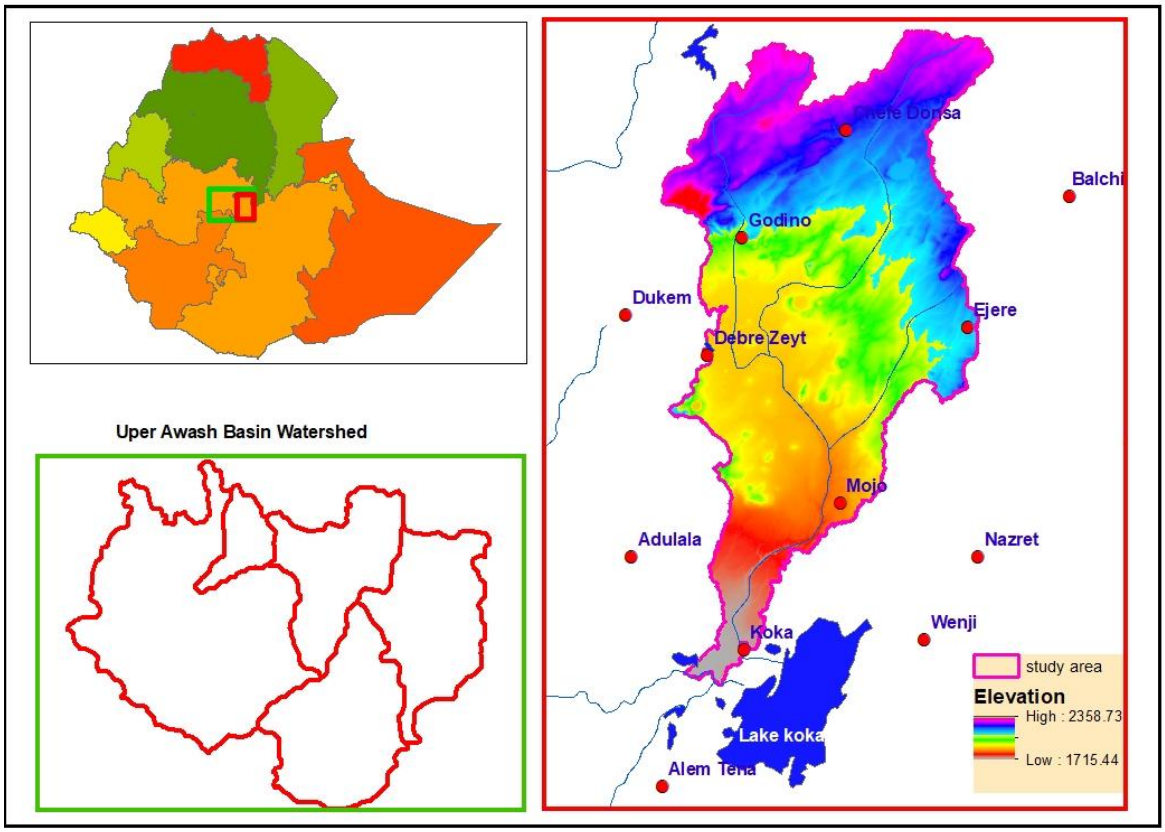
Adama Science and Technology University

School of Civil and Architectural Engineering.

Sub Watershed Prioritization for Integrated Watershed Management Using GIS and Remote Sensing Techniques



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February, 2018

ACKNOLEDGMENT

I would like to forward my great thanks to Adama Science and Technology University for the provision of the research fund and also ASTU Civil and Architectural Engineering staffs for their kind cooperation facilitating all the financial and material support (to respond my request).

My appreciation goes to all Geodesy and Geomatics Engineering department for their support when I was engaged in this research work.

My great thanks extended to all my friends who didn't mentioned here for their encouragement during the time when I was in this study.

ABSTRACT

The main aim of this proposal is to prioritize the sub watersheds for integrated watershed management and conservation measures and to evaluate the temporal change of the land use/cover using GIS and Remote Sensing techniques. In addition to this study also assessed or estimates the amount of soil erosion in the catchment area through RUSLE model and map areas which are susceptible for soil erosion.

Multi temporal satellite imageries LandSat ETM 2000, LandSat ETM 2005, 2010 and LandSat8 OLI/TIRS 2017 have been utilized for LULC change detection analysis. And an average annual rainfall data, soil map (data), and DEM have been considered for soil erosion risk analysis. The land cover map of 2000 and 2017 were used to produce the soil erosion risk maps and to estimate the rate of soil erosion and applied for analyzing SI and DSI for sub watershed prioritization. As a result, LULC maps of 2000, 2005, 2010, and 2017 and potential soil erosion risk map of the study area were generated.

In the period 2000-2017, 3.76 km^2 of Water body, 42.96 km^2 swampy areas, 75.52 km^2 of grass land, 10.16 km^2 bare land, 29.72 km^2 Forest land, 73.66 km^2 shrub land, 234.75 km2 crop/cultivated land, and 143.14 km^2 area of built up/settlement were changed to other classes from their initial state. Within this period 6.54 km^2 of Water body, 0.91 km^2 swampy area, 14.32 km^2 of grass land, 1.47 km^2 bare land, 4.24 km^2 Forest land, 9.69 km^2 shrub land, 842.99 km^2 crop/cultivated land, and 38.15 km^2 built up/settlement area not changed to other classes of LULC.

Generally in this time interval 613.67 km^2 land out of the total area coverage had been changed in this dynamics from one class to the other class. In the other hand about 918.31 km^2 out of the total area coverage had not changed to other LULC class, it was as its initial state

Regarding soil erosion risk assessment the result of annual soil loss of the study area (Upper Awash Basin) showed that the value range from 0 to 673.05 ton/ha/year in 2000 and 0 to 866.02 ton/ha/year in 2017. The average annual soil loss rate in 2000 was 20.86 t/ha/yr and in 2017 is 23.98 t/ha/yr.

From the final result it's identified that around four sub watersheds (45 rural kebeles) in very high priority class, five sub watersheds (46 rural kebeles) are in high priority class; two sub watersheds (27 rural kebeles) are in medium level priority class, around two sub watersheds (14 rural kebeles) are in a very low priority class and around three sub watersheds (12 rural kebeles) are in low priority class

Therefore detail assessment on micro watershed on prioritization, LULC management, soil conservation practice are recommended.

Key Words: LULC change, RUSLE, rate of soil erosion, soil erosion risk, sub watershed prioritization, GIS, and Remote Sensing.

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ACRONYM

LULC - Land use land cover

SWC - soil and Water Conservation

ISODA - Interactive Self-Organizing Data Analysis

AOI - area of interest

GHG - greenhouse gas

RS - remote sensing

GIS - geographic Information system

RUSLE - Revised Universal Soil Loss Equation

DSI - Degradation speed index

SI - sensitivity Index

TM - Thematic Mapper

ETM - Enhanced Thematic Mapper

GPS - Global positioning System

DEM - Digital Elevation Model

PC - presents Condition

Chapter one

1. Rationale

Watershed degradation is the global problem, which is more serious in developing countries like Ethiopia. As Ethiopia is mountainous country, a large number of watersheds can be delineated with different aerial coverage and most of them are in degraded condition. While considering the watershed conservation work, it is not feasible to take whole area at once. This calls to divide the watershed in small units that is sub watershed, by considering its drainage system. As the condition of sub watersheds may not similar, they can be prioritized for conservation work.

Watershed deterioration is the common phenomena in most parts of the world. Among several causes for this, improper and unwise utilization of watershed resources without any conservation work is the prime one which is more severe in developing countries (FAO, 1985).

Among several factors, the major one is deforestation followed by unsuitable agricultural practices. Therefore, it is necessary to develop a sustainable land management system that does not cause the degradation of such valuable resources. This is especially important in a predominantly mountainous country like Ethiopia (Thapa & Weber, 1990). For this, effective monitoring of land use/land cover change is the basic and essential step. Further analysis, like land degradation, sub watershed prioritization etc., has to be done so that protective measures can be better planned and implemented.

Both the reservoir and the dam are threatened by increasing sedimentation caused by environmental degradation. The greatest threat to Lake Koka itself is sedimentation. Recent studies show the rate of sedimentation to be 25 million m3 annually

In Ethiopia, the construction of dams has caused social, environmental, and economic problems by increasing the relocation of communities against their will and inducing watershed land degradation. The failure to recognize people as partners in the planning and implementation processes is a major characteristic of watershed-based

development projects. Soil erosion is a serious problem in the Ethiopian highland areas, threatening the agricultural sector and causing increased sedimentation of reservoirs and lakes.

Unfortunately, there is very little reliable information on the spatial dynamics of the land use types, the factors driving the changes, and the implications of these changes in watersheds where a reservoir has been created. Such information is, however, very important for planning watershed-based development projects such as soil and water conservation (SWC). Studies have shown that despite some achievements, SWC programs in Ethiopia have not triggered the voluntary adoption of conservation practices outside the project areas.

Accelerated type of soil erosion has started when human beings used land for settlement and agricultural practices. Throughout the history of human beings in the world, these human interventions have had environmental problems (Mohadi, 2001:1).

The rate of erosion can be determined by the amount of soil cover which intern is affected by the consequence of land use. Soil erosion can be caused by the extent of change in the land use system of a given area. Once forest land converted into agricultural land the rate of erosion increase; this is because of the removal of vegetation cover, over grazing and preparation of land for growing crops (ILIRI, 2002:23).

Globally, 1094.6 million hectare of land is degraded due to water erosion. Deforestation, poor agricultural practices urbanization, road building and other disturbances expose the soil to erosion (Leosmith, 1991: 153). Soil erosion in agricultural areas is the major problem, which is mainly enhanced by water erosion (Matheson, 1996:77). Accelerated soil erosion is the most serious and least reversible form of land degradation in Ethiopia (Milkessa, 1986: 40). According to ILIRI (2002: 35) it is estimated that about 1500 million tone of soil per year was lost from the high lands of Ethiopia.

As population increases in number and density more water will be required for agriculture and house hold use (Borrow, 1987: 59 and GWCU, 1996:16). These has environmental out comes like reduction in quantity of surface water and ground water, water pollution, land degradation and disruption of the hydrological cycle (GWCU, 1996: 6 and Roose, 1996: 42).

Land use and land cover change is taken as a serious problem in changing the environment, which intern could lead to global climatic change (Dale, 1997; Imbranaon, 1999; Meyer, 1991). This change could be the result of intricate interactions of socioeconomic and biophysical situation (like economic, technological advancement, demography, etc.)

This situation also holds true for Ethiopia. Few researchers, for example, (Solomon, 1994) in Metu area; Gete and Huri, 2001) in Dembecha area ;(woldemelak, 2002) in Chemoga area worked on the land use land cover dynamics using remote sensing techniques. The main causes of the land use/cover change in these local areas are identified as a result of increased population pressure.

Flooding in rivers and siltation in lakes and reservoirs are the major problems caused by land degradation in an area (Matheson, 1996:76). Due to siltation, the volume and depth of lakes reduced. For instance, Lake Lange in Eastern Hararghe has dried up while Lake Alemaya is filled with silt (ILRI, 2002:35-36).

Generally the problem mentioned above are currently creating serious problem at the Upper Awash Basin, Koka reservoir.

1.1 General objectives

The main aim of this proposal is to prioritize the sub watersheds for integrated watershed management and conservation measures and to evaluate the temporal change of the land use/cover using GIS and Remote Sensing techniques.

1.2 Specific objectives

1. To map land use land cover changes over different periods.
2. To estimate the amount of soil erosion in the catchment area through RUSLE model and map areas which are susceptible for soil erosion.
3. To prioritize the watershed
4. To recommend the sub watershed conservation activities

1.3 Significance of the Study

The final outcome of this study will have contribution for the community as well as for the scientific world. Some of the importance of the study are:

- It provides enormous information for the regional government as well as the federal government for planning and policy making
- It helps for governmental or non-governmental organizations, privet companies or sectors and individuals that need to work in social, economic and environmental conditions.
- It helps for agro industrial development and related projects in the area and the surrounding people in their future career and harmonious co-existence.
- It negotiates the many conflicting social, economic and environmental elements that can be obstacles of local and/or regional development and their sustainability.
- It is one of the important ways of teaching and sharing of some practical experiences for students from the different fields of studies Adama University and other Universities.

1.4 Description of the study area

The study area is located in the Eastern Shewa Zone of the Oromia Region, close to the capital and largest city of Ethiopia, Addis Ababa. The study area is about 1532 km^2 which has about 110 rural kebelas. The boundary of the study area intersects Akaki, Adea, Liben, Berch, Gimbichu, Lomme and Ejere weredas. Koka, mojo, Debre Zeyte, Ejere, Godino and Chefie Donsa are the major towns in the watershed.

The Koka Reservoir is one of the lakes which are found in the study area. This is popular with tourists and city-dwellers. There is a variety of wildlife and birds around the lake. The reservoir supports a fishing industry; according to the Ethiopian

Department of Fisheries and Aquaculture, 625 tons of fish are cached each year, which the department estimates is either 52% or 89% of its sustainable amount.

The Koka Reservoir (also known as Lake Gelila) is an artificial lake (or reservoir) in south-central Ethiopia. It was created by the construction of the Koka Dam across the Awash River in 1960. The reservoir has an area of 180 square kilometers.

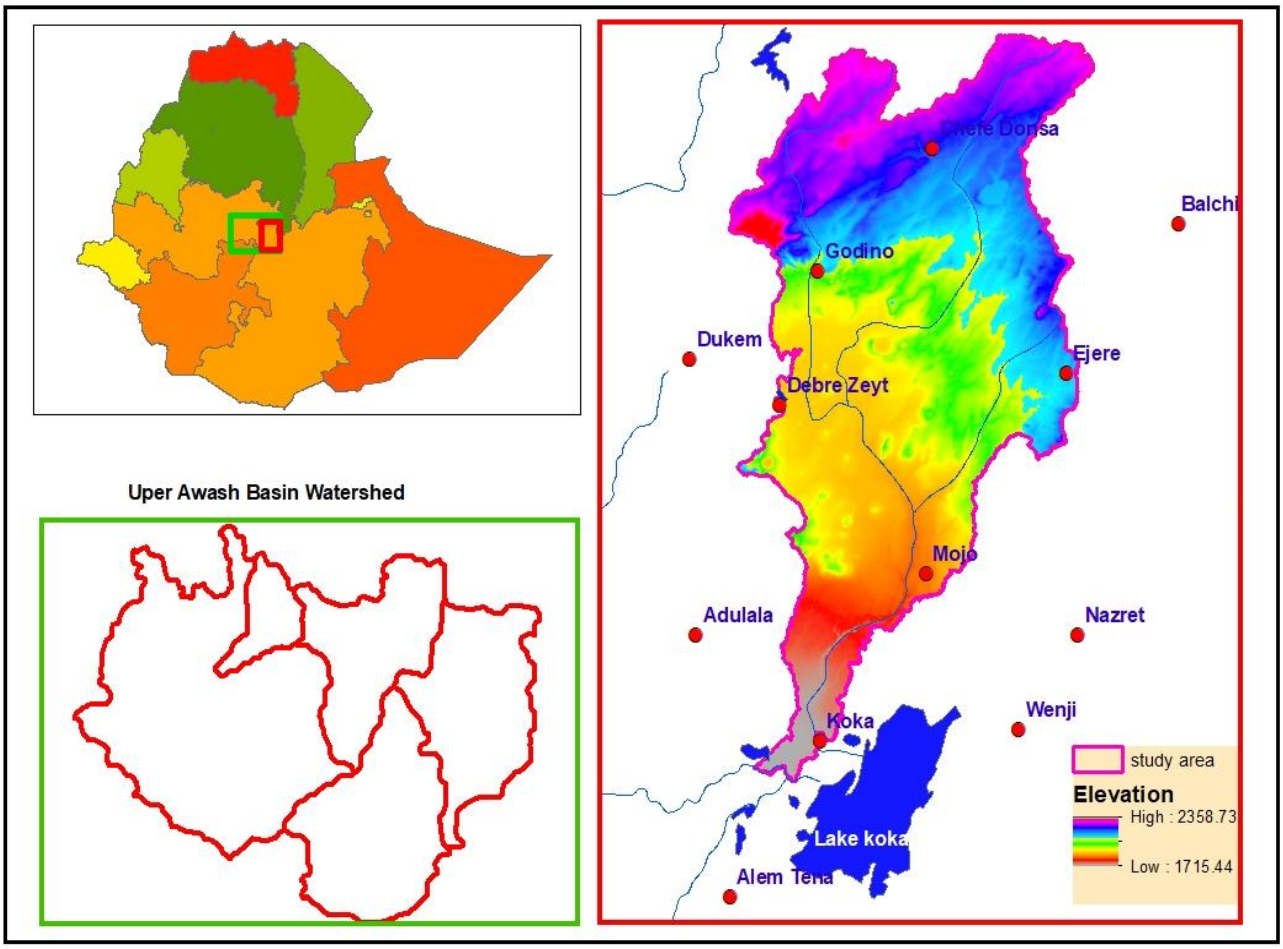

Figure 1.1 Map of the study area (Upper Awash Basin)

Lake Gelila, has an area of 180 km², and originally had a storage capacity of 1,850 million m^3, although sedimentation has reduced this by 35%. The other main habitats are the surrounding farmland, an area of partly protected woodland beside the dam site, and the river and hot-spring area below the dam.

Lake Gelila and its shoreline used to be fairly clear of vegetation, but *Eichhornia crassipes* has invaded the area and is spreading rapidly. As a result of crop cultivation

the only large trees that are left in the area are figs, e.g. *Ficus vasta* and a few others generally associated with churches or other ceremonial places. The main activity in the area is farming and the most widely grown crop is *Eragrostis tef*. The farmers using the alluvial soil around the lake also grow horticultural crops and pulses, particularly haricot beans.

The Upper Awash Basin has about 12832 km^2 areal coverage. There are a number of rivers that inter into the reservoir (Koka). The basin includes the small and big Akaki watersheds, which emerge from the Entoto highlands, in Addis Ababa, there by Aba Samuel Lake. There are a number of rivers and tributaries that drain to the Koka reservoir.

Chapter two

2. Literature Review

2.1. Prioritization of Watershed

Due to limited resources, always it is not possible to treat the entire area of the watershed at a time. Therefore, sub watersheds with more vulnerable areas yielding comparatively more prone to erosion should be treated with priority. Thus, the watershed prioritization is the ranking of different sub watersheds according to the order in which they have to be taken for treatment and water conservation measures.

Soil degradation is undesirable. It results in our land being less useful and less productive. The soil becomes less able to support plant and animal growth as there is a decline in levels of available moisture, available nutrients, and biological activity. As soil degradation develops, land can become unsuitable for particular uses. In extreme cases it can stop nearly all plant growth (e.g. salt pans and areas of severe sheet erosion). In less extreme (and less visible) cases it will restrict production (e.g. compaction reducing plant growth and grain yields). It may even prohibit specific activities (e.g. acidification preventing sub-clover growth).

Controlling sediment loads also requires knowledge and quantitative assessment of soil erosion and the sediment transport process.

2.1 Land use and land cover change.

Globally, land cover today is altered principally by direct human use. This includes clearing vegetation for expanding farming land, cut forests and trees for fuel wood and charcoal and overgrazing, forest harvesting and management, and urban and sub urban construction and development which all are anthropogenic effects. On the contrary, natural events such as weather, flooding, fire, climate fluctuations, and ecosystem dynamics may also initiate modifications up on land cover.

Even though natural processes may also contribute to changes in land cover; the major driving force is human induced land uses (Allen and Barnes, 1985). Changes in

the land use and land cover are pervasive, increasingly rapid and can have adverse impacts and implications at local, regional and global scales. But effects are felt in the developing countries than developed countries because of high population growth rate and associated rapid depletion of natural resources (Wilson 1992).

In Ethiopia deforestation, sedentary agriculture, soil erosion and over grazing have changed the land cover. Even the low level development, the pressure exerted by population growths exerted pressure for change of the environment. Conversion of woodlands and shrub-lands in to croplands has resulted in loss of the natural vegetation cover and has caused severe soil erosion (Mc Dougall et.Al., 1975; Vigro and Munro, 1977).

