



**Land use/land cover change and soil erosion risk mapping in
Shebedino woreda, Sidama zone, southern Ethiopia**

MSc Thesis

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Shebedino woreda, Sidama zone, southern Ethiopia**

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ADVISOR’S APPROVAL SHEET
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This is to certify that the thesis entitled **Land use change and soil erosion risk mapping in Shebedino woreda, Sidama zone, southern Ethiopia**, submitted in partial fulfillment of the requirements for the degree of masters of sciences in **Biosystems and Environmental Engineering with specialization in Soil and Water Conservation Engineering** to the school of graduate studies, Hawassa University through the school of Biosystems and environmental engineering done by Addisu Amare is an authenticated work carried by him under my guidance, and no part of the thesis has been submitted for any other degree or diploma for best of my knowledge and believe,

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DEDICATION

This piece of work is dedicated to the memory of my late father AMARE HABTE

DECLARATION

I declare that this thesis is my bonafied work and all sources of materials used for this thesis have been duly acknowledged. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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ABBREVIATIONS

AOI	Area of Interest
ArcGIS	Arc Geographic Information System
asl	Above Sea Level
CSA	Central Statistical Agency
DA	Development Agent
DEM	Digital Elevation Model
EHRS	Ethiopian Highland Reclamation Study
EMA	Ethiopian Mapping Agency
ENVI	Environment for visualization of image
ERDAS	Earth Resource Development application System
ETM ⁺	Enhancement Thematic Mapper
EPA	Environment Protection Authority
GIS	Geographic Information System
GTZ	German Technical Cooperation
GPS	Global positioning System
LULCC	Land Use Land Cover Change
MSS	Multi -Spectral Scanner
SRTM	Shuttle Radar Topographic Mapping
SWCE	Soil and water Conservator Engineering
SWCM	Soil and Water Conservation Measures
SWC	Soil and Water conservation
TM	Thematic Mapper
USLE	Universal soil Loss Equation
WSDP	Watershed Development Practices
UTM	Universal Transverse Mercator

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Land use/land cover change and soil erosion risk mapping in Shebedino woreda, Sidama zone, southern Ethiopia

ABSTRACT

Soil erosion is one of the major environmental problems that threaten sustainable agricultural production. Estimates of soil erosion risks and changes in the land use land cover will assist effective and sustainable land management and soil and water conservation (SWC) measures implementations. This study reported assessments of Land use/land cover changes between periods of 1973 and 2014 using GIS and Remote Sensing technique of Shebedino woreda. The study also attempted to map soil erosion risk by water and estimated the rate of soil erosion using Universal Soil Loss Equation in combination with GIS and Remote Sensing applications. Two satellite imageries (Landsat MSS 1973 and Landsat ETM+2014) have been used for change detection. Ethiopia soil map and soil survey data, 23 years rainfall data, a digital elevation model image, and land cover map for the year of 2014 have been used to estimate rate of soil erosion. Subsequently, land use/land cover map of the year 1973 and 2014, and soil erosion risk map of the study area have been produced. The study revealed that in the last four decades significant changes have been detected on LULCC. Forest cover and grazing land significantly decreased at a rate of 184.22 ha/yr and 38.08 ha/yr respectively; on the other hand cultivated land has shown increment in area at a rate of 179.91 ha/yr; and settlement has shown increment as well. The soil erosion risk analysis result shows that the woreda exhibited soil erosion rate of between 0 to 50 tonnes per hectare per year. The total annual soil loss in the study area was about 77200.50 tonnes, with 3.92 tonnes per hectare per year of mean annual rate of soil loss. A significant increment (159 %) in total annual soil loss has been observed. The total annual soil loss amount increased to 77200.50 tonnes in 2014 compared to 31076.05 tonnes 1973 situation. Based on the finding of this study, it was concluded that there were significant land use/ land cover change happened in the woreda. Part of the worda is prone to soil erosion risks. Therefore, all woreda level actors should give emphases to the situation and devise appropriate interventions measures for better and effective management of land recourses.

Key Words: LULC, Erosion, GIS, Remote Sensing, USLE

1. INTRODUCTION

1.1. Background

Soil erosion and land degradation are the major environmental problems facing the earth. Land degradation could be caused by determinant agents such as biophysical (land use and land management, including deforestation and tillage methods), socioeconomic (e.g. land tenure, price, marketing and income, institutional support), and political (e.g. incentives, political stability (Mitiku, 2006)). Soil degradation includes declining of soil quality caused by its improper use, usually for agricultural, pastoral, industrial or urban purposes which encompasses physical, chemical and biological deterioration of soil.

Soil erosion loss assessment and mapping hazards, and understanding land use / land cover features are very important resources for SWC measures planning, land resource management and policy drafting purposes. The impacts of soil erosion on environmental degradation in general and on agricultural production, and water quality in particular have long been recognized as a serious problem. Ringrose et al. (1997 cited in Abiy 2010) reported that land use / land cover in Africa is currently accelerating and causing widespread environmental problems and thus needs to be studied and mapped.

Assessing land use / land cover change and erosion hazard assessment and risk mapping using remote sensing technology along with GIS is very vital for supporting the endeavor towards sustainable agricultural economic sector development. Identifying and mapping of specific areas susceptible for environmental hazards in order to develop tailored mitigation measures are very vital. Hurni (1993) stated that although it is disclosed that the Ethiopian highlands are highly degraded due to soil erosion and soil degradation, rapid changes in Land use/land cover, population density yet there is very little spatial and quantitative data base that can substantiate these arguments. This tells us that knowledge and information about land use / land cover and erosion hazards for specific areas are very relevant to take appropriate and tailored management measures.

The Ethiopian economy is mainly dependent on rain-fed agriculture in the highlands. About 85% of the population is engaged in subsistence agriculture. The highlands are highly degraded (EI-Swaify and Hurni, 1996) due to intensive agricultural practices and such loss and depletion of soils and plant biodiversity are recognized to be the two most important forms of environmental degradation in rural Ethiopia (Muluneh, 2003). In Ethiopia, anthropogenic factors such as overgrazing, land mismanagement; rapid population growth biomass fuel consumption (including dung and crop residue), and deforestation are the major causes of land degradation. Due to these unsustainable use practices of natural resources the country has shown considerable Land use/land cover changes during the second half of the 20th century (Gete, 2000). According to Wegayehu (2003) among the various forms of land degradation, soil erosion is the most important and an ominous threat to the food security and development prospects of Ethiopia and many other developing countries.

Different traditional soil erosion controlling measures and local knowledge that have been practiced for centuries in Ethiopia which justifies the fact that in most cases farmers are aware of soil degradation problems in their locality. For the last several decades awareness raising training campaigns, professional trainings like training and assigning Development Assistance (DAs) at Kebele level in all regions of the county has further raised the awareness of the farmers and rural households which is also a confirmation for recognition of soil erosion problems by the farmers. However, different studies reveal that, though there are positive progresses, the results are yet not to the satisfactory level.

It is reported in Kerr (1998 cited in Wegayehu 2003) that in spite of rapidly growing awareness about soil erosion, its physical causes and effects, together with increased understanding of methods of protecting and multiplying conservation efforts in the past few decades, erosion remains widespread and adoption of conservation practices by farmers remain limited. Limitations of resources and circumstances impair their capacity to alleviate the problem. In the short term, incentives will

be required to encourage farmers to get involved in soil conservation activities (Bekele and Holden, 1999).

Ethiopia has a long history of intensive agriculture and human Built-up particularly in the highlands due to the presence of favorable climatic and ecological conditions. However, the high population pressure and associated depletion of the scarce resources have made agriculture of the country unsustainable, forcing its expansion into marginal areas such as steep slopes, swampy plains, and traditionally untapped part of the environment and putting tremendous pressure on soil, vegetation and water resources (Engidawork, 1997). As a consequence, considerable land use and land cover changes have occurred in Ethiopia during the second half of the 20th century (Solomon, 1994; Gete, 2000).

Ethiopia loses about 1.5 billion tonnes of soil per year, and about 1- 1.5 million tonnes of grain, as a result of soil erosion. It is also known that the soil formation rate for Ethiopia is less than 2 ton hectare per year, which is very low compared to soil erosion rates (Hunri, 1988; Mahmud, et al., 2005). The Sidama zone of SNNPR's is also one of the region known for its high population density and the continuous land degradation due to sever soil erosion more agricultural land is being lost there by land productivity is declining which is seriously affecting the livelihoods of the farming community in the area. Therefore, this study aimed to assesses land use/land cover change and examine soil erosion loss by water in Shebdino woreda, southern region.

1.2. Statements of the problem

Annual deforestation rate in SNNPR is estimated to be 1.6 percent, representing one of the highest deforestation rates in the country. Despite it's relatively better endowment of forest resources including the nation's renowned high tropical forests of south-west, SNNPR is also known for its highest rate of deforestation mainly due to its extraordinarily high population densities that exert enormous pressure on the bio-physical environment in general and woody biomass resources in particular (GIZ

2010). This in turn contributes to high soil loss due to erosion and LULCC from forest to agriculture land.

The Sidama zone of SNNPR's is also one of the region known for its high population density and the continuous land degradation due to severe soil erosion more agricultural land is being lost there by land productivity is declining which is seriously affecting the livelihoods of the farming community in the area. The traditional cultivation system of the parts of Sidama is under stress mainly because of rapidly increasing human population. Symptoms are not only the high proportion of children acutely or chronically affected by malnutrition but also the progressive degradation of resources in an environment once extremely fertile.

According to Sidama ZBoARD report (2007 cited in Tigne 2009) due to land degradation, erratic rainfall and population pressure, parts of the zone have been food insecure. In 2006, 18,040 people from Hawassa, 41,855 people from Boricha and 14,808 from Shebedino woreda were registered as food insecure and have been under the support of safety net program. Land degradation and soil erosion is commonly observed in the area though no significant SWC/WSDP activities undergoing. Low information and data on soil erosion risks and Land use/land cover change for farmers exists.

Assessing the Land use/land cover, rate of soil loss, and mapping potential erosion risk areas and recommending appropriate measures for the study area is important. This can help to assess the level of soil erosion hazard and to take appropriate and necessary management interventions that help to tackle the major causative factors at their specific locations in one hand and to serve as a supporting and additions to existing endeavor towards developing implementation guide line and plan in the areas of natural resource protection activities.

In study woreda low information and data on soil erosion risks and land use/land cover change for farmers exists and not much is known about changes in Land

use/land cover. Soil loss due to water and associated with changes in Land use/land cover has not been quantified. Spatial distribution of changes in Land use/land cover and soil loss for planning and management is very important for landscape specific intervention. Hence, the result of this study, in addition to primarily benefiting the local actors in area of SWC conservation, watershed development and agricultural activities including land planners and development practitioners, local NGOs etc., it attract research institutes/individuals to conduct further researches, compare this study with previous studies and could help both as a baseline and additions in the national and international knowledge pool and research database in the field.

1.3. Objectives

1.3.1. General objective

The general objective of this study was to assess the land use/land cover and examine soil erosion loss by water using remote sensing and GIS application in Shebedino woreda of the Sidama zone of the SNNPR region, Ethiopia.

1.3.2. Specific objectives

The specific objectives of this research are;

- To assess the land use/ land cover changes in the last four decades (40 years) from 1973 to 2014;
- To classify and map potential soil erosion using USLE model (1973 and 2014);
- To relate Land use/ land cover changes (1973 to 2014) and soil erosion (1973 and 2014);

1.4. Research questions

The above objectives are envisaged to be achieved through the following research questions:

- What is the magnitude of land use change in the last four decades in the study area?

- What is the estimated mean annual soil loss rate of 1973 and 2014 in the study area?
- Is the woreda prone to high soil erosion and degradation? How prone?
- Which parts of the study areas are very sensitive to high erosion risks?
- How is the Land use/land cover changes linked to soil erosion risks?

2. LITERATURE RVEIW

2.1. Overview of soil and land degradation

The U.N. Convention to Combat Desertification defines land as “the terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system”. Similarly the same document define land degradation as “reduction or loss of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from processes such as (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, biological or economic properties of the soil; and (iii) long-term loss of natural vegetation” (Pagiola 1999 cited in Mahmud et.al 2005)

Land degradation is a composite term that can be used differently across a wide range of conditions depending upon the need. Studies recommend that it is vital to describe and differentiate related concepts such as land degradation, soil degradation, and soil erosion, as these are sometimes used interchangeably by different users incorrectly though. Land degradation is a broader term; it has no one easily identifiable characteristic, but instead describes how one or more of the land resources such as soil, water, vegetation, rocks, air, climate, relief has changed for the worse.

It is reported in Kerr and Pender (2005) that land degradation is a complex phenomenon influenced by natural and socio-economic factors. Most cost estimates of land degradation do not distinguish between soil erosion, soil degradation and land degradation in their analyses. In many economic analyses, there is a tendency to attribute soil fertility decline only to soil erosion. All definitions of land degradation can be included under three categories namely physical (include water and wind erosion, crusting and sealing, compaction, water logging and reduced infiltration), chemical (acidification, salinization, nutrient depletion, pollution) and biological degradation (soil organic matter decline, biomass burning and depletion of vegetation cover and soil fauna) (FAO, 2001).

Land degradation could be caused by determinant agents such as biophysical (LU and land management, including deforestation and tillage methods), socioeconomic (e.g. land tenure, price, marketing and income, institutional support,), and political (e.g. incentives, political stability. The various processes of land degradation have been grouped into six classes; water erosion, wind erosion, soil fertility decline, salinization, water logging, and lowering of the water table (FAO 2000a documentation). However, there are other forms of land degradation such as deforestation, forest degradation and rangeland degradation (Tsigneh 2009). One thing that need due consideration, however, is that while dealing with defining land degradation, often times a problem is that what one group of people might view as degradation, others might view as a benefit or opportunity. For example, conducting farming activities at steep slopes would accelerate soil erosion and create environmental concern, yet farmers could view the location as appropriate one for crop yields.

Soil degradation is a narrower term for declining soil quality caused by its improper use, usually for agricultural, pastoral, industrial or urban purposes which encompasses physical, chemical and biological deterioration of soil. Loss of organic matter and decline in soil fertility, decline in soil structural condition, erosion, salinity, acidity or alkalinity, and the effects of toxic chemicals, pollutants or excessive flooding are some of the major features of soil degradation. Soil degradation describes a decline in the soil quality encompassing the deterioration in physical, chemical, and biological attributes, which commonly manifest itself through soil erosion, soil fertility depletion, soil compaction and soil pollution (Alemneh et al., 1997).

Soil erosion is a particular physical process that causes land and soil degradation, and refers to the wearing away of the land surface by water and/or wind as well as to the reduction in soil productivity due to physical loss of topsoil, reduction in rooting depth, removal of plant nutrients, and loss of water. Other forms of soil degradation include other types of physical degradation, such as compaction, surface

sealing and crusting, water logging and acidification; chemical degradation, including depletion of soil nutrients, acidification, salinization, and pollution; and biological degradation, including loss of soil organic matter (which also affects physical and chemical properties of the soil), flora and fauna populations or species in the soil (e.g., earthworms, termites and microorganisms) (Scherr, 1999).

Soil degradation is a serious global environmental problem and it is a natural process that always happening. Over utilizing natural resources such as soils basically implies the risk of overusing and degrading these resources. The term soil degradation comprises a whole palette of human induced degrading processes, out of which soil erosion by water is considered the most prominent one. The “Global Assessment of Human induced Soil Degradation” (GLASOD, 1990 cited in Mitiku et al. 2006) under the United Nations Environment Program (UNEP) states that about one-sixth of the earth’s terrestrial surface, including one-third of its agricultural land, is already affected by human-induced soil degradation . Soil erosion is a two-phase process consisting of the detachment of individual particles from the soil mass and their transport by erosive agents, such as water and wind. When sufficient energy is no longer available to transport the particles a third phase, deposition, occurs (Morgan, 1986).

Among the different human activities that accelerate soil erosion processes, agriculture is the most important and most soil erosion occurs on cultivated lands (Hudson, 1986). Soil erosion occurs at varying rates and with varying degrees of severity in different parts of the world, and even in different locations within the same country. Rates are generally higher in Asia, Africa, and South America, averaging 30 to 40 tonnes per hectare per year, and lower in the United States and Europe, averaging about 17 tonnes per hectare per year (Pimentel et al., 1995 cited in Wegayehu 2003). Substantial differences also exist within regions. For example, de Graaff (1993) showed that annual soil loss from cropland in selected developing countries ranges from 1 – 800 tonnes per hectare per year depending on

the slope of land under cultivation, the type of crop grown and other environmental factors Wegayehu 2003)

2.2. Land and soil degradation in Ethiopia

Land degradation is a process in the value of the biophysical environment is affected by a combination of human-induced processes acting upon the land. Land degradation is a serious problem in Ethiopia, both in the highlands and low lands. Land degradation is one of the major causes of low and in many places declining agricultural productivity and continuing food security and rural poverty in Ethiopia (IFPRI, 2005). The anthropogenic factors such as biomass fuel consumption (including dung and crop residue), overgrazing, non-scientific farming systems; rapid population growth and deforestation are the major sources of soil and land degradation. However, soil degradation and deforestation are major forms of environmental degradations which directly or indirectly affects land productivity and thereby ultimately results into food insecurity.

Land degradation mainly caused by soil erosion and environmental protection has been one of the chronic problems in Ethiopia (Berry, 2003; Nyssen et al., 2003a; Dregne, 1990; Hurni, 1988a cited in Tsigneh 2009). The average annual soil loss from arable land in the Ethiopia was estimated to be about 42 tonnes per ha per year and the average annual productivity decline in cropland was 0.21% (Hurni, 1993, Wegayehu, 2003). The FAO (2000b) states soil erosion is the most widely recognized cause of falling productivity; and the effect may include diminished food security, reduced calorie intake, economic stress and loss of biodiversity. Land degradation, in particular soil degradation, poses a serious threat to national and household food security (Bekele and Holden, 1999 cited in Awdenegest and Holden, 2006).

