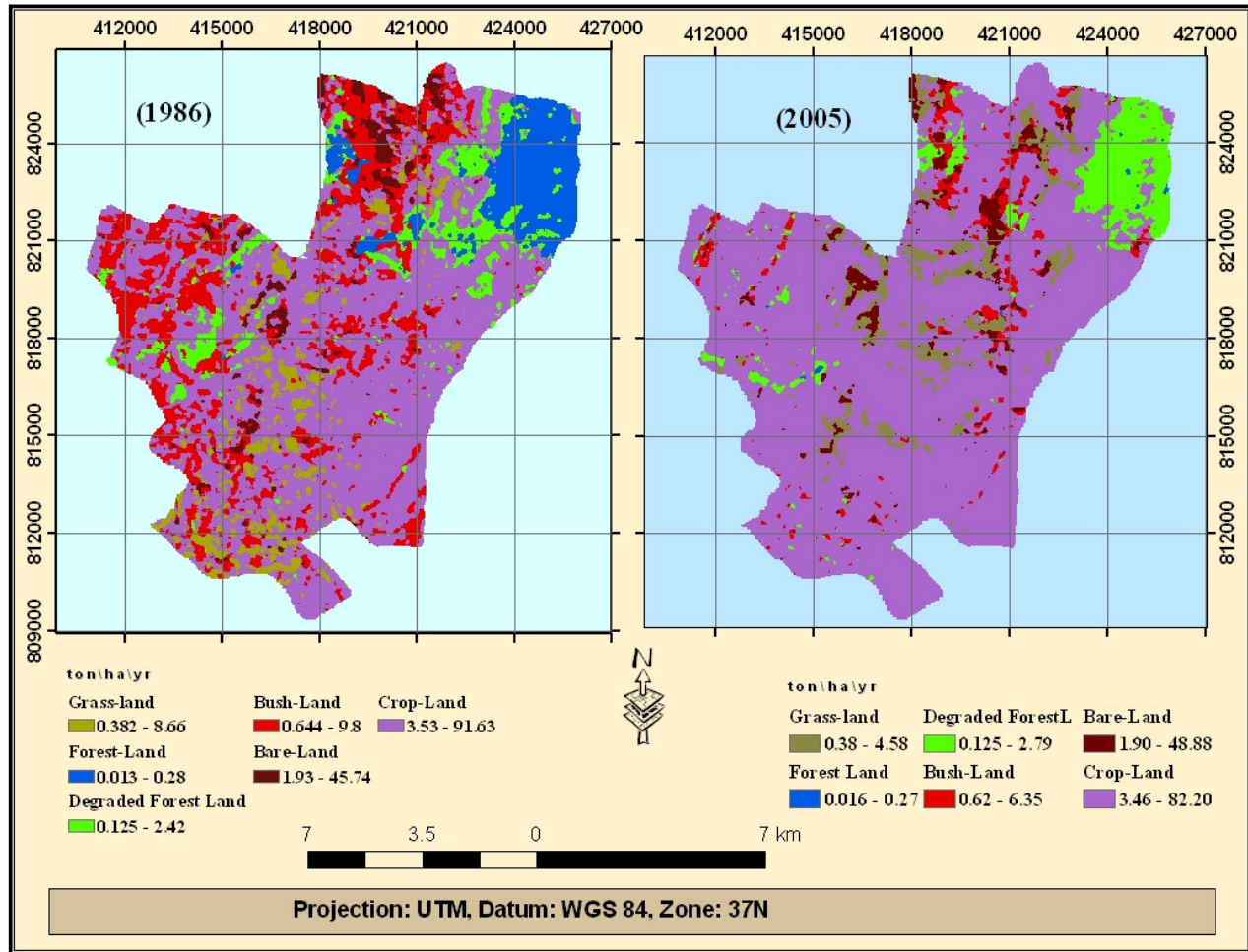


Fig 6.5: Spatial and temporal variation of soil loss rate at different LULC for the period of 1986 and 2005

Crop-land in both periods took the maximum shares of soil loss from the region. So, as it is revealed in 1986, the amount of soil loss from this region was 77840 ton/yr, which was 89.35% of the total soil loss. The estimated mean soil erosion rate was 10.04ton/ha/yr. In the same land-use type, in 2005, the soil loss accounted for 95.55% of the total soil loss and the estimated amount of soil loss was 112731.4ton/yr. This region exhibited an overall mean soil loss of 10.4ton/ha/yr. Although the difference between the mean soil erosion rates was small, the difference between the amounts of soil loss from the region was very significant and it took 44.82% of the soil loss in the year 1986. This could be justified due to the expansion of crop-land and frequency of tillage. Cropping is one of the main factors of degradation, not only because it replaces vegetation, but also because crops are mostly grown on slopes and seed beds have to be ploughed several times,

resulting in the breaking up of soil aggregates that are easily eroded (Constable and Belshaw, 1989). The second most land-use/land-cover type that contributed large percentage of soil loss in 1986 was bush-land, but it was not the case in 2005.

The contribution of forest and bush-land to soil loss was decreased significantly during 1986 to 2005 even though there was soil erosion in smaller rate. Hence the difference was mainly due to the shrinkage of land coverage in both the land-use types. In general, the total amount of soil loss estimated in 1986 was changed by 35.43% in 2005 and mean soil erosion rate was changed from 6.2 to 8.43ton\ha\yr. Hence, this increment in amount of soil loss and rate are evident for land degradation condition in the region. Such situation not only reduces land productivity and income, but also poses threat to household food security in the region.

### 6.3 Change in Soil Erosion Hazard from 1986 to 2005

As it is evidenced in the Table 6.8 soil erosion hazard condition and extent in area coverage changed significantly from one state to the other. This was helped us for the analysis of change in level of land degradation together with the change in land-use/land-cover change in the region.

Table 6.8. Area coverage of different soil loss hazard at different periods (1986 to 2005).