According to Robinove (1981), the use of remotely sensed data for mapping land use land cover has become an essential component of modern land use studies and can be used as substitute data of landscape features. The utilization of remotely sensed data enables substitute mapping due to the impracticality of direct measurement of the land escape.

In addition the impotency of the availability of reliable land cover and land use data for sustainable management of the earth's natural resources was emphasized at the UN conference, known as the "Earth summit", which took place in Rio de Janeiro in 1972 and Johannesburg in 2002. The earth summit recommended the use of remote sensing and GIS technologies for coordinated, systematic, systematic and harmonized collection and assessment of data on land cover and environmental degradation (Johannesburg, 2002).

Digital Image Processing

Digital Image refers to Sensors on board record electromagnetic radiation reflected or emitted by the surface of earth. Sensors generate electric signals that represent energy variation (brightness) and record in digital number ranging 0-255 for which 0 is black and 255 white while the rest represented by gray scale. Digital Image is composed of two dimensional array of discrete picture elements (pixel) representing the average brightness or radiance measured (Lillesand et al., 2007). 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 (Lillesand et al., 2000). Digital Image Processing is largely concerned with four basic operations: image rectification and restoration, image transformation, image enhancement, and image classification (Ibid). It is a very broad subject that often involves complex mathematical procedures to manipulate and interpret digital image with the aid of computer. The computer inserts the data into equation or series of equations and stores the results of the computation for each pixel that may be displayed or recorded into picture format or could be manipulated further representing certain features of earth.

Image Classification

Digital image classification is the process of identifying pixels, which are produced in several spectral bands within a satellite image. The process creates clusters of similar pixels into the same informational categories (Campbell, 2002). The classification executed by automated (unsupervised) or semi-automated (supervised) approaches are widely used in many LULC studies (Campbell, 2002; Lillesand, 2004; Jensen, 2005). Image classification is the process of creating thematic maps from satellite imagery. A thematic map is an informational representation of an image that shows the spatial distribution of a particular theme. The computerized interpretation of images from remote sensors is known as a quantitative analysis due to its ability to identify pixels based on the numerical properties. For quantitative analysis usually different procedures of classification are used (Diday, 1994). Classification is a method that assigns categories to different pixel groups according with the spectral character. There are two main spectrally oriented classification procedures for land cover mapping: unsupervised and supervised classifications

A. Unsupervised classification

Unsupervised classification identifies natural groups or structures within an image and detects uniform groupings of pixels that can be clustered into distinct categories in a multidimensional data space. In this study, the Interactive

Self-Organizing Data Analysis (ISODA) technique was selected to perform the unsupervised classification. For ISODA, the interpreter needs to provide the maximum number of classes. Then, the algorithm generates the clusters, calculates centroid of each cluster, and assigns image pixels into the neighboring cluster mean. The process will run iterations until the clusters' centroids remain the same (Campbell, 2002; Lillesand, 2004; Jensen, 2005).

The unsupervised classification approach is an automated classification method that creates a thematic raster layer from a remotely sensed image by letting the software identify statistical patterns in the data without using any ground truth data (Lillesand et al., 2004).The spectral classes obtained from the unsupervised classification are based solely on natural groupings in the image values. The Unsupervised approach does have its advantages. Since there is no reliance on user provided training samples (which might not represent "pure" examples of the class / feature desired and which would therefore bias the results), the algorithmic grouping of pixels is often more likely to produce statistically valid results. Consequently, many users of remotely sensed data have switched to allowing software to produce homogenous groupings via unsupervised classification techniques and then use the locations of training data to help label the groups (Erdas Field Guide, 1999).

B. Supervised classification

Supervised classification can be defined as: "A procedure for identifying spectrally similar areas on an image by identifying 'training' sites of known targets and then extrapolating those spectral signatures to other areas of unknown targets" (Canada Centre for Remote Sensing, 2010). In case of supervised classification, the user develops statistical description for various known land cover types that is called signature development. Then a procedure is used to identify the similar pixels/signature for different land cover types for the whole image.

Supervised classification utilizes samples of pixels that are already known informational categories to classify unknown pixels on an image. The interpreter selects training areas which contain training samples of known information classes and matches spectral values of these samples to pixels of unknown identity. If the pixels of unknown identity fall in the same category of training samples, the

interpreter can classify those pixels into the known classes (Campbell, 2002; Lillesand, 2004). Using the area of interest (AOI) tool from ERDAS to select the training areas, we generated spectral signatures that matched each spectral lass from ISODATA and assigned class names for the signatures. Selecting the appropriate bands to use in the color image on the other hand does have a huge impact on which features can be seen in a particular image during classification.

Accuracy Assessment

Classification accuracy refers to the extent of correspondence between the remotely sensed data and reference information (Congalton, 1991). One of the most common means of expressing classification accuracy is the preparation of classification error matrix (Lillesand and Kiefer, 2007). According to Anderson et al (1976), the recommended standard of accuracy in the identification of Land use and land cover change mapping from the remote sensor data should be 85 - 90%. On the other hand, Kappa coefficient is important information in accuracy assessment. The overall accuracy and a Kappa analysis were used to perform a classification accuracy assessment based on error matrix analysis.

Kappa coefficient is used to measure the agreement or accuracy between the remote sensing derived classification map and the reference data as indicated by the major diagonals and the chance agreement, which is indicated by the row and column totals (Jensen 2003). The Kappa coefficient expresses the proportionate reduction in error generated by a classification process compared with the error of a completely random classification. For example, a value of 0.82 implies that the classification process is avoiding 82 percent of the errors that a completely random classification generates (Congalton, 1991). According to Monserud (2002) as quoted by Moges et al.(2015) The overall accuracy gives the overall results of the confusion matrix. It is calculated by dividing the total number of correct pixels (diagonals) by the total number of pixels in the confusion matrix. Monserud 2002) suggested the use of kappa coefficient value less than 0.4 as poor, 0.4-0.55 % fair, 0.55-0.7 % good, 0.7-0.85 % very good and greater than 0.85 % as excellent classification result.

2.2 Soil erosion and siltation

Soil erosion by water becomes apparent when rainwater begins to move soil particles. When the raindrops, it beats the soil with great intensity and causing the splashing action, this action then carries away grains of sediments (Mller, 1985:12). The current extent of human induced soil erosion is recorded for different parts of the world. The total loss of soil in Ethiopia has estimated at 3 billion ton/year (NMSA, 2001:41). From 1.5 to 1.9 billion ton of soil eroded from the highlands of the country (Taye, 2001:43).

Cultivating land without proper soil management, overgrazing, excessive, tillage and urbanization causes soil erosion (Miller, 1994:11 and Matheson, 1996:67).
Soil erosion is not harsh on forestlands and rangeland than cropland. Since vegetation, organic matter and litter providing soil cover, prevent rain splash and run off the removal of these materials makes the ground easily erodible (Miller, 1996:517 and ILRI, 2002:28). However, once forestland converted to agriculture, the rate of erosion increases too. Removal of cow dung and crop residues from the fields for fuel and fodder further reduces the organic matter of high land soil (ILRI, 2002:28).

Silt is a fine-grained or muddy material made up of tiny particles of rock that settle at the bottom of water bodies (World Book, 1993 v.17). Silt and other nutrients enter in to the lake facilitated by reduction of vegetation cover in the catchment areas (Zinabu, undate: 199). When structure of the soil is disturbed and the soil washed by running water this eroded soil may silt up dams and pollute water supplies. Siltation on dams and reservoirs is as a result of land degradation (Matheson, 1996:69).

Human activities like deforestation; over gazing, poor soil management and construction of houses have been practiced in the watersheds of lakes, reservoirs, rivers and streams. Because of these practices for a long period of time, huge amount of sediment have accumulated in rivers, lakes and reservoirs. As a result of this, siltation leads to the disappearance of these water bodies (ILIRI, 2002:23). “Small lakes can be filled by deposits of mud, sand and silt” (world book, 1993: v 35). As ILIRI (2002:37) pointed out, Lake Alemaya is “almost filled up with silt”.

2.3 Soil Erosion causes and process of soil erosion

Soil erosion is one of the biggest global environmental problems resulting in both onsite and off-site effects. The economic implications of soil erosion are more serious in developing countries because of lack of capacity to cope with it and also to replace lost nutrients. These countries have also high population growth which leads to intensified use of already stressed resources and expansion of production to marginal and fragile lands. Such processes aggravate erosion and productivity declines, resulting in a population-poverty-land degradation cycle. Fast population growth, cultivation on steep slopes, removing of vegetation, and overgrazing are the major factors that increases soil erosion in Ethiopia. Ethiopia losses annually over 1.5 billion tons of topsoil from the highlands by erosion, that could have added about 1 to 1.5 million tons of grain to the country's harvest (Taddese, 2001).

The impact of soil erosion can be worst in the developing countries where farmers are highly dependent on intrinsic land proprieties and unable to improve soil fertility through application of purchased inputs. In Ethiopian highlands only, an annual soil loss reaches to 200 - 300 ton per hectare, while the soil loss movement can reach to 23400 million ton per year (FAO, 1984; Hurni, 1993). These highlands account 43 % of the countries and dominated by high soil fertility that covers 95 percent of the cultivated land. The removal of natural forests for the expansion of arable land, for fuel wood, charcoal and construction materials, overgrazing, intensive cultivation and poor cultural and land management practices have been stated as the major cause of soil erosion (MoA ,1989).

Level of soil erosion and severity of land degradation is aggravated by the agricultural activities expanding to marginal lands that are not suitable for cultivation. Moreover, the increase in population pressure also caused more deforestation as a means of income generation through the sale of fuel wood and charcoal to cope with the low level of income and unemployment in the rural areas. All these conditions led to exploitative use of the land (i.e. using the land beyond its capacity with the result of low agricultural productivity and income, leading to poverty in the rural areas).

Soil erosion is a physical process of soil degradation and the most widespread form of land degradation Lal as quoted by Argaw (2005). It is the detachment and transportation of soil particles from one place to another with a degree ranging from splash erosion to the alarming stage of gully formation.

Erenstein as quoted by Tibebe and Bewket (2010) stated that the economic and social effects of soil erosion are more severe in the developing countries than in developed countries because of the direct dependence for livelihoods of the majority of the population on agriculture and land resources. In Ethiopia soil erosion by water contributes significantly to food insecurity among rural households and poses a real threat to the sustainability of the existing subsistence agriculture, (Hurni, et al. as quoted by Bewket, 2006; Tibebe et al., 2010). Hurni as quoted by Haile et al. (2006) report that all physical and economic evidence shows that land resource productivity is a serious problem in Ethiopia with the continued population growth the problem is going to escalate in the future. Beyene, (2011) report that the predominant cause of land degradation and soil erosion stem from excessive human pressure or poor management of the land specifically overgrazing, over-cultivation of crop land and deforestation.

Another dimension of the problem is that the quantity of soil lost each year varies depending on the different agro-ecological zones. Haile et al. (2006) indicate that soil erosion which is particularly severe in Ethiopia is the major indicator of loss in soil fertility. The average annual loss from agricultural lands is estimated at 130 tons per hectare per year in the highlands. However, Bezuwerk, Tadesse and Getahun (2009) report that the degradation and loss of soil resulting from soil erosion in Ethiopian highlands is estimated at about 200 tons per hectare per year.

2.4 Land Degradation

Land degradation is defined as the loss or the reduction of the potential utility or productivity of the land (Lal 1994). Land degradation can be generalized as the physical, biological, and chemical property of one or more of land resources such as water, vegetation, soil, rock, air, climate, and relief productivity declines and become less worth to grow crop in the agricultural context (UN/FAO). 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).

2.5 Role of GIS and Remote Sensing

GIS is the tool for input, storage and retrieval, manipulation and analysis, and output of spatial data (Marble et al. 1984). GIS functionality can play a major role in spatial decision-making. Considerable effort is involved in information collection for the amount of soil loss and erosion susceptibility. This information should present both opportunities and constraints for the decision maker (Ghafari et al. 2000). GIS have the ability to perform numerous tasks utilizing both spatial and attribute data stored in it. It has the ability to integrate variety of geographic technologies like GPS, Remote Sensing etc. The ultimate aim of GIS is to provide support for spatial decisions making process (Foote and Lynch 1996). In multi-criteria evaluation many data layers are to be handled in order to arrive at the susceptibility, which can be achieved conveniently using GIS.

Remote sensing (RS) provides the information about the various spatial criteria/factors under consideration. RS can provide us the information like land use/cover, drainage density, topography etc. Many of the non-spatial parameters can also be inferred by looking at the various spatial parameters. RS in combination with GIS is a powerful tool to integrate and interpret real world situation in most realistic and transparent way. Research by Leingsakul et al. (1993) shown that integrated GIS and Remote Sensing technology apart from saving time and yielding good data quality have the ability to locate potential new cropland sites.

2.6 Land use and land cover concept

The Food and Agriculture Organization (FAO, 1995) defines land as “Land is a delineable area of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface. Land represents earth surface that provides and grow food, stores water and it is a basic physical resource for urban and industrial development and a range of social and

cultural activities (FAO, 2002). Land is the major natural resource that economic, social, infrastructure and other human activities are undertaken on. Thus, changes in land-use have occurred at all times in the past, are presently ongoing, and are likely to continue in the future (Lambin et al., 2003)

The land which is covering the Earth's surface has its own uniqueness in terms of the cover it owns (Meyer, 1995). Land is an example of the prime natural resources. Land use and land cover is a vital component in the interactions of the human activities with the environment understanding. Land use can be defined as the human activities towards the land. Human uses land for varies activities such as for agriculture, urban development, logging, grazing and mining among many others. While land cover defined as the kind and state of vegetation such as forest, cropland, grass cover, wetland, pastures, roads, urban area and etc (Meyer, 1995).

Land cover and land use are two key elements of the terrestrial environment that reflect natural processes and human activities. The following definitions of land cover and land use are fundamental because in many existing classifications and legends land cover is confused with land use (Jansen & Di Gregorio 2002):

Land cover (LC) is the observed (bio) physical cover on the earth's surface. It refers to objects that are located on the earth's surface that are of either natural or anthropogenic origin. Land cover in a very pure and strict sense is comprised of vegetation and man-made features. Thus, it is disputable whether water surfaces can be classified as land cover. How-ever, in practice, the scientific community usually uses the term land cover for those aspects.

Land use (LU) is characterized by the arrangements, activities, and inputs imposed by human on a certain land cover type to produce, change, or maintain it. It refers to objects that represent human activities aimed at the production of goods and services for society. This definition establishes a direct link between land cover and the actions of people in their environment.

2.7 Land use and land cover change

Land use/land cover (LULC) change is a dynamic and complex process that can be exacerbated by a number of human activities. Factors driving LULC change include an increase in human population and population response to economic opportunities (Lambin et al., 2001). Despite the social and economic benefits of LULC change, this conversion of LULC usually has an unintended consequence on the natural environment. Land cover change can be sub-classified as land cover conversion or land cover modification. Land cover conversion is the complete replacement of one cover type by another, whereas land cover modification refers to subtle changes that affect the character of land cover, but do not necessarily change its overall classification. Hence, land use is the modification of land cover type, an example of which would be the intensification of agricultural uses (Lambin, 2006).

Major causes of Land use and land cover change Land Use and Land Cover dynamics is a result of complex interactions between several biophysical and socio-economic conditions which may occur at various temporal and spatial scales (Reid et al., 2000). Underlying causes of LULC changes leading to deforestation and land degradation include rapid economic development, population growth and poverty (Bolland et al., 2007). Land use/land cover changes reflect the dynamics observed in the socio-economic condition of a given area. Similarly, changes in the socio-economic situations cause land use/land cover changes through their influence on land management techniques used and other various aspects of the farming systems, institutional settings, environmental policy and others (Mengistu and salami, 2007).

Like many other developing countries across the globe, significant land-cover changes have occurred in Ethiopia since the last century. These changes were primarily due to anthropogenic activities, in connection with the population increase and due to land use changes, including deforestation, over grazing, and improper cultivation of agricultural land which led to accelerated soil erosion and associate soil nutrient deterioration (FAO, 1986; Hurni, 1993). A change in the land-cover of an area can negatively affect the potential characteristics of the

area, and may ultimately lead to degradation and loss of productivity (Zewdu et al., 2014).

According to Kahsay (2004) human beings are the major contributors to land cover changes and are the ones experiencing the consequences of these changes, it will be of paramount importance to understand the interaction between humans and the terrestrial environment. This need becomes more imperative as changes in land use become more rapid affecting the livelihoods of societies. In Ethiopia, inappropriate agricultural practices, deforestation and overgrazing are affecting crop and livestock productivity of the rural poor and hence their livelihoods. Therefore, understanding the driving forces behind land-use changes and developing appropriate measures to control or at least minimize the effects will then be very important.

2.8 Land use and land cover change detection

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Essentially, it involves the ability to quantify temporal effects using multi temporal data sets (Singh, 1989). Change detection is an important process in monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution of the population of interest. Macleod and Congation (1998) list four aspects of change detection which are important when monitoring natural resources:

i. Detecting the changes that have occurred
ii. Identifying the nature of the change
iii. Measuring the area extent of the change
iv. Assessing the spatial pattern of the change

The basis of using remote sensing data for change detection is that changes in land cover result in changes in radiance values which can be remotely sensed. Techniques to perform change detection with satellite imagery have become numerous as a result of increasing versatility in manipulating digital data and increasing computer power.

2.9 Environmental consequences of LULC change

Land use and land cover dynamics affects most of environmental factors such as physical and chemical characteristics of soil, climate parameters, topography and vegetation distribution pattern (Asmamaw, 2013). According to Abdo (2008) as sited in Moges et al., (2015) the impact of land use and land cover change in environment, it has a high and continuous impact on crop production which leads to food insecurity. Therefore, Land use and land cover change and dynamics is central issue that requires thorough scientific investigation for sustainable land use planning and development (Lambin, 2003)

Land use and land cover change (LULC) is one of the major phenomena of global environmental change and vital to the sustainable development debate. For example, in the past two decades between 1980-2000 periods, more than half of forest area in the tropics has been converted to agricultural land due to globalization process and its economic pressures (Lambin and Mayfroidt 2011). These changes have severe impacts on a broad range of environmental and landscape, characteristics including the quality of water, land and air resources, ecosystem processes and function, and the climate system itself through greenhouse gas fluxes and surface albedo effects.

According to the measurement of greenhouse gas (GHG) emissions, 18 percent of total greenhouse gases come from land use/land cover changes by deforestation (World Bank, 2008). Land use and land cover are two chief constituents describing the terrestrial environment in the relationship between natural processes and anthropogenic intervention activities. According to Mayer and Turner (1994) as quoted by Abate (2011) land use land cover change is taken as a serious problem in changing the environment. The change is due to human activities and natural processes. Moreover, the change could be the result of complicated interactions of socio economic and biophysical situations like economic diversification, technological advancement, demographic pressure and many other related conditions (Reid et al., 2000).

In response to the increasing demands for food production, agricultural lands are expanding at the expense of natural vegetation and grasslands (Lambin et al., 2000). These changes in land use/land cover systems have great impact, among others, on agro-biodiversity, soil degradation and sustainability of agricultural production (Lambin et al., 2003). In parts of sub-Saharan Africa where small scale agriculture remains the major source of rural livelihoods, deforestation remains a primary environmental concern. This is more typical to Ethiopia with over 83% of the total population living on small-scale agriculture (Central Statistics Agency, CSA 2012).

Chapter three

3. Data Source, Methodology and Materials used

3.1 Data Source

Reliable data is necessary to realize the designed objectives. The study has been based on both the primary and secondary data. In addition to this observation in the study area to generate primary information is used together with the GPS readings to accesses the ground truth i.e. the land cover of the watershed and to collect soil sample

Primary data is collected by the use of structured interviews of the community and formal and informal discussion with elders of the community, concerned bodies from Ministry of Agriculture (agricultural office of the towns) and Ministry of Water Resources (Water supply service) about the culture on agricultural practices in the watershed. In addition to this the satellite image of the catchment area of at least three different years to assess the land use land cover change has been accessed from the internet (Global Land Cover Facilities).