Among different forms of land degradation processes in Ethiopia, soil erosion by water is the most important environmental problem that poses an ominous threat to the food security of the population and future development prospects of the country

(Wegayehu, 2003). In Ethiopia the highlands are densely populated and at the same time they are the area where large amount of agricultural production is made. On the contrary, different studies show that the highlands are continued degrading beyond the acceptable rates. According to the Ethiopian Land Reclamation Study (1995) it is estimated that only 20% of the total area of the Ethiopian highlands have relatively minor problems of erosion; 76% are significantly or seriously eroded and 4% have outstripped their capacity to be of any value for production. According to Dramis et al. (2003); Nyssen et al. (2003) and cited in Mitiku (2006), in Ethiopia human induced mismanagement of natural resources is a root cause of soil degradation together with the concomitant climatic changes. In concern to this, different soil and land degradation studies have been conducted. As the soil and land degradation extent, degree and fashion is different from location to location, researches and developments on land degradation assessment methods that focus on particular aspects of land degradation are required.

2.3. Soil conservation activities in Ethiopia

In Ethiopia soil and water conservation practices have a related history with agriculture. Almost all types of soil and water conservation interventions are practised in different part of the country. In most of the cases acquiring information on the past interventions and getting adequate data could be not easy. In Ethiopia, the agricultural sector is the main source of employment (FAO, 1993). It also contributes to a very large proportion of the country's GDP; employs 85% of the population and the main income-generating sector for the majority of the rural population. It also serves as the main source of food and generates 90% of the foreign exchange earnings. Despite its importance in the livelihood of the people and its potential, the sector has remained at subsistence system and characterized by low productivity level.

It is discussed in Mitiku (2006) that in an attempt to increase agricultural productivity and improved food security at both national and household level, efforts have been underway to generate and disseminate improved agricultural technologies among

smallholder farmers. Different biological and engineering SWC measures have been put in place to promote and enhance sustainable agriculture, to reduce soil erosion there by improve food productivity and food security in one hand and for sustainable environmental management and climate change combat measures through reducing soil land degradation on another.

Soil erosion is one of the major environmental problems that threaten sustainable agricultural production in today's developing world (Yoshin & Kefi, 2010). Concerns about food security will increase in the coming decades due to impacts from climate change, deforestation, erosion, depletion of water resources, and other climate change consequences (SWCS Board, 2011) Conservation policies must be directed to mitigating social costs and improving the economic conditions of farmers. Among the policies needed for soil and water conservation include providing training and financial incentives for good soil stewardship & identification and development of site-specific conservation practices based on local and regional biophysical, social, cultural, and political forces (Blanko and Lal 2006)

There are different traditional SWC measures and local knowledge that have been practiced for centuries in Ethiopia. In most cases farmers are aware of soil degradation problems in their locality. For the last several decades awareness raising training campaigns, professional trainings like for instance training and assigning Development Assistance (DAs) at Kebele level in all regions of the county has further raised the awareness of the farmers and rural households which is also a confirmation for recognition of soil erosion problems by the farmers. However, different studies reveal that, though there are positive progresses, the results are yet not to the satisfactory level. Limitations of resources and circumstances impair their capacity to alleviate the problem. In the short term, incentives will be required to encourage farmers to get involved in soil conservation activities (Bekele and Holden, 1999).

Despite the recent positive economic development that disclosed mainly impacted the farmers, studies shows that millions of farmers yet not able to invest on relative costly and very effective physical and biological SWC measures by their own. The reasons for not investing are different and interlinked which encompasses economic and social issues where food insecurity is believed the major factor. Farmers are unlikely to adopt conservation measures if there is no immediate threat to the productivity of their land or if the main justification for their use is to prevent pollution and other off-site damage (Napier 1990), unless there are either incentives for their adoption or meaningful penalties for not using conservation production systems (Morgan 2005). This suggests that the food insecurity problem reduces farmer willingness to take action to protect land as they give priority to activities related to their immediate food requirements (Awdenest and Holden 2007) and there must be clearly designed incentive mechanisms that benefits farmers and land owners for effort towards SWC measures put in place.

2.4. Soil Conservation programs' approach in Ethiopia

There are different programs that have been undergoing in the country in connection with SWC works such as food for work incentives, subsidies etc, and their success in bringing the intended result is disputable though. It has been argued by Mulat et al. (2004) that at the national level, attempts to carry out conservation activities through food-aid have not reversed the depletion of the natural resources in Ethiopia. However, Barrett (2006) suggested that 'although food-aid can have negative unintended consequences, the empirical evidence is thin and often contradictory. Different studies reported that food- aid does not have disincentive effect at the household level in Ethiopia

Food-aid unfortunately is still required to relieve the day-to-day pressure on farmers but may be having some negative impact on soil degradation problems (Awdenest and Holden 2007). Society must continue to develop conservation systems to address varying climate impacts (SWCS board 2011) for sustainable and long term livelihood and productivity improvement hence the SWC activities must geared towards this

objectives. Bekele and Holden,(1999) also discussed that subsidies that become obstacle for conservation activities by farmers must lifted. Incentives should be limited to stimulating the involvement of farmers and not aimed at buying their participation (Morgan 2005).

Fortunately, at this present day, there are different initiatives and programs are already available in connection with climate change, environmental protection, promotion and dissemination renewable energy technologies including biomass improved cook stoves for Greenhouse Gas Emission and deforestation reduction purposes which are being under implementation worldwide including Ethiopia. Among others(which are being directly supporting the SWC measure initiatives), the wildly spoken global Clean Development Program (both mandatory and voluntary) which is currently benefiting programs for reforestation and afforestation for their carbon offset potential. Soil and water conservation (SWC) measures, beyond their effectiveness to restore complete barren land, improve soil fertility and increase agricultural productivity, as side products they also generate soil carbon sequestration and storage that contribute meaningfully to mitigating the negative effects of climate change and can be an opportunity to incentives farmers for their effort in SWC measures in agricultural soils through funds like CDM.

In most cases causes, reasons and indicators associated with soil degradation are known by farmers. Farmers consider their land to be declining in productivity and they see mainly internal factors as causes of soil degradation. Farmers are also aware of solutions to the problem. The issues of financial and economic capacity of the farmers are what hindering them to take appropriate actions. These shows in order to make SWC measure more effective, demand driven and to the capacity of the farmers there by reduce soil degradation and increase food productivity sustainable and integrated incentive mechanisms should be devised and practiced. This could potentially reduce soil degradation by encouraging farmers to take actions at field level.

Large households draw labor from investment in conservation for search of food for survival. Like the house hold size, studies show that household labor size is negatively correlated with the application of conservation technique (Bekele and Holden 1998; Bekele and Lars; 2002). They argued that, being other things kept constant, large households have large labor supply. They are food insecure in most cases. To secure food for their household they rush into their income generating activities with drawing labour always from investment in conservation.

During the last years, with support from WFP under the MERET project, GTZ, USAID under the AMAREW project and other organizations, the FDRE has worked with communities within micro-watersheds to develop and implement natural resources conservation and community watershed management plans (RVB, 2007). To reinforce such efforts guidelines on watershed management planning have been published by the MoARD and are generally accepted by almost all practitioners. This would give a favourable condition for implementation of watershed management programmes at community level.

In SNNPR different NGOs have been involved in supporting soil and water conservation activities in the basin, but most of the emphasis has been on physical measures. In Alaba FHI International is involved in structural measures, plantations and road construction. Similarly, World Vision Ethiopia is working in Damot Gale and Mirab Abaya on physical measures, plantations and area closure. The UNDP Environment Support Programme was also involved in implementation of physical and biological measures such as seedling production and distribution to the community in Mirab Abaya woreda (RVB, 2008)

It is well known that a long tradition of stone bunds and hillside terraces are in existence in the Konso and Humbo areas. These traditions were reinforced by some modern physical and biological techniques through a support from UNDP environmental rehabilitation programme over the last years. Other than these, recent efforts were envisaged by the government under the regular extension and

package programme, focusing mainly on composting and household water harvesting. Since 2005, development of small community watersheds have been reportedly in place in all food in-secure woredas in the SNNPR region, most of which are still at the planning stages (RVS, 2008).

2.5. Land use/land cover change

A very extended and informative definition of land according to UN's Food and Agriculture Organization FAO 1995 is, it is an area of the earth's surface, the characteristics of which embrace all reasonably stable, or predictably cyclic attributes of the biosphere vertically above and below this area including those of the atmosphere, the soil and underlying geology, the hydrology, the plant and animal populations, and the results of past and present human activity, to the extent that these attributes exert a significant influence on present and future uses of the land by man.

The terms "land cover" and "land use" are often confused. Land cover is "the observed physical and biological cover of the earth's land, as vegetation or man-made features." In contrast, land use is "the total of arrangements, activities, and inputs that people undertake in a certain land cover type" (FAO, 1997a; FAO/UNEP, 1999 cited in IPCC 2000).

Land use change is defined to be any physical, biological or chemical change attributable to management, which may include conversion of grazing to cropping, change in fertilizer use, drainage improvements, installation and use of irrigation, plantations, building farm dams, pollution and land degradation, vegetation removal, changed fire regime, spread of weeds and exotic species, and conversion to non-agricultural uses. Land use/land cover changes may be grouped into two broad categories as conversion and modification. Conversion refers to changes from one cover or use type to another, while modification involves maintenance of the broad cover or use type in the face of changes in its attributes (Quentin et al., 2006)

The manipulation of the land is also affected by the type and extent of the cover it possesses. LU changes can move in two directions: either, in the negative sense, leading to land degradation and loss of (production) potential, or, in the positive sense, resulting in a higher value or potential (Abiy 2012). Land use/land cover changes influence climate and weather conditions from local to global scales. They can have such impacts by affecting the composition of the atmosphere and the exchange of energy between continents and the atmosphere, which can lead to global warming (Pielke et al 2002, IPCC 2000 cited in Mengistie et al 2013).

About 29 percent of the global land surface was originally under forest cover. Presently, however, it is only a fifth of this original which remains undisturbed (FAO, 2001). It is estimated that in Ethiopia, 40 percent of the country was covered with forests at the beginning of the 19th century. According to EFAP (2002), only 2.7 percent of Ethiopia's land mass is currently estimated to be under forest cover, with a loss of 150,000 to 200,000 hectare of natural forest per annum. The country's forest cover in 1989 was 12.9 percent. A decade later, in 1997, the forest cover was estimated to be only 4.2 percent. The estimates of the rate of deforestation have also been variable. For example, the annual rate of deforestation estimated by EFAP ranged between 150,000 and 200,000 hectares per annum. However, FAO (2001) reported a much lower estimate of about 40,000 hectares per annum.

The Global Forest Resources Assessment 2000 estimated that the world's natural forests decreased by 16.1 million hectares per year on average during the 1990s; that is a loss of 4.2% of the natural forest that existed in 1990. However, some natural forests were converted to forest plantations. Gains in forest cover arose from afforestation on land previously under no forest land use (1.6 million hectares per year globally) and the expansion of natural forests in areas previously under agriculture, mostly in Western Europe and eastern North America (3.6 million hectares per year globally). The net global decrease in forest area was therefore 9.4 million hectares per year from 1990 to 2000. The total net forest change for the

temperate regions was positive, but it was negative for the tropical regions (FAO, 2001). According to Lambin & Geist (2006), there were significant global historical changes in LULC occurred between 1700 and 1990, when the area of cropland expanded from about 3.5 million km² to some 16.5 million km². Much of this expansion occurred at the expense of forest, which has decreased from about 53 million km² to 43.5 million km².

FAO estimated that tropical regions lost 15.2 million hectares of forests per year during the 1990s. Recent estimates for only the world's humid tropical forests based on a sampling strategy of remote sensing data, revised downward by 23% FAO's net rate of change in forest cover for the humid tropics, which exclude tropical dry forests. According to Achard *et al.*, (2002) between 1990 and 1997, 5.8 and 1.4 million hectares of humid tropical forest was lost each year. Forest re growth accounted for 1.0 and 0.32 million hectares. The annual rate of net cover change in humid tropical forest was 0.43% during that period. A further 2.3 and 0.7 million hectares of forest were visibly degraded. This figure does not include forests affected by selective logging. Southeast Asia has experienced the highest (FAO, 2001).

Land use and habitat conversion are, in essence, a zero-sum game: land converted to agriculture to meet global food demand comes from forests, grasslands, and other natural habitats. Today, 1.54 billion ha (or 15.4 million square km.) is in cropland, and 3.47 billion ha is in pastureland, and these are projected to increase 1.89 billion hectares and 4.01 billion ha respectively by 2050. Thus, by 2050 approximately 45 percent of the world's land surface will be dedicated, in one way or another, to agriculture Tilma *et al.*, (2001).

Land use and land cover changes result from various natural and human factors within social, economic and political contexts. Hence, the local human activities expressing the drivers can be determined by measuring the rates and types of changes and analyzing other relevant sources of data like demographic profiles, household characteristics and policies related to land resources administration. To

achieve this, it is crucially important to consider multiple sources of information and to acquire temporal, spatial and other non-spatial forms of data (Teshale, 2015).

2.6. Land use/ land cover and soil erosion nexus

Vegetation cover and dead plant biomass are known to reduce soil erosion by intercepting and dissipating raindrops and wind energy. Under this situation, lowest erosion rates have been recorded from undisturbed forests, with ranges from 0.004 to 0.5 t/ha per year (Bezuayehu *et al.*, 2002). However, once forestland is converted to agriculture, erosion rates increase because of vegetation removal, overgrazing, and continuous cultivation. On the other hand, there is a better understanding that forests burnt in certain parts of the world are important contributors to greenhouse gases and contributing to climate change. Overall these changes affect the livelihoods of societies (FAO, 2001).

Landuse and landcover patterns are interrelated with the types and properties of soils. The rate and severity of soil erosion and land degradation partly depends on land use pattern. The problem of soil erosion starts with the removal of land cover (natural vegetation) for various purposes. The relationship between land use and soils is two dimensional i.e. land use affects soils and in reverse soils affect land use. Land cover characteristics and water cycle have many connections. The type of land cover, obviously, can affect both rate of infiltration and runoff amount by following the coming of precipitation (Woldeamlak, 2002).

The type of LC, obviously, can affect both rate of infiltration and runoff amount by following the coming of precipitation. According to Turner and Meyer (1994) both surface and ground water flows are significantly affected by type of LC. For example, forest canopy and leaf litter help to reduce the erosive action of rain drops. On the other hand, the formation of sheet, rill and/or gully erosion are common in areas where ground cover is insufficient. Impacts of Land use/land cover change on atmospheric components of the hydrologic cycle are increasingly recognized.

Conversion of agricultural, forest, grass, and wetlands to urban areas usually comes with a vast increase in impervious surface, which can alter the natural hydrologic condition within a watershed. It is well understood that the outcome of this alteration is typically reflected in increases in the volume and rate of surface runoff and decreases in ground water recharge and base flow (Andersen et al., 2007). This eventually leads to larger and more frequent incidents flooding of farm land and aggravate erosion.

2.7. Land use/land cover change in Ethiopia

Farm land and forests conversion to urban development reduced the amount of land for food and grazing land which results soil erosion, siltation and other soil degradation associated with deforestation reduced the quality of land resources (Lubowsik, et, al, 2006). With an area of 1,130,000 km², and as one of the most populous countries in Africa, Ethiopia is experiencing huge Land use/land cover changes from natural vegetation to farming practices and human settlement. Forest loss affecting, the livelihood and the environment particularly the rural population of Ethiopia in different ways including shortage of firewood, shortages of non-timber forest products and accelerated soil erosion which affects agricultural productivity. The decline of forest has a significant impact on various functions such as production, biomass, biological habitat filtration and sources of raw materials (FAO, 2001).

The problem of land cover changes is more severe in the highlands of Ethiopia, which account nearly 44% of the country's landmass and have been cultivated for millennia (Kidanu 2004, CSA 2007, Eshetu 2000, Hurni and Gete 2005 cited in Mengistie et al 2013). According to Mahamud et al. (2005) several studies using remote sensing information at a micro scale have found large changes in land use in different parts of Ethiopia during the past several decades. Most of these studies found that cropland has expanded, usually at the expense of forests or grazing area, although there are exceptions in different places and times. Studies revealed that major

causes of Land use/land cover changes are agricultural expansion, wood extraction, infrastructure expansion socio- economic and political processes.

The Ethiopian Highland Reclamation studies revealed that the Ethiopian highlands, which cover 44% of the country's total land area, are seriously threatened by land degradation. The country is noteworthy as the country of famine. Food shortages are endemic and since 1970 severe famine has occurred almost once a decade (1973; 1982 – 1984 early and late 1990's and 2002 –2003). As it is obvious, most of the agricultural production system is located on the Ethiopian Highlands where larger amount of the population lives. Nationally, forest reserves have been heavily depleted sequentially over much of the 20th century from over 40 percent to around 2.7 percent in today (Berry, 2003). On average Ethiopia losses 12 tonnes of soil per hectare per year, and 1493 million tonnes of soil per year due to water erosion. On the other hand, the soil formation rate for Ethiopia is less than 2 ton hectare per year, which is very low compared to soil erosion rates. Annually, Ethiopia loses about 1-1.5 million tonnes of grain due to soil erosion (Hunri, 1988; Muhammed, *et al.*, 2005).

In Ethiopia, population pressure is inducing, the clearing of forests for agriculture and other purposes, and the attendant accelerated soil erosion, is gradually destroying the soil resource. 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. In Ethiopia forests may have existed long before history was recorded, but the present day forest cover does not correlate with human population in recorded history, even though environmental problems such as droughts may have also contributed to this phenomenon (Hurni, 1990).

Land use and land cover patterns are interrelated with the types and properties of soils. The rate and severity of soil erosion and land degradation partly depends on land use pattern. The problem of soil erosion starts with the removal of land cover (natural vegetation) for various purposes. The relationship between land use and soils

is two dimensional i.e. land use affects soils and in reverse soils affect land use. Land use and land cover is by far the most important determinant of erosion in the highlands of Ethiopia (Woldeamlak, 2002). The northern and central highlands of Ethiopia are relatively, unstable, compared to the south and south-western highlands. Consequently, the land use and cover pattern in northern and central highlands contribute a lot to soil loss due to erosion (Amare, 1996).