<b>Erosion hazard</b>	<b>Area coverage (%)1986</b>	<b>Area coverage (%) 2005</b>	<b>Change in area coverage (%)</b>
Low to medium	82.64	70.91	- 11.73
Medium to high	12.07	20.19	8.12
High to very high	5.29	8.89	3.6

Although the change in “low to medium” soil erosion hazard indicated shrinkage (11.73%) in the area coverage, the change is favored for the expansion of the next level of erosion hazard. Therefore, 8.12% of the land which was “low to medium” soil erosion hazard in 1986 was converted to “medium to high” erosion hazard condition. Also 3.6% of the land mass in the region which was in state of “low to medium” erosion hazard condition in the year 1986 has been shifted to state of “high to very high’ erosion hazard

condition in the year 2005. The farming system coupled with the ever increased population in the region could worsen the condition if no corrective measure is introducing in the region.

## 6.4 Soil Degradation Index (DI)

Even though there was deterioration in all soil nutrient level in zone one, but the level of deterioration was better than the other zones. The better status of nitrogen and SOC could be low soil loss rate (4.88ton\ha\yr), N-containing artificial fertilizer supply and residual effect of recent past forest material. As it was explained in Table 6.10, 25.74% of this zone was covered by forest in the year 1986. Similar phenomena with slight difference observable in the region of zone three where deterioration was characterized in all soil properties (Table 6.9), better status than zone two. The positive value for bulk density did not mean improvement rather it was deterioration and the reverse is true for negative value. On the other hand, zone two depicted different phenomena than the two zones. This difference could be explained due to large soil loss rate (12.45ton/ha/yr) in the region than the rest of the zones.

Table 6.9. Zonal degradation indices (%) for some soil properties relative to the forest region of study area.

Soil Properties (top 20cm depth)	Average Value				Degradation Index(DI)		
	Forest region	Zone one	Zone two	Zone three	Zone one	Zone two	Zone three
Organic Matter (%)	2.91	2.87	2.8	2.81	-1.39	-3.93	-3.56
Total Nitrogen (%)	0.31	0.29	0.275	0.3	-6.89	-12.72	-3.33
Bulk density(gm/cm <sup>3</sup> )	1.21	1.31	1.41	1.28	7.63	14.18	5.46
CEC [ (cmol)(+) /Kg]	42.83	40.5	39.2	40.1	-5.75	-9.26	-6.81
Available Potassium(mg/Kg)	591.1	588.2	579.5	585.4	-0.49	-2.00	-0.97
Total					-6.902	-13.73	-9.2

Source: Alaba Wereda Bureau of Agriculture and Rural Development

Soil properties in the three zones illustrate that, some of them show positive status where as some of them in state of deterioration for different reasons Table 6.9. But the overall DI for all zones are negative, which means soil is deteriorated due to the process of soil erosion. Similar explanations were made by Adejuwon and Ekanade (1988) and Mulugeta (2004), the overall soil properties could be shifted as land management changes. If some corrective measure is not applied for each zone, condition could be worsening in the future for sustain crop production and natural resource utilization

### 6.5 Resource Status at Different Zone

The total value of degradation index in each zone that was estimated in Table 6.9 was used for land resource status assessments in different region as it is explained in the Table 6.10. The result shows that, in 1986, 25.74% of zone one was covered with forest. However, the forest cover in 2005 was changed and shared 0.2% of the region. Although there was such tremendous amount of forest loss from zone one, the annual soil loss rate from this region was the smallest of all zones. As compared to other zones, this zone was relatively less sensitive to soil loss with the shrinkage in forest coverage.

Table 6.10: Resource status at different zones

Locations	Forest cover (%)			Soil loss(t/ha\yr)			% contribution to soil loss			DI	SI
	1986	2005	change	1986	2005	change	1986	2005	change		
Zone one	25.74	0.2	25.54	3.09	4.88	1.79	16.8	19.05	9.73	6.9	0.07
Zone two	0.213	0.103	0.11	9.23	12.45	3.22	45.2	45	15.79	13.73	29.3
Zone three	0.11	0	0.11	6.54	8.35	1.81	38	35.95	10.55	9.2	16.45

Although small size of forest coverage was identified in the years 1986 and 2005 in zone three, annual soil loss rate was significant. Table 6.10 clearly explains the relation of deforestation and change in soil loss from the region. The analysis revealed that zone two was more sensitive for land degradation than that of zone one with slight change of forest cover in the region. The forest coverage in the same zone in year 1986 and 2005 was very

small and the change during this period. However, the change in annual soil loss rate was the greatest as compared to other two zones Fig 6.6. From these analyses it was drawn regression equation and correlation coefficient which explained the relation of sensitivity index and degradation index. The outcome depicted that the two variables are highly correlated ( $R^2= 0.9359$ ). Hence, there was a direct relationship between degradation index and sensitivity index. Therefore areas, which were highly sensitive for small forest cover loss to soil loss were also be highly deteriorated (Fig 6.7).