The secondary data, meteorological data has been from the office of National Meteorological Service Agency for the previous years.

Some of the data required to achieve the designed objectives are:

1. Physiographic survey: Soil samples has been taken for soil texture and color for cross checking with the existing secondary data
2. Satellite data: TM, ETM + Landsat satellite images and LandSat8 OLI/TIRS 2017 of path 158 and 53 row has been acquired
3. DTM (DEM) at least 30 meter resolution of the watershed
4. Field observation for socioeconomic data (agricultural activities, etc) of the society
5. Rainfall data was purchased from National Meteorological Agency.

3.2 Methodology

The RUSLE soil erosion model is applied to predict the amount of annual rate of erosion in Upper Awash Basin. The model encompasses six parameters, which are directly linked to variables (climate, topography, vegetation cover, Management practices) that affect soil erosion. Geographic Information System is imperative in such studies to generate such physically distributed parameters, integration of the layers using the principle of the model and put across the out comes in the form of maps and attributes. In our country, the availability of data in digital or even in well-organized paper collection is one of the biggest constraints for application of modeling and in quantification of erosion or other related processes.

RSLE is a simple multiplicative model that was derived from over 10,000 plot years of data (Wischmeier and smith 1978). The factor values were recently updated following the analysis of thousands of new measurements (Renard et al., 1993) and a revised version of the model has been substituted in place of the original model for farm conservation planning in the United States. It considers the climatic, topographic, soil cover, and human interaction with the landscape.

An integrated approach of digital image processing of satellite data combined with GIS and Universal Soil Loss Equation (RUSLE model) has been carried out for land use/cover change and soil loss estimation. Perhaps degradation speed index and sensitivity index has been analyzed for prioritizing the watershed for conservation measures.

By using these data (mentioned under 3.1); the general methodology is as follows presented in Figure 3.1.

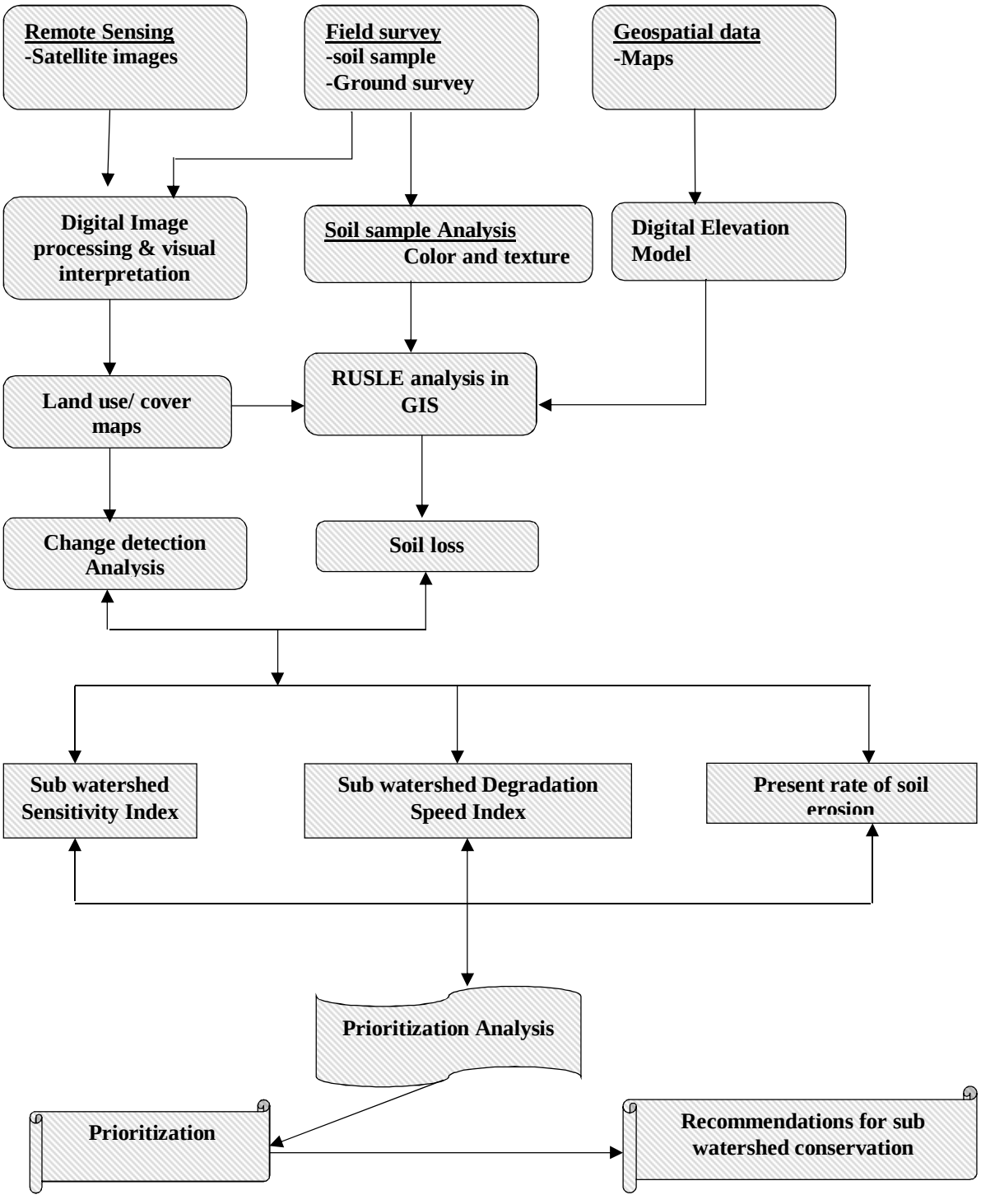

Figure 3.1 Flow diagram of the general methodology

3.2.1 Land use land cover change

In this study multi temporal Landsat images has been used. The paper promotes the classification of LULC based on remote sensing information obtained mainly through

the utilization of Thematic Mapper (TM), and Enhanced Thematic Mapper (ETM+) scenes to generate data products.

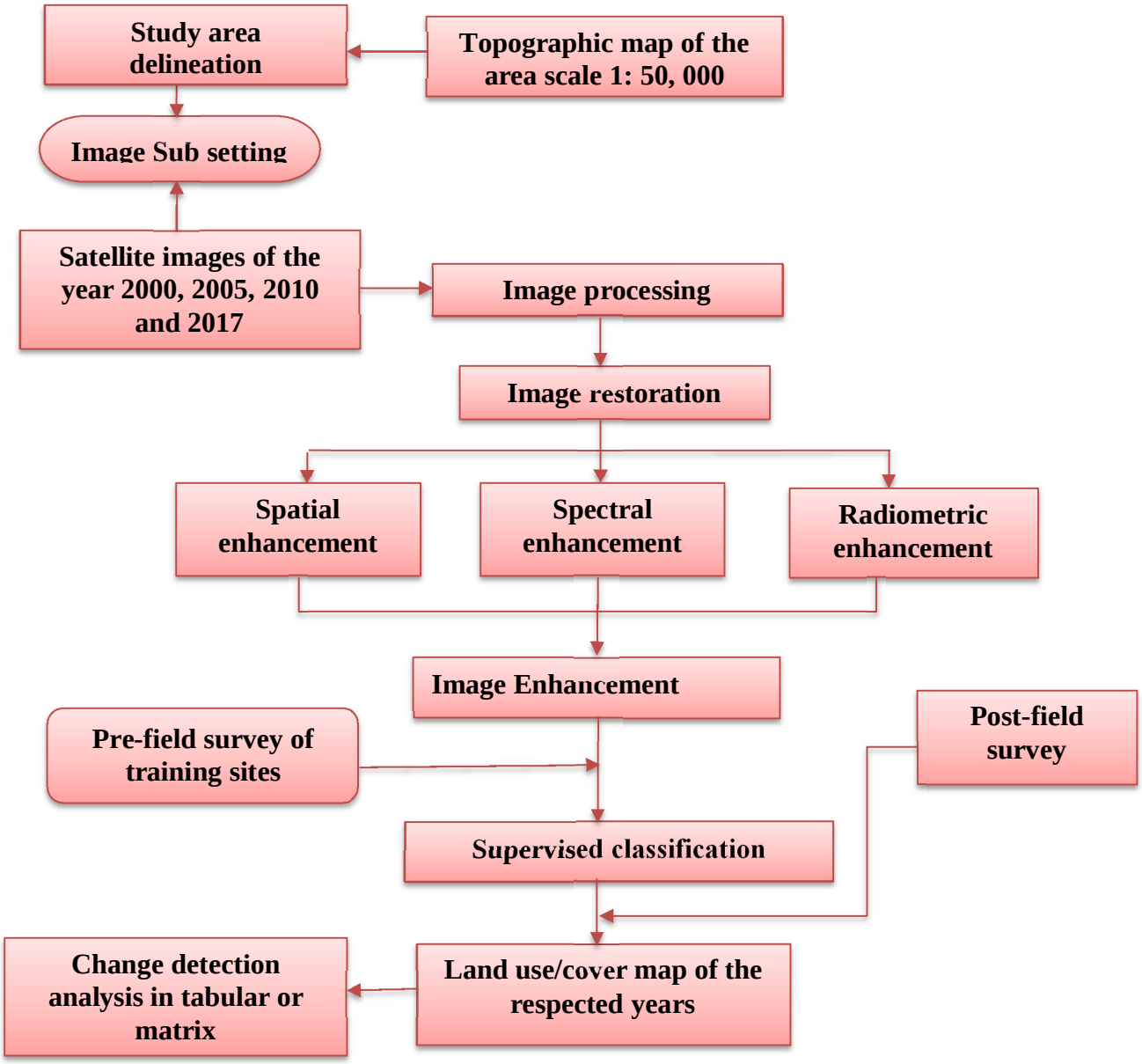

Figure 3.2 General Flow of land use/cover classification and change detection

Land cover map has been obtained by using digital interpretation of satellite images with the help visual interpretation of aerial photograph, while supervised digital image processing has been adopted for satellite data. After comparison of land cover of 2000, 2005, 2010 and 2017, the land use/land cover loss has been obtained.

In the land use land cover classification intensive field work has been done in order to collect the ground truth to have reliable and good area of interest or region of interest for the sample signatures during classification.

3.2.2 Revised soil loss equation (RUSLE) model

In 1985, the U.S. Department of Agriculture (USDA) decided to revise the RUSLE in order to improve its performance. As a result, a new equation, the Revised Universal Soil Loss Equation (RUSLE), was developed (Renard et al., 1997). Although this model still has the basic structure of the RUSLE the algorithms for calculating the individual factors have changed significantly. The RUSLE equation reads:

$$E(r) = R \times K \times LS(r) \times C \times P$$

Where:

E(r) is the annual average soil loss **R** is the rainfall intensity factor,

K is the soil erodibility factor, **LS(r)** is the topographical (length-slope) factor,

C is the land cover factor, and **P** is the soil conservation or prevention practices

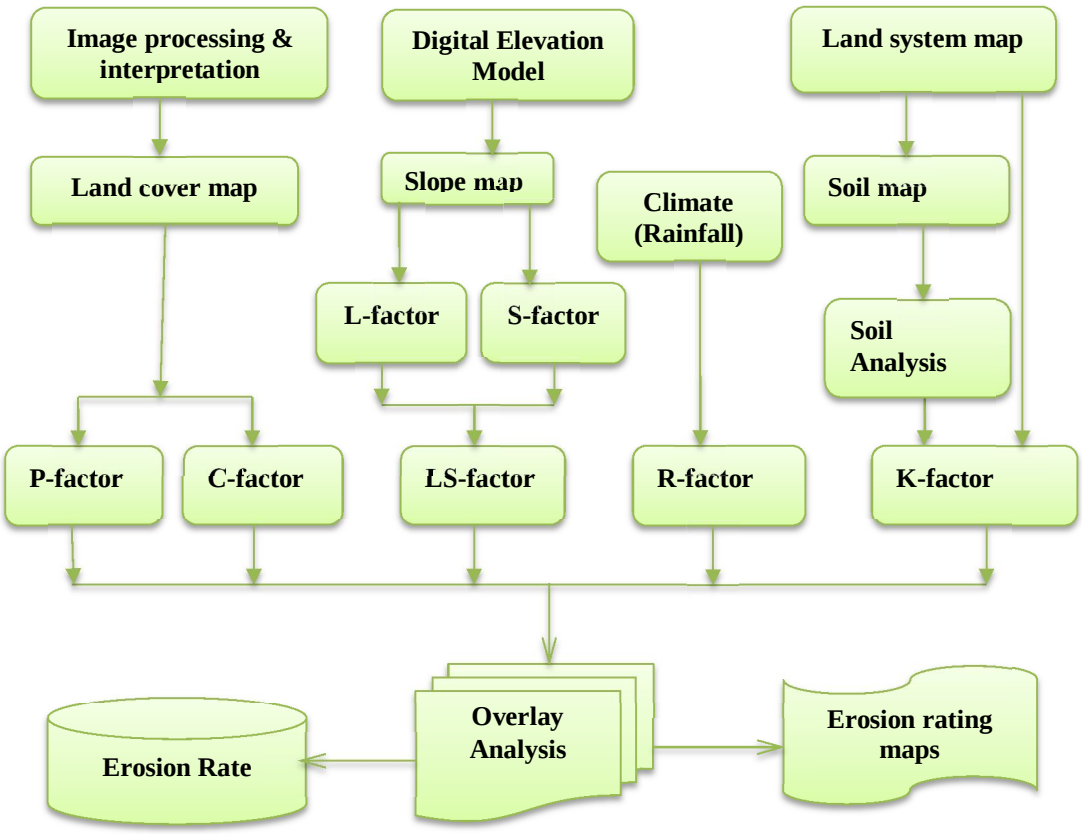

Figure 3.3 the flow diagram of the RUSLE model

3.2.3 Sub watershed Sensitivity Index (SI)

Impact of forest loss in sub watersheds causes various level responses, which is soil loss increase in this case. It depends on the characteristics such as steepness of sub watersheds of way of cutting tree. For example forest loss in steep slope is more critical than in flat area. To assess this characteristic, land sensitivity has been proposed and SI is defined

SI = Soil loss increment (t/ha/yr.)/Forest loss (%)

3.2.4 Sub watershed Degradation Speed Index (DSI)

The soil and forest and main resources of the watershed their amount of change in specified period of time is the indication of the status changing speed. So by assessing the land use/cover and soil loss change between 2000, 2005, 2010 and 2017 and contribution to the total soil loss form each sub watershed. DSI has been formulated. The DSI is defined as the degradation speed of the sub watersheds.

DSI = 0.3*forest change (%) + 0.45 rate of soil loss change (t/ha/yr.) + 0.25 contribution to soil loss change (%) (Sah et al, 1997)

The weight of individual factor has been decided on the basis of their importance to the land degradation.

3.2.5 Prioritization

As discussed earlier, the DSI, SI and present condition (PC) has been taken as the condition and used for the prioritization analysis by simple matrix method.

From the qualitative rating, the two-dimensional overlay matrix has been created by taking two indicators at a time. First the matrix analysis between DSI and SI has been done and they have been grouped, which has been used for second matrix analysis with PC.

Materials and software used

Remote sensing and Geographic Information Systems (GIS) are useful and effective technologies for investigating environmental changes caused by human

activities or natural phenomena in general, and for land use/land cover change analysis in particular (Serra et.al., 2008).

The satellite images of three different periods were classified by INVI 4.2 image processing software through remote sensing techniques for determining the LULC changes on the study area. ArcGIS 10.2 (ESRI) software package for RUSLE model was employed for the potential soil loss estimation with a combination of various factors in GIS environment. Global mapper 16 was used for DEM processing for elevation data extraction for slope length and slope steepness of the study area used as an input for RUSEL model.

The Global positioning system (GPS) was used for collecting the soil Sample and field verification purpose of the accuracy assessment of the land use/cover map of the study area

Chapter Four

4. Data Processing, Data Analysis, Results and Discussion

4.1 LULC Change Analysis

4.1.1 Remote sensing data Analysis

4.1.1.1 Image preprocessing

Preprocessing of satellite images has been done to generate more precise representation of the original scene. Preprocessing of satellite images prior to image classification and change detection is essential. Selecting appropriate satellite imagery is the first task in image preprocessing.

In this study, the Landsat imagery of 2000, 2005, 2010 and 2017 used for the analysis. The aforementioned satellite images were used for image analysis. All the downloaded satellite images contain different types of bands and layer stacking was performed to get the composite image in ERDAS Imagine 10.2 with interpreter main icon and utilities and finally with layer stack function. Other image enhancement techniques like histogram equalization are also performed on each image for improving the quality of the image. Then from the stacked satellite image the study area has been sub sated by using the study area layer of the sub water shade.

4.1.1.2 Band selection

To improve the visualization of the image for the required classification different false color composite were formed in addition to the true color composite. The application of each color composite for different Land use/cover features identification and training site selection for supervised classification were used according to table 4.1. In this study different false color composite including (4,3,2); (4, 5, 1) ;(7,4,2) and (5,4,3) and true color composite (3,2,1) were employed.

No	Band combination	Properties
1	3,2,1	The "natural color" band combination. Because the visible bands are used in this combination, ground features appear in colors similar to their appearance to the human visual system, healthy vegetation is green, recently cleared fields are very light, unhealthy vegetation is brown and yellow, roads are gray, and shorelines are white. This band combination provides the most water penetration and superior sediment and bathymetric information.
2	4,3,2	The standard "false color" composite, Vegetation appears in shades of red, urban areas are cyan blue, and soils vary from dark to light browns.
3	4,5,1	Healthy vegetation appears in shades of reds, browns, oranges and yellows. Soils may be in greens and browns, urban features are white, cyan and gray, bright blue areas represent recently clear cut areas and reddish areas show new vegetation growth, probably sparse grasslands.
4	7,4,2	This combination provides a "natural-like" rendition, while also penetrating atmospheric particles and smoke. Healthy vegetation will be a bright green and can saturate in seasons of heavy growth, grasslands will appear green, pink areas represent barren soil, oranges and browns represent sparsely vegetated areas. Dry vegetation will be orange and water will be blue.
5	5,4,3	Like the 4 5 1 combination, this combination provides the user with a great amount of information and color contrast. Healthy vegetation is bright green and soils are mauve.

Table 4.1 Basic band combinations for Landsat Image

4.1.1.3 Image classification

Image classification is necessary to convert image data to thematic data. According to Lillesand and Kiefer (1994), the overall objective of image classification procedures is to automatically categorize all pixels in an image into land use/land cover classes. Notice that data are transformed into information. Multispectral classification is one of the most often used methods of information extraction (Jensen, 1996). Land cover maps are commonly created from remotely sensed data through unsupervised or supervised classification techniques (Jensen, 2003). The LULC change of the study area was made based on 2000, 2005, 2010, and 2017 satellite images and field observations. The pre-processed satellite image classification can be done based on two classification techniques namely supervised and unsupervised classification.

In Supervised Classification, the image analyst "supervises" the pixel categorization process by specifying, to the computer algorithm, numerical descriptors of the various land cover types present in a scene. In the supervised classification technique the maximum likely hood algorithm will classify the image based on the training sites (signatures) provided by the user based on his field knowledge. The training data given by the user tells the software, that what types of pixels are to be selected for certain land cover type. Each pixel in the data set is then compared numerically to each category in the interpretation key and labeled with the name of the category it "looks most like".

In this study the training point's supervised and classification was performed by applying maximum likelihood classifier algorithm using ENVI software. Finally, seven LULC classes namely; water body, Swampy area, Built up/settlement, Crop land, Grass land, bare land, forest and shrub land was identified in the study area. Generally, the LULC classes in the study area are described in the following table (table 4.2).