The land use systems in Eastern Africa are severely affected by forms of land degradation such as over cultivation, overgrazing, deforestation and others. Places where vertisol is common, like most parts of Ethiopia, are suffering from overgrazing with shrub invasion and soil erosion (Girma et. al, 2002). Because of the increasing intensity of grazing, shrubs and perennial grasses may change into annual grasses and bare land. Heavily grazed plots result in poor quality of physical and even chemical properties of soils. High soil compaction that leads to low infiltration rate is clearly observed in heavily grazed plots than less grazed plots. (Girma et.al, 2002)

In Ethiopia, the expansion of cultivated land at the expense of bush lands, natural pasture and forest, caused by ever increasing human population, has strongly affected the number of livestock and the quality of the products. In addition, shrinking of grazing land would force the livestock to move into upper slopes and roadsides. This in turn induces overgrazing and soil erosion in different parts of the country (Hoekstra et al. 1990).

2.8. Assessment of erosion hazards

2.8.1. Forms of soil erosion

The major forms of soil erosion are sheet erosion/splash erosion (which involves the displacing soil particles due to raindrop impact and removal of thin layers of topsoil from an eroded site), rill erosion(which involves the formation of small channels and rills due to concentrated shallow flow) , gully erosion (involves the formation of relative large “U” or “V” channels/gullies on a slope), the structural failure of part

of a hillside (in the case of a landslide); stream bank erosion refers to collapse of banks along streams, creeks, and rivers, due to the erosive power of runoff from uplands fields (Blanco and Lal 2008), wind erosion (caused by wind force), tunnel erosion (refers to underground soil erosion caused by percolation). Often gully erosion and mass-wasting contribute more to erosion than surface erosion phenomena such as sheet erosion in uplands and highlands, even without human influences (El-Swaify, 1997 cited in Muhamud et al 2005)

2.8.2. Factors affecting soil erosion

The factors that affect soil erosion on a field scale are diverse and interlinked where climate; soil, topography, and LU are the major ones. The major factors controlling water erosion are precipitation, vegetative cover, topography, and soil properties (Blanco and Lal 2008). According to Morgan (2005), soil loss is closely related to rainfall partly through the detaching power of raindrop striking the soil surface and partly through the contribution of rain to runoff. This applies particularly to erosion by overland flow and rills, for which intensity is generally considered to be the most important rainfall characteristic. The other main factor, erodibility, defines the resistance of the soil to both detachment and transport. Erodibility varies with soil texture, aggregate stability, shear strength, infiltration capacity and organic and chemical content.

Slope length steepness and shape, on the other hand, are the topographic characteristics that most affect erosion and deposition. Erosion would normally be expected to increase with increases in slope steepness and slope length as a result of respective increases in velocity and volume of surface runoff. Further, while on a flat surface raindrops splash soil particles randomly in all directions, on sloping ground more soil is splashed downslope than upslope, the proportion increasing as the slope steepens. Similarly LU is the single most important factor affecting soil erosion and it is strongly enhanced by the human activities. Ground cover provides a significant moderating impact on dissipating the energy supplied agents of soil erosion (Morgan, 2005).

According to the study by MoWR 2007, rates of soil formation in Ethiopia were reported to vary between 2 and 22 t/ha per annum. In the Ethiopian rift valley, the values of zonal variability range from 6 to 10 t/ha per annum, with rates decreasing southwards to less than 2 t/ha per annum near the Kenyan border. The zonal variabilities are primarily the result of rainfall and temperature variances, while other parameters are minor contributors.

Regarding variations with altitude, highest rates of soil formation were assessed as occurring between 1,600 masl and 2,200 masl, with rates decreasing significantly at higher and lower altitudes. Above 3,200 masl, however, all areas have again similar formation rates, which quickly decrease towards the climatic vegetation limit at about 4,000 to 4,400 masl because of decreasing mean annual temperatures (00 C at about 4,200 masl). Many parts of the rift valley fall within the favourable altitudinal ranges for higher rates of soil formation. However, in these areas the rates of soil erosion seem to be higher than the rate of formation.

2.9. Modeling soil erosion: using Universal Soil Loss Equation

The Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1978) is the most frequently used empirical soil erosion model worldwide. The Universal Soil Loss Equation (USLE) and its derivative revised USLE are universally used models for erosion hazard assessment. The first attempt to develop soil loss equation for hill slopes was initiated by Zinge (1940) based on steepness and slope length. Further developments led to addition of climatic factor based on the Maximum 30-min rainfall by Musgrave (1947). Then Smith (1958) included a crop factor, a conservation factor and soil erodibility factor. Finally, in Wischmeier & Smith (1962) produced the universal soil loss equation by converging climatic factor to rainfall erosivity (Morgan, 1993).

Universal soil loss equation (USLE) is an empirical model designed to predict the long time average soil losses in runoff from specific field areas in specified cropping and management systems. It was developed for predicting erosion on a cultivated

field so that erosion control specialists could choose the kind of measures needed in order to keep erosion within acceptable limits given the climate, slope and production factors (Morgan, 1986). The model has been widely used to estimate soil erosion, to assess soil erosion risk, and to guide development and conservation plans in order to control erosion under different land cover and land use conditions.

In USLE model, erosion is seen as a multiplier of rainfall erosivity (the R factor, which equals the potential energy); this multiplies the resistance of the environment, which comprises K (soil erodibility), SL (the topographical factor), C (plant cover and farming techniques) and P (erosion control practices).

The model is explained as: $A=R*K*L*S*C*P$ 2.1

Where:

R, the rainfall Erosivity, equals E, the kinetic energy of rainfall, multiplied by I30 (maximum intensity of rain in 30 minutes expressed in cm per hour). This index corresponds to the potential erosion risk in a given region where sheet erosion appears on a bare plot with a 9% slope.

There are different ways of analyzing the R factor, such as:

(i) $R = 9.28 * P - 8838$ 2.2

In this case mean annual erosivity (KE > 25) where P is mean annual precipitation (Morgan 1994);

(ii) (ii) $R = 0.276 * P * I30$ 2.3

Mmean annual EI30, where P is mean annual precipitation [Foster et.al (1981) cited Morgan (1994)] ;

(iii) $R = 0.5 * P$ (in US unit) and $R = 0.5 * P * 1.73$ (in Metric unit).....2.4

[Roose 1975) cited in Morgan (1994)];

(iv) $R= 0.36P + 47.6$ 2.5

(Kaltenrieder , 2007) and;

(v) $R = -8.12 + 0.56 * P$ 2.6

Adapted by Hurni, 1985 for Ethiopian conditions.

K, Soil erodibility, depends on the organic matter and texture of the soil, its permeability and profile structure. It varies from 70/100 for the most fragile soil to 1/100 for the most stable soil. It is measured on bare reference plots 22.2 m long on 9% slopes, tilled in the direction of the slope and having received no organic matter for three years.

SL, the topographical factor, depends on both the length and gradient of the slope. It varies from 0.1 to 5 in the most frequent farming contexts in West Africa, and may reach 20 in mountainous areas like this proposed study area.

C, the plant cover factor, is a simple relation between erosion on bare soil and erosion observed under a cropping system. The C factor combines plant cover, its production level and the associated cropping techniques. It varies from 1 on bare soil to 1/1000 under forest, 1/100 under grasslands and cover plants, and 1 to 9/10 under root and tuber crops.

P, support practice factor, takes account of specific erosion control practices such as contour tilling or mounding, or contour ridging. It varies from 1 on bare soil with no erosion control to about 1/10 with tied ridging on a gentle slope.

Where E is the mean annual soil loss, R is the rainfall erosivity factor, K is the soil erodibility factor, L is the slope length factor, S is the slope steepness factor, C is the crop management factor and P is the erosion-control practice factor. Since K represents mean annual soil loss per unit of R, E has the same units as K. Thus, if K is in t ha⁻¹ for one unit of metric R, multiplication by the metric R value will give the value of E in t ha⁻¹ (Morgan, 1986)

2.10. Remote sensing and GIS in Land use/land cover change analysis and soil erosion modeling

Satellite imagery and GIS maps for Land use-land cover, soil erosion hazard and risk assessment and mapping and detecting its changes is a great key to diverse

applications such as agriculture, geology, hydrology, environment and forestry. Remote sensing is the science and art of acquiring information (spectral, spatial, and temporal) about material objects, or area, without coming in to physical contact with the objects or areas, under investigation (Lillesand, 2004 cited in Beyene 2012). Remote sensing technology along with GIS has become the key tool for Land use/land cover change analysis and erosion hazard assessment and risk mapping in recent years.

Geographic information system (GIS) can be defined as a computerized system that facilitates the phases of data entry, data analysis, and data presentation / visualization. Geographic information system (GIS) is a computer-based system that provides the capabilities for input, data management (data storage and retrieval), manipulation and analysis, and output to handle georeferenced data (Aronoff, 1995 cited in Beyene 2012).

GIS has been used for decades in assessing soil erosion and LULCC. The GIS provides a broad range of tools for determining Land use/land cover change analysis and change detection, soil erosion hazard assessment and risk mapping.

The LANDSAT Program has operated continuously since LANDSAT 1 (then the Earth Resources Technology Satellite (ERTS) 1) was launched on July 23, 1972 and landsat imageries have been available since then. It has been continuing providing images of the earth surface with three primary sensors (MSS, TM and ETM+). The temporal extent of the collection, the characteristics and quantity of LANDSAT data, and the ability to collect new data directly comparable to that in the archive, make LANDSAT data a unique resource, one used extensively to address a broad range of issues in earth science, global change science, and monitoring and assessing land and coastal zone resources.

The use of remote sensing and geographical information system (GIS) techniques makes soil erosion estimation and its spatial distribution feasible with reasonable

costs and better accuracy in larger areas (Millward and Mersey, 1999 cited in Abiy 2012). GIS will be extensively used to assemble information from different maps, aerial photographs, satellite images and digital elevation models (DEM). Census data and other relevant statistical abstract will also be used to make the risk map more oriented to need of the local inhabitants (Beyene, 2012).

As reported in Abiy 2012 remote sensing and GIS with USLE have been used and showed its efficiency by different researchers in estimating rate of soil erosion and in mapping erosion risk areas (Millward and Mersey 1999, Boggs et al, 2001, Bartsch et al, 2002, Wang et al, 2003). They all conformed that the use of remote sensing and geographic information system (GIS) techniques with USLE makes estimating soil erosion and mapping its spatial distribution feasible. For instance, Lillesand et al. (1995) and Wolter et al. (2005) (cited in Abey, 2010) have showed the importance of the multi- temporal images for land classification.

Lillesand et al., (2004) reported that Digital Image Processing refers to the manipulation and interpretation of digital images, by a computer system, to prepare an image for display and interpretation and/or to extract useful information from the image. The possible forms of digital image manipulation are literally infinite. Digital Image Processing is largely concerned with four basic operations: image restoration, image transformation, image enhancement, and image classification.

Table 2.1 Landsat image spectral bands and their reflectance

Band	Band name	Application
0.45-0.56	Blue	Soil and vegetation discrimination Bathymetry and coastal mapping Cultural/ urban features
0.52-0.66	Green	Green vegetation mapping and cultural/urban features
0.63-0.69	Red	Vegetated and non-vegetated mapping Cultural/urban features
0.76-0.90	NIR	Delineation of water body -Soil moisture discrimination
1.55-1.75	MIR	Vegetation moisture discrimination Soil moisture discrimination Differentiation of snow and ice
10.4-12.5	TIR	Vegetation and soil moisture analysis Thermal mapping
2.08-2.35	NIR	Discrimination of minerals and rocks - Vegetation

Adaptedfrom: <http://biodiversityinformatics.amnh.org>

2.10.1. Image classification

Prior to application of remote sensing technology product satellite imagery, digital image processing such as image rectification and restoration (preprocessing), image enhancement and image classification shall be employed. Image rectification and restoration (preprocessing) is a process conducted to correct distorted or degraded data to create a more faithful representation of the original scene. This typically involves the initial processing of raw image data to correct for geometric distortions, to calibrate the data radiometrically, and to eliminate noise present in the data. Image enhancement is a procedure applied to image data in order to more effectively display or records the data for subsequent visual interpretation.

The classification process involves translating the pixel values in a satellite image into meaningful categories. In the case of LC classification these categories comprise different types of land cover defined by the classification scheme that is being implemented (Anderson et al., 2004). It is divided into supervised and unsupervised classification.

2.10.2. Accuracy analysis

The accuracy analysis procedures involve the production of references or facts from the field that evaluate the produced classification. These references could be produced from maps, aerial photos or visits to the field with help from the GPS system and may be represented by points or areas.

There are always errors in maps and before we can evaluate the utility of a particular map we need to have an idea of how accurate it really is and how accurate it should be to sufficiently meet the requirements for the intended application. The only way to reliably check the accuracy of a map is to design and implement an accuracy assessment. Two types of accuracy are producer's accuracy and consumer's accuracy.

Producer's accuracy is a reference-based accuracy that is computed by looking at the predictions produced for a class and determining the percentage of correct predictions. In other words, if it is known that a particular area is hardwood, what is the probability that the digital map will correctly identify that pixel as hardwood? (Horning 2004)

Consumer's accuracy is a map-based accuracy that is computed by looking at the reference data for a class and determining the percentage of correct predictions for these samples. For example, if I select any hardwood pixel on the classified map, what is the probability that I'll be standing in a hardwood stand when I visit that pixel location in the field?

2.10.3. Post-classification change detection methods

This is likely the most common and intuitive change detection method. Surprisingly, however, it rarely produces the best results. In this method, a LC map is produced for each of the two dates and then these two land cover maps are compared (Horning 2004). Post classification is among the most widely applied techniques for change detection purpose. Numerous studies have been carried out using post-classification approach. In post classification change detection approach two images from different dates are classified and labeled. The area of change is then extracted through the direct comparison of the classification results. Main advantages of post-classification include: detailed “from – to” information. It by passes the difficulties associated with the analysis of images acquired at different times of year or sensor. The main disadvantage of the post classification approach is the dependency of the LC change results on the individual classification accuracies. Therefore, it is imperative that the individual classification be as accurate as possible.

2.10.4. Spectral change detection method

In spectral change vector analysis, changes in vegetation cover are noted by a change in brightness value (intensity) from one date to the next, and the direction of that change (change in color) (Nid Hoing 2004). According to Chen (2000), a large number of techniques are in the spectral change identification category. Spectral change detection techniques rely on the principle that LC changes result in persistent changes in spectral signature of the affected land surface. These techniques involve the transformation of the two original images into a new single band or multiband image, in which the area of spectral change is highlighted. Most of the spectral change detection techniques are based on some type of image differencing or image ratioing. The advantage of spectral change detection techniques is that they are based on the detection of physical changes between image dates. This avoids the errors introduced in post-classification change detection where inaccuracies in the LC classification are propagated into LC change analysis.

3. MATERIALS AND METHODS

3.1. Description of study area

3.1.1 Geographic location

Shebedino Woreda is found in Sidama zone of Southern Nations' Nationalities and peoples' Reginal State (SNNPRS) of Ethiopia. Shebedino is one of the 19 Woredas of Sidama zone. The Woreda is situated 275 kilometer south of Addis Ababa and 27 kilometers south of the zone capital-Hawassa. The Woreda lies between the latitudes of $6^{\circ}45'10''$ - $6^{\circ}58'30''$ N and longitudes of $38^{\circ}21'23''$ - $38^{\circ}31'56''$ E. The Woreda is divided in to 35 kebeles, 32 rural and 3 urban, and it borders Dale to the South, Borcha Woreda to the west, Hawassa to the North and Gorche Woreda to the East.

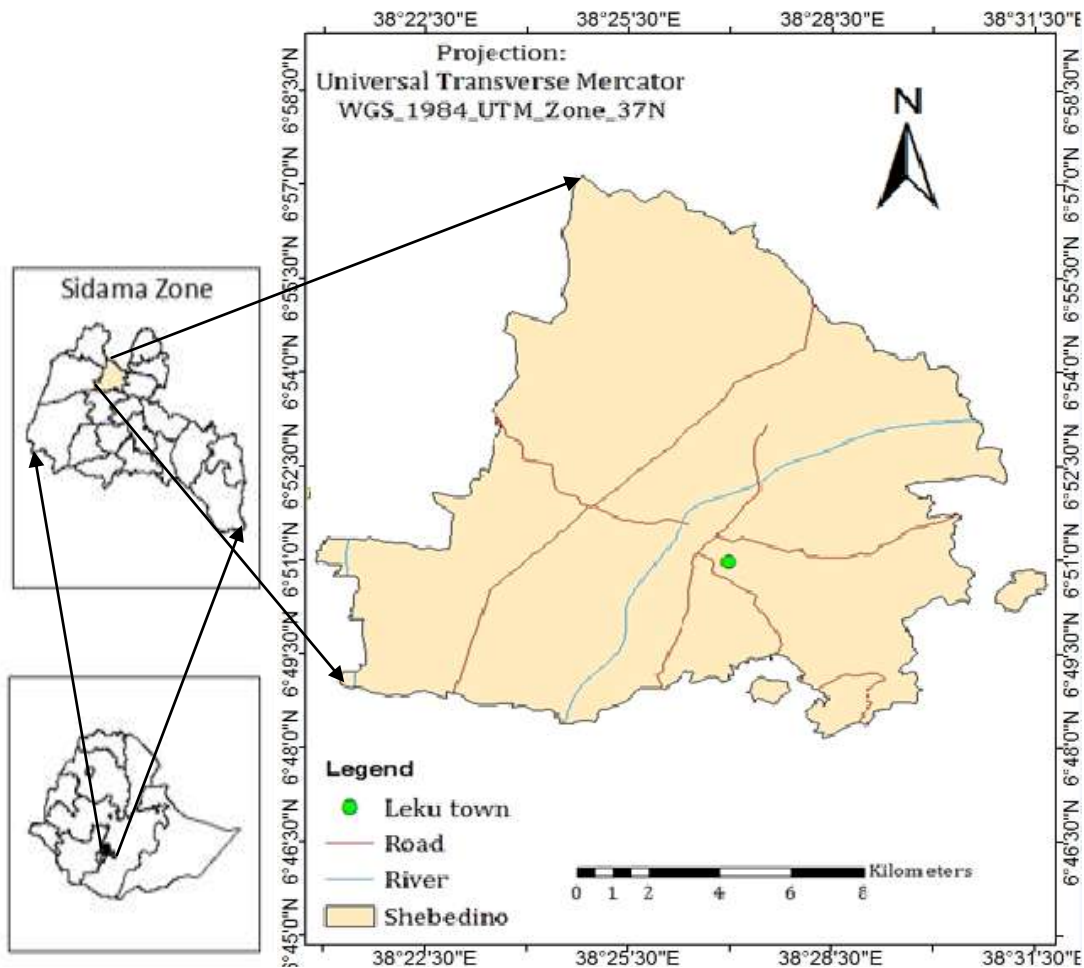


Figure 3. 1 Location of Shebedino woreda

3.1.1. Population and socio-economic activities

Based on the 2014 census, the total population of Shebedino woreda is 285,880. 144,256(50.46%) of the population is male while 141,624 (49.54 %) is female. Shebedino is one of the most densely populated areas of the zone with 1024 persons per sq. km (CSA, 2014).