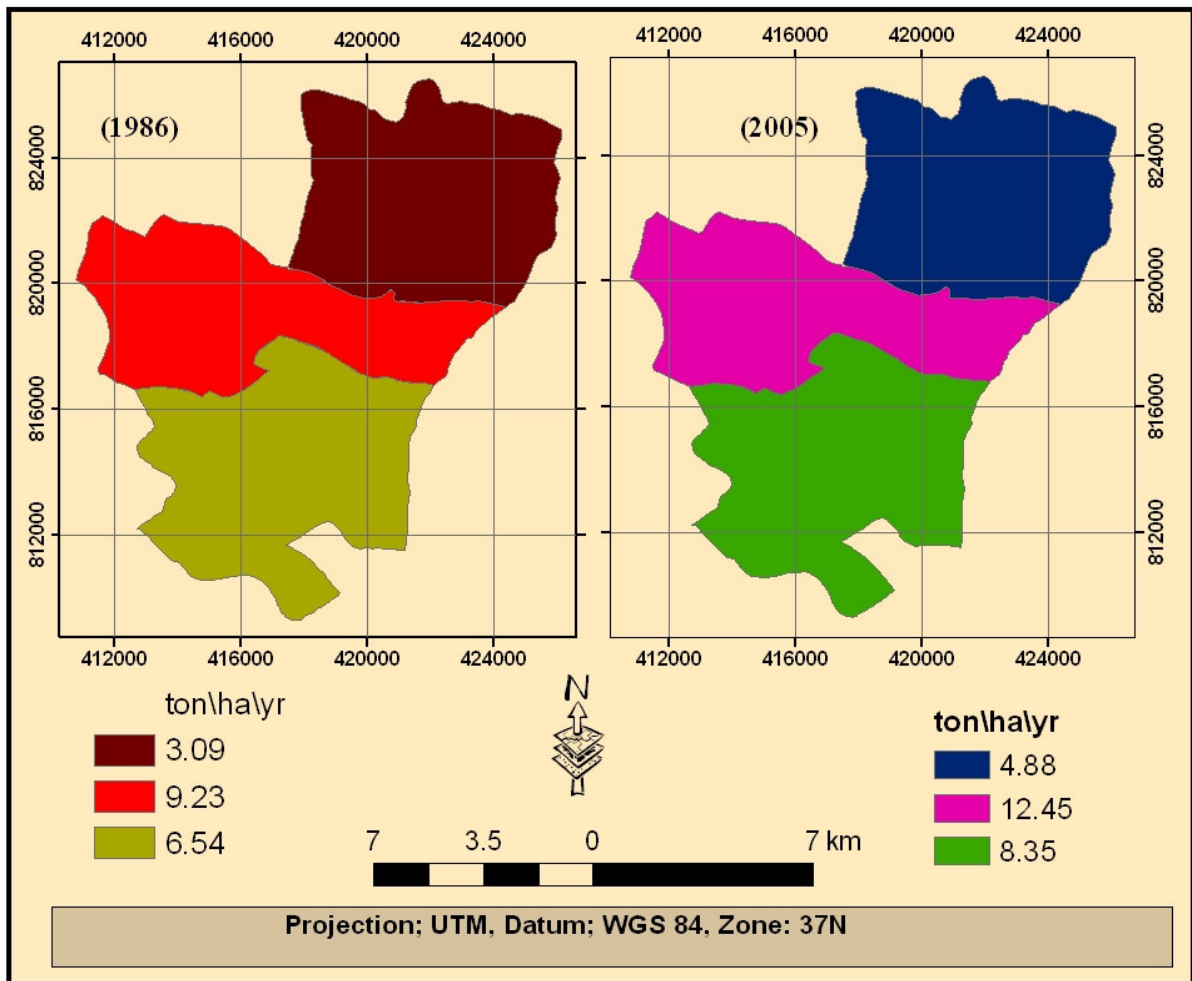


Fig 6.6 Mean soil loss at different zones for the period of 1986 & 2005

In general, forest clearance combined with other factors like the case of zone one aggravate soil erosion and consequently land degradation in the region. Although, other factors which worked together for the cause of land degradation, deforestation was one of the major factors, which alter land degradation process. Similar phenomena observed at

country level (Tamir, 1997). According to him the rate of deforestation in Ethiopia is alarming and the rate of afforestation is very negligible in light of the very high rate of forest clearing for fuel, expanding agricultural land and construction purposes. Deforestation leaves the land surface barren and open to serious land degradation processes.

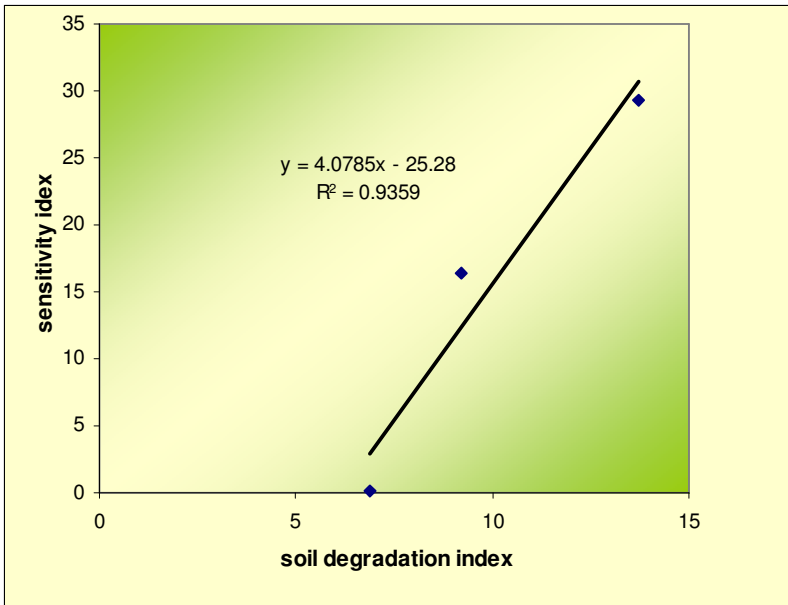


Fig 6.6: zonal soil loss sensitivity Vs degradation index (DI)

## 6.6 Socio-economic Characteristics

### 6.6.1 Household characteristics

The largest average family size found in zone three was 6.15 persons, which was followed by zone two in which 5.8 persons and the smallest was zone one which had 5.2 persons. Similar variations were observed in the average land holding size in each of the zones of the study area. The maximum average land holding size was 2.23ha which was a characteristic of zone one. The second maximum average land holding size was 1.95ha which was observed in zone three. The minimum average land holding size is 1.71ha and this was in zone one.

The age group in each zone varies differently. The maximum percentage observed was the age group of 0-10 which was 15.38% in the region of zone three. The second

maximum percentage score under the same age group in the region which was 15.13% zone two. The minimum score for this age category was 14.2% in the region of zone one. Similarly, variation was observed in the age group 10-14. The maximum percentage observed was 34.2% in this region of zone three, followed by 31.93% in the region of zone two. The minimum score in this age category was 28.5% in the region of zone one. However, different age groups of 15-64 showed variation pattern observed in those different zones as compared to the above two age group category. Accordingly, the maximum percentage observed was 56.73% in the region of zone one followed by 52.94% in the region of zone two. The minimum score within the same age category was 42.74% in the region of zone one. According to the survey, zero percentage recorded in the region of zone one and zone two but 7.7% in region of zone three in the age category of >65 year.