No	LULC classes	Description of Land use/cover type
1	Bare land	Area of land with in and around forests that have no vegetation cover, degraded lands, bare ground and quarry/mine excavation areas.
2	Built Up/settlement	Include resident area, rural settlements educational, health, industrial and socio-economic facilities and shops.
3	Shrub land	Areas covered with sparse woody plants mixed with shrubs, bushes. It is a low-density forest forming vegetation.
4	Crop Land	Areas allotted to rain fed and irrigated cultivation, including fallow plots, cultivated land,
5	Forest	Land covered with dense trees which plantation forests.
6	Grass Land	All areas of land used for open grazing and as well as in some extent kept for grass production to make hay for livestock.
7	Water bodies	Areas covered by man-made, small dams, seasonal water bodies and permanent water bodies.
8	Swampy Area	An area of low-lying land that is frequently flooded, characterized by slow-moving to stagnant waters

Table 4.2 Descriptions of Land use/cover categories of the study area

4.1.2 LULC

There are eight major LULC classes for four periods in 2000, 2005, 2010 and 2017 in the study area which includes Crop Land, Built up area/settlement, Grass land, Forest, Bare land, Shrub land, swampy area and Water body as shown in the Table below. The LULC classes and their coverage at the four periods are presented in the table 4.3 and figures 4.1.

LULC Class	2000		2005		2010		2017	
	Area (%)	Area (Km2)	Area (%)	Area (Km2)	Area (%)	Area (Km2)	Area (%)	Area (Km2)
Bare Land	0.76	11.63	0.66	10.09	0.37	5.67	1.14	17.49
Crop Land	70.35	1077.91	73.84	1131.41	71.92	1101.91	72.21	1106.36
Forest Land	2.22	33.99	1.19	18.25	1.67	25.58	1.83	28.03
Grass Land	5.86	89.84	5.39	82.52	5.41	82.84	3.53	54.14
Built Up/ Settlement	11.83	181.32	12.32	188.80	14.12	216.37	15.78	241.75
Shrub Land	5.44	83.36	5.17	79.24	4.64	71.09	4.58	70.13
Swampy Area	2.86	43.88	0.92	14.11	1.36	20.84	0.48	7.31
Water Body	0.67	10.30	0.50	7.73	0.51	7.88	0.45	6.91
Total		1532		1532		1532		1532

Table 4.3 LULC classes and their area coverage

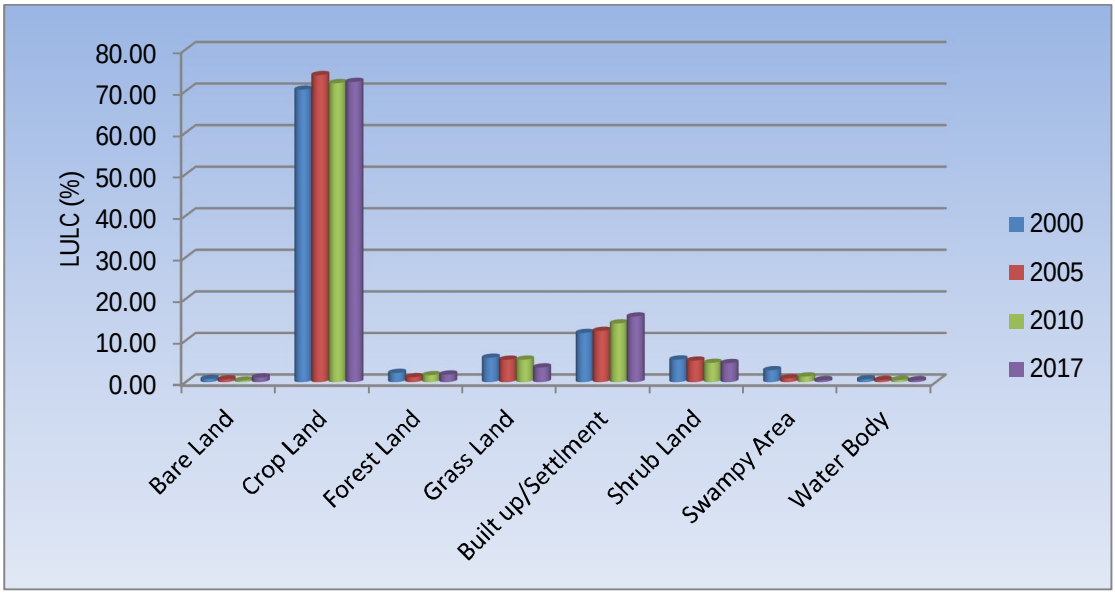

Figure 4.1 LULC class and their percentage of area coverage

4.1.3 LULC Class of 2000

The LULC classes in the study area in the year 2000 were forest, bare land, built up/settlement, shrub land, crop land, grass land, swampy area and water body. Among these LULC classes crop land was the dominant LULC class; which is about 70% (1077.91 km^2). As presented in the above table, Shrub land and grass land covers about 6% and 5% respectively out of the total aerial size the study area. As shown in the above table during the period 2.22% of the area was covered with forest. On the other hand bare land and water body covered relatively small area.

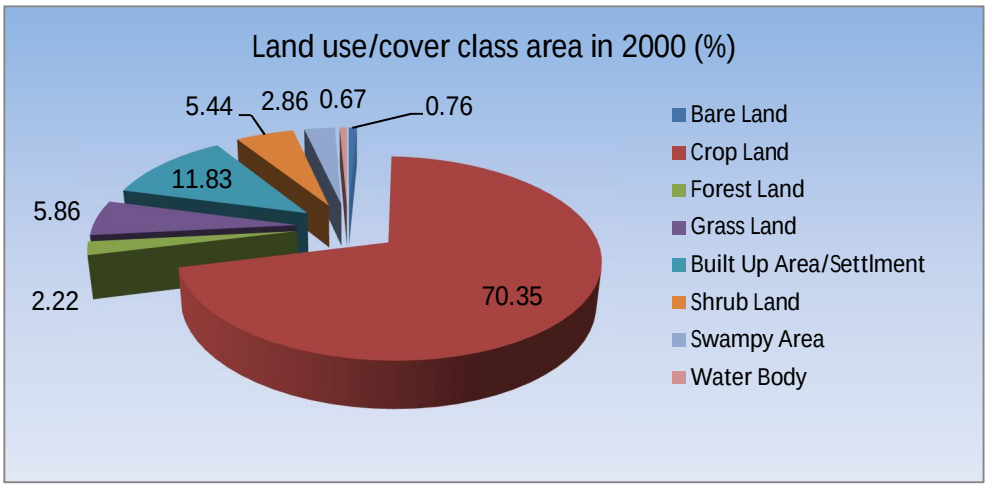

Figure 4.2 Land use/cover class area in 2000

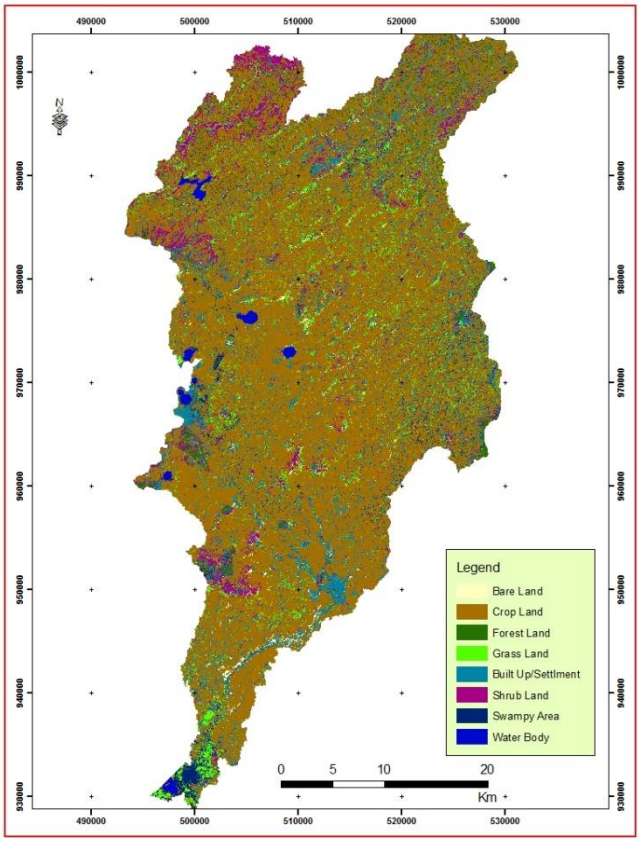

Figure 4.3 Land Use/Land Cover class in year 2000

4.1.4 LULC Class in 2005

The LULC class area coverage depicted in table 4.3 above and figure 4.4 and 4.5 below; as the data presented in table, about three fourth of the area was covered with cultivated land (73.84%). In 2005 Shrub land and grass land covers 5.17 % and 5.39 % respectively out of the total aerial size the study area. As indicated in this table, in 2005 1.19 % of the area was covered with forest. Bare land, water body and swampy area LULC classes covered the smallest area.

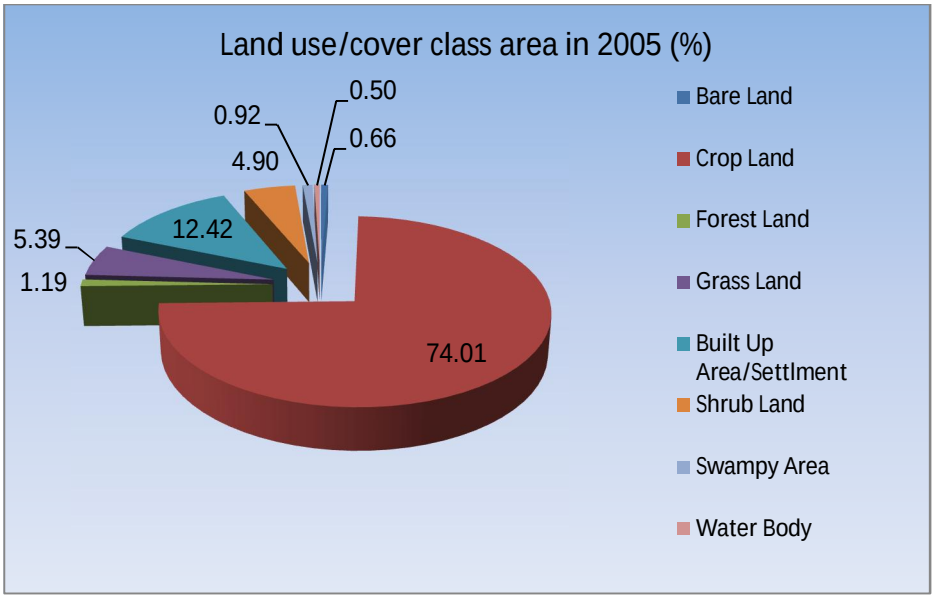

Figure 4.4 Land use/cover class area in 2005

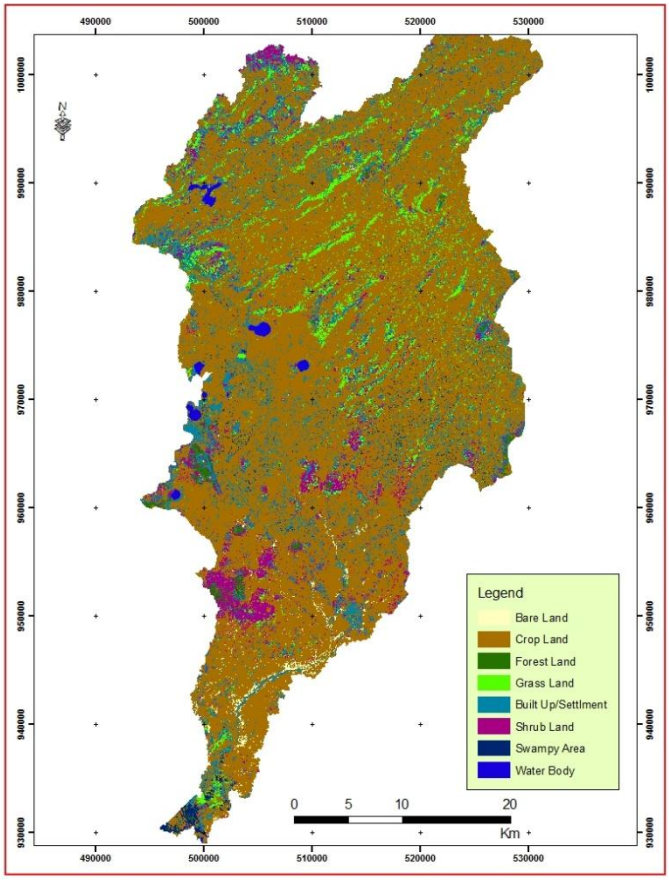

Figure 4.5 land use land cover type in 2005

4.1.5 LULC Class in year *2010*

The LULC class area coverage in 2010 result depicted in table 4.1 about 71.92 % of the study area was covered with cultivated land. Similarly, in the mentioned period bare land and water bodies covered smallest area next to swampy area and forest land in the study area (see table 4.3 and figure 4.6 & 4.7).

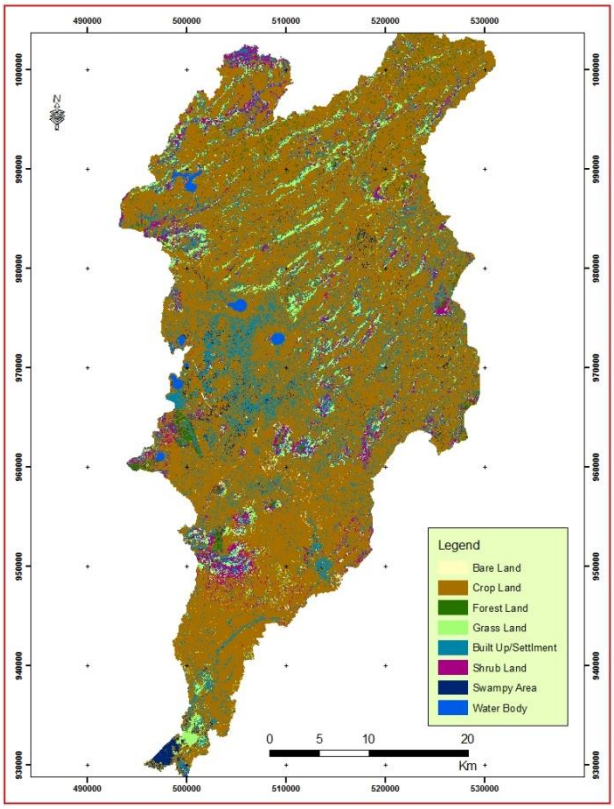

Figure 4.6 land use land cover type in 2010

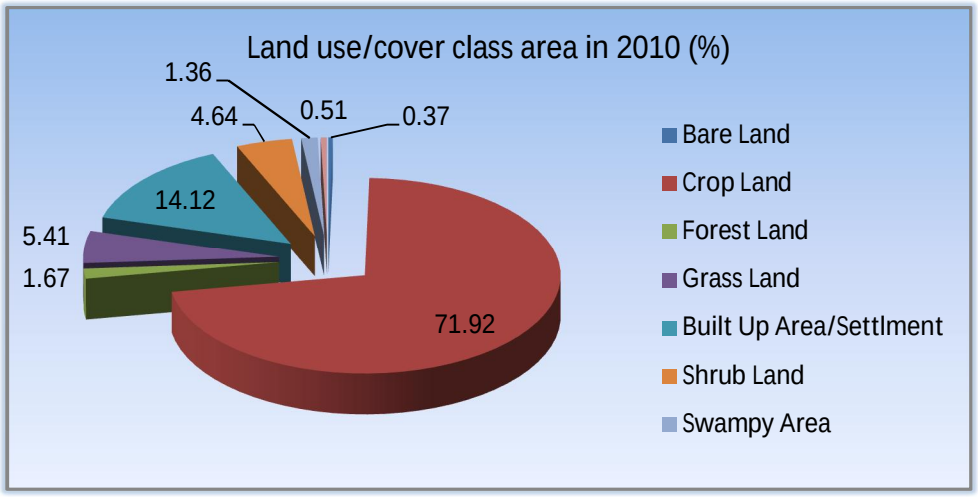

Figure 4.7 Land use/cover class area in 2010

4.16 LULC Class in year 2017

The year 2017 image analysis result shewed us the very recent land use land cover of the study area. In this year the dominant LULC is the cultivated or crop land followed by the built up/settlement area with about 72 % and 16 % of the study area respectively. The water body and the swampy area share the smallest part of the area coverage compared to the other classes (see table 4.3 and figure 4.8 and 4.9).

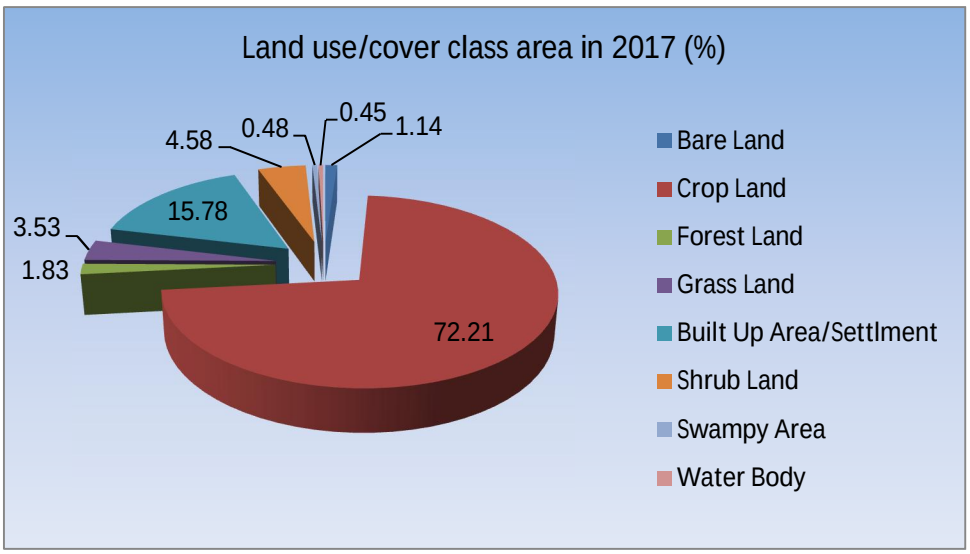

Figure 4.8 Land use/cover class area in 2017

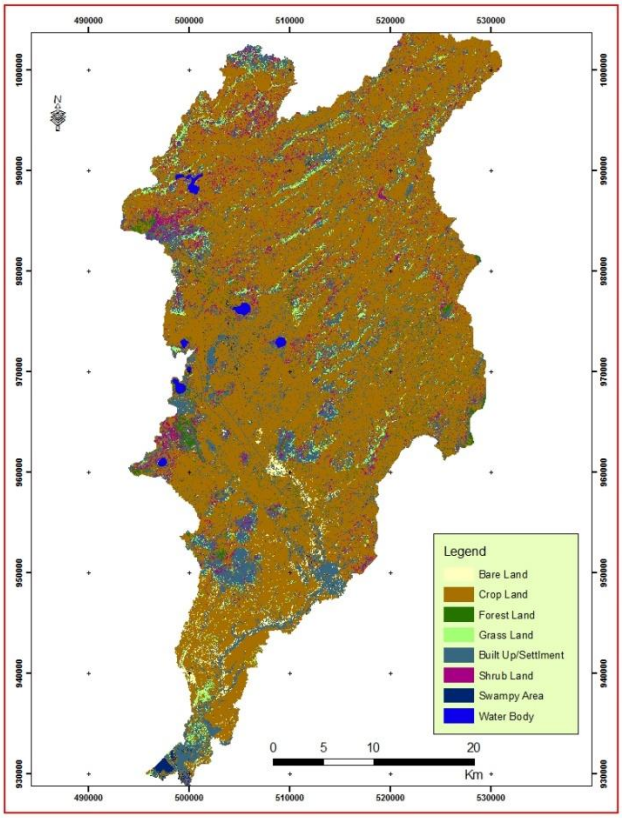

Figure 4.9 land use land cover type in 2017

4.1.7 LULC Change

In the four periods there is a variation in records on the LULC area coverage. When the four periods LULC records compared, as the data presented in table 4.4, the cultivated area coverage (73.84 %) is higher in 2005 than the other periods. However, the trend in change in these different periods is not uniform. It showed an increment from 2000 to 2005 by 3.5 %; from 2005 to 2010 it showed a decreasing trend by 1.93 %, from 2010 to 2017 the cultivated land showed an increment by 0.29 %, from 2000 to 2010 the cultivated land showed an expansion by 1.57%, and from 2005 to 2017 the cultivated land decreased in its area by 1.63%. This increasing and decreasing in the cultivated land may be associated with different factors.