According to information obtained from the Shebedino woreda Agriculture and Rural Development Office, agriculture is the predominant source of the community's livelihood. The dominant crops are: Enset, maize, and coffee. Other crops such as pulse, wheat, barley, fruits, vegetables and teff are also grown in the woreda. However, the population of the woreda consists of subsistence producers in 19 rural kebeles and three urban kebeles who are food insecure and need food aid every year due to the multifaceted problems which hinder the growth of agricultural production and productivity. The woreda is also known for good potential of livestock. In the year 2014, there were 186,532cattle, 27,715 goats, 41,547 sheep, 99,803hens, 5,626 donkeys, 102 horses and 7 mules as well as identified traditional & modern beehives for which a figure is not yet available.

3.1.2. Climate and soil

Shebidino woreda is found in two agro climatic zones; with Woyna dega covering about 86% and Dega about14% with the mean annual temperature ranging 16-25C0 and the mean annual rainfall between 900-1500 mm. The altitude of the woreda ranges from 1500- 2150 meter asl.

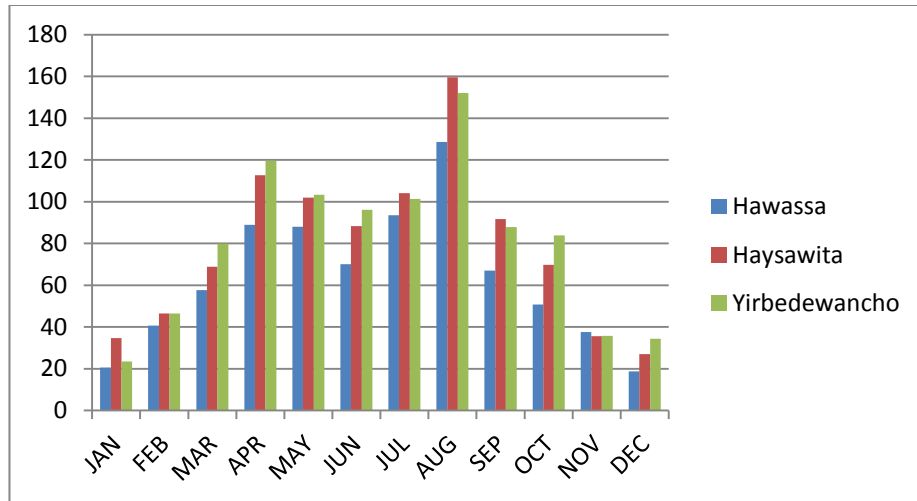


Figure 3. 2 Mean monthly rain fall distribution (1971 to 2014)

The rainfall data collected from meteorological stations depicts that significant rain starts during March and continues to increase up to May and then it slightly decreases during June, which is followed by the main growing season from July to September. During this time the annual rainfall generally decreases on average from 1400mm in the east and southeast to 1000mm towards northwest. Using thiessen method, the estimated mean annual rain fall in the study area is 1022mm.

The soil for the study area includes predominantly Vertisols and Luviosols, where the Vertisols dominate the big central and western part of the Woreda and the Luvisols occupy the majority of Eastern part of the area. In addition, Andisols, Fluvisols and Nitisols cover northern and south western parts of the woreda (Figure 3.3)

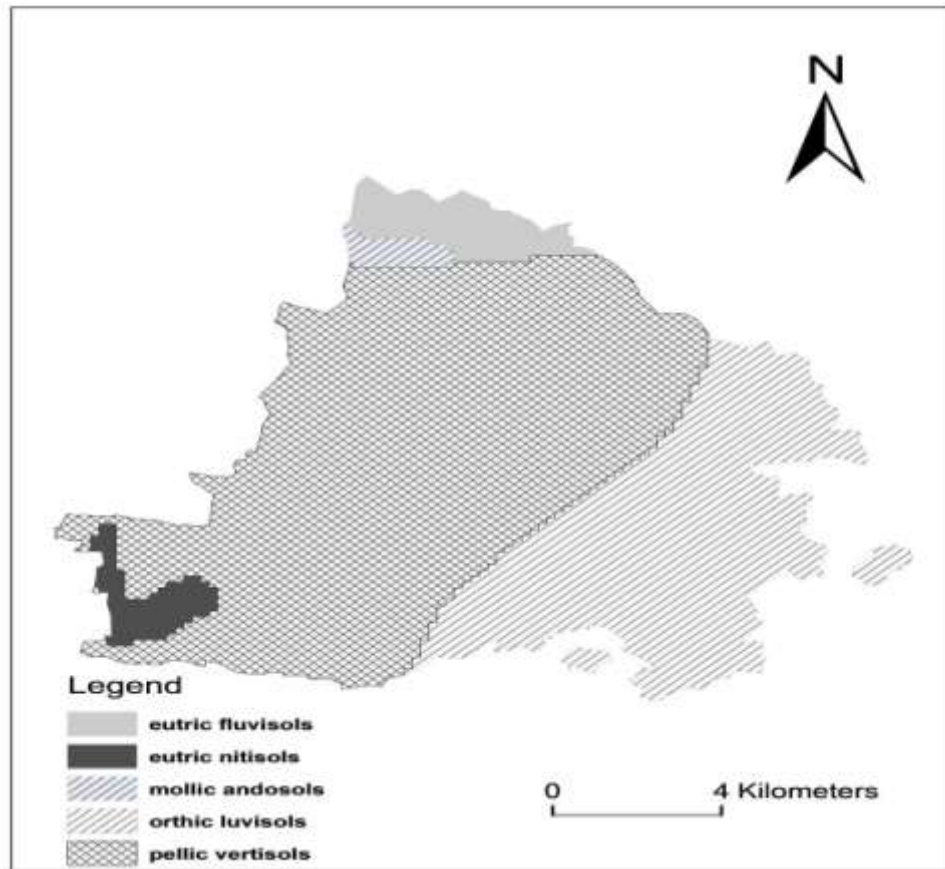


Figure 3. 3 Soil Map of Shebedino woreda (Source: MWR, 2007)

3.1.3. Land use/ land cover

According to the information from Shebedino Woreda Agriculture and Rural Development Office (ARDO, 20014), the woreda covers a total area of 27,690 hectares. Out of this total area, agricultural potential, which accounts for 23,980 hectares, is the largest land use/cover of the woreda. Forest and shrub area covers 557.6 hectares, grazing land accounts for 2,632.4 hectares, 260 hectares potential to be used for agriculture if treatment is applied and the remaining 260 hectares of the woreda is covered by other land uses such as settlements, roads, etc. There is a difference in total area of the woreda used in this study (using Ethio GIS) and provided by the woreda ARDO office. This may be because of the measurement methods used: the actual field level measurement versus measurement using satellite imagery.

3.2. Data and material used

In this study, two main data sources were used to achieve the intended results. The sources used are primary and secondary data sources. The data were collected through both direct and indirect spatial data acquisition methods.

The primary data is generated from Global Positioning System (GPS) surveying. In addition data was collected from the field using observations, and key informant interviews in the study area. Most of the spatial data is generated from DEM and Satellite Imageries in combination with ground control points collected using GPS.

Secondary data such as remote sensing sources such as satellite imageries, Shuttle Radar Terrain Model (SRTM), and meteorological data, agricultural survey reports, shapefiles of the study woreda, and data on soil conservation and farm management were collected from concerned governmental organizations and development stakeholders in the area.

Major materials used in the study include Satellite imageries 1973 (MSS) and 2014 (ETM+) purchased from the Ethiopian Mapping Agency (Table 3.2); SRTM-DTED from NASA source DEM with a spatial resolution of 30m with the acquisition date of March 2006 was collected from the Ethiopian Mapping Agency; Digital soil map of FAO (1986) with (1:1000000 scale) to develop the soil map; Topographic Map was taken from the Ethiopia Mapping Agency to support supervised classification and to assure the rectification of imageries: sheets of scale covering the study area with sheet code and Name: 0738-C4 Hawassa and 0638-A2 Leku; Meteorological data, mainly rainfall and temperature, from the 1971 to 2014 were collected from National Meteorological service Agency; and, Garmin GPS and Digital Camera were used for the ground truthing field data collection to aid different steps of image processing and classification for change detection.

In addition, softwares such as Arc GIS 10.1: for clipping, geo referencing to cross tabulate (to compute the Land use/land cover class matrix between images of different

time), preparation of map layout, for extraction of polygon from raster, digitization of different features; ERDAS Imagine 2010: for sub-setting, clipping, Stacking bands (combining different bands) together, performing the classification of the different Land use/land cover categories, computing area, assessing the accuracy of classification; and Google Earth 2015: for data referencing and accuracy assessment in Land use/land cover classification were used,

Table 3.1 Satellite image used in this study

No	Sensor	Path-row	Date of acquisition	Spatial resolution (m)	Source
1	MSS	181-55	30/02/1973	60*60	EMA
2	ETM+	168-55	26/03/2014	30*30	EMA

3.3. Methods

Two major methodologies were followed for the materialization of this study. Firstly the Land use/land cover change analysis of the study area over the period of 4 decades has been analyzed and quantified, secondly estimating soil erosion and mapping using Universal Soil Loss Equation (USLE) adapted for Ethiopia and applicable to the study area (GIS and Remote Sensing based) has been quantified. For Ethiopian conditions, the applicability of the USLE model was studied by Hurni under Soil Conservation Research Program (SCRIP) (Hurni, 1985) and Kaltenrieder, (2007). In addition, the relation between Land use/land cover change and soil erosion has been analyzed, identified and discussed.

3.3.1. Land use/land cover change analysis

Satellites Images of MSS and ETM+ of years 1973 and 2014 respectively have been imported to ERDAS imagine 10.0 image processing software. Image preprocessing, enhancement, and classification were conducted on each image. Accuracy assessment was applied on the classified images and the classified images were used

to extract information on land cover condition and change quantification using ArcGIS 10.1 software. Information collected from the field using observation, focus group discussion, interviews with agriculture office officials in the study area were also used. Garmin GPS and Digital Camera were used for the ground truthing field data. In addition, Topographic Map was taken from Ethiopia Mapping Agency to support the supervised classification.

The land cover conditions of the two periods were compared and changes were detected using post classification comparison method. Finally, changes in Land use/land cover have been quantified. In addition, Land use/land cover conversion matrix was produced & conversion comparison was generated. Figure below describes Land use/land cover analysis flow chart.

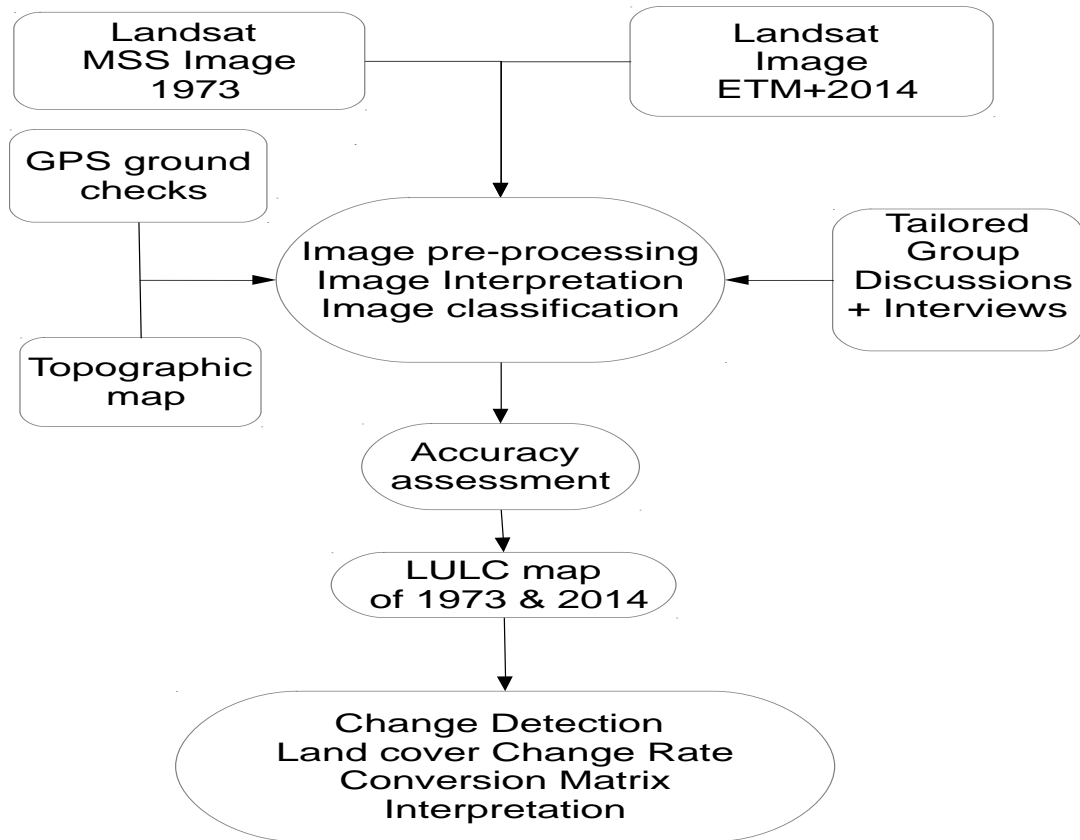


Figure 3. 4 Land use/ land cover change analysis flow chart

3.3.2. Soil erosion estimate and mapping

The universal soil loss equation is an empirical model developed by Wischmeir and Smith (1978) to estimate soil erosion from fields. Different factors causing erosion such as climate, soil properties, vegetation cover and management practices are considered for estimating soil loss

Mathematically the equation is denoted as:

$$A \text{ (tonnes/ha/year)} = R * K * L * S * C * P \dots\dots\dots (1)$$

Where:

A= mean annual soil loss/ ton\ha*yr

R= rainfall erosivity factor/ MJ* mm\ha*yr

K= soil erodability factor/ ton*ha*h/ha*MJ*mm

L= slope length factor/dimensionless

S= slope steepness factor/dimensionless

C= crop management factor/ dimensionless

P= erosion control practice or land management factor/dimensionless

In this study, the Universal Soil Loss Equation (USLE) adopted for the Ethiopian condition by Hurni (1985) was used. Modifications have been employed in specific USLE factors in raster GIS environment/grid-based approach employed using ArcGIS software.

Individual GIS files relevant for the USLE were built for each factor and combined on a cell-by-cell grid modeling procedure in ArcGIS 10.1, to predict soil loss in a spatial domain. Each factor grid had a cell size of 30 m, and all layers were projected with UTM Zone 37N using the WGS 1984 datum. This corresponds to the standards used by the Ethiopian Mapping Agency. Figure 3.4 below shows the general framework followed for this study

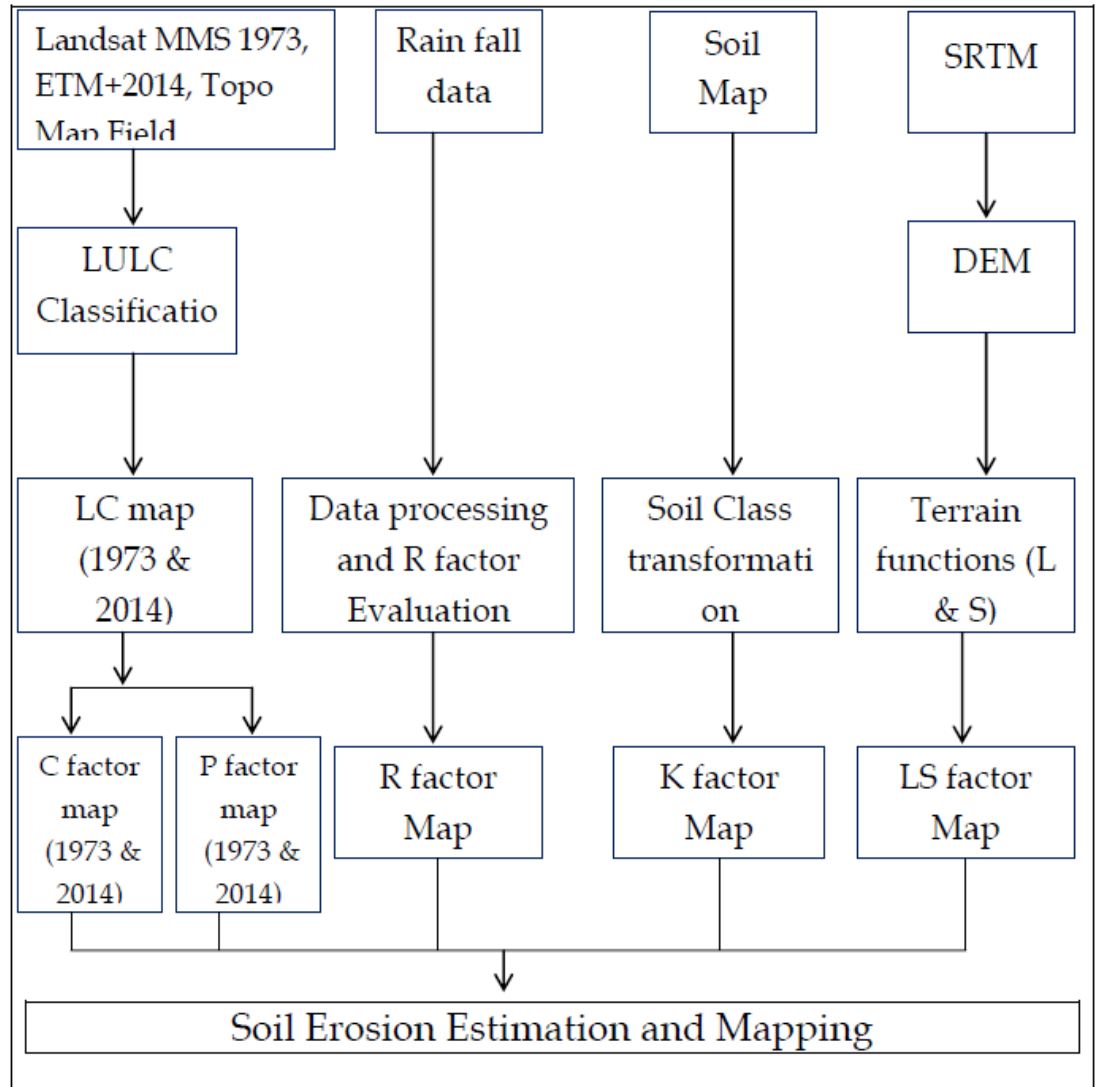


Figure 3. 5 Flow chart of USLE modeling for analysis of soil erosion loss and mapping

3.4. Land use/land cover change analysis

3.4.1. Land use/land cover class identification and selection of training site

To know and better understand the location of specific Land use/land cover types of the study area, a field data collection mission was conducted in March and April 2015 and June 2016. Unsupervised classification was employed on the landsat images of 2014 prior to the field trip. Based on the results of unsupervised classification, sample training sites and dominant Land use/land cover classes were selected. Farmers, including local residents and agricultural and conservation specialists from the woreda bureau of Agriculture and Rural development office, have

been interviewed to decide on the type and number of Land use/land cover classes based on indigenous knowledge and understanding of major land features of the study area. Accordingly, a number of Land use/land cover classes have been identified. The major Land use/land cover classes identified were cultivated land, forest land grazing land, bare land and Built-up and their coordinates were recorded using Germin GPS (Table 3.3). These coordinates along with their specific Land use/land cover class were used during the accuracy analysis of classified images.