Table6.11: Household profile for three zones in the study area.

Zone	Average LH (ha)	Average HH size	Age group (%)				Educational status (%)			
			0-10	10-14	15-64	>65	Illiterate	Read and write	primary	secondary
Zone one	2.23	5.2	14.4 2	28.85	56.73	-	60.63	10.5	23.1	5.77
Zone two	1.71	5.8	15.1 3	31.93	52.94	-	65.8	10.92	21.6	1.68
Zone three	1.95	6.15	15.3 8	34.2	42.74	7.7	62.7	9.3	25.7	2.3

LH= landholding, HH= household

It was believed that the level of educational background of the household member was an important characteristic for the readiness of the household for new idea and innovations. Based on the survey result (Table 6.11), the percentage of illiteracy in three zones varied. The maximum percentage of illiterate was 65.8% and literate was 39.37% in zone two and zone one, respectively. The next maximum percentage of illiterate was 62.7% and literate was 37.3% is zone three. The minimum percentage of illiterate was 60.3% and literate was 34.2% in zone one and zone two respectively.

## 6.6.2 Crop production

Generally, the area characterized with mixed agriculture activities where crop production and livestock rearing goes side by side (Plate 1). According to the survey agricultural activity is the sole economic sector in the region which generated income and other basic needs. The major crops grown in the study area were maize, wheat, finger millet and teff. There were other important crops cultivated in the region which cover very small area and small share of annual crop production in the region.

The average annual crop productivity varied from zone to zone (Table 6.12). The maximum average maize productivity was observed in the region of zone one which exceeded the productivity of zone two by 15.14% and zone three by 5.5%. The average maize productivity of zone three was in excess of the average productivity of zone two by 9.15%. In a similar fashion, the maximum average wheat productivity was in the region of zone one. It exceeded 3.72% and 12.6% of the average productivity of zone three and zone two, respectively. Similarly, the average wheat productivity of zone three was exceeded 7.9 % of zone two. In the same way the maximum average finger millet productivity was in zone one which exceeded 2.95 % and 9.2% of zone three and zone two, respectively. The minimum productivity observed in crop type teff. Meanwhile, the maximum average teff productivity was observed in zone one which was in excess of 7.5% and 1% of zone two and three, respectively.

Table 6.12: Major crop productivity.

Major crop produced	Average crop productivity (qt/ha)		
	Zone one	Zone two	Zone three
Maize	19.011	16.51	18.02
Wheat	13.4	11.4	12.92
Teff	7.47	6.95	7.4
Millet	11.53	10.47	11.2
TOTAL	12.85	11.33	12.38

Source: Alaba Wereda Bureau of Agriculture and Rural Development



Plate1: Cultivation production and crop-land expansion.

In general the crop productivity varied from zone to zone. The survey result agreed with the finding of Greenland *et al.* (1994), the immediate consequence of land degradation was reduced crop yield, followed by economic decline and social stress. Accordingly, the overall crop productivity of zone one exceeded by 13.41% and 3.8% of zone two and zone three, respectively. These variations of crop productivity across the zones could be attributed on the variations of land degradation caused by soil erosion. Soil loss caused by erosion reduces soil depth, consequently decreasing the amount of soil moisture and leading to the loss of plant nutrients. This contributes to the loss of grain production (NCS, 1992; FAO, 1984).

### **6.6.3 Farmer Perception for Crop Production Constraint**

As it is observed in the Table 6.13, the majority of farmers, whom counts 60.87%, in zone one perceived an increment of crop productivity for the last five years. However, the

majority of farmers in the rest of the zones perceived that crop productivity decreased. According to the Table 6.13 65% and 50% of the respondents in zone two and zone three, respectively, believed crop productivity decreased in the last five years.

Table 6.13: Crop productivity based on farmer's perception for the last five years.

Crop productivity	Farmer's perception (%)		
	Zone one	Zone two	Zone three
Increased	60.87	35	40
Decreased	39.13	65	50
Unchanged	-		-
Unknown	-		10

Based on the farmers' perception presented in the Table 6.14 major problems which took the first rank for crop production in different regions were shortage of cultivated land, low land productivity and poor agricultural input supply for zone one, two and three, respectively. A study on Ethiopian farmers' attitudes to land degradation and conservation by Admassie and Gebre (1985) indicated that farmers were aware of the problems of land degradation. Erosion was identified as the main cause for land degradation, followed by drought, deforestation, rainfall, and improper farming practices. According to the farmers, the effects of land degradation were famine, drought, reduced yield and poverty. But almost in all zones, farmers perception for land degradation was very low and gave it the least rank as constraints for crop production. This could be reasoned that land degradation is often a very slow process and may be almost invisible. A research in Beressa watershed in central highland of Ethiopia revealed that most of the farmers in this watershed associated severity of erosion problems with the appearance of visual evidence (rills and gullies) only (Aklilu, 2006). Farmers, thus may not observe ongoing erosion or nutrient depletion problems, or perceive them as immediate problems. But, they do observe low or declining of crop yield. The main explanation why farmers perceive decline of yield as a main consequence of soil erosion was probably caused by the fragmentation and decline of soil fertility, which farmers can easily recognize (Aklilu and Graaff, 2006).

Table 6.14: Major crop production constraints ranked according to farmers perception in each zone.

Major crop production constraints	Farmer's perception (rank 1= highest)		
	Zone one	Zone two	Zone three
Cultivated land shortage	3	1	2
Land degradation	5	5	4
Low land productivity	2	3	1
Poor market facility	4	4	3
Poor agricultural input supply	1	2	5

Farmers perceived the severity of erosion differently (Mekuria *et al.*, 2009). Most of the farmers considered fragmentation of agricultural and grazing lands, decline of soil fertility, and decline of crop yield (which in turn leads to poverty) as the main consequences of soil erosion.