On the other hand observable difference was found on built up area/settlement area coverage. As presented in table 4.4 and figure 4.10 below, the area covered with built up area/settlement was in an increasing way. By the year 2000 the area covered with built up area/settlement was about 11.83 %. After 5 years, in 2005, the area covered with built up area/settlement was increased to 12.32 %. In 2010, after 7 years the area

covered with built up area/settlement increased to 14.12 % subsequently in 2017 the built up area/settlement area coverage became 15.78 %. Dissimilar reducing changes also found in the case of grass lands and shrub land. The forest cover showed an increment as well as reduction in its area extent. For example, from 2000 to 2005 the cover reduced by 1.03 %, from 2005 to 2010 it shows an increment by 0.48 %, from 2010 to 2017 increased by 0.16 %. Generally the forest cover within the 27 year period showed a variable trend due to different factors. The remaining changes in the LULC in the area shown in the table 4.4 below.

LULC	2000-2005	2005-2010	2010-2017	2000-2010	2005-2017
Bare Land	-1.54	-0.29	0.77	-0.39	0.48
Crop Land	3.66	-2.09	0.29	1.57	-1.80
Forest Land	-1.03	0.48	0.16	-0.55	0.64
Grass Land	-0.47	0.01	-1.87	-0.46	-1.86
Built Up Area/settlement	0.59	1.70	1.66	2.29	3.36
Shrub Land	-0.54	-0.26	-0.06	-0.80	-0.32
Swampy Area	-1.94	0.44	-0.88	-1.50	-0.44
Water Body	-0.17	0.01	-0.06	-0.16	-0.05

Table 4.4 the change in land use/cover in different time period

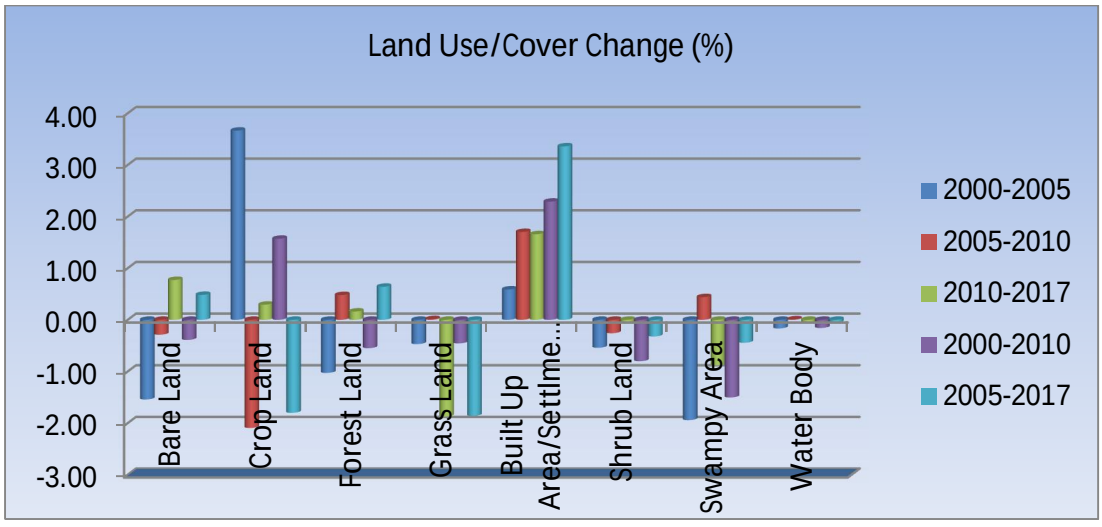

Figure 4.10 land use land/cover change

4.1.8 Rate of LULC Change

The study period includes 17 years (2000 – 2017). In order to study the change and dynamics of the land use/land cover the study period was divided in to three periods 2000 – 2005, 2005 – 2010 and 2010-2017. Which gives an opportunity to study the change and dynamics through the indicated years. Knowing the rate of change provides information about the tendency of conversion of land use/land cover in terms of time. It also enlightens us to perform comparison among the different LULC classes in time bases.

LULC Class	2000-2005		2005-2010		2010-2017		2000-2017	
	Area change (km^2)	Rate of Change (Km^2/yr)	Area change (km^2)	Rate of Change (Km^2/yr)	Area change (km^2)	Rate of Change (Km^2/yr)	Area change (km^2)	Rate of Change (Km^2/yr)
Bare Land	-1.54	-0.31	-4.42	-0.88	11.82	2.36	5.86	0.22
Crop Land	56.06	11.21	-32.06	-6.41	4.45	0.89	28.44	1.05
Forest Land	-15.76	-3.15	7.35	1.47	2.46	0.49	-5.96	-0.22
Grass Land	-7.20	-1.44	0.21	0.04	-28.70	-5.74	-35.70	-1.32
Built Up Area/Settlement	8.98	1.80	26.06	5.21	25.38	5.08	60.43	2.24
Shrub Land	-8.30	-1.66	-3.98	-0.80	-0.96	-0.19	-13.24	-0.49
Swampy Area	-29.77	-5.95	6.72	1.34	-13.53	-2.71	-36.57	-1.35
Water Body	-2.56	-0.51	0.14	0.03	-0.96	-0.19	-3.38	-0.13

Table 4.5 Rate of Land use/Land covers change

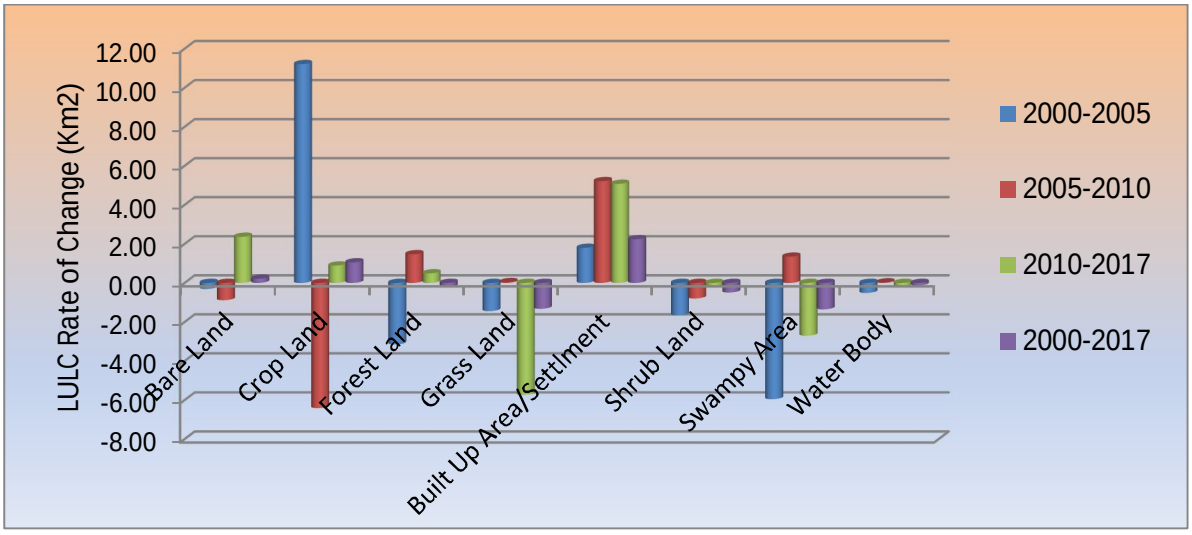

Figure 4.11 Rate of LULC change in four years (ha/yr)

As a result in the time 2000 – 2005 (5 years) there was a significant increment in cultivated land by 56.06 km^2 or 11.21 km^2/yr, as the same time built up area/settlement also had an increment by 1.8 km^2/yr. On the contrary the forest, shrub land, grass land, water body, swampy area, and bare land showed a reduction by 3.15 km^2/yr, 1.66 km^2/yr, 1.44 km^2/yr, 0.51 km^2/yr, 5.95 km^2/yr, and 0.31 km^2/yr respectively. Where as in the year 2005 – 2010 the built up area/settlement, forest land, grass land, water body, and swampy area showed an increment by the rate of 5.21 km^2/yr, 1.47 km^2/yr, 0.04 km^2/yr, 0.03 km^2/yr and 1.34 km^2/yr; but on the other hand there is a reduction of bare land, crop land and shrub land by the rate of 0.88 km^2/yr, 6.41 km^2/yr, and 0.8 km^2/yr respectively identified. In the year 2010-2017 crop land, bare land, forest land, and built up area/settlement LULC classes showed an increment by the rate of 0.89 km^2/yr, 2.36 km^2/yr, 0.49 km^2/yr, and 5.08 km^2/yr as shown in the (see table 4.5 and figure 4.11).

4.1.9 LULC Change Detection

The Change Detection Statistics to compile a detailed tabulation of changes between two time period classification images. The changes detected using this routine differs significantly from a simple differencing of the two images. While the statistics report does include a class-for-class image difference, the analysis focuses primarily on the initial state classification changes; that is, for each initial state class, the analysis identifies the classes into which those pixels changed in the final state image. The statistics tables list the initial state classes in the columns and the final state classes in the rows. However, the columns include only the selected (paired) initial state classes, while the rows contain all of the final state classes. This is required for a complete accounting of the distribution of pixels that changed classes. For each initial state class (that is, each column), the table indicates how these pixels were classified in the final state image

Changes in land use/cover can be driven by two types of categories: Modification and conversion. Modification is the change of condition with a cover type, whereas conversion is the change from one cover type to another. In this study the major changes of LULC classes have been discussed based on change detection of each class. But in order to understand the LULC dynamics in the study area the

change detection statistics were employed and analyzed for the study period. The land use/land cover change detection statistics used to analyze the source (initial) and destination (final) of cover type with in the considered study period. The change detection statistics was conducted in the year 2000 – 2005, 2005 – 2010 and 2010 – 2017. The table presents all the results of the cross tabulation matrices of the cover and land use change showing conversion from one class to another class. In such a way that the columns represent the year of source (initial) and the rows represent year of destination (final).

4.1.11 LULC Change Matrix for 2000 – 2005

In the period 2000 – 2005, 3.28 km^2 of Water body, 40.76 km^2 swampy areas, 67.88 km^2 of grass land, 9.72 km^2 bare land, 28.94 km^2 Forest land, 61.8 km^2 shrub land, 191.82 km2 crop/cultivated land, and 143.26 km^2 area of built up/settlement were changed to other classes from their initial state. Within this period 7.02 km^2 of Water body, 3.11 km^2 swampy area, 21.95 km^2 of grass land, 1.91 km^2 bare land, 5.01 km^2 Forest land, 21.55 km^2 shrub land, 885.91 km2 crop/cultivated land, and 38.03 km^2 area not changed to other classes of LULC. Generally in this time interval 547.46 km^2 land out of the total area coverage had been changed from one class to the other class. In the other hand about 984.49 km^2 out of the total area coverage had not changed to other LULC class, it was as its initial state. The detail land use/cover dynamics of 2000-2005 is shown in the table 4.6 below and figure 12.

4.1.12 LULC Change Matrix for 2005 – 2010

In this study years in the period 2000 – 2010, 1.08 km^2 of Water body, 11.7 km^2 swampy areas, 54.21 km^2 of grass land, 9.84 km^2 bare land, 13.4 km^2 Forest land, 54.99 km^2 shrub land, 236 km2 crop/cultivated land, and 150.54 km^2 area of built up/settlement were changed to other classes from their initial state. Within this period 6.65 km^2 of Water body, 2.41 km^2 swampy area, 28.42 km^2 of grass land, 0.25 km^2 bare land, 4.83 km^2 Forest land, 20.06 km^2 shrub land, 897.67 km2 crop/cultivated land, and 39.71 km2 built up/settlement area not changed to other classes of LULC. Generally in this time interval 531.76 km^2 land out of the total area coverage had been changed in this dynamics from one class to the other class. In the other hand about 1000 km^2 out of the total area coverage had not changed to other LULC class, it was

as its initial state. The detail land use/cover dynamics is shown in the table 4.7 below and figure 12.

4.1.13 LULC Change Matrix for 2010 – 2017

In the period 2010-2017, 1.26 km^2 of Water body, 18.66 km^2 swampy areas, 54.07 km^2 of grass land, 4.96 km^2 bare land, 20.77 km^2 Forest land, 59.63 km^2 shrub land, 210.79 km2 crop/cultivated land, and 166 km^2 area of built up/settlement were changed to other classes from their initial state. Within this period 6.61 km^2 of Water body, 2.18 km^2 swampy area, 28.77 km^2 of grass land, 0.71 km^2 bare land, 4.81 km^2 Forest land, 11.76 km^2 shrub land, 891.12km2 crop/cultivated land, and 50.37 km^2 area not changed to other classes of LULC. Generally in this time interval 535.84 km^2 land out of the total area coverage had been changed from one class to the other class. In the other hand about 996.33 km^2 out of the total area coverage had not changed to other LULC class, it was as its initial state. The detail land use/cover dynamics of 2010-2017 is shown in the table 4.8 below and figure 12.

4.1.13 LULC Change Matrix for 2000 – 2017

In this study years in the period 2000-2017, 3.76 km^2 of Water body, 42.96 km^2 swampy areas, 75.52 km^2 of grass land, 10.16 km^2 bare land, 29.72 km^2 Forest land, 73.66 km^2 shrub land, 234.75 km2 crop/cultivated land, and 143.14 km^2 area of built up/settlement were changed to other classes from their initial state. Within this period 6.54 km^2 of Water body, 0.91 km^2 swampy area, 14.32 km^2 of grass land, 1.47 km^2 bare land, 4.24 km^2 Forest land, 9.69 km^2 shrub land, 842.99 km^2 crop/cultivated land, and 38.15 km^2 built up/settlement area not changed to other classes of LULC. Generally in this time interval 613.67 km^2 land out of the total area coverage had been changed in this dynamics from one class to the other class. In the other hand about 918.31 km^2 out of the total area coverage had not changed to other LULC class, it was as its initial state. The detail land use/cover dynamics is shown in the table 4.9 below and figure 12.

The major factors for the land use / land cover dynamics in the study area, from field observation and informal discussion with the elders of the community, are expansion of rural settlement or villages, expansion of urban areas, changing of the local houses

with corrugated sheet houses, investment expansion in agricultural lands like industries, construction of new roads like express road and wind farms, natural phenomena like the dwindling of water bodies and swampy areas in time and human impact like cutting of trees for house hold use, and construction purposes.

However, in recent years there is a conservation measure for watershed development program in wereda and kebele level.

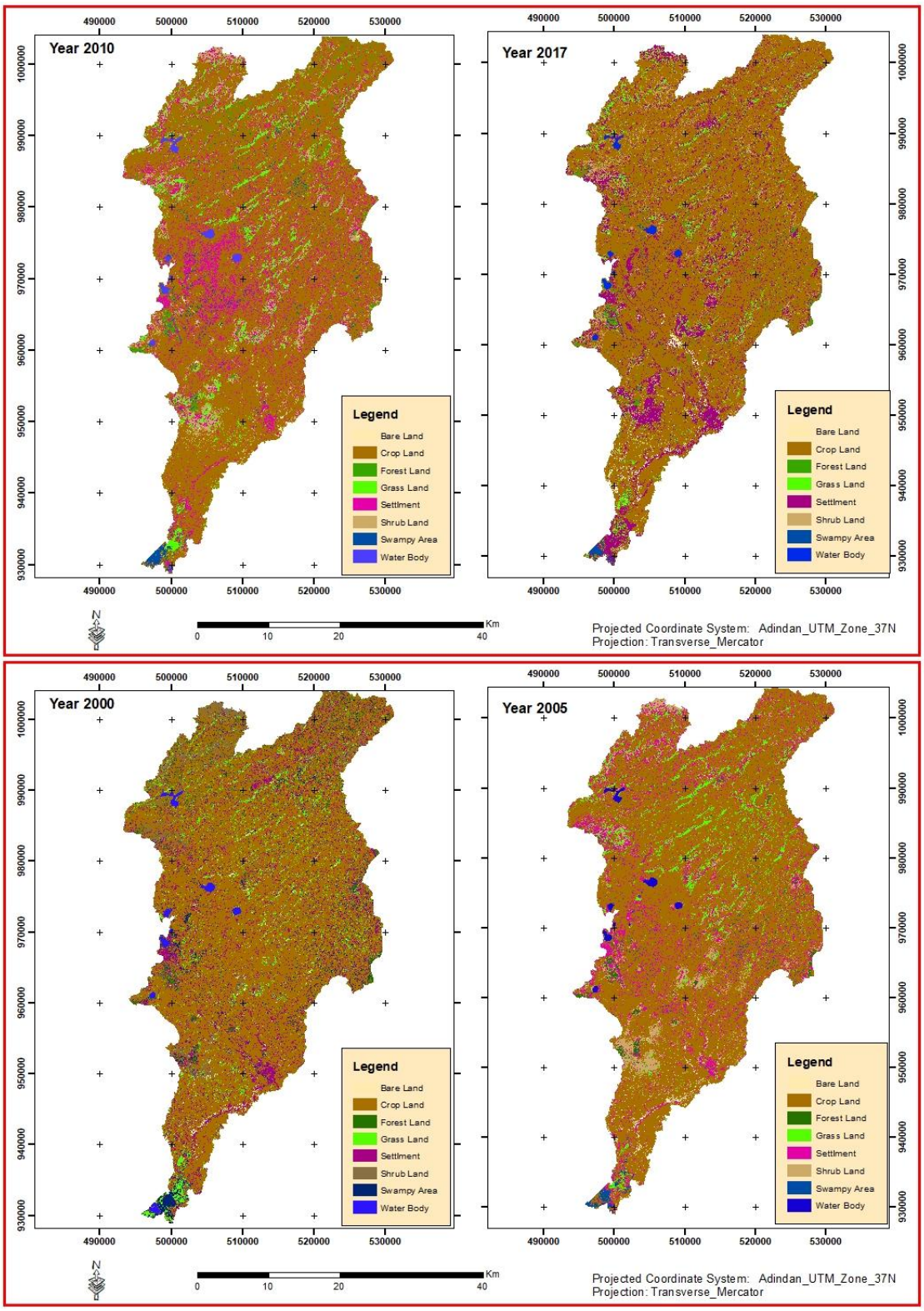

Figure 12 LULC maps of 2000, 2005, 2010 and 2017

Area (Square Km)		Initial (2000)									
		Water Body	Swampy Area	Grass Land	Bare Land	Forest Land	Shrub Land	Crop Land	Built up/ settlement	Row Total	Class Total
Final (2005)	Water Body	7.02	0.18	0.05	0	0.05	0.03	0.32	0.07	7.71	7.72
	Grass Land	0.02	1.5	21.95	3.21	0.31	11.76	35.08	8.71	82.56	82.6
	Shrub Land	0.01	1.45	4.01	1.06	1.45	21.55	37.13	8.11	74.79	74.92
	Forest Land	0.03	1.5	0.53	0.01	5.01	1.84	6.89	2.38	18.2	18.26
	Crop Land	1.9	28.49	46.21	4.34	21.89	23.52	885.91	119.82	1132.09	1132.94
	Built up/settlement	0.99	7.48	14.76	1.06	4.68	24.18	98.79	38.03	189.97	190.15
	Bare Land	0	0.02	0.18	1.91	0.02	0.09	4.96	2.86	10.03	10.05
	Swampy Area	0.31	3.11	1.98	0.02	0.33	0.14	7.18	1.03	14.1	14.13
	Class Total	10.3	43.87	89.83	11.63	33.95	83.35	1077.73	181.29		
	Class Changes	3.28	40.76	67.88	9.72	28.94	61.8	191.82	143.26		