In addition to ground control points, photographs of the different ground features have been taken using a digital camera and were used along with the Topographic map of the study area purchased from EMA in the process of supervised classification.

Table 3.2 Land use/ land cover class's description of Shebedino woreda

Cultivated land	An area of land used for cultivation of different crops. The main Cropping system is mixed cropping system where a combination of trees, shrubs, and perennial crops such as coffee, Enset, and chat are grown together as an agroforestry system.
Forest land	An area of land covered by natural forest and manmade trees including trees being planted by man such as fuel woodland. It is composed of various indigenous trees, shrubs, and bushes.
Bare land	All vacant spaces, sands, rocky areas including bare soil
Grazing land	An area of land used as grazing for cattle and is considered as communal grazing land. It is adjacent to the protected forest area and owned by a group of farmers in which other farmers who do not belong to this group have no right to use. This land use system also includes grass lands of predominantly of very short grasses and situated within the protected area and is free for everyone to use for grazing purpose.

Built up land	Continuous and discontinuous urban fabric, residential, industrial and commercial units, road networks and other associated lands. This includes urban and rural settlements and asphalted roads.
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Source: Adapted from Awdenegeest and Holden, 2009, and field survey, 2015 and 2016

3.4.2. Image pre-processing

Initial processing of raw images data has been conducted both on images of 1973 and of 2014. The widely known methods of image pre-processing techniques used in this study were (1) radiometric correction which deals with correcting the data for sensor irregularities, unwanted sensor, and/or atmospheric noise, and for converting the data so that they accurately represent the reflected or emitted radiation measured by the sensor and (2) geometric corrections which includes correcting for geometric distortions due to sensor-Earth geometric variations, and for the conversion of the data to real world coordinates (latitude and longitude) on the Earth's surface that is projecting it to Universal Transverse Mercator-UTM, WGS84, Zone 37N.

Subsequent to this, image enhancements including both spatial and spectral enhancements were made to improve the appearance of the imagery to assist in visual interpretation and analysis. Its function includes contrast stretching to increase the tonal distinction between various features in a scene, and spatial filtering to enhance (or suppress) specific spatial patterns in an image. In the ERDAS 10.1 software, each band of all the satellite images (year 1973 and 2014) have been stacked using interpreter main icon utilities with a layer stacked function. Consequently, from the stacked satellite image the study area image has been extracted by clipping the AOI layer of the Shebedino woreda shape file from Ethio GIS in ArcGIS 10.1 software.

In addition to the true color composite, different false color composite were produced to improve the visualization of the images for the classification processes. Different

color composites were used to assist the different Land use/land cover features identification and training site selection for supervised classification. Different false color composite (5,4,1), (7,4,2), (4,5,3) and (4,2,1) , and true color composite (3,2,1) in the order of Red- Green-Blue (RGB) respectively were employed in this study.

3.4.3. Image classification

Image classification and analysis operations have been used to digitally identify and classify pixels in the data. Classification was performed on multichannel data sets and the process assigns each pixel in an image to a particular class or theme based on the statistical characteristics of the pixel brightness values.

In this study a supervised classification method was carried out using training areas and test data for accuracy assessment in order to compare the Land use/land cover changes from year 1973 to year 2014. A Maximum Likelihood Algorithm was employed to detect the land cover types in the ERDAS Imagine10.1 environment. The different temporal images were cross-referenced with ground truth and a topographic map to make the classification as accurate as possible. The GPS data that was collected during field visits with sufficient sample sizes from different cover classes was used as a major tool for this classification. Five different classes were identified and put in the legend. A nonparametric signature was used based on an AOI that defines the specific feature on the image file being classified. The classification was carried out several times to ensure that the classification is as accurate as possible.

3.4.4. Accuracy assessment

A confusion matrix was employed to assess the classification accuracy. The confusion/error matrix consists of rows and columns. The rows represent the classification values and the columns represent facts from the field. The diagonal line of the error matrix represents the number of pixels that were correctly classified. The overall accuracy index is produced by dividing all the pixels correctly classified by the total number of pixels in the matrix. The producer accuracy index is produced by

dividing the number of correctly classified pixels that belong to a class by the sum of the values of the column of the same class. The user accuracy index is produced by dividing the total number of correctly classified pixels that belong to a class by the sum of the values of the rows of the same class.

Ground truth points collected during field visits and points taken from topographic map have been used to generate the confusion matrix using ERDAS 10.0 software with the interpreter main icon and utilities and finally with accuracy assessment functions. As a result, an overall classification accuracy of 82.14 and an overall Kappa statistic of 0.78 have been achieved (Table 4.1). This shows that results are reasonable for further use and application. The reasons for the errors may include the similarity of reflectance of Built- up, cultivated areas and bare lands. Moreover, there is also an error in the classification of areas covered by forest, shrub land and grazing land due to the reflectance proximity. Eventually, the fast Land use/land cover change dynamic nature of the area may introduce the classification error.

Table 3.3 Overall classification accuracy and Kapa statistics

	Reference	Classified	Number	Producers	Users
Bare	41	42	32	78.05%	76.19%
Cultivated	42	42	35	83.33%	83.33%
Grazing	40	42	33	82.50%	78.57%
Built-up	36	42	33	91.67%	78.57%
Forest	42	42	32	76.19%	76.19%
Totals	201	210	165		
Overall Classification Accuracy			82.14%		
Overall Kappa Statistics			0.7872		

3.4.5. Land use/land cover change detections

The Land use/land cover maps of the two periods (1973 and 2014) were generated after a supervised maximum likelihood classification was employed on the satellite imageries collected from Ethiopian Mapping Agency. Consequent to this, the Land use/land cover change rate and Land use/land cover conversion matrix were employed to analyze the LC structural changes. Based on the rate of change, a map of the two periods was analyzed and information on the trend of changes from one class to another in terms of time was generated.

To get information about which Land use/land cover goes to where; or the contribution of each Land use/land cover class for the change in spatial extent of the other, the Land use/land cover rate of change in the study woreda change comparison matrix was employed and analyzed for each period. The degree of Land use/land cover changes from 1973 to 2024 for the study woreda was analyzed. In addition, the statistics of Land use/land cover were computed and summarized to detect the nature of the major changes which occurred during the two periods. Results were explained using corresponding tables and figures.

3.5. Soil erosion loss analysis

The universal soil loss equation is an empirical model developed by Wischmeier and Smith (1978) to estimate soil erosion from fields. Worldwide, it is the empirical soil erosion model most frequently used to estimate soil erosion, to assess soil erosion risk, and to guide development and conservation plans in order to control erosion under different land cover conditions. Different factors causing erosion such as climate, soil properties, vegetation cover and management practices are considered for estimating soil loss.

Mathematically the equation is denoted as:

$$A \text{ (tonnes/ha/year)} = R * K * L * S * C * P \dots\dots\dots 3.1$$

The equation estimates sheet and rill erosion, where forest management and agricultural activities expose the soil surface to rainfall impact and runoff. However, it does not estimate gully, landslide or soil creep erosion. For Ethiopian conditions, the applicability of the USLE model was studied by Hurni under Soil Conservation Research Program (SCRIP) (Hurni, 1985).

3.5.1. Parameterization of USLE

To identify the spatial pattern of potential soil erosion in the study area, all the considered erosion factors (R, K, LS, C and P) had been surveyed and calculated depending on the recommendations of Hurni (1985) to the Ethiopian context and other related studies. The parameters/factors that are included in the model were processed with 30m by 30m cell size and the final model output was set to same cell size to obtain the annual soil loss per hectare per year.

3.5.1.1. Erosivity index - R factor

The R factor is called the erosivity index, which means the active force of the rain which causes detachment and successive transport of soil particles. Precipitation is a very important erosion factor particularly in arid areas, where the soil is usually directly exposed to rain drops and its composing particles do not have a great cohesion power. From these bases the R factor expresses the power of the rain to start an erosion process.

The most suitable expression for the erosivity of rainfall is an index based on the kinetic energy of the rain. However, there is no data to estimate the kinetic energy, thus estimate based on annual rainfall suggested to be appropriate (Hurni, 1985; Kaltenrieder 2007).

In this study, the equation which had been developed by Kaltenrieder, (2007) was used.

According to Kaltenrieder, (2007):

$$R = 0.367P + 47.6 \dots\dots\dots 3.2$$

Where:

R= Rainfall Erosivity

P = the mean annual precipitation measured at nearby rain gauges.

The Hurni (1985) and Kaltenrieder (2007) R- factor estimations were compared. Kaltenrieder estimates R-factor values that are reduced by nearly 25 %, which would have a significant impact on the final USLE result. As the study area is located in relatively heavy rainfall zone, Kaltenrieder equation was found more appropriate.

Each grid cell of mean annual rainfall was calculated based on this equation in order to obtain the R-value using ArcGIS. To compute this calculation, the study area raster data for annual precipitation was generated and used and processed in ArcGIS software to get R values for the entire study area. Finally, R factor map was produced and used for further processing with other USLE factors data.

The altitude of the woreda varies between 1500 to 21500m asl with a range of only about 650m asl, which hasn't made the distribution and amount of rainfall fairly varied both in spatial and temporal terms across the area. Therefore, it is relevant to consider the distribution of rainfall when making a variety of decisions, including those related to soil erosion risk analysis. As a result, the average rainfall factor (P) was calculated by interpolating the rainfall data over the study area. In this study, historic rainfall data for the year 1971 to 2014 was collected from three rain gage stations. The coordinates and the map of the rain gauge stations are shown in Table 3.5 and Figure 3.6 below, respectively.

Table 3.4 Coordinates of Rain gauge stations

No	Station	X (Longitude)	Y (Latitude)	P-Value	R-Factor
1	Hawassa	443299	778698	987	402.92
2	Haysawita	452745	763034	1036	420.56
3	Yirbaduwancho	431498	765321	1078	435.68

For each altitude class a corresponding mean annual rainfall was assigned and the R value was calculated from the rainfall map using raster calculator function of ArcGIS

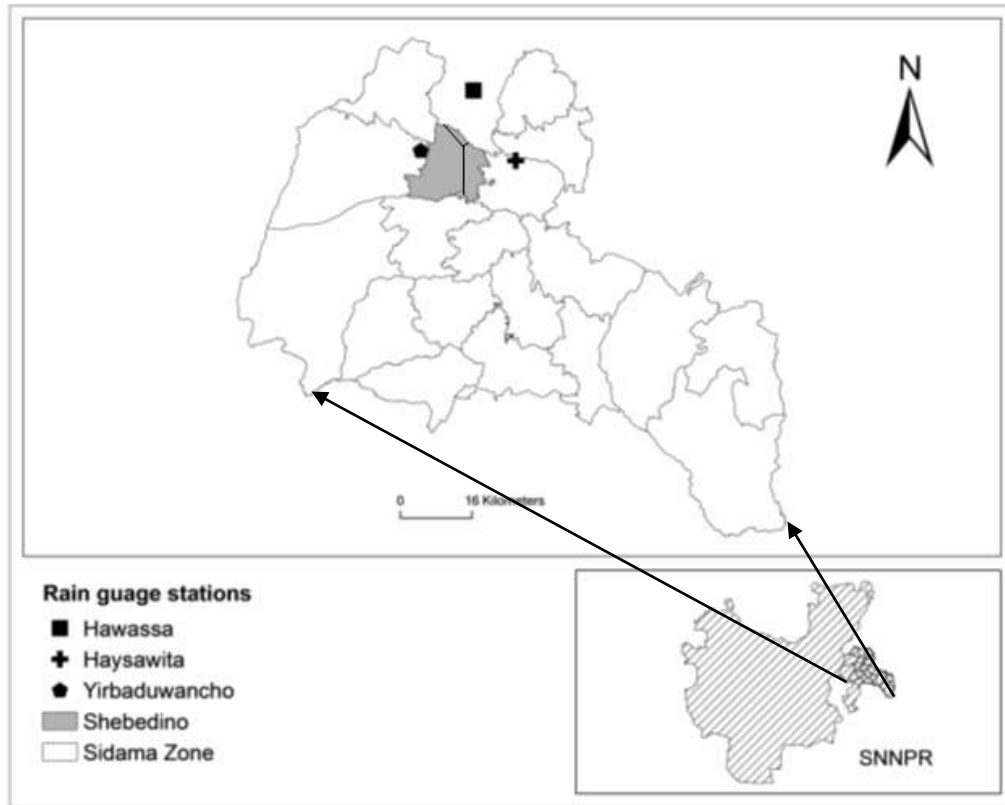


Figure 3. 6 Rain gauge stations map of the study area

3.5.1.2. Soil erodibility - K factor

K factor is the soil erodibility factor defined as mean annual soil loss per unit of R for a standard condition of bare soil, recently tilled up-and-down with no conservation practices on a slope of 50 and 22 m length (Morgan, 1994). K factor represents both susceptibility of soil to erosion and the rate of runoff. It depends on a lot of biological and chemical soil characteristics such as its mineralogical composition, particle size, permeability and the presence of organic matter. This is an empirical formula expressing soil loss for a specific soil present in standard rectangular plots of 22.1m of length (along the maximum sloping direction) and with 9% steepness, free of vegetation and left in a seedbed condition.

The value of K ranges from 0 to 1. Determining these data, especially at local level, is often difficult and may not be suitable for extrapolation from one place to another. For this particular study, a combination of Hurni (1985) adapted and later modified by the Rift valley Lake Basin Master Plan study and Kaltenrieder (2007) K-factor estimations for different soil types is used. Then these K values were assigned for each soil types in the study area and from this a soil map was generated, which aided in the creation of a K factor map using ArcGIS. The K-factors for the soil types of Shebedino is presented in Table 4.3 below.

Table 3. 5 K-Factor estimates for different soil types

No	Soil Type	K- value
1	Eutric Fluvisol	0.28
2	Eutric Nitosol	0.32
3	Molic Andosol	0.26
4	Orthic Luvisol	0.14
5	Pellic Vertisol	0.22

Source: MoWR (2007) and Kaltenrieder (2007)

3.5.1.3. Slope steepness and length - LS factor

The slope steepness and length(LS) factors of slope length (L) and slope steepness (S) can be combined in a single index, which expresses the ratio of soil loss under a given slope steepness and slope length to the soil loss from the standard condition of a 5° slope, 22m long, for which $LS = 1.0$. The appropriate value can be obtained from monographs (Wischmeier & Smith 1978; Hellden 1987).

For the current study, the slope gradient was determined from the Digital Terrain Model (DTM). Ascertaining the dominant slope length was difficult due to the need to separate each segment of the slope, and the possibility of not being able to identify

shorter and flat slopes. Rather than computing the slope length from the DTM, it was preferred to employ a recommendation given for Ethiopian conditions where slope length is not available (SCRIP, 1996), combining the L and S factors as indicated in Table 3.9 below. The principal logic behind this approach is that slope gradient and slope length have a positive correlation in most Ethiopian terrain, with little error present in the lowlands. The combined LS values corresponding to the ranges of slope gradient were applied to the slope class map in ArcGIS so that the resulting map was the LS factor map. This map was one of the information layers employed for compiling erosion potential map.

Table 3. 6 Slope length and gradient factor combined Shebedino woreda,

Slope Gradient	% LS factor	Slope Gradient	% LS factor
<2	0.19	13-25	3.80
2-4	0.38	25-40	6.08
4-6	0.66	40-55	7.98
6-8	1.14	55-100	10.45
8-13	1.90	>100	19

Source: MoWR (2008) and Kaltenrieder (2007)

After the slope gradient of the study area was produced from DEM and the slope length value was assigned to each slope class, the LS map was generated

3.5.1.4. Cover management – C factor

The crop management factor represents the ratio of soil loss under a given crop to that of bare soil. Since soil loss varies with the erosivity and the morphology of the plant cover, it is necessary to take into account the changes which occurred during the year when determining an annual value (Morgan 1994). The crop management factor (C) reflects the effect of ground and vegetation cover on the reduction of soil loss by reducing rainfall and runoff (Wang, 2003). It adjusts the value of soil loss for the standard bare soil condition to that from a cropped field. This is the cover

management parameter and it ranges between 0 (ideal case when there is no soil loss) and 1, corresponding to the greater amount of soil loss. This dimensionless factor measures the ratio of soil loss between a specific area with given cover management conditions and an experimental plot under reference conditions clean tilled continuous fallow conditions.