#### 6.6.4 Livestock production and its constraints

Livestock production constitutes the second important economic sub sector, next to crop production upon which the livelihood of the community is based in all regions of the study. Livestock are insurance against the risk of crop failures. Household use their animals as source of disposal income, saving food, means of transportation, source of energy and organic fertilizer. Besides, draught animals provide traction power for plowing and trashing.

As it is evidenced in the Table 6.15 the total grazing area available in each zones are very far from the total land required for grazing land. Therefore, excluding the arable land and assuming the other land-use type serves all for grazing up on which the livestock expected to graze especially during the rainy season, when the arable land are under crop, the total grazing area would be 2252.3ha, 1161.14ha and 956.13ha of zone one, two and three, respectively. Thus, assuming the topographic features of all these areas are accessible to all livestock with minimum risk of sliding and falling, but still their capacity

to host the existing livestock population in zone three and two less than by 2153.37 ha and 1134.79ha, respectively. In the after-math of crop harvest, every pinch of grass and crops residues as coppices of trees and shrubs which, if they had been retained in the field, could have contributed a lot to minimize soil erosion and maximize fertility, are grazed to their root (Plate 2). Alemneh (1990) identified grazing land in most parts of Ethiopian highlands, not only does it demand more clearing of vegetation, but it also affects areas under temporary crop cultivation because uncontrolled grazing for crop residues commences immediately after harvesting. This results in soil crusting, which reduced rainfall infiltration and the ability of the soil to absorb moisture.

Table 6.15: Total livestock population and grazing area required to host the population

Livestock unit	TLU factor	Total livestock (zone)			Total TLU			grazing area available(ha) (zone)			Total area Required (ha)		
		1	2	3	Zone1	Zone 2	Zone3	1	2	3	Zone 1	Zone2	Zone 3
1 Cattle	1	4235	5756	7796	4235	5756	7796				1411.7	1918.7	2599
1 Goat	0.2	804	1093	1480	160.8	219	296				53.6	72.86	98.7
1 Sheep	0.2	773	1050	1422	154.6	210	284.4				51.53	70	94.8
1 Equine	0.8	649	879	1191	519.2	703	952				173	234.4	317
<b>Total</b>					5069.6	6888	9328	457	356	405	1698	2295.9	3109

- Livestock population data source Alaba Bureau of Agriculture and Rural Development.
- Available grazing area was obtained from classified satellite imagery of 2005.
- Required grazing area obtained from the relation of 1ha for 3TLU, (Tiku, as cited Tamire 1997).

Livestock has been blamed for land degradation in Ethiopia. Research has generally shown that as vegetation cover declines under heavy stocking rates, the water infiltration rate decreases and sediment production increases (Mwendera and Mohamed Saleem 1996, 1997, Mwendera *et al.*, 1997a, b; Asadu *et al.*, 1999 as cited in Girma Taddese 2001). The action of animal hooves, especially the small cloven hooves of sheep and

goats, is extremely damaging to the surface soil as it destroys vegetation cover. The mechanical pulverization often greatly increases erodability. In addition, heavy grazing denudes the land of vegetation or vegetative residue, which causes serious wind or water erosion. The footpaths used by humans and cattle, in time, develop into rills and then into gullies. Even with limited or controlled grazing, the concentration of animal traffic in watering areas or through gates or lanes often becomes the site of initial wind erosion that which may spread to other parts of the study area.

Although large population of livestock considered as an asset for the farmer but constraint of grazing land evident to the low productivity of livestock especially in the region of zone two and three.



Plate2: Grazing land condition in the study area.

### 6.6.5 Feed source

Feed sources for livestock mainly come from crop residues and crop aftermath, forest-land and natural pasture. The commonly used crop residues were those of wheat, teff, maize and finger millet. Grass collected from pasture land and forest area stored as dry matter for livestock feed.

Across all zones the main feed source comes from crop-land. This includes crop stubble and aftermath of harvested crop. Almost 75% of the respondents in the region of zone one and two and 70% of in zone three were generating feed for their livestock from crop-land

(Table 6.16). Next to crop-land the second major feed source was forest-land. Households in different zones harvested and stored grass as dry matter for their livestock. The households in zone three, zone two and zone one used 20%, 15% and 12.5% forest as source of feed for their livestock, respectively. The least option for feed source in each zone was pasture land. This could be due to the absence or very little private pasture (grass) land availability across the zones.

Table 6.16: Livestock feed source and farmer dependence in the study area

Feed source	Zone one (%)	Zone two (%)	Zone three (%)
Crop-land	75	75	70
Forest-land	12.5	15	20
Pasture land	2.5	-	10

### 6.6.6 Household Energy Source

Table 6.17 gives the sampled households have different sources of energy for different purposes. The sources of energy were kerosene, fuel wood, crop residue and animal dung. Although there was a tendency of using petroleum product as source of household energy consumption, but its purpose was limited only for lighting. Except zone one, all the zones used 100% kerosene together with fuel wood, crop residue and animal dug for the purpose of lighting and/or heating. The entire respondent in zone one and zone three used fuel wood for cooking. In addition to this 35% and 20% of the respondent in zone one and three used it for heating and/or lighting, respectively. Similarly, 82%, 80% and 75% of the respondent utilized animal dung for the purpose of cooking in zone two, zone three and zone one, respectively. Besides this purpose, animal dung was used in these zones for heating and/or lighting purpose. The same phenomena was notified in crop residue consumption, 42%, 35% and 25% of the respondents in the sampled household of zone one, zone two and zone three utilized crop residue for cooking purpose, respectively.

Table 6.17: Energy source and consumption pattern across each zone.

Source	Zone one (%)		Zone two (%)		Zone three (%)	
	Cooking	Heat & lighting	Cooking	Lighting & Heat	Cooking	Lighting & Heat
Kerosene	-	90	-	100	-	100
Fuel wood	100	35	85	60	100	20
Animal dung	75	30	82	35	80	25
Crop residue	42	-	35	-	25	-

Crop residue and animal dung that should be incorporate in to the soil as fertility management input and to keep the land alive were devoted for house energy demand satisfaction. The fuel wood which has been consumed in all zones was supposed to protect the land against land degradation caused by erosion. Heavy consumption of fuel wood was evidenced for decrease of forest and bush-land cover in all the region and land degradation at large (Plate 3). Not only fuel wood consumption that cause for degradation but also removal of crop residue from crop-land and animal dung as source of energy in the region.