Table 4.6 LULC change detection statistics from the year 2000 to 2005

Area (Square Km)		Initial (2005)									
		Water Body	Shrub Land	Grass Land	Forest Land	Built up/ Settlement	Bare Land	Swampy Area	Crop Land	Row Total	Class Total
Final (2010)	Water Body	6.65	0.01	0.03	0.01	0.41	0	0.06	0.7	7.86	7.88
	Crop Land	0.56	25.94	29.86	9.18	113.11	8.55	8.32	897.67	1093.19	1101.84
	Swampy Area	0.11	0.64	0.49	0.97	2.73	0	2.41	13.23	20.57	20.83
	Forest Land	0.02	1.44	0.26	4.83	3.24	0	0.33	14.88	25.01	25.58
	Shrub Land	0.02	20.06	6.68	0.92	14.63	0.22	0.06	27.58	70.16	71.08

	Built up/Settlement	0.35	15.69	16.23	1.5	39.71	0.92	1.71	138.66	214.77	216.36
	Bare Land	0	1.12	0.21	0.01	0.26	0.25	0.02	3.74	5.61	5.67
	Grass Land	0.01	8.7	28.42	0.49	14.19	0.12	0.99	29.46	82.38	82.84
	Class Total	7.73	75.05	82.63	18.23	190.26	10.09	14.11	1133.67		
	Class Changes	1.08	54.99	54.21	13.4	150.54	9.84	11.7	236		

Table 4.7 LULC change detection statistics from the year 2005 to 2010

Area (Square Km)		Initial (2010)									
		Water Body	Crop Land	Swampy Area	Forest Land	Shrub Land	Built up/ Settlement	Bare Land	Grass Land	Row Total	Class Total
Final (2017)	Water Body	6.61	0.15	0.04	0	0	0.11	0	0	6.91	6.91
	Crop Land	0.61	891.12	13.46	17.07	23.82	137.28	2.46	20.56	1106.38	1106.38
	Swampy Area	0.05	3.55	2.18	0.05	0.18	0.96	0.02	0.34	7.32	7.32
	Forest Land	0.05	19.12	0.62	4.81	0.46	2.9	0.03	0.05	28.03	28.03
	Shrub Land	0.01	42.13	0.39	1	11.76	13.77	0.13	0.93	70.13	70.13
	Built Up/Settlement	0.55	121.28	3.87	2.62	29.31	50.37	2.18	31.59	241.77	241.77
	Bare Land	0	14.6	0.01	0	0.34	1.22	0.71	0.61	17.49	17.49
	Grass Land	0.01	9.97	0.26	0.03	5.21	9.76	0.15	28.77	54.15	54.15
	Class Total	7.88	1101.91	20.84	25.58	71.09	216.37	5.67	82.84		
	Class Changes	1.26	210.79	18.66	20.77	59.33	166	4.96	54.07		

Table 4.8 LULC change detection statistics from the year 2010 to 2017

Area (Square Km)		Initial (2000)									
		Water Body	Swampy Area	Grass Land	Bare Land	Forest Land	Shrub Land	Crop Land	Built up/ settlement	Row Total	Class Total
Final (2017)	Water Body	6.54	0.05	0.03	0	0.03	0.01	0.21	0.03	6.9	6.91
	Crop Land	1.44	29.42	46.6	3.31	22.74	30.58	842.99	121.38	1098.46	1106.06
	Swampy Area	1.2	0.91	0.9	0.05	0.07	0.27	2.63	1.06	7.09	7.29
	Forest Land	0.14	1.37	0.54	0.02	4.24	1.7	16.4	2.99	27.4	27.9
	Shrub Land	0.03	1.09	2.09	0.19	2.06	9.69	46.81	7.53	69.5	70.17
	Built up/settlement	0.83	9.3	23.46	4.75	3.49	29.43	129.48	38.15	238.91	241.62
	Bare Land	0	0.12	1.19	1.47	0.01	0.56	10.12	3.78	17.25	17.54
	Grass Land	0.07	1.02	14.32	1.82	0.15	9.63	21.6	5.06	53.66	54.11
	Class Total	10.3	43.87	89.83	11.63	33.95	83.35	1077.73	181.29		
	Class Changes	3.76	42.96	75.52	10.16	29.72	73.66	234.75	143.14		
	Image Difference	-3.38	-36.58	-35.72	5.91	-6.05	-13.18	28.33	60.33		

Table 4.9 LULC change detection statistics from the year 2000 to 2017

4.2 Soil erosion Analysis

More recently, Renard et al. (1997) has modified the USLE into a Revised Universal Soil Loss Equation (RUSLE) by introducing improved means of computing the soil erosion factors. The USLE has been used extensively all over the world either in the same or modified forms. Hurni (1985) also used this model to assess soil erosion in Ethiopia by modifying Rainfall erosivity (R factor), land cover (C factors) and Management (P factor) of the USLE for Ethiopian conditions.

RUSLE model is applied for this study. climate, soils, vegetation cover, topography and management are the control factors of soil erosion combined in the empirical Revised Universal Soil Loss Equation (Renard et al., 1997).where the climate, vegetation cover and management factors are adapted with in Ethiopian condition. The model estimates sheet and rill erosion as a function of six major factors which are mentioned under chapter three: A= R *K*LS* C* P

The estimated soil loss potential expressed as tone per hectare per year for the study area was determined using the RUSLE model in a GIS environment. The general methodology of this study involved the use of the RUSLE in a GIS environment, with factors obtained from meteorological stations, soil surveys, Satellite Images, Digital Elevation Model and results of other relevant studies. Individual GIS layers were built for each factor in the RUSLE and combined by cell-grid modeling procedures in ArcGIS to predict soil loss in a spatial domain (Eastman, 1999).

4.2.1. Determining model (RUSLE) Parameters

The RUSLE Estimates average soil loss for a given area as a function of six major factors and the method used to generate each raster format input parameters in GIS environment for RUSLE model are explained below.

4.2.1.1 Rainfall Erosivity (R) factor

The rainfall erosivity factor quantifies the effect of rainfall impact and also reflects the amount and rate of runoff likely to be associated with precipitation events (Habtamu and Amare, 2016). The 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 (Morgan, 1994). Rainfall erosivity is the property of rainfall that can quantitatively evaluate the potential capacity of rain to cause erosion in a given conditions and given as the Product (EI30) of the total energy of rainstorm (E) and the maximum 30 min intensity (I30) (Wischmeier & Smith, 1958). EI is a statistical interaction term that reflects how total kinetic energy and peak intensity are combined in each particular storm. The calculated erosion potential for an individual storm is usually designated EI.

The total annual R is therefore the sum of the individual EI values for each rainfall storm event. The energy of a rainfall storm is a function of the amount of rain and of all the storm's intensity components. According to Renard et al. (1997), the numerical value used for R in RUSLE must quantify the effect of raindrop impact and must also reflect the amount and rate of runoff likely to be associated with the rain. Within the USLE, rainfall erosivity is estimated using the EI30 measurement. However, rainfall kinetic energy and intensity data were not available for this study. So, the erosivity R factor was calculated according to the formula given by Hurni (1985) derived from a spatial regression analysis (Hellden,1987) for Ethiopian conditions the Equation below. Therefore, the erosivity factor R was calculated according to the equation given by Hurni (1985), derived from a spatial regression analysis (Hellden, 1987) for Ethiopian conditions based on the easily available mean annual rainfall (P). It is given by a regression equation:

R = - 8. 1 2 + (0. 5 6 2 x P)

Where P - mean annual precipitation [mm] (Hellden 1987)

The mean annual rainfall data of eight stations were used to get the mean annual rainfall (P) and then calculated erosivity factor (R) for the study area and are presented in the table 4.10

	Station	Altitude	Easting	Northing	Mean annual RF(mm)	R(Erosivity)
1	Akaki	2057	476817.2	980279.2	853.150	471.3503
2	Chefedonsa	2392	513098.2	991330.5	758.825	418.33965
3	Ejere	2254	528503	969227	719.464	396.4638
4	Koka Dam	1618	516417.8	936053.7	761.050	419.5901
5	Mojo	1763	512010.6	951529.9	932.250	515.8045
6	Nazeret	1622	530720.6	944906.1	733.550	404.1351
7	Debre Zeyte	1500	606114.3	1140747	748.600	412.5932
8	Sendafa	2569	502104.8	1011229	749.737	749.737

Table 4.10 Weather Stations inside and outside the study area

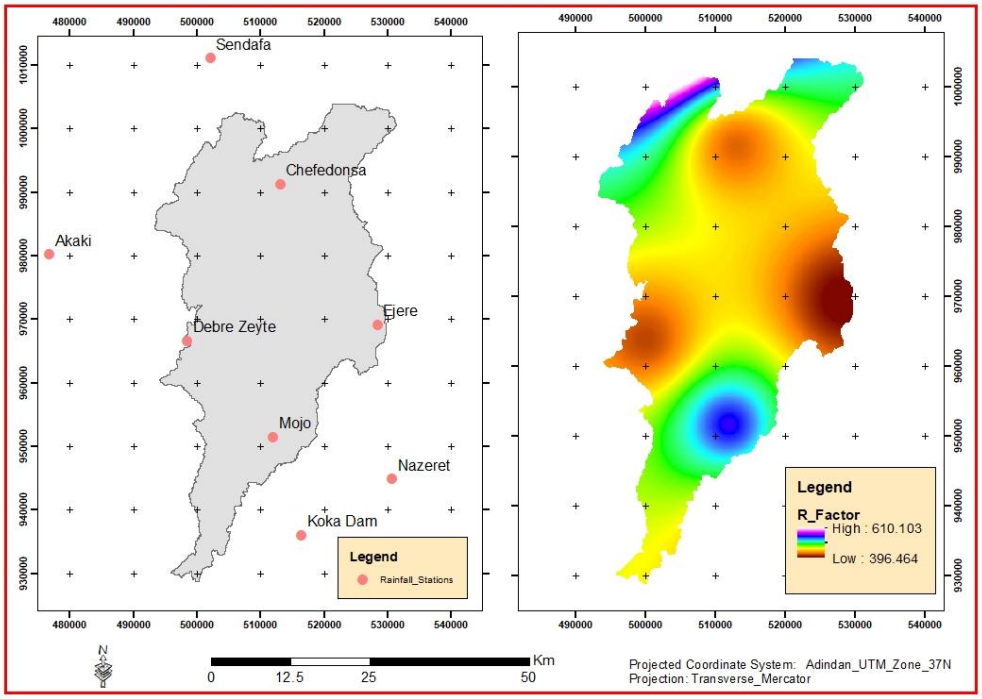

Figure 4.12 Interpolated erosivity map (R-factor)

4.2.1.2 Soil Erodibility (K) factor

Soil erodibility is the manifestation of the inherent resistance of soil particles for the detaching and transporting power of rain fall (Wischmeier & Smith, 1978). The K-factor is empirically determined for a particular soil type and reflects the physical and chemical properties of the soil, which contribute to its erodibility

potential (Habtamu and Abate, 2016). The K value for each soil type was assigned in the study area classified by FAO, 1996 using GIS attribute table level editing which was developed by Hellden (1987) and later adopted to Ethiopian conditions by Hurni (1985). Provided that there classification the raster soil map was done according to the soil color class given by Hurni (1985a) and Hellden (1987).

The original vector format soil map was converted into grid (raster) format. The grid format was then reclassified based on K-factor value for each soil class in ArcGIS using reclassification geoprocessing (spatial analyst) tools. Therefore, the soil erodibility (K) factor for this study was based on Hurni (1985) for Ethiopian condition, the color of the soil assigned with soil erodibility factor. Study area Soil types, color texture and their erodibility value are shown in table 4.13 and figure 4.14.

Major_soil	Soils Color	Texture	K_Factor
Vertisols	Very dark gray	Clay	0.2
Leptosols	Very Dark Red brown	Loam	0.32
Luvisols	dark brown	Clay Loam	0.15
Cambisols	Dark Gray brown	Loam	0.23
Fluvisols	Dark Gray brown	Clay loam	0.2
Regosols		loam	0.15

Table 4.13 K- factor Value of soils in the study area

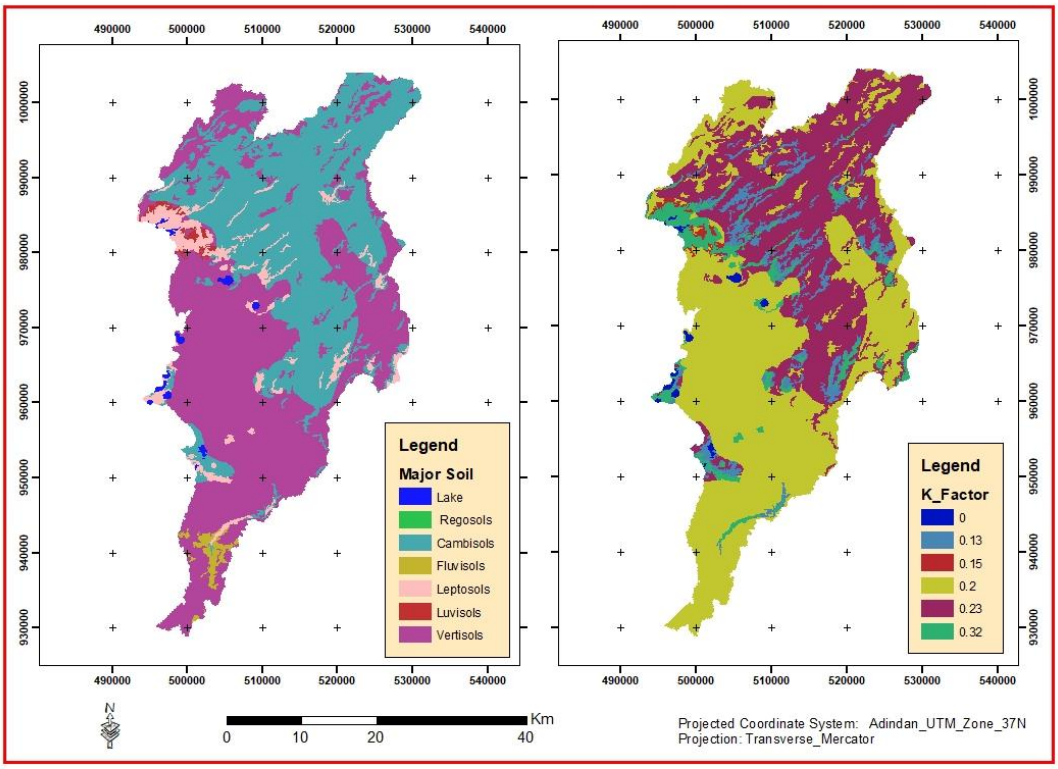

Figure 4.14 Major soil type and K factor Map of the area

4.2.1.3 Slope length and slope steepness (LS) factor

LS factor is the slopes to that from a 22.13m length of uniform 9% slope under otherwise identical conditions (Wischmeier &Smith, 1978). Slope length 'L' is the horizontal distance from the origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or runoff becomes concentrated in a defined channel (Wischmeier and Smith, 1978) and slope gradient 'S' mean the influence of slope gradient on erosion. In erosion estimation both slope length 'L' and slope gradient 'S' can be assessed together and considerably affects sheet and rill erosion estimated by RUSLE. In general, as slope length (L) increases, total soil erosion and soil erosion per unit area increase; due to the progressive accumulation of runoff in the down slope direction and the slope steepness (S) increases the velocity and erosivity of runoff increase. Wischmeier and Smith (1978). Several methods of LS factor determination is developed with different GIS professionals at different time. To generate the LS factor map for this study the following formula (Equation) was applied.

Power("baro_dem_acc" * 30/22.1,0.6) * Power(Sin("baro_slope") * 0.01745/0.09,1.3)

Power("FlowAcc_Flow4" * 30/22.1,0.6) * Power(Sin(0.01745 * "Slope_tif5")/0.09,1.3)

LS=Pow [(Flow Accumulation)*Resolution/22.1,0.6]*pow[sin(slope)*0.01745) / 0.09,1.3] (Source, Griffin et.al (1988)

The basic input for generating an LS factor grid in GIS is a DEM dataset of suitable scale that has been subset to area of interest (sub watershed). Therefore, for this study the slope gradient (in percent) was determined from SRTM Digital Elevation Model (DEM) of 30 meter resolution. Establishing the dominant slope length was difficult because of the need to separate each section of slope and the possibility of not being able to identify shorter and flat slopes.

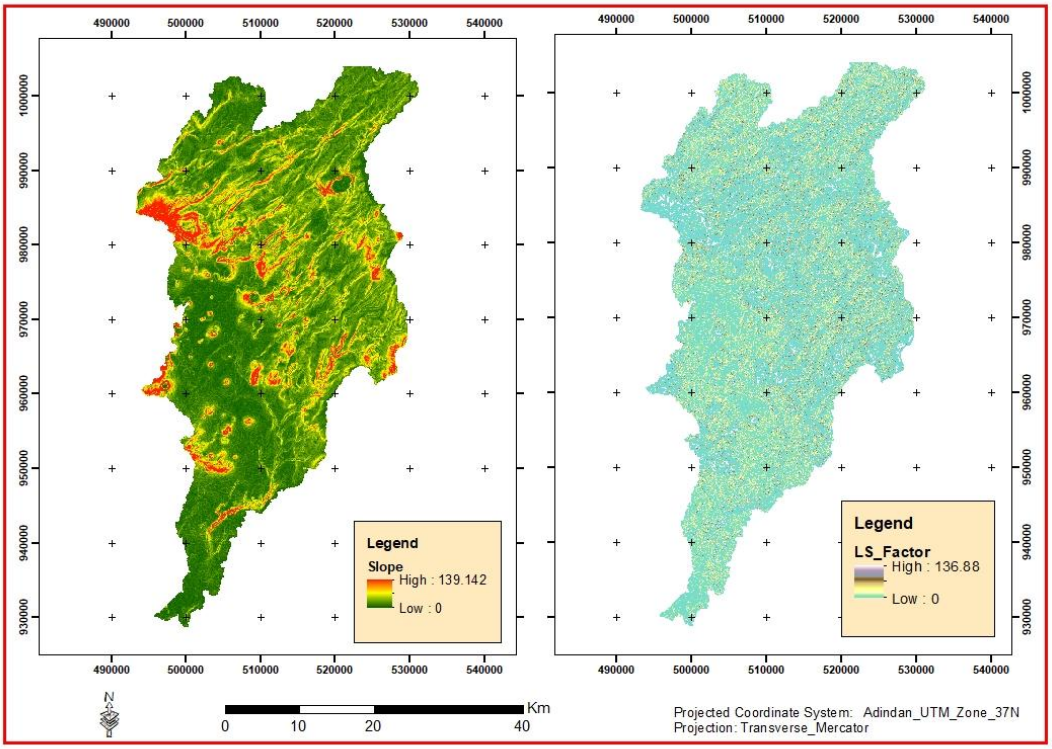

Figure 4.15 Combined slope length and gradient factor

4.2.1.3 Cover management(C) factor map

The crop cover factor C measures the combined effect of all the interrelated cover and management variables (Wischmeier and Smith, 1978). The cropping factor(C) is the ratio of soil loss under a given land cover/land use to that of the base soil from cultivated, continuous fallow on identical soil, and slope with the same rainfall (Morgan, 1994). In this respect, the raster map has been converted to vector data and column is added to the look up table that the value of C is

adjusted. In all study period the LULC of the study area was classified in to eight major category based on landsat ETM+ imageries of (2000, 2005, 2010 and 2017) path (158) Raw (053) by using supervise classification technique. Then, the classified image has been changed into vector format. After changing the classified raster data to vector, a corresponding C-value was assigned to each land use classes based on (Hurni, 1985) proposed to Ethiopian condition by using reclassify method of Arc GIS environment see table 4.14 and figure 4.16 and 4.17

The land use land cover of the study area was classified based on the satellite image of year 2017 acquired by supervised classification technique. The major land use/land cover types described in this study area are forest, crop land, and shrub land, grass land, water body, swampy area, built up/settlement and bare land. The classified raster image data has been changed in to vector format and a corresponding C-value was assigned to each land use/land cover classes adopted by Hans Hurni 1985. Then the C-value column is added and C Factor map was produced.