Determining the C factor often faces more accuracy constraints than any other factor. Land cover needs to be recorded by the use of different measuring and surveying techniques, although more often it is the satellite imagery interpretation which is key tool to this work. In the present, based on information from farm management, cropping pattern, cultivated crop types, practices and surface cover, the C-factor derived by Wischmier and Smith (1978), adapted for Ethiopia by Hurni (1985) was used for the USLE model. In generating the C factor, Landsat image of ETM+ from 2014 and information collected from the field and from different offices such as Shebedino woreda, Sidama Zone Agriculture and Rural Development Department have been used. Data and information from field observations, focus group discussions and key informant interviews have also been utilized to generate the C-factor map. A Normalized Difference Vegetation Index (NDVI) map was generated to assist the C- map development (figure 4.5).

3.5.1.5. Support practice – P factor

Values for the erosion-control practice factor were 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, $P = 1.0$ (Morgan 1994). P is the support practice factor and reflects the impact of support practices and the average annual erosion rate. It is the ratio of soil loss with a specific support practice on croplands to the corresponding loss with upslope and down slope tillage. This factor considers any practice applied by humans to reduce erosion degree and soil loss amount deriving from water erosion process. It includes a variety of agriculture management activities such as tillage and planting along contour lines (contouring), fields alternated to sod

strips along the contours (strip cropping), and tree lines planted along agricultural fields and terracing.

These management activities are highly dependent on the slope of the area. Wischmeier and Smith (1978) calculated the P-value by delineating the land in to two major land uses, agricultural land and other land. The agricultural land was subdivided in to six classes. When determining P_factor values in this particular study, soil and water conservation works implemented in the study area was evaluated from relevant zonal and woreda documents and reports. In order to get more realistic results, physical observation was also conducted for verification of the reports.

Very little is known about the types and overall extent of the measures implemented in the woreda. However, recent soil and water conservation interventions and water harvesting techniques that have been implemented by communities under the support of the Safety Net Programme were observed during the field visits. The programme supports the implementation of public works such as soil and water conservation that are expected to be carried out on communal lands on a sub-watershed basis. Moreover, the safety-net programme operates in the woredas believed to be food in-secure according to criteria set by the government, although little information could be obtained on the extent of the programme. Some indications were given verbally in discussions with the zonal agriculture office at Hawassa and with experts at woreda level.

Finally, the p-factor values used for the model were determined based on Hurni (1985) and Kaltenrieder (2007) estimations for Ethiopia. However, for situations of intercropping, mixed land use system averages of the C-factor values were taken (Table 3.10).

Table 3. 7 C and P factor estimate, Shebedino woreda, 2014

No	Land cover/crop type	C factor value	P factor value
1	Bare land	0.25	0.9
2	Cultivated land	0.1	0.85
3	Grazing land	0.05	0.8
4	Built-up	0.01	0.8
5	Forest	0.01	0.7

Source: Hurni (1985) and Kaltenrieder (2007)

4. RESULTS AND DICUSSION

4.1. Land use/ land cover classification

Based on spectral categorization of information classes from the land sat imageries, five major Land use/land cover classes were identified for both 1973 and 2014. The Land use/land cover classes include bare land, cultivated land, grazing land, built-up and forestland (Table 4.1

Table 4. 1 Land use /land cover of Shebedino woreda 1973 and 2014

	Land use/land cover	1973		2014	
		Area (ha)	Area (%)	Area (ha)	Area (%)
1	Bare	299.16	1.52	2037.51	10.34
2	Cultivated	7808.04	39.62	15364.17	77.96
3	Grazing	2285.08	11.59	685.78	3.48
4	Built-up	171	0.87	213.12	1.08
5	Forest	9144.72	46.40	1407.42	7.14
	Total	19708	100	19708	100

As revealed in Table 4.1 above, the results of the land cover classification from the 1973 landsat MSS image (figure 4.1) indicate that about 46.4% was forest land, 39.62% was cultivated land, 11.59 % was grazing land, 1.52 was bare land and 0.87% was built-up land.

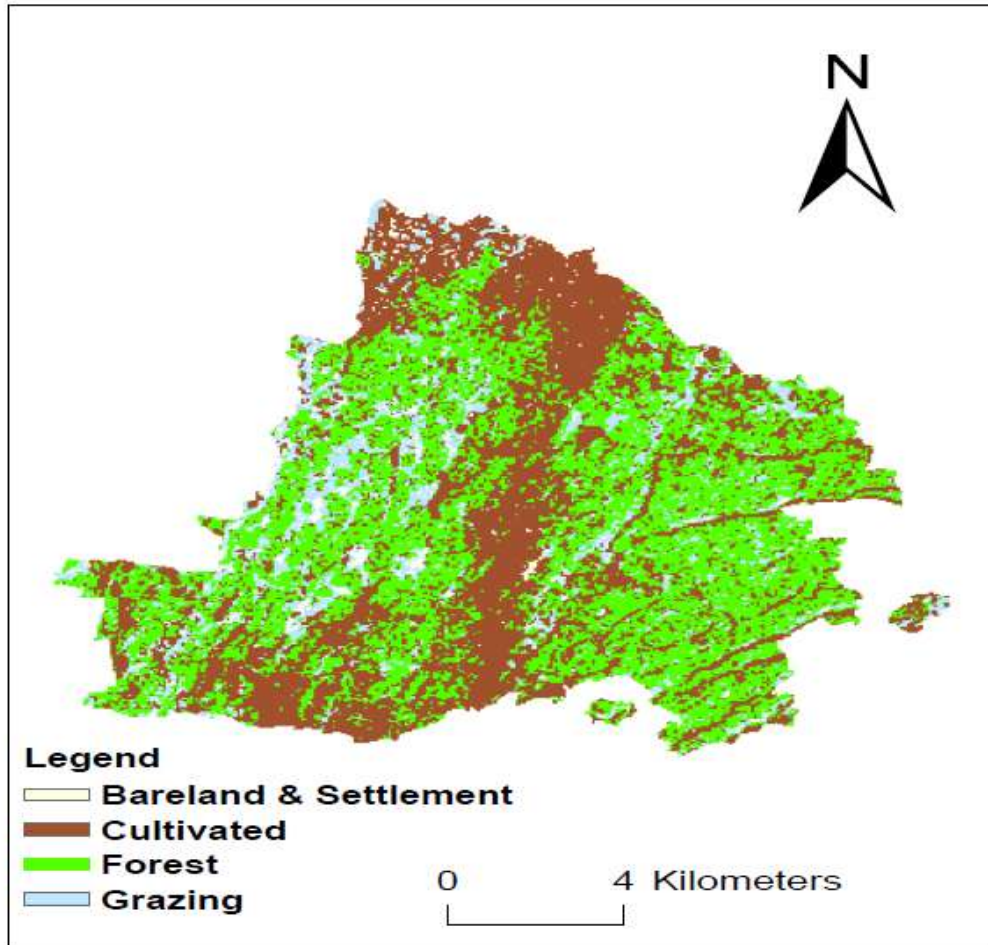


Figure 4. 1 Land use/land cover map of 1973

Similarly, the result of the land cover classification for 2014 from Landsat ETM+ image (figure 4.2) indicates that about 7.14 was forest, 77.96 was under cultivation, 3.48 was grazing land, 10.34% was bare land and 1.08% was built-up land. This shows that cultivated land were dominant.

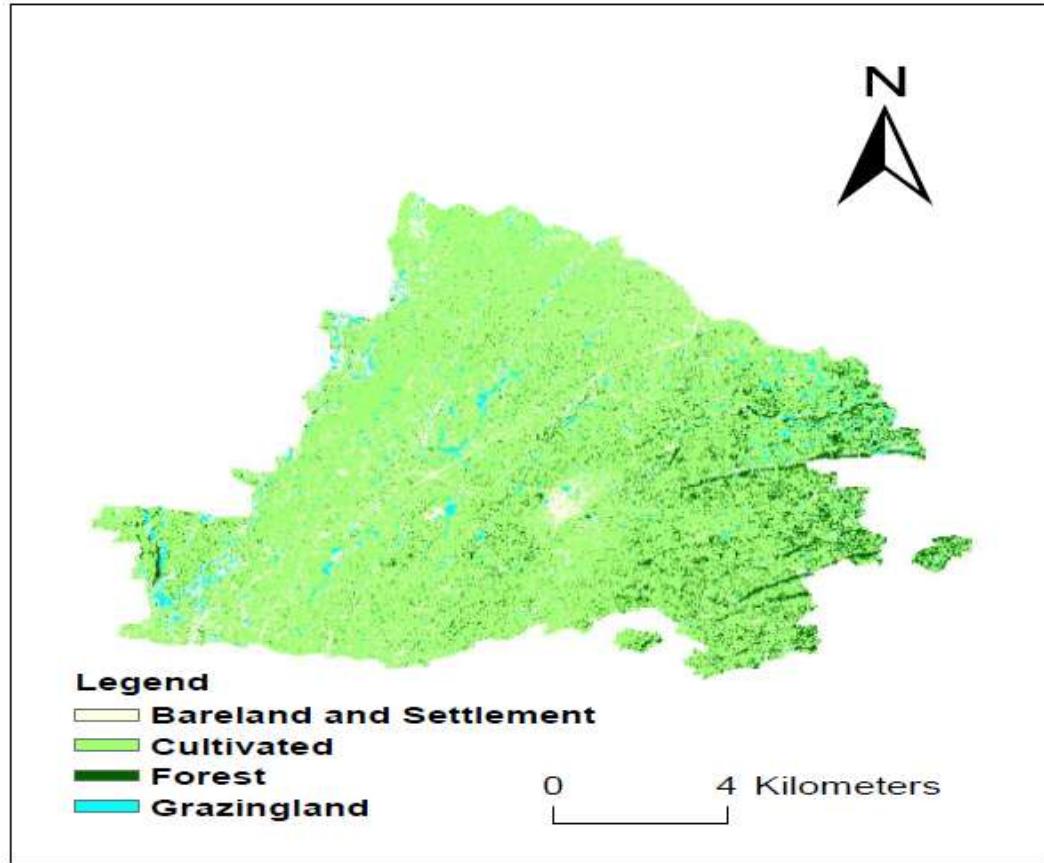


Figure 4. 2 Land use/land cover map of 2014

4.2. Land use/land cover change

In 1973, forest, cultivated and grazing land constituted a relatively large proportion of the area, with forest covering 46.4%, cultivated land covering 39.62% and grazing land covering 11.59%. A relatively small amount of the area was identified as being either bare (1.52 %), or built-up (5.94%). These conditions were considered as a baseline for change detection over the study years (between 1973 and 2014). In 2014, after four decades, the forest land dramatically declined to 7.14 %. Despite its relative large size, cultivated land increased to 77.96 %. Similarly, bare land and built-up land were showed a slight increase; while grazing land has experienced a small decline. The change in the area coverage of the different Land use/land cover classes during this period was relatively high and there was continuous dynamic change among them (figure 4.1).

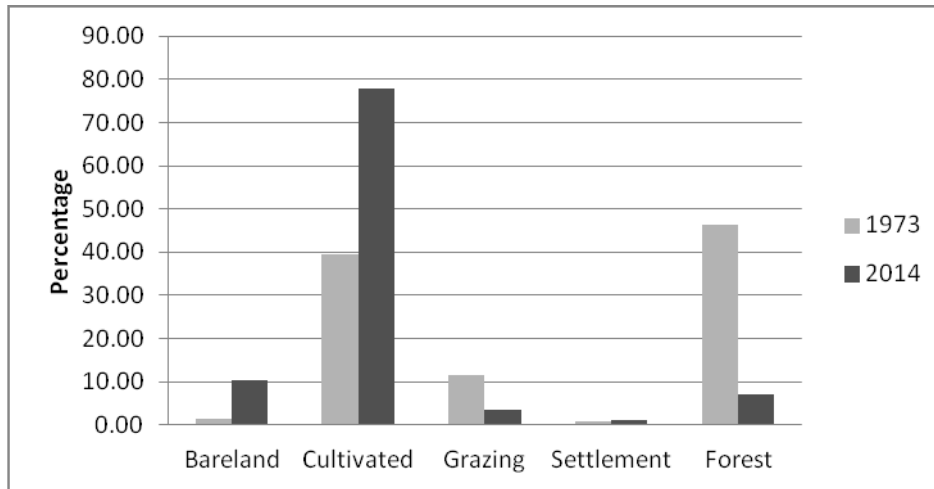


Figure 4. 3 Land use/land cover class of 1973 and 2014

In the period considered, the following major important changes were observed. Firstly, deforestation in all areas especially on the eastern and western part of the woreda occurred. Secondly, the majority of the deforested area was converted to other land cover classes particularly to cultivated land. Thirdly, cultivated land and bare land was found to have expanded. Moreover, settlements have also slightly increased. Most studies indicated that in the highlands, where part of the study area is found, vast areas of forest and woodland were cleared due to high population growth coupled with serious land degradation and the low productivity of steep slopes brought under cultivation (Markos Ezra, 1997).

4.2.1. Rate of land use/land cover change

The rate of change was discussed by comparing the rate of change of each of the Land use/land cover classes over the period considered. The study period comprises four decades from 1973 to 2014. The rate of change of each Land use/land cover class can provide the information to make a comparison among the different classes. Hence, the Land use/land cover map of the two periods was analyzed based on rate of changes

As indicated in Table 4.2 and Figure 4.4, bare land, cultivated land and built-up have each exhibited a positive rate of changes. Cultivated land exhibited the highest positive rate of change (179.91 ha/yr); while bare land exhibited the second highest rate of change (41.39 ha/yr).

Table 4. 2 Rate of Land use/land cover change of Shebedino woreda, 1973 to 2014

No	Land use/land cover	1973	2014	Changes from 1973 to 2014	
		Area (ha)	Area (ha)	Area change (ha)	Rate of change (ha/yr)
1	Bare	299.16	2037.51	1738.35	41.39
2	Cultivated	7808.04	15364.17	7556.13	179.91
3	Grazing	2285.08	685.78	-1599.3	-38.08
4	Built-up	171	213.12	42.12	1.00
5	Forest	9144.72	1407.42	-7737.3	-184.22

On the other hand, forest land and grazing land have both exhibited a negative rate of change in the study period. Forest land has shown the highest rate of reduction (-184.22 ha/yr) and grazing land has exhibited a reduction of -38.08 ha/yr the study period.

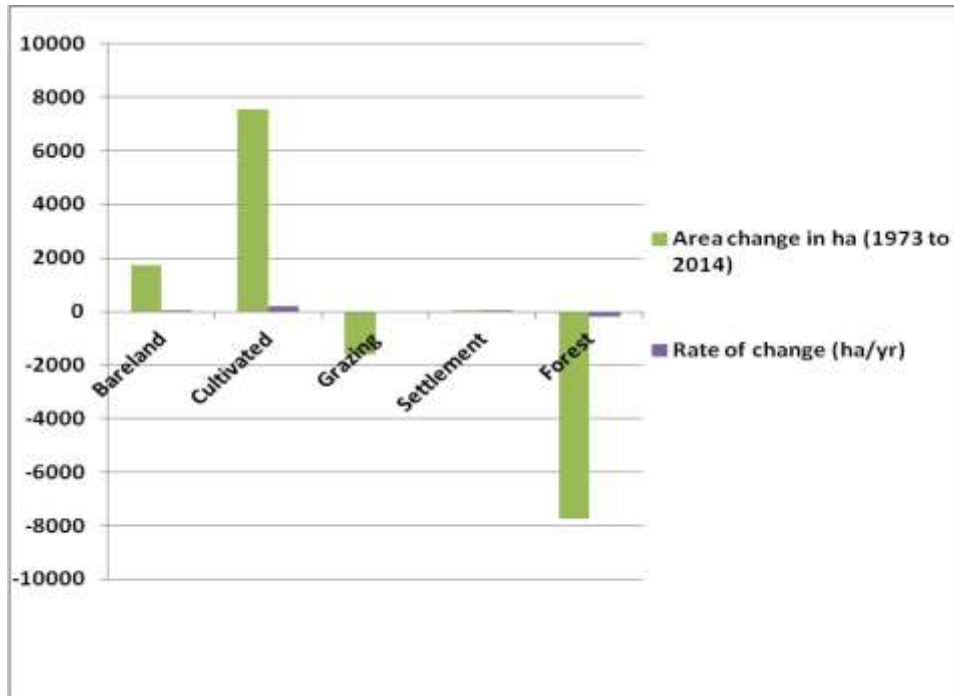


Figure 4. 4 Rate of Land use/land cover change of Shebedino woreda

4.2.2. Land use/land cover change matrix

The general view of the major changes of the Land use/land cover classes over the study period was discussed based on a change comparison of each class. A change comparison matrix was employed for each Land use/land cover class over the study period to understand the Land use/land cover changes in the study woreda.

The Land use/land cover conversion matrix used to analyze the source and destination of each cover type within the considered study period. The conversion matrix analysis was conducted in ERDAS 2010 software and a conversion comparison map was prepared for

1973 and 2014 in such a way that the columns represented the year of source and the rows represented the year of destination. Finally, to make the results more explanatory, a corresponding table and figure were prepared using Microsoft Excel.

The result of Land use/land cover change matrix (1973_2014) of the Shebedino worada has shown that during the indicated period a significant Land use/land cover dynamic change exists (table 4.3 and figure 4.5).