Plate3: Fuel-wood fetch for house hold consumption.

### 6.6.7 Household income and expense

All households in each zone need a certain amount of cash income to cover household expenditure, agricultural inputs, financial and social commitments. If this is not met by sales of crop and livestock products which were surplus to household requirements, then it must come from sale of crop and livestock products which represent consumption for gone and disinvestment or from off-farm activities.

Table 6.18 shows that the maximum annual mean income and expenses are 10361.111 and 3467.46; respectively in zone one but the standard deviation by far higher than the other zones. The next maximum income was 8698.57 birr and expenses was 1934.9 birr in zone three and zone two respectively. The minimum annual mean income is 4703.97 birr and expense was 1652.5 birr are in the region of zone two and zone three respectively.

Table 6.18: Annual mean household income and expenses with their standard deviation in each zone.

Item	Zone one		Zone two		Zone three	
	M	SD	M	SD	M	SD
Annual Household income	10361.11	2573.38	4703.97	1184.97	8698.57	1992.98
Annual Household expense	3467.46	1550.78	1934.9	250.98	1652.5	474.04

Variation in crop productivity coupled with livestock production across zones brought differences among the zones income and expenditure pattern. Besides this the sample survey results revealed that there was no off-farm income generated in any of the zones. The only income is from the agricultural sector in the region. It was also observed that agricultural developments in the study area depend on land quality. Hence, the variation for income and expenditure could be attributed for the variation of land degradation condition. Other research showed that agricultural costs of degradation for a period of 25 years (1990–2014) are estimated to be about \$2500million, and this would mean a

substantial decrease of per capita income (by a mean of 30%) in the Ethiopian highlands, with the low potential cereal crop (LPC) zone as one of the most seriously affected areas (Constable and Belshaw, 1989). This will also mean destruction of farmlands of some 10 million highlanders, 60% of them in the LPC zone (Constable and Belshaw, 1989).

## 6.6.8 Socio-economic Status

Socio-economy refers to the environmental, economic, social and institutional relationships and patterns, which compose the concept of development (Sheng, 1989). Socio-economic status is a measure of an individual's or group's standing in the community. It usually relates to the income, occupation, educational attainment and wealth of either an individual or a group. These types of variables are summarized into a single figure or socio-economic index. There is no general agreement on the definition of socio-economic status and hence there can be different socioeconomic indexes are constructed for different uses.

### 6.6.8.1 Socio-Economic Status Index

Although there was variability in socio-economic index factors across the zones, but the summarized variable indexes were showing that there were differences in indexes among zones (Table 6.19). So when we compare the total socio-economic status index of the three zones, relatively zone one, with value of 2.274, was the best in socio-economic status, compared to the other two zones. Next to this, zone three with the value of 2.1, is in a better socio-economic status as compared to zone two. The least socio-economic status was observed in zone two, where SEI value was 1.71.

Table 6.19: Socio-economic status index at different zones

Indicator	Units	Zone			Total region	Index		
		Zone 1	Zone 2	Zone 3		Zone 1	Zone 2	Zone 3
HH size	No	5.2	5.8	6.15	5.72	-0.91	-1.01	-1.08
Land holding	ha	2.23	1.71	1.95	1.96	1.14	0.87	0.99

Education	%	24.37	21.7	22.8	22.96	1.06	0.94	0.99
Male	%	15	12.5	14.5	14	1.07	0.89	1.03
Female								
Gross cash income	Birr	10361.11	4703.97	8698.57	7921.21	0.6	1.1	1.3
Gross cash expense	Birr	3467.46	1934.9	1652.5	2351.62	0.82	0.702	1.47
Crop productivity	Qt/ha	12.025	12.83	11.83	12.23	0.98	1.05	0.97
Fodder supply								
From forest	%	12.5	15	20	16.1	-0.8	-0.93	-1.24
From farm land	%	75	75	70	73.2	1.024	1.024	0.96
Fire wood consumption	%	100	100	100	100	-1	-1	-1
Occupation								
Agriculture	%	100	100	100	100	-1	-1	-1
Non agriculture	%	-	-	-	-	-	-	-
Livestock population	TLU	5069.6	6887.8	9329.2	7095.5	-0.71	-0.97	-1.31
Total socio-economic status index						2.274	1.71	2.1

## 6.7 Relations between Resource and Socio-economic Status

It was known that the major cause for land degradation in Ethiopia is soil erosion. Overgrazing, poor land management and deforestation accelerate soil erosion (land degradation) and the area characterized with poor resource condition which hardly to sustain any crop and livestock production. According to Tripathi *et al.* (1999), soil fertility declines due to soil erosion provide that restrict supply of external inputs. This

scenario resulted poverty. Crop productivity and livestock stocking condition together with household characteristics across the three zones signify land degradation as the major factor for socio-economic status disparity among the zones (Fig.6.8).