No	LULC classes	Source	C Factor
1	Cultivated Land	Hurni,1988	0.15
2	Built up/Settlement	Gizachew,2015	0.09
3	Shrub land	Woldeamlak and Ermias,2009 Wischmeier and Smith, 1978	0.014
4	Grazing land	Hurni,1988Gelagay, H. S., & Minale, A.S.,2016	0.01
5	Water bodies/Swampy Area	Erdogan etal.2006	0
6	Forest	Hurni,1988	0.001
7	Bare land	Hurni,1988	0.05

Table 4.14 LULC categories and the corresponding C-value

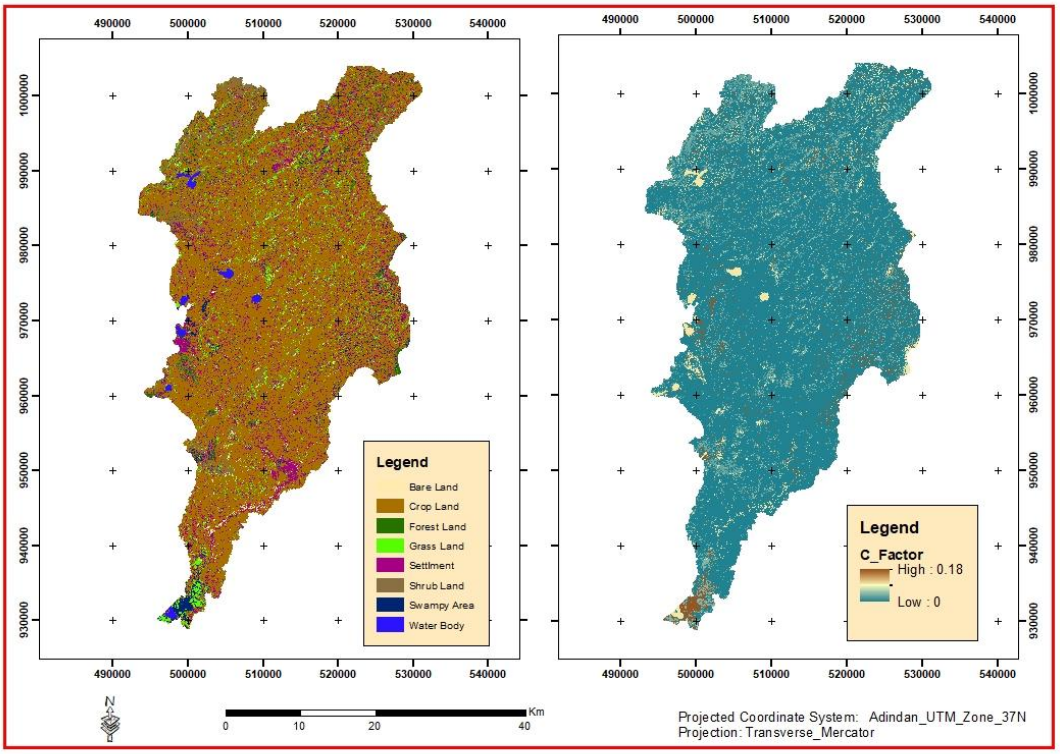

Figure 4.16 LULC types and the corresponding C values (2000)

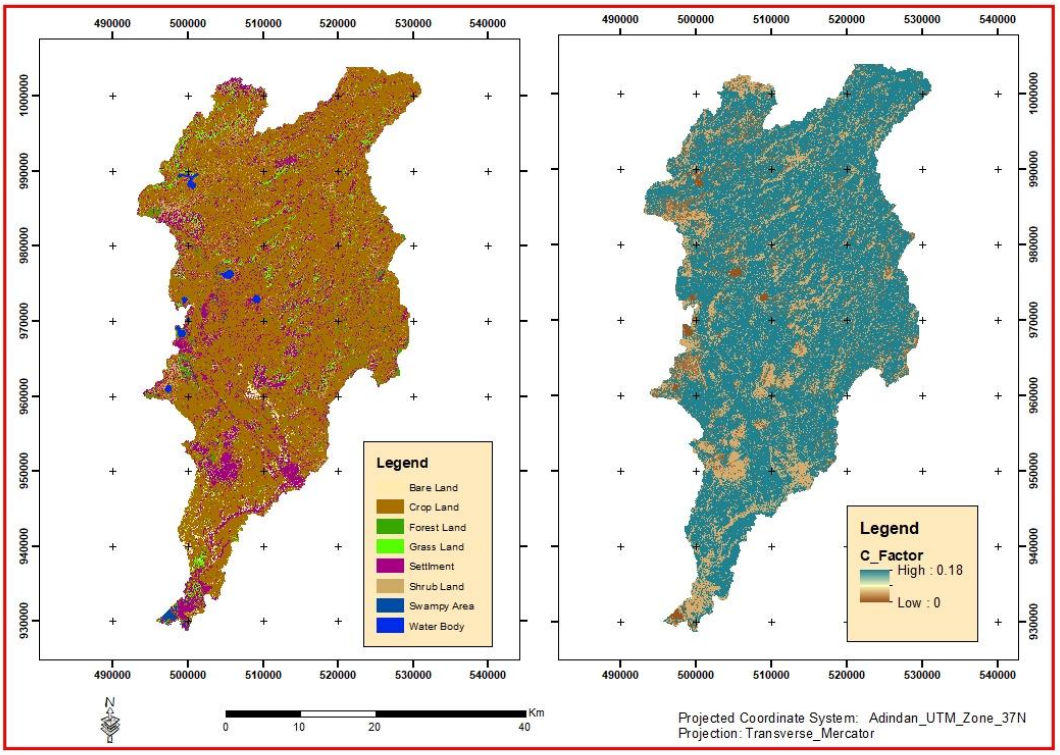

Figure 4.17 LULC types and the corresponding C values (2017)

4.2.1.4 Management/support practice (p) factor

The support practice factor (P) in RUSLE is the ratio of soil loss with a specific support practices to the corresponding loss with upslope and down slope tillage. These practices principally affect erosion by modifying the flow pattern, grade, or direction of surface runoff and by reducing the amount and rate of runoff (Renard and Foster, 1983). The conservation practice factor (P) is also called as support factor. It represents the soil loss ratio after performing a specific support practice to the corresponding soil loss, which can be treated as the factor to represent the effect of soil and water conservation practices (Renard et al., 1997). The range of P factor varies from 0 to 1. The lower the value is the more effective the conservation practices and the Higher the value is the lesser management or conservation practice. The result of classified LULC map of the study area has been changed in to vector format and followed from this corresponding P-factor values were assigned to each of LULC categories, and finally P factor map was produced see table 4.15 and figure 4.18 & 4.19.

No	LULC classes	P Factor
1	Cultivated Land	0.37
2	Built up/Settlement	0.8
3	Shrub land	1
4	Grass land	1
5	Water bodies/Swampy Area	0
6	Forest	1
7	Bare land	1

Table 4.15 Land Use/Land Cover types and the corresponding P values

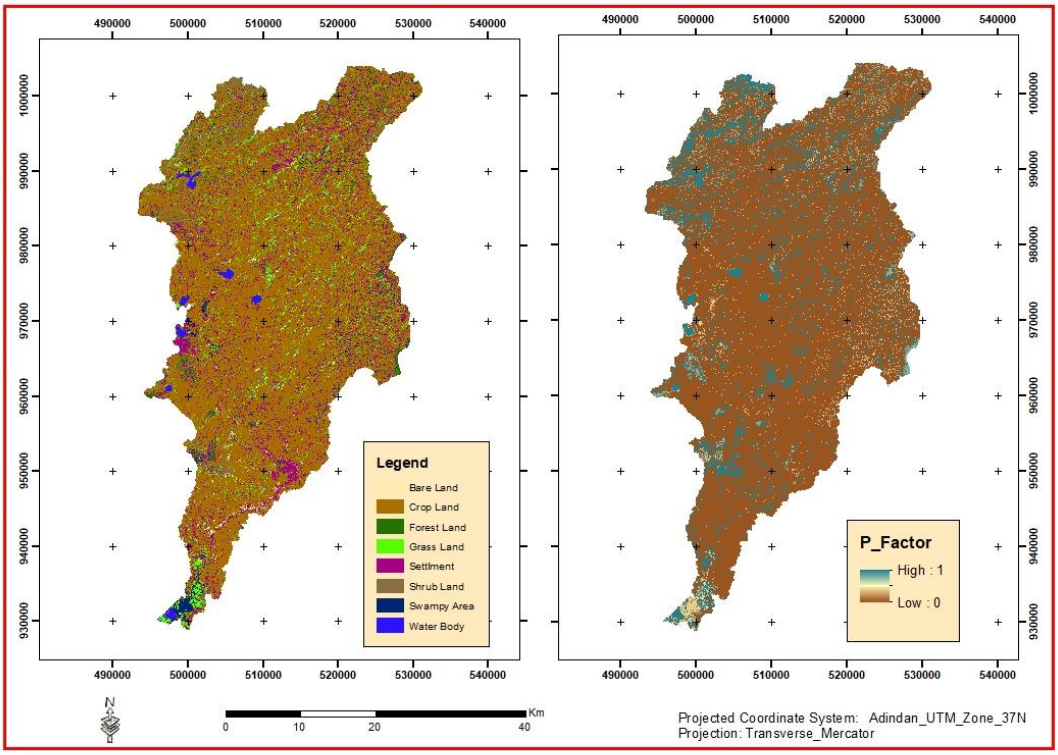

Figure 4.18 Land Use/Land Cover types and the corresponding P values (2000)

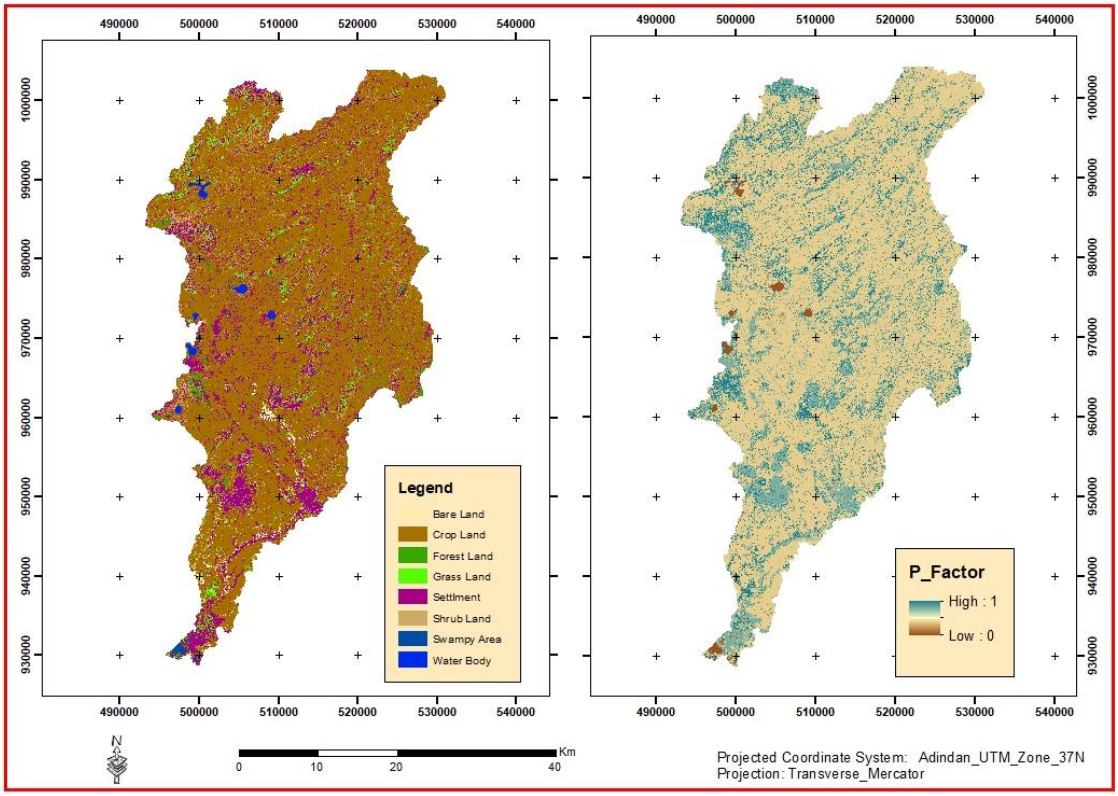

Figure 4.19 Land Use/Land Cover types and the corresponding P values (2017)

4.3 Assessment of soil erosion risk

In this study, the RUSLE soil erosion model with Geographic Information System (GIS) was applied to map soil erosion risk areas and predict amount of potential annual rate of erosion in Koka Watershed. The considered erosion factors were combined with Geographic Information System (GIS) to identify erosion risk areas. The map of erosion risk with the specified levels is also presented in table 4.16 figure 4.20 and figure 4.21. The final assessment of the mean annual soil loss is calculated using map algebra (raster calculator) tool of GIS spatial analysis. The soil loss is calculated from parameters of RUSLE which is discussed in the previous sections. The RUSLE parameter Rainfall Erosivity (R), Soil Erodibility (K), Slope length and steepness (LS), Land cover factor (C) and Management factor (p). Each layer was organized and computed in ArcGIS based on the relationship defined by RUSLE model. Hence, by multiplying the six parameters of RUSLE model using raster calculator in a GIS environment the final potential annual soil loss of the study area was generated. The result of annual soil loss of the study area (koka

watershed) showed that the value range from 0 to 673.05 ton/ha/year in 2000 and 0 to 866.02 ton/ha/year in 2017. The average annual soil loss rate in 2000 was 20.86 t/ha/yr and in 2017 is 23.98 t/ha/yr, which is greater than the average annual soil loss tolerable level 10 t/ha/yr according to Hurni, 1983.

In order to obtain a better understanding and also to compare areal extent of soil loss, the quantitative output of potential soil erosion rate for the study area resulted from the current LULC (i.e 2017) class and farming practice were grouped in to five soil loss severity classes in ArcGIS software. Hence the study area soil erosion severity classes with relative area coverage of each class which specified as very high class cover an area 0.9 % with an erosion risk of > 60 t/ha/yr, high level cover an area of 11.38 % (25-60 t/ha/yr), moderate level of erosion class covers 12.86 % (10–25 t/ha/yr), and low level of erosion class covers an area of 14.73 % (1 –10 t/ha/yr) and very low level of erosion class covers 60.14 % (0-1 t/ha/yr). The area coverage has been derived from the soil erosion map of the study area.

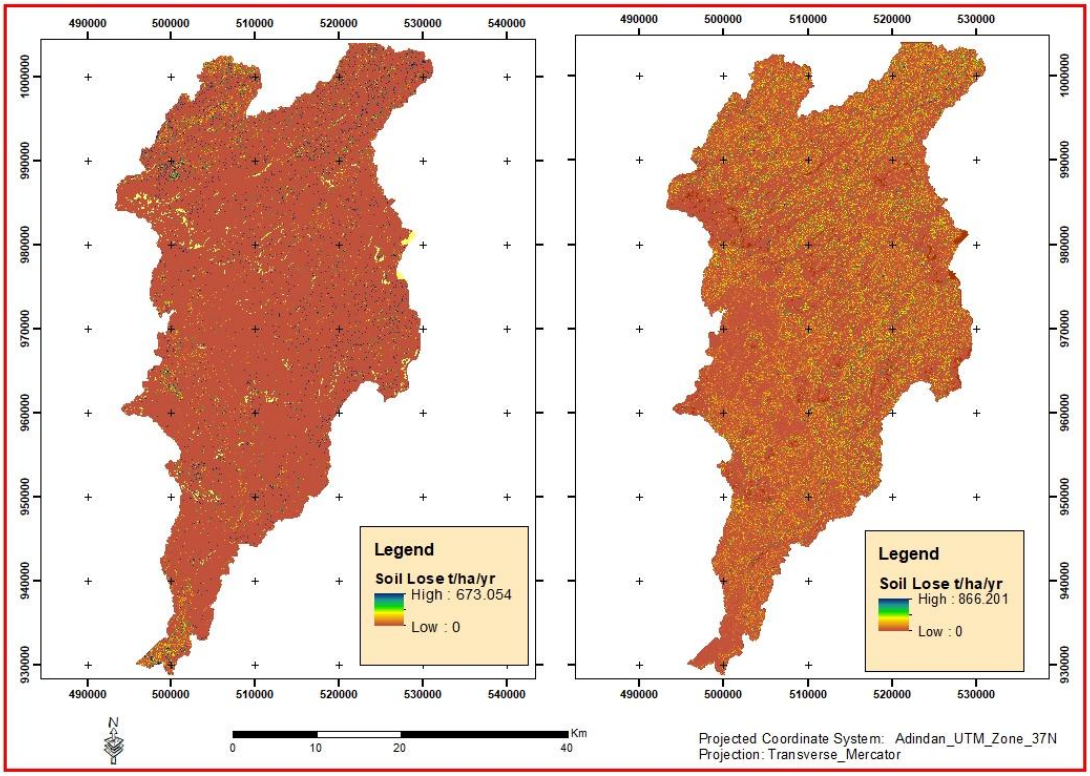

Figure 4.20 Soil risk map (2000 in left, 2017 in the right)

Soil lose (t/ha/y)	Severity class	Area (ha)		Change (ha)	Area (%)		Change (%)
		2000	2017		2000	2017	
0-1	Very low	89646.8	87075.3	2571.58	61.93	60.14	1.79
1_10	Low	21423.2	21323.8	99.44	14.80	14.73	0.07
10_25	Medium	17843.5	18614.2	-770.72	12.33	12.86	-0.53
25-60	High	14205.7	16474.4	-2268.7	9.81	11.38	-1.56
>60	Very high	1640.0	1309.2	330.8	1.13	0.90	0.23

Table 4.16 soil erosion severity classes

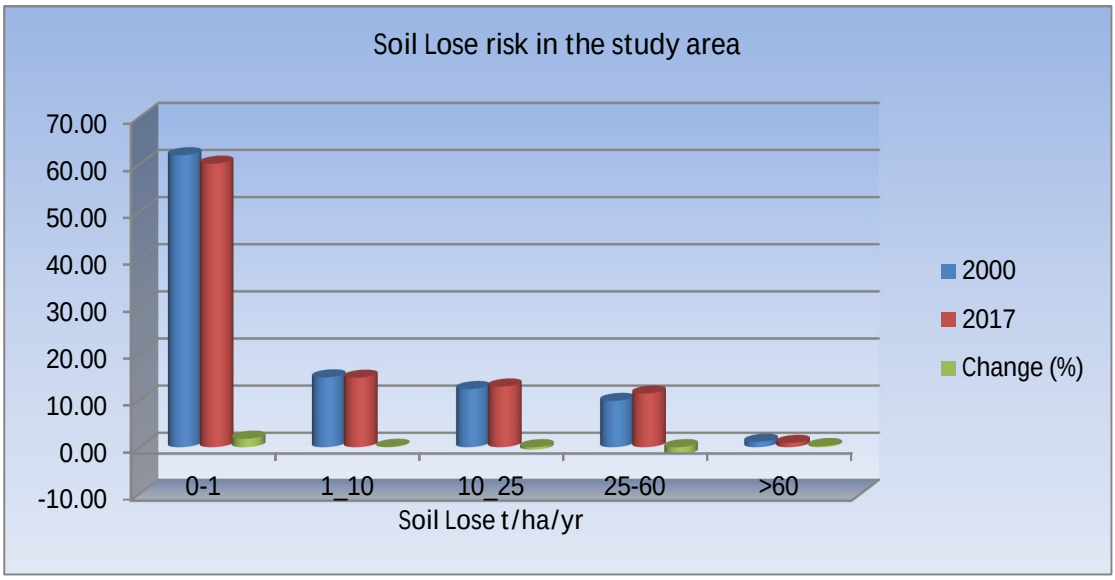

Figure 4.21 soil lose risk in the year 2000 and 2017

According to this study (see table 4.16) about 75 % of the study area has a potential soil erosion less or equal to 10 ton/ha/year which is a relatively low erosion risk area. The very high, high, medium soil erosion risk area covers almost one-fourth of the study area. The very high erosion risk area was identified almost about less than one percent.