Table 4. 3 Land use/land cover Change Matrix for the year 1973 and 2014 in ha

		1973					
		Bare	Cultivated	Grazing	Built-up	Forest	Raw total
2014	Bare	65.16	903.42	313.38	20.07	735.5	2037.51
	Cultivated	184.68	5977.35	1664.19	129.06	7409	15364.2
	Grazing	35.01	276.12	152.73	12.15	209.8	685.78
	Built-up	6.84	89.1	37.44	3.96	75.78	213.12
	Forest	7.47	562.05	110.34	5.76	721.8	1407.42
	Column total	299.16	7808.04	2278.08	171	9152	

A considerable amount of forest land has changed to different Land use/land cover classes including cultivated land (7409 ha), bare land (735.5 ha) and grazing land (209.8 ha), which has resulted in an overall reduction in the amount of forest cover. Similarly, large areas of grazing land have been changed to other forms of Land use/land cover types, particularly to cultivated land (1664.19 ha) and bare land (313.38 ha). On the other hand cultivated land, which covered an area of 7808.04 ha (39.62 % of the area) during 1973, exhibited a net increment to 15364.17 ha (77.96 % of the area) in 2014. The additional land which shifted to cultivated land was from bare land (4.47 ha), grazing land (110.34 ha) and forest land (7409 ha). However, a considerable amount of cultivated land has been converted into grazing land (276.12 ha), forest land (562 ha) and bare land (7903.42ha)

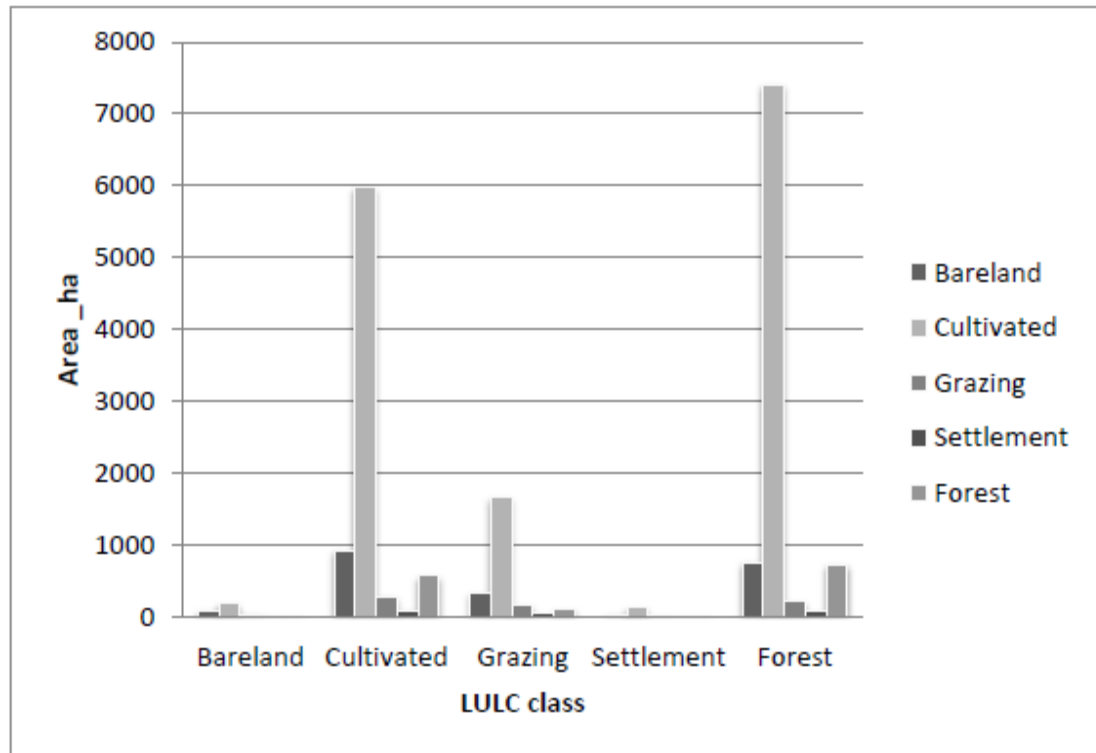


Figure 4. 5 Land use/land cover comparison matrix for the year 1973 and 2014

From the results of the Land use/land cover dynamics analysis, it is observed that in the last four decades the area has undergone a significantly active Land use/land cover processes. Different studies also confirmed that there is an ongoing active Land use/land cover dynamics situation in different part of Ethiopia due to several factors. The main identified factors that accelerate the Land use/land cover dynamics processes include lack of appropriate, integrated and participatory Land use/land cover management and supportive policies and corresponding laws (Million, 2002; Solomon, 1994).

Deforestation and soil erosion is a complex process. Population growth and declining crop productivity were the most important underlying driving forces to Land use/land cover change and soil erosion (Efrem, 2012). The Ethiopian Highland Reclamation studies revealed that the Ethiopian highlands, which cover 44% of the country's total land area, are seriously threatened by land degradation. The country is noteworthy as the country of famine. Food shortages are endemic and since 1970

severe famine has occurred almost once a decade (1973; 1982 – 1984 early and late 1990's and 2002 2003). Most of the agricultural production system is located on the Ethiopian Highlands where the majority of the population lives. Solomon (1994) also indicated that land-use and land cover changes and socioeconomic dynamics have a strong relationship; as a population increases the need for cultivated land, grazing land, fuel wood and settlement areas also increase to meet the growing demand for food, energy, and livestock.

From the results it was concluded that the area has been in a continuous Land use/land cover changes. The reasons behind these changes are likely related to the absence of clear and integrated land use/land cover management interventions/policies and the dynamicity in the socio-economic conditions of the area. This is supported in other studies, for instance, the main causes according to Million (Million, 2000 cited in Abiy 2012) showed that the lack of appropriate landuse and forest policies and the absence of corresponding laws are responsible for decline of forests in the highlands of Ethiopia. Similarly, land tenure systems and government policies have also been realized as the main causes behind the dynamic LU changes (Million, 2000; Solomon, 1994). The results of this study are consistent with the above findings.

4.3. Soil erosion rate assessment

In this study five parameters, derived from different data sources such as DEM (SRTM), soil map, climate (rainfall data), and remotely sensed data, were used in the USLE (figure 4.7). Each layer was organized in a grid format with a cell size of 30 x 30 meters. The layers were combined by multiplying each cell of identical position from all existing surface information based on the relationship defined by the USLE model. By multiplying the five parameters using raster calculator in ArcGIS, the final map that shows the potential annual soil loss of the woreda was produced (figure 4.8).

The final soil loss result (figure 4.7) was achieved with due consideration of some 23 years of meteorological data, as well as from soil and water conservation activities collected from the study woreda and from information on the farming practices obtained during field visits.

Moreover, the statistic tool has been used to calculate the amount of the soil loss potential and to classify the level of soil loss potential in the study area (table 4.4). The statistics of erosion hazards with the specified levels is also presented (table 4.5).

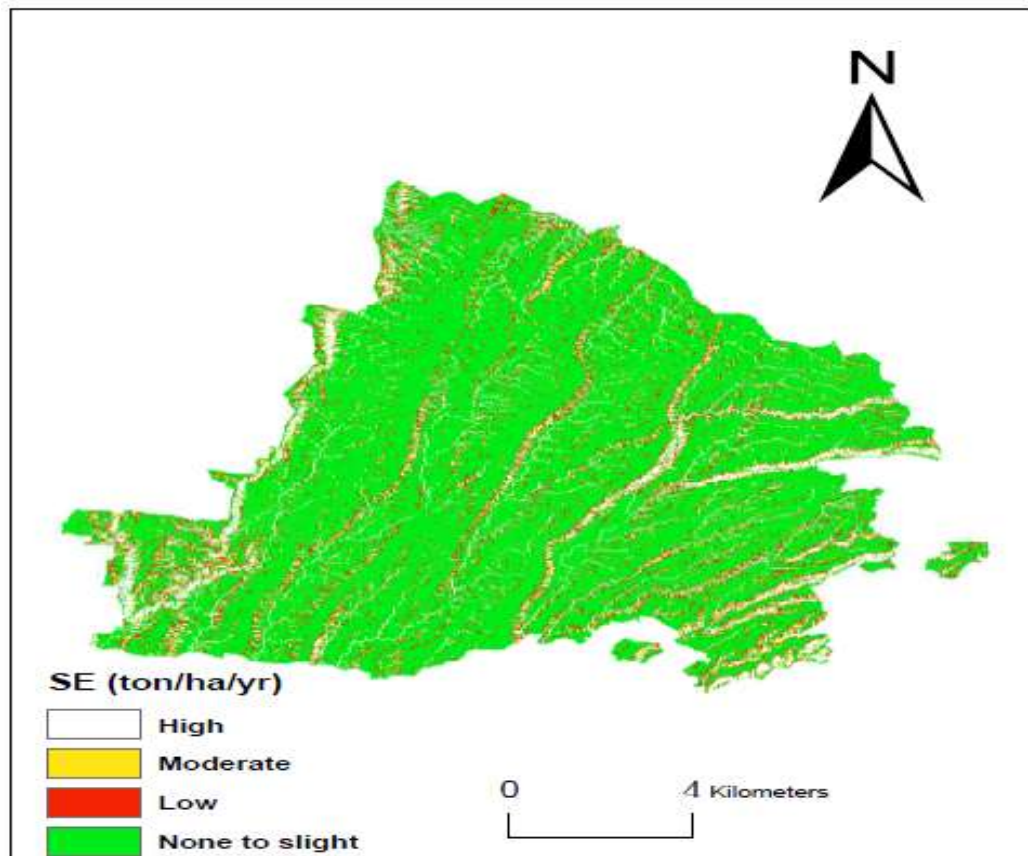


Figure 4. 6 Soil erosion map, Shebdino woreda 2014

The product of each parameter gave annual soil loss per hectare per year at the pixel level. The soil loss rate map shows various soil erosion rates with an estimated soil loss ranging from 0 tonnes per hectare per year in weak erosions zones such the plains and forested areas, to a little over 50 tonnes per hectare per year in relatively strong erosion zones such as agricultural lands, waterways and drainages. The total

annual soil loss in the study area (from an estimated area of 19708 ha) was about 77200.50 tonnes. The average annual soil loss for the entire district is 3.92 tonnes per hectare per year.

For easy comparison, the study area has been divided into the following four severity levels based on MoWR (2008) annual soil loss rates classification: soil loss less than 5 tonnes per hectare per year; between 6 and 15 tonnes per hectare per year; between 16 and 50 tonnes per hectare per year; and above 50 tonnes per hectare per year. The area coverage and relative percentage of each class has been also derived from the soil erosion map of the study woreda (table 4.4).

Table 4. 4 Annual soil loss rates and severity classes of Shebedino woreda, 2014

No.	Soil erosion rate class	Numeric range of soil erosion potential (t/h/y)	2			
			Area (ha)	% total	Total soil loss (tonne)	Total mean soil loss (tonne)
1	none to slight	<5	15309.60	77.69	19,071.68	1.25
2	low	6-15	3128.40	15.8	21898.80	7
3	moderate	16-50	819.32	4.1	13928.44	17
4	high	>50	449.68	2.2	22484.00	50
Total			19707	100	77200.50	3.92

Source: Adopted from MoWR, 2008

The results show that about 15309.60 ha (77.69 % of the area) disbursed across the woreda have a potential soil erosion of less than 5 tonnes per hectare per year, which is a relatively low erosion risk zone (table 4.4). These are areas where perennial crops such as coffee and fruit trees are grown and which are dominated by flat to gentle slopes. About 820 ha (4.16%) are shown to have a moderate to high annual soil erosion rate. These areas are found predominately in the western and

south western sections of the woreda with small sections being identified in the central and south eastern areas where steep slope characteristics have been noted. Similarly, about 500 ha (2.28 %) areas of the woreda have the highest potential erosion rate of above 50 tonnes per hectare per year, notable where the slope gradients are relatively high and framing activity exists. This study discovered that the level of erosion risk in Shebedino woreda varies with factors such as socio-economic activities, farming practices, topography, forest and vegetation cover, and different human interferences.

Annual soil loss estimation and mapping was done for the year 1973 (Table 4.5 and Figure 4.8). The estimation was done based on the assumption that all the factors (R, K, and) that was generated using the present condition (2014) are constant and only the LULC is changed. That means, only a different C factor map was generated and used based on the Land use/ land cover map of 1973. The results show that about 17539.23 ha (89% of the area) disbursed across the woreda had a potential soil erosion of less than 5 tonnes per hectare per year, which is a relatively low erosion risk zone (table 4.5).The total soil loss in the woreda was 31076.05 tonnes with average mean annual soil loss of 1.58 tonnes per hectare per year

Table 4. 5 Annual soil loss rates and severity classes of Shebedino woreda, 1973

No.	Soil erosion rate class	Numeric range of soil erosion potential (t/h/y)	1			
			Area (ha)	% total	Total soil loss (tonnes)	Mean soil loss (tonnes)
1	non to slight	<5	17539.23	89 %	2895.04	0.17
2	low	6-15	1379.49	7	8276.94	6
3	moderate	16-50	591.21	3	10050.57	17
4	high	>50	197.07	1	9853.50	50
Total			19707.00	100	31076.05	1.58

Source: Adopted from MoWR, 2008

The finding of this study revealed a drastic increment that is 159 % in total annual soil loss in 2014 compared to situation 1973. In the same manner, the average annual soil loss is shown a significant increase; from 1.58 tonnes per hectare in 1973 to 3.92 tonnes per hectare in 2014.

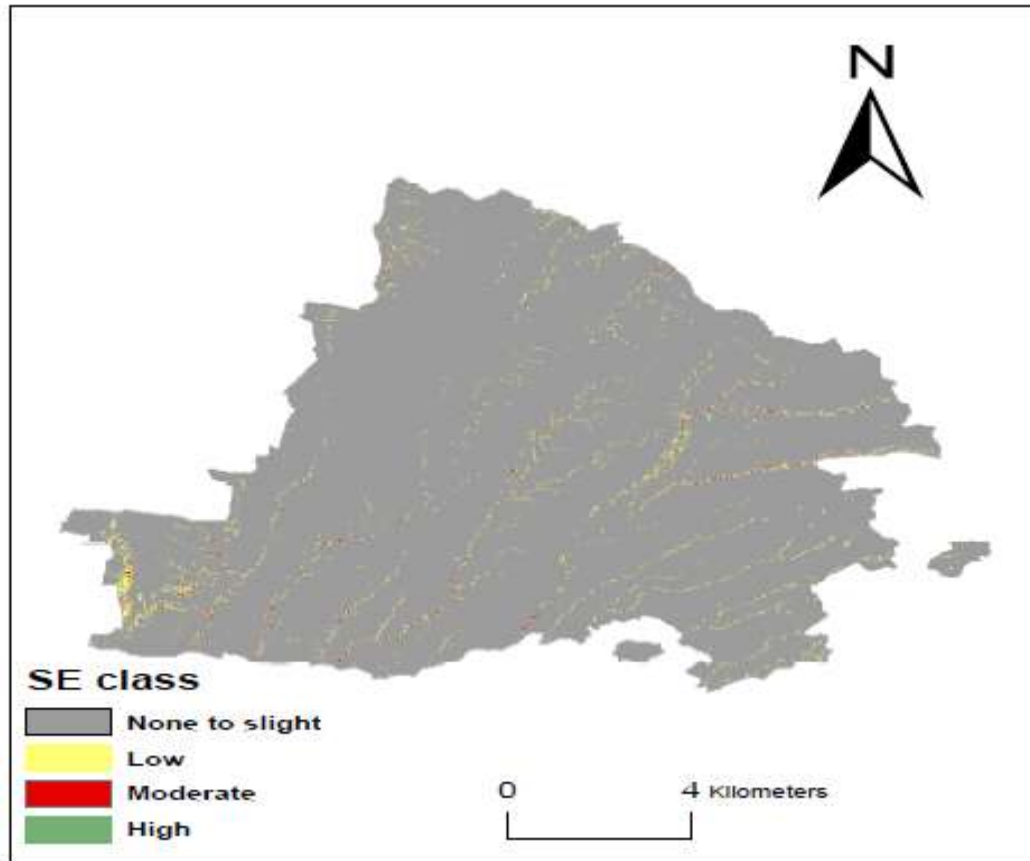


Figure 4. 7 Soil loss map of Shebedino woreda, 1973

Annual soil loss estimation was done for each landuse classes for both the year the year 1973 and 2014 (Table 4.6). The result shows that both in 1973 and 2014, cultivated lands were the major contributor for the annual soil loss. In 1973 the annual soil loss from cultivated land was about 16837.68 tonnes. After four decades this amount has increased to 44120.08 tonnes. Similarly, Forest land was the second highest contributor for annual soil loss in 1973; where as in 2014 it was from bare land that the second highest annual soil loss recorded.

Table 4. 6 Soil erosion from different land use classes of, 1973 and 2014

No.	LULC	1973			Soil loss (%)	2014			Soil loss (%)
		Area (ha)	Area (%)	soil loss (tonnes)		Area (ha)	Area (%)	Soil loss (tonnes)	
1	Bare	299.16	1.52	3486.96	11	2037.51	10.3	19547.4	25
2	Cultivated	7808.0	39.6	16837.6	54	15364.1	77.9	44120.08	57
3	Grazing	2285.0	11.5	4358.70	14	685.78	3.48	3007.3	4
4	Built-up	171	0.87	871.74	3	213.12	1.08	2255.47	3
5	Forest	9144.7	46.4	5521.01	18	1407.42	7.14	8270.07	11
	Total	19708	100	29058	100	19708	100	77200.500	100

From the results of this study it is possible to conclude the LS factor was found to be the other factor that significantly determines the loss of soil in the study area. This is true in areas where mountainous topography with farming practice exists. In the study woreda, the mean slope gradient of the woreda is 6° and the maximum reaches 35° in some parts of western, south western and south eastern areas where potentially moderate to high potential soil erosion is observed (Figure 4.8).