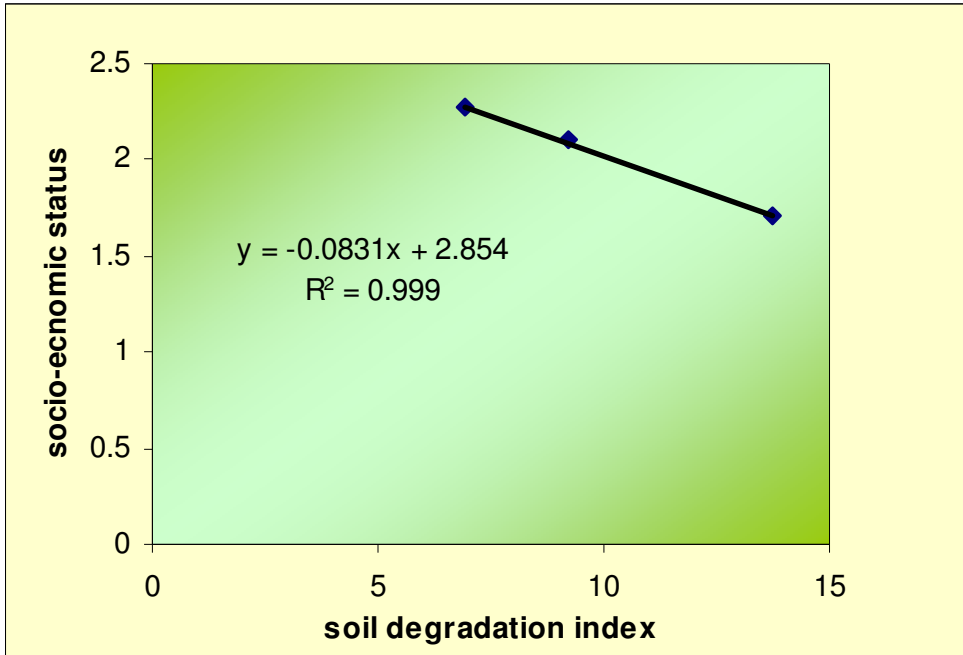


Fig.6.8: Relation between degradation and socio- economic status.

It has been well explained how soil erosion (loss) affect the status of DI in each zone and so also the socio-economic status indicator for SEI. The relation between these two variables is evidenced for the impact of land degradation on socio-economic status of the society in the study area. Agriculture was the only economy sector in the region which entirely depend on the natural resource pool. Then from this relation the regression equation was drawn and correlation coefficient was made. The result proofed that the two variables are highly correlated ( $R^2=0.999$ ). Therefore, as the land gets deteriorated due to soil erosion the socio-economic status gets lower. From this relation as socio-economic status get worse the land degradation condition will be getting tough. Hence the cause and effect for land degradation and poverty are cyclic in nature.

### 6.8 Formulation of Empirical Model for Land Degradation Estimation

Agricultural developments depend on the land resource condition in an area with poor infrastructure, low agricultural input supply and traditional farming practice. The study

area was characterized with these observable facts. Owing to these facts, the variation of land degradation condition and sensitivity index among zones brought variation in agricultural developments across the zones. Hence, this variation of agricultural development (crop production and animal husbandry) in the regions has had essentially altered the socio-economic status across the regions. Therefore land degradation condition had direct influence on the socio-economic status of the study area.

From the discussions in session 6.4, 6.5 and 6.6.10, it can be summarize the state of land degradation as a function of sensitivity index and socio-economic status condition of the region. Hence  $D = f(\text{sensitivity and socio-economic status})$

<b><math>D = 0.026S - 10.75E + 31.349</math></b>	-----Equation 1
--	-----------------

Where, D – degradation status  
S – soil loss to forest sensitivity  
E – socio-economic status

It can be understandable that degradation has positive relation with sensitivity. This is due to positive coefficient of sensitivity in the model. It implies that degradation is directly proportional to sensitivity. The relation of socio-economic status has an inverse relation with land degradation status. This is evident for the negative coefficient of socio-economic status in the model presented in Equation1. This model can be used to estimate land degradation at different levels of sensitivity and socio-economic status of the people in the region.

## 7. Conclusion and Recommendations

### 7.1 Conclusion

LULC change detection and dynamics after post classification analysis for the period of “1973 to 1986” and “1986 to 2005” revealed that few land-cover changes were consistent in all sub periods. Crop-land and bare-land in the period of “1973-1986” and 1986-2005” showed a continuous increment in its coverage in the region. Crop-land was increased during these periods by of 10.760% and 52.964%, respectively; bare-land was increased during these periods by 36.04% and 17.042%, respectively. The general increment of these land-use types resulted in reduction of other land-use types. Forest-land exhibited the largest reduction, followed by bush-land. The smallest land transformed was degraded forest-land.

In general the findings has rendered that the land-use/land-cover dynamics is not merely a change in type and area of different land-use classes .It has, however brought land-use structural changes that resulted a change in land management practice in the region and this result in shift of land-cover from permanent to temporary and cause to the land highly susceptible for land degradation, which is caused by soil erosion.

Based on the result found in this study there was increased in land degradation situation from the period of 1986 to 2005. These differences in soil erosion (land degradation) attributed for shift in LULC in the study area. This was clearly observable on soil loss in the study area during this period. The result of soil loss range and mean soil loss rate were 0.013 – 91.63ton/ha/yr and 6.2ton/ha/yr respectively in 1986. In 2005 the soil loss range (0.018 -82.23ton/ha/yr) less as compare that of 1986. However the mean soil loss rate in this period increased significantly and reached to 8.43ton/ha/yr. The land degradation scenarios have been worst in this period and clearly evident on the size of land exposed for soil erosion agent (water) in the region. The change was due to expansion of crop and bare land in the study area.

Comparison on the basis of estimated annual soil loss, forest cover loss and soil chemical property analysis were attempted to differentiate which sub study area is more susceptible

to land degradation. The result of assessment in DI, sensitivity index (SI) and soil erosion among the three zones disclosed that zone two was found to be more exposed for soil erosion hazard, deteriorated and sensitive for slight loss of forest. The area also characterized with lower socio-economic status. Hence the land degradation scenario had influence the socio-economic status of the region.

The study on land degradation and socio-economic status depicted, there were an inverse relation between the two across the zones. Zones two was more degraded relative to other zones and so also lower socio-economic status. Followed to this zone, zone three and one takes the next place orderly. Therefore, land degradation impedes social and economic development of the community which entirely depends on the natural resource pool for their survival.

Finally the developed empirical model relates the socio-economic status, land degradation and sensitivity index can be used for land degradation estimation across the region.

## **7.2 Recommendation**

From the findings and the conclusions of the study the following recommendations are forwarded.

- ❖ There is a need in revising the land-use system with full participation of local people before the land degradation condition become irreversible stage.
- ❖ Beside soil erosion, deforestation for fuel wood, utilization of crop residue for animal feed and energy source coupled with animal dung as fuel to the house hold interrupt the nutrient cycle and result in further deterioration of the land. Hence, introduction of energy saving technology and alternative energy source for household is indispensable.
- ❖ Although farmers noticed the decline of land productivity but they are less aware the level and extent of land degradation. Hence, there is a need to improve awareness of the farmers through training and scale up the literacy level of the society.
- ❖ Livestock production is an asset for the household in time crop failure. But excess number of livestock with limited grazing land result in over grazing which leads

to land degradation in addition to poor productivity from the sector. The study area characterized to this phenomena. Therefore there is a need in boosting up of this sector through intensification of livestock production so as to get to benefit of increase in livestock production and protection of the land against over grazing

- ❖ The zone two has large DI and SI which call improving soil fertility status and sustainable forest-land management through introduction of soil and water conservation in the region.
- ❖ The livelihoods of all the households in the study area are totally dependent on agricultural sector. Hence, as part of sustainable land management it is important to develop an appropriate rural infrastructure to encourage alternative livelihoods.
- ❖ Further study on the relation of land degradation and socio-economic status of the household and deforestation and change in soil loss rate should be carried out for better understanding of cause and consequences of land degradation and reclamation option.

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## Appendixes

### Appendix 1 soil erodibility K-factor

Soil type	K value	Soil type	K value
humic Acrisol, moderately deep	0.22	vertic Luvisol	0.14
humic Acrisol, very deep	0.16	eutric Nitosol	0.32
humic Andosol	0.26	eutric Nitosol, stony	0.24
humic Andosol, stony	0.16	humic Nitosol	0.12
ochric Andosol	0.25	haplic Phaeozem	0.20
Cambisol	0.33	haplic Phaeozem, lithic, shallow	0.19
chromic Cambisol	0.23	haplic Phaeozem, lithic, very shallow	0.32
chromic Cambisol-Regosol	0.20	haplic Phaeozem, moderately deep to deep	0.31
chromic Ranker Cambisol	0.27	haplic Phaeozem, very deep	0.29
eutric Cambisol luvisol	0.35	Phaeozem	0.16
Fluvisol	0.33	Ranker	0.15
eutric Fluvisol	0.28	Regosol	0.27
dystric Gleysol	0.31	eutric Regosol	0.22
mollic Gleysol	0.33	chromic Vertisol	0.19
Lithosol	0.24	chromic-pellic Vertisol	0.25
Lixisol	0.10	pellic Vertisol	0.22

If soil types can not be determined, the K Factor can be estimated based on the soil colour as follows: black = 0.15, brown = 0.20, red = 0.25, yellow = 0.30

### Appendix 2 land-use class and their corresponding C-factor

Land-use\land-cover	C-factor
Forest-land	0.001
Wood land	0.01
Bush-land	0.05
Shrub land	0.1
Grass land	0.03
Cultivated land	0.25
Cultivated land\fallow	0.1
Non dense forest 0.01	0.01
Degraded grasscover, grazing, hard bad land	0.05

**Appendix 3 Questionnaire**

**Questionnaire for Socioeconomic Survey**

**Part1. General Information**

1. peasant association \_\_\_\_\_
2. farmer's name \_\_\_\_\_ sex \_\_\_\_\_
3. Are you born in this area?  
A. yes B. no
4. marital status, single \_\_\_\_\_ married \_\_\_\_\_ widow \_\_\_\_\_
5. total farm size(in local unit of measurement) \_\_\_\_\_ in hectare \_\_\_\_\_
6. House hold composition

Age (yrs)	Sex		Education											
	M	F	Did not attend school		Read & write		1°		Junior 2°		2°		Above 2°	
			M	F	M	F	M	F	M	F	M	F	M	F
Under 10														
10 – 14														
15 – 64														
Older than 65														
Total														

7. What kind of crop production trend have you observed for the last five years?  
A. increase B. decreasing C. no change D. I don't know
8. Major problem for crop production? (Rank)
  1. Land shortage
  2. Erosion
  3. Labor shortage
  4. Low productivity
  5. Poor market facility
  6. Less access to input
  7. Other specify \_\_\_\_\_

**9** Did the total area you cultivate from year to year

Increase \_\_\_\_\_

Decrease \_\_\_\_\_

No change \_\_\_\_\_

**10.** If it increased reason(s):

1. Expanding in forest \_\_\_\_\_

2 Expanding in bush land \_\_\_\_\_

3. expanding in grazing land \_\_\_\_\_

4. Other specify \_\_\_\_\_

**11.** If it decreased, reason(s):

1. Fragmented to married children \_\_\_\_\_
2. Abounded due to loss of productivity \_\_\_\_\_
3. Other specify \_\_\_\_\_

**12.** What measures do you take when the productivity of your land (farm) declines?

Look for additional land \_\_\_\_\_

Improve the fertility \_\_\_\_\_

Fallow \_\_\_\_\_

Other (specify) \_\_\_\_\_

**13.** If you look for additional land, what kind of land do you select for?

1. Forest-land \_\_\_\_\_

2. Shrub land \_\_\_\_\_

3. Grazing land \_\_\_\_\_

4. Other specify \_\_\_\_\_

17. Livestock production

Type of livestock	Number	Purpose		
		Consumption	Draft	Sale
oxen				
Cow				
Goat				
Sheep				
Chicken				
Pack animal				
Others, specify				

19. Do you think the grazing land is sufficient? A. yes B. no

If no, is the condition getting worse in recent past? A. yes B. no

20. Where do you get fodder for livestock?

A. from forest B. from farm land C. from pasture land

D. others, specify

21. House hold energy source and consumption

Energy\ fuel source	Purpose		
	Cooking	Light energy	Others
Petroleum product			
Firewood			
Animal dung			
Crop residue			
Electric power			
Others, specify			

22. House hold income and expenditure

i. income source and amount gained in year

Item	Gross cash earn (birr)
Grain	
Crop residue	
Firewood	
Livestock	
Off farm activity	
Others, specify	

ii. causes expenditure and amount

Item	Gross cash expenditure (birr)
Food	
Firewood	
Fertilizer	
Miscellaneous	