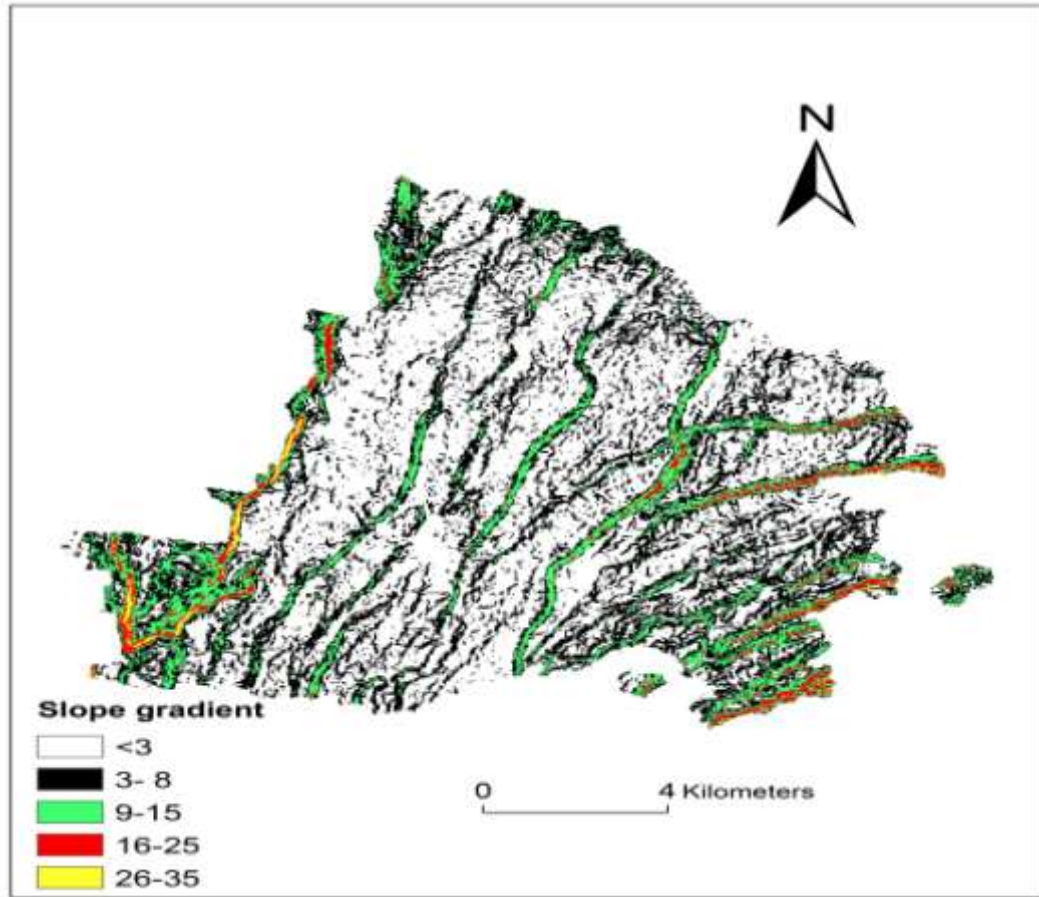


Figure 4. 8 Slope gradient of Shebedino woreda,

Assessing the soil erosion rate will help to identify the degree of erosion hazard in the study area. The USLE model result was reclassified to different erosion hazard classes. Studies have shown that the USLE model is more appropriate for indicating areas with differing degrees of erosion hazard rather than their qualitative soil loss (Van Remortel, 2001 cited in Tigneh 2011). Based on the WBISPP (2001) classification of soil loss classes, the extent of soil erosion in the study area was classified into six erosion hazard classes (table 4.5).

Table 4. 7 Erosion hazard classes of Shebedino Woreda, 2014

No	Soil loss in tones per hectare per year	Equivalent top soil removal in mm	Area (ha)	Level of hazard
1	<0.78	0	8761	None
2	0.78-3.125	0.25	2560	Very low
3	3.125-6.25	0.25-0.5	2309	Low
4	6.25-12.5	0.5-1	2678	Moderate
5	12.5-25	1-2	1300	High
6	>25	>2	2100	Very high

Source: WBISPP, 2001

In highland areas of Sidama which includes the current study woreda, Shebedino, agro- forestry and multiple cropping are very common. The traditional measures such as the agronomic and vegetative methods aimed at diversifying and integrating the benefits from both annual and perennial crops. According to the information obtained through different approaches, trash-lines are used in some areas of the woreda particularly in the lowlands. Farmers in Enset farming areas traditionally develop soil heaps around Enset plant as a means of storing adequate quantities of water and protecting the land from erosion.

Studies show that there is no robust model or method for assessing soil erosion, even in relative terms. Moreover, detailed assessments of soil erosion in specific areas require intensive and long lasting efforts on a research basis (MoWR, 2008), which is not possible for the current study. The findings of this study shows that mean soil loss of 3.92 tonnes per hectare per year is found in the study area. According to Hurni (1985), the estimated range of soil loss for Ethiopia is from 0 to 300 tonnes per hectare per year, and the mean soil loss is 12 tonnes per hectare per year. Hence, the results of this study fall within the ranges estimated for Ethiopia, but are far below the national average.

Research assessing the soil erosion loss in the study area also estimated different soil loss rate compared to this study. For example; Tigne (2009) estimated a mean soil loss of 3.43 tonnes per hectare per year which is very close to the finding of this study. On the other hand, Girma (2005) estimated a mean soil loss of 8 tonnes per hectare per year which is much higher than the finding of this study. The MoWR (2008) estimated the rate of soil erosion of the study woreda from 16- 30 tonnes per hectare per year; while the findings of this study show that a large portion (77.68%) of the woreda has an erosion rate of below 5 tonnes per hectare per year. Similarly, SOS Sahel (2014) estimated the soil loss for the parts of the woreda included in its study as low (5-12 tonnes per hectare per year); again very close to the result what this study has come up with.

The difference between this study and some of studies explained above might be aroused due to differences in parameter setting and weightings. For example, one obvious reason for the difference in results is due to different algorithms of USLE used in the parameter estimation of the R factors estimated using the new improved USLE algorithms based on Kaltenrieder (2007), which takes in to account rainfall distribution pattern in the study woreda. Nevertheless, despite the fact that there is significant difference between results from USLE model and results from actual field measurements, the finding of this study could be considered as a good input as concerns land use/ land cover changes and soil erosion assessment in the study area.

4.4. Relation of land use/land cover change and soil erosion in the study area

Vegetation cover and dead plant biomass used as mulching are known to reduce soil erosion by intercepting and dissipating raindrops and wind energy. Under this situation, lowest erosion rates have been recorded from undisturbed forests, with ranges from 0.004 to 0.5 tonnes per hectare per year (Bezuayehu *et al.*, 2002). However, once forestland is converted to agriculture, erosion rates increase due to factors such as vegetation removal, over-grazing, and continuous cultivation.

Land use and land cover patterns are interrelated with the types and properties of soils. The rate and severity of soil erosion and land degradation partly depends on land-use pattern. The problem of soil erosion starts with the removal of land cover (natural vegetation) for various purposes. Under the findings of the current study, it is indicated that the conversion of 7737 ha of forest land into different land use systems contributed to the acceleration of forest degradation and soil erosion in the study woreda. The average annual soil loss revealed a dramatic increment to 3.92 tonnes per hectare compared to situation in 1973 that was 1.58 tonnes per hectare.

The type of land cover can affect both the rate of infiltration and the runoff amount following precipitation. Both surface and ground water flows are significantly affected by type of land cover (MoWR, 2008). For example, forest canopy and leaf litter help to reduce the erosive action of rain drops while the formation of sheet, rill and/or gully erosion are common in areas where ground cover is insufficient. Accordingly, the common agroforestry practice of limiting the exposure of farmland in the study woreda has benefited farmers in minimizing erosion.

Land with regular vegetal cover tends to resist the effect of erosive mechanisms, and for cultivated land, more erosion occurs during the period of time when the land is left bare. Thus the trend in the change of land use and land cover from moderate to intensive cultivation and from dense vegetal cover to non-vegetal cover indicates an increase in erosion arising from exposure of land to erosive mechanisms, thereby increasing the level of land degradation. Conversion of agricultural, forest, grass, and wetlands to urban areas usually comes with a vast increase in impervious surface, which can alter the natural hydrologic condition within a watershed. It is well understood that the outcome of this alteration is typically reflected in increases in the volume and rate of surface runoff and decreases in ground water recharge and base flow (Andersen et al., 2007). This eventually leads to larger and more frequent incidents of flooding in farm land, which increases erosion. The findings of

this study show an expansion of settlements which has increased farm land flooding and erosion.

Population growth and declining crop productivity were identified as the most important underlying driving forces of land use/ land cover change and soil erosion (Efrem, 2012). Soil erosion is recognized as one of the most serious soil degradation processes in several part of Ethiopia. Various studies show that soil erosion is initiated and aggravated in particular by deforestation, over cultivation, over grazing, over population as well as rural development policies and the past and present agricultural activities. Mountainous and hilly topography, torrential rainfall and low degree of vegetative cover have been the major causes and aggravating factors of the destructive soil erosion in the highland areas of Ethiopia (Solomon Abate, 1994; and Markos Ezra, 1997). Based on this study, deforestation for the purpose of farm land expansion has played a significant role in erosion in the study woreda; from 31076.05 tonnes of total annual soil loss i n 1973 to 77200.50 tonnes in 2014.

Soil and water conservation interventions may prevent soil erosion. For example, terraced steep side slopes reduce the length and gradient of land and lead to a decline in soil erosion (MoWR, 2008). The assessment on existing soil and water conservation shows a lack of effort in the entire woreda, and that data on the extent and quantities of such interventions is unobtainable as they are little recorded. Land degradation is one of the major causes of low agricultural productivity and continuing food insecurity and rural poverty in Ethiopia (IFPRI, 2005). In areas similar to that of the current study, where the rate of deforestation is very high, the absence of these types of interventions may lead to series erosion problem. One of the major environmental problems in the study area is land degradation in the form of vegetation destruction and soil erosion.

Key informants stated that one the major factors leading to accelerated deforestation and soil erosion in the study area is population pressure. The demands for expansion of settlements and cultivated lands eventually aggravate the destruction of forests

and, in the absence of proper SWC measures, result in the conversion of forest land into cultivated areas. In addition, high population growth increases the demand of cultivation along the marginal land and steep slope areas that aggravated land use/land cover change, deforestation, and soil erosion in the study area.

Temesgen et al, (2014) indicated that land degradation in Ethiopia is mainly caused by population increase and unwise use of natural resources. Although some aspects of environmental problems are caused by natural factors such as drought and desertification, most of it is derived by poverty driven human activity. Soil degradation, mainly soil erosion coupled with climate variability, population pressure, pest infestations, declining farm size, technological gaps, poor infrastructure and inadequate institutional support have been resulting in serious environmental stress (Awdenest and Holden ,2007). Therefore, the findings of this study indicate that land use/land cover changes aggravated by the different factors discussed above have a direct relation in intensifying soil erosion in the study woreda.

5. SUMARRY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary

Land and soil degradation are the major environmental problems facing the earth. Land degradation in the form of deforestation and erosion is a complex process. Population growth and declining crop productivity were identified as the most important underlying driving forces to Land use/land cover change (Efrem, 2012). Land degradation could be caused by determinant agents such as biophysical (LU and land management, including deforestation and tillage methods), socioeconomic (e.g. land tenure, price, marketing and income, institutional support.), and political (e.g. incentives, political stability). Soil degradation is a narrower term for declining soil quality caused by improper use, usually for agricultural, pastoral, industrial or urban purposes which encompasses physical, chemical and biological deterioration of soil.

Soil erosion loss assessment and hazard mapping, tools used for better understanding land use/ land cover features, are very important resources for SWC measures towards planning, land resource management and policy drafting purposes. Though the Shebedino woreda is potentially rich in natural resources, it is at a very high risk due to land degradation caused by continuous unsustainable land use/ land cover practices aggravated by continuous deforestation which leads to soil erosion. Today, factors such as deforestation, soil degradation, erratic rainfall, agricultural activities in marginalized lands, and over grazing are found to be the major drivers for environmental degradation and for the decline of agricultural productivity, consequently causing food insecurity. Now more than ever, knowledge of the trends of land use/ land cover changes and the process of soil erosion, their causes, and their impact on such a vulnerable environment must be a priority issue in order to devise effective control mechanisms and suitable land management practices.

Assessing land use/ land cover change analysis and soil loss by water erosion using remote sensing technology along with GIS is vital for supporting the endeavor towards sustainable economic development. The identification and mapping of

specific areas susceptible to environmental hazards in order to develop tailored mitigation measures is also a matter of importance. Hence, land use/ land cover change analysis as well as soil erosion rate assessments and mapping were the main objectives the study. The Universal Soil Loss Equation using GIS and remote sensing techniques were methodologies adopted for conducting land use/ land cover change and soil loss analysis and mapping.

The result of the land use/ land cover change analysis of the Shebedino woreda over the last four decades showed that in 1973, forest, cultivated and grazing land constituted a relatively large proportion of the area (46.4 %, 39.62 % and 11.59, respectively). A relatively small amount of the area was categorized as bare (1.52 %), and built-up (5.94%). These conditions were considered as a baseline for change detected over the study years (between 1973 and 2014). In 2014, after four decades, the forested land dramatically declined to 7.14 %. Despite its relatively large size, cultivated land increased to 77.96 %. Similarly, bare land and built-up showed a slight increase; while grazing land experienced a small decline. The change in the area coverage of the different land use/ land cover classes during this period was high and there was a continuous dynamic change among them.

Furthermore, this study revealed that the total annual soil loss in the study area (for an estimated area of 19708 ha) was about 77200.50 tonnes. The average annual soil loss for the entire district is 3.92 tonnes per hectare per year. About 15309 ha (77.69%) of the area disbursed across the woreda has a potential soil erosion risk of less than 5 tonnes per hectare per year, which is a relatively low erosion risk zone. These are areas where perennial crops such as coffee and fruit trees are grown and which is dominated by flat to gentle slopes. Whereas, the remaining portion of the woreda is categorized as low risk (15.87 %), moderate risk (4.16%), and high risk (2.28%). The result of this study falls within the ranges estimated for Ethiopia (0-300 tonnes per hectare per year); but are far below the national average of 12 tonnes per hectare per year. Compared to the situation in 1973, the area exhibited a drastic increment that is 159 % in total annual soil loss in 2014. Similarly, the average

annual soil loss has shown a significant increase; from 1.58 tonnes per hectare in 1973 to 3.92 tonnes per hectare 2014.

5.2. Conclusion

The following conclusions are drawn on the basis of the results obtained and discussed from this research problem.

- Over the last four decades the area has been a significantly considerable and active land use/ land cover process.
- A large amount of forest land has changed to different land use/ land cover classes including cultivated land (7409 ha), bare land (735.5 ha) and grazing land (209.8 ha), which has resulted in overall reduction in the amount of forest cover.
- Furthermore, large areas of grazing land has changed to other forms of land use/ land cover types—particularly to cultivated land (1664.19 ha) and bare land (313.38 ha).
- Cultivated land and built-up land have exhibited a positive rate of changes. Cultivated land exhibited the highest positive rate of change (179.91 ha/yr); while bare land has exhibited the second highest rate of change (41.39).
- Forest land and grazing land have exhibited negative rates of changes in the study period. Forest land has shown the highest rate of reduction (-184.22) and grazing land has exhibited a reduction of - 38.08 ha/yr. during the study period.
- A large portion of the study area is less prone to soil erosion. About 15309 ha (77.68%) of the area disbursed across the woreda has a potential soil erosion of less than 5 tonnes per hectare per year, which is a relatively low erosion risk zone. These are areas where perennial crops such as coffee and fruit trees are grown and which are dominated by flat to gentle slopes
- The total annual soil loss in the study area (from an estimated area of 19708 ha) is about 77200.50 tonnes. The average annual soil loss for the entire district is 3.92 tonnes per hectare per year.

- A significant increment (159 %) in total annual soil loss has been observed. The total annual soil loss amount increased to 77200.50 tonnes in 2014 (mostly from cultivated lands) compared to 31076.05 tonnes 1973 situation.
- The soil loss results fall within the ranges estimated for Ethiopia (0-300 tonnes per hectare per year); but are far below the national average of 12 tonnes per hectare per year.
- Land use/ land cover change and soil erosion has a direct relation in the study area.
- Deforestation for farm land expansion has played a significant role in the erosion problem in the study woreda. In addition, population growth increases the demand of cultivation along the marginal land and steep slope areas which contributes to land use/ land cover change, deforestation, and soil erosion.

5.3. Recommendations

From the results obtained and the field observations made during the study, the following recommendations are forwarded:

- Permanent tree plantation in bare and affected grazing lands should be implemented. In addition measures such as agronomic SWC (strip cropping and grass strips) in cultivated land should practiced.
- To control land degradation in the steeper slopes areas in western and eastern parts, urgent land rehabilitation interventions such as afforestation programs and terracing are recommended
- Awareness to the farming community on LULC change and soil erosion link, concerning the optimum use of natural resources, conservation systems has to be provided.
- The results of the study will serve as important baseline data for resource allocation, management and natural resource conservation planning activities in relation to land use/land cover change and soil loss by water. Concerned actors in the area of SWC activities should consider the findings during panning.

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7. APPENDIX

7.1. Field study check list

Annex 1: Focus Group Discussion (FGD) selected farmers and Woreda experts

Purpose: The purpose of the FGD was to enable the researcher better understand the level of environmental degradation and land use change in the study area including soil erosion and land degradation and the mitigation measures being undertaken and required for future applications. Moreover perceptions concerning climate change have been discussed and relevant data collected.

Approach: The woreda offices (agriculture and environmental protection) was officially requested by the researched for overall cooperation and support. Explanation about the whole work has been given to all involved parties including peasant association leaders, key informants and FGD participants. The participants for FGD were selected with the help of the DAs' in the area. The DAs' were informed by the researched prior to this work. In addition potential selected areas for ground truth checking were will be conducted.

General, discussion subject:

- Environmental degradation: land use change, land degradation, soil degradation, soil erosion;
- Environmental protection and SWC activities;
- Perception on Climate change, impact on agriculture, environment etc;
- Socio-economic activities;
- Detail discussion points shown in the table below:

Table 7. 1 Detail discussion points with relevant woreda agriculture staff

Land-use/ land-cover	Soil/land degradation/ erosion	Environmental protection (SWC measures and others)	Weather/Climate change
General situation Current and past land use system/types Built-ups/eroded areas/grazing areas Crops coverage and farming system/livestock	Past/current trends, satiation Affected areas Types/indicators Extent/coverage Potential causes	Type, where Modality/approach Community Government Farmers NGOs Started/duration	Perception Type/ indicators Mitigation Impact

From Woreda Agriculture office:

- Climate, Hydrology, soil and topography
- Land use,(Cultivated land : Annual crops& Perennial crops, Grazing land, Forest & bush land Currently un-utilizable & unproductive)
- Population and socioeconomic activities

Required resources/ Materials

- Photo/video camera, GPS, stationeries
- Guide person, DA 's, Key informants, FDG participants, and district officials
- Means of transportation