Soil loss tolerance refers to the maximum soil loss that can occur from a given land without leading to degradation of the soil (Hurni, 1983).These soil erosion loss severity class classifications are based on various studies and mainly by considering soil loss tolerable level 10 ton/ha/yr estimated for Ethiopia by (Hurni, 1983).

Moreover it is noted that poor land use practices, improper management systems, and a lack of appropriate soil conservation measures have played a major role in land

degradation in Ethiopia. Based on this about 12 % of the study watershed (35,088 ha) need urgent conservations practice because it is intolerable level of soil erosion risk.

4.3 Delineation of sub watershed

From the Digital Elevation Model (DEM) sixteen sub watersheds were delineated as shown in the figure 4.22 below. The vegetation cover of the sub watershed and the soil loss status of the year 2000 and 2017 were taken as the basis for prioritization. Furthermore, the contribution from each sub watershed to the total amount of soil loss from the whole watershed area was also considered for such evaluation.

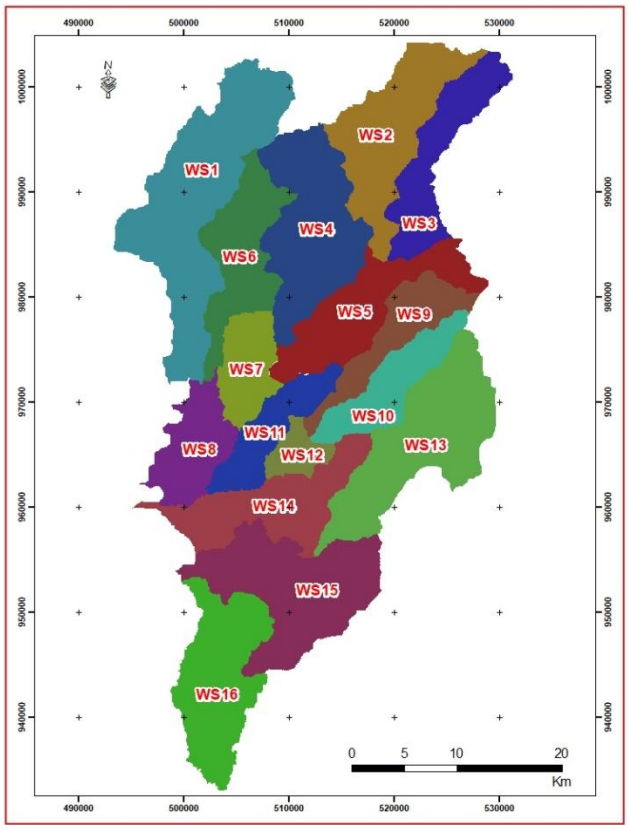

Figure 4.22 Delineated sub watershed

4.4 Sub watershed Degradation Speed Index (DSI)

In the above sections this study tried to point out and quantify the most important issues related to the land use land cover dynamics, soil erosion potential and soil erosion risk. These quantitative values could lead to the qualitative type of conclusion and recommendation but the spatial or geographical justification for conservation work not yet discussed. This section and the following section try to clearly justify

and point out the way the quantitative values identified in the previous sections in LULC dynamics and soil erosion analysis integrated and the spatial relationships created in a micro watershed level for conservation practices.

The DSI is defined as the degradation speed of the watersheds. In order to calculate the sub watershed DSI the vegetation change the period between 2000 and 2017, rate of soil loss change between the period 2000-2017, and the contribution of micro watersheds to soil loss change parameters were prepared and the final result is shown in the table below (table 4.17). The following formula used:

DSI= 0.3*vegetation change (%) + 0.45*rate of soil loss change (t/ha/yr) + 0.25*contribution to soil loss change (%)

4.4 Sub watershed Sensitivity Index (SI)

Due to loss of vegetation cover there are various impacts on the response of sub watersheds, one of this is the increment of soil erosion or soil lose. Soil lose depends on various factors; for example steepness of sub watersheds. To assess these characteristics land sensitivity has been proposed and sensitivity index defined. The land sensitivity index result shows that some sub watersheds are very sensitive as slight loss of vegetation cover produced tremendous amount of soil lose. The SI result of sub watersheds shown in the table below (table 4.17).

SI = Soil loss increment (t/ha/yr) / vegetation loss (%)

4.5 present condition

The soil erosion rate of the 2017 is considered as present condition (PC) of the sub watersheds. Among several indicators, the higher rate of soil erosion can be considered as an indicator of the condition of the sub watersheds.

Sub Watershed	LULC_2017 (%)	LULC_2000 (%)	Change (%)	Average Soil lose(t/ha/yr)	Average Soil lose(t/ha/yr)	Change (%)	Contribution for soil loss (%)		Change	DSI	SI
	2017	2000		2017 (PC)	2000		2017	2000			
WS1	21.19	24.03	2.84	27.53	25.23	-2.30	114.77	120.92	6.15	1.36	-0.81
WS2	6.49	10.63	4.14	24.17	26.24	2.06	100.78	125.76	24.97	8.41	0.50
WS3	3.77	7.14	3.37	26.49	29.12	2.63	110.43	139.57	29.14	9.48	0.78
WS4	10.45	10.06	-0.39	27.27	30.65	3.38	113.70	146.91	33.21	9.71	-8.68
WS5	7.60	5.09	-2.51	26.91	25.90	-1.01	112.21	124.16	11.95	1.78	0.40
WS6	4.91	4.41	-0.50	25.42	13.85	-11.57	105.97	66.38	-39.60	-15.26	23.18
WS7	1.21	1.13	-0.08	14.65	7.35	-7.30	61.07	35.23	-25.84	-9.77	89.96
WS8	3.43	4.71	1.29	26.23	18.55	-7.67	109.35	88.93	-20.42	-8.17	-5.97
WS9	5.10	3.08	-2.02	27.60	25.23	-2.37	115.07	120.93	5.86	-0.21	1.17
WS10	3.64	2.87	-0.76	29.58	26.49	-3.08	123.30	126.99	3.68	-0.69	4.05
WS11	2.09	1.47	-0.61	18.82	16.24	-2.58	78.47	77.84	-0.63	-1.50	4.23
WS12	1.43	0.78	-0.65	19.70	11.80	-7.90	82.13	56.54	-25.58	-10.15	12.20
WS13	8.53	7.51	-1.03	28.64	10.64	-18.00	119.42	51.02	-68.41	-25.51	17.54
WS14	4.86	4.03	-0.83	19.59	21.26	1.66	81.69	101.89	20.20	5.55	-2.00
WS15	7.24	5.91	-1.33	27.03	28.10	1.06	112.71	134.68	21.97	5.57	-0.80
WS16	8.07	7.13	-0.94	14.13	17.16	3.03	58.91	82.26	23.35	6.92	-3.23

Table 4.17 vegetation loss and soil status in the sub watersheds

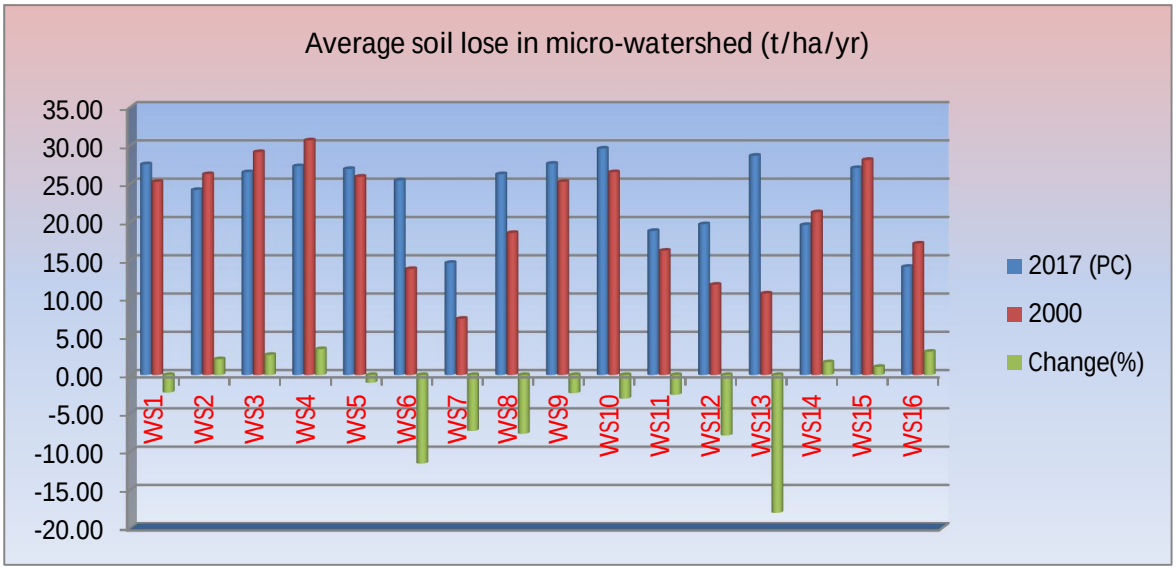

Figure 4.23 Average soil lose in sub watershed by the year 2000 and 2017

4.5 Prioritization

The DSI, SI and Present condition (PC) were taken as a condition for prioritization using simple matrix method. In order to set and create this matrix the range of quantitative values has been defined for qualitative value. Table 4.18 shows the qualitative values of DSI, SI and PC.

Rating	DSI	SI	PC
Very Low (VL)	_	< 1.0	_
Low (L)	< 0.2	1.0-2.0	5.0-15.0
Medium (M)	0.2-1.0	2.0-5.0	15.0-20.0
High (H)	1.0-2.0	5.0-15.0	20.0-25.0
Very High (VH)	> 2.0	> 15.0	> 25.0

Table 4.18 condition indicator for DSI, SI and PC

From the qualitative rating, the two dimensional overlay matrixes had been created by taking two indicators at a time. First the matrix analysis between DSI and SI had been done and they were grouped in to five classes, which were used for second matrix analysis with PC. Lastly they were again grouped in to five qualitative classes as shown in table 4.19 and 4.20. The group had been decided on the basis of the logical combination of the indicators. For example the combination of high DSI and SI were grouped as first priority group. The output of the matrix analysis is given in table

4.21, where all sixteen sub watersheds were classified in five groups. The map in figure 4.24 shows the spatial distribution of the sub watershed for conservation prioritization work.

SI/DSI	L	M	H	VH
VL	5	5	4	3
L	5	4	3	2
M	4	3	2	2
H	3	2	1	1
VH	2	2	1	1

Table 4.19 matrix analysis between DSI and SI

PC/DSI-PC	L	M	H	VH
VL	5	4	3	3
L	5	3	2	2
M	4	2	2	2
H	3	2	1	1
VH	2	2	1	1

Table 4.20 matrix analysis between DSI/ SI and PC

DSI	SI	PC	DSI	SI	PC	Priority	Sub Watershed
-9.4771	-8.67904	14.13017	L	L	L	5	WS13
-5.97488	-5.96766	14.64775	L	L	L	5	WS6
-4.15003	-3.23186	18.82171	L	L	M	4	WS12
-3.71252	-2.00343	19.59378	L	L	M	4	WS7
-3.38665	-0.80848	19.69882	L	L	M	4	WS8
-1.58137	-0.80196	24.17337	L	L	H	3	WS9
-1.55778	0.403075	25.41762	L	L	H	3	WS10
-1.35513	0.498121	26.22789	L	L	VH	2	WS11
-1.0209	0.780746	26.48745	L	L	VH	2	WS5
-0.08534	1.17284	26.91475	L	L	VH	2	WS1
0.423967	4.046751	27.03471	M	M	VH	2	WS15
0.81509	4.227741	27.27183	M	M	VH	2	WS14
1.447865	12.1963	27.52695	H	H	VH	1	WS16
1.922401	17.53597	27.59878	H	VH	VH	1	WS4
2.560641	23.17838	28.64411	VH	VH	VH	1	WS2
2.649881	89.9599	29.57506	VH	VH	VH	1	WS3

Table 4.21 sub watershed priority

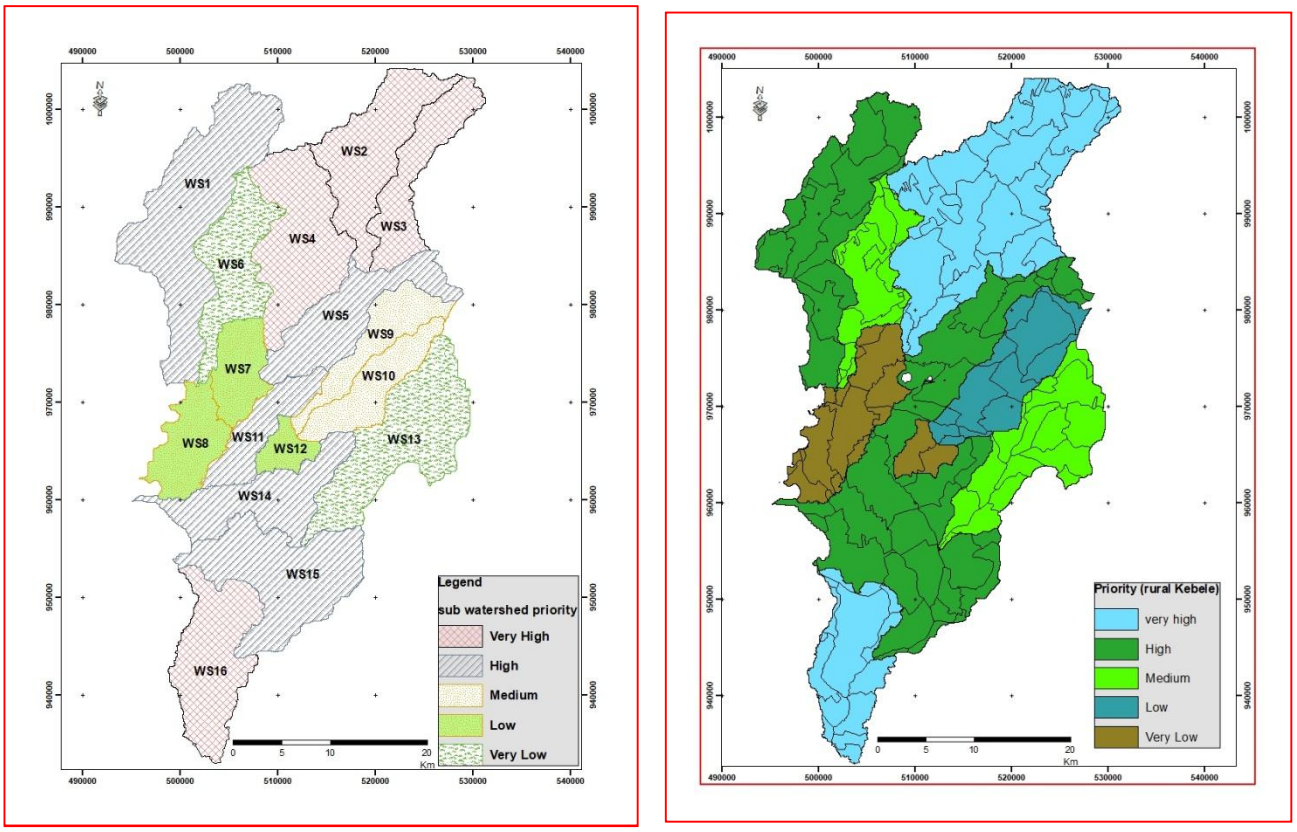

Figure 4.24 Priority based on sub watershed (left) and rural kebele (right)

5. Conclusion and Recommendation

5.1 Conclusion

The main aim of this proposal is to prioritize the sub watersheds for integrated watershed management and conservation measures and to evaluate the temporal change of the land use/cover using GIS and Remote Sensing techniques. In addition to this study also assessed or estimates the amount of soil erosion in the catchment area through RUSLE model and map areas which are susceptible for soil erosion.

The study inspects the change in LULC in the past 27 years (2000–2017) in which the findings of this study shows that an observable change was recorded during this period.

In 2000 and 2017, about 70 % and 72 % of the land was covered by cultivated land respectively which is the highest share from the total area of the study area. Besides 11.83 % of the area was covered by built up/settlement during the initial year of the study but in 2017 this LULC class covered 15.78 % out of the total area from the study area. The outcomes of the present study shows the LULC dynamics in the koka watershed over the last 17 years (2000–2017) showed increasing from time to time comparing with the initial study period 2000 to 2017. These shows there are an expansion of urban and rural settlement as well as construction of roads, industrial parks, floriculture and other investment purpose constructions with the expense of other LULC.

On the contrary a continuous reduction in aerial coverage observed in grazing land, Bush/Shrub land and forest cover through the study period. In which 0.22 ha/yr, 1.32 ha/yr, 0.49 ha/yr, 1.35 ha/yr and 0.13 ha/yr reduction identified in forestland, grass land, swampy area, shrub and water body lad respectively during the period between 2000 and 2017. Also the reduction continued 88.31 hectare/ year between the years (2000 – 2015). The basic reason for the reduction of LULC is due to high population growth in the study area. In general active LULC dynamic observed in the area in the period between 2000 and 2017, this change in LULC continued over the study period in the expense of one cover type to another.

Thus by considering the RUSLE parameters the result showed that the study area is very liable to soil erosion. The result of annual soil loss of the study area (koka watershed) showed that the value range from 0 to 673.05 ton/ha/year in 2000 and 0 to 866.02 ton/ha/year in 2017. The average annual soil loss rate in 2000 was 20.86 t/ha/yr and in 2017 is 23.98 t/ha/yr, which is greater than the average annual soil loss tolerable level 10 t/ha/yr according to Hurni (1983).

From the final result it's identified that around four sub watersheds (45 rural kebeles) in very high priority class, five sub watersheds (46 rural kebeles) are in high priority class; 2 sub watersheds (27 rural kebeles) are in medium level priority class, around 2 sub watersheds (14 rural kebeles) are in a very low priority class and around 3 sub watersheds (12 rural kebeles) are in low priority class (see annex A and B, figure 4.23).

5.2 Recommendation

The findings of the study showed that the study area was under continuous LULC dynamics and vulnerable to soil erosion problem.

As a result this particular research suggests the following:

- Based on the result of the study the four sub watersheds of the area fallen under very high class of priority which needs an immediate action in order to retain the soil from erosion potential and/or degraded land cover should get attention and priority of rehabilitation.
- The regional government, zone administration, wereda administration intervention needed for conservation program by motivating the population of the sub watershed, such as in afforestation, and other conservation program.
- Local planners and decision makers should implement both long and short-term timely updated natural resource management systems including the necessary forest laws.
- The local communities should adopt immediate soil conservation measures in their cultivated lands by applying indigenous means of soil conservation techniques like mulching, strip cropping, terracing, contour plowing, multiple cropping and other
- Further micro watershed level studies will be recommended to decide what conservation structure will be required for each classes of priority level to tackle the problem.

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Annex A prioritized sub watershed rural kebele list

RK_ID	Zone	Wereda	RK_Name	priority		RK_ID	Zone	Wereda	RK_Name	Priority
1	East Shewa	Lomme	Ejere Town	Medium		73	East Shewa	Lomme	Mojo Town	High
2	East Shewa	Lomme	Deni Jateni	Medium		74	East Shewa	Bishoftu Town	Bishoftu Town	High
3	East Shewa	Lomme	Ejere Wolkite	Medium		75	North Shewa	Bereh	Aburoge	High
4	East Shewa	Lomme	Ardega Kordida	Medium		76	North Shewa	Bereh	Konitoba Wegecha	High
5	East Shewa	Lomme	Nanawa	Medium		77	North Shewa	Bereh	Repa Denibel	High
6	East Shewa	Lomme	Tilti Gerbi	Medium		78	North Shewa	Bereh	Lenicho Choba Sululita	High
7	East Shewa	Lomme	Finchawa Mariam	Medium		79	North Shewa	Bereh	Meta Guta Bole	High
8	East Shewa	Lomme	Dildila Gonbore	Medium		80	East Shewa	Lomme	Kiltu Beja	High
9	East Shewa	Lomme	Danse Shanbure	Medium		81	East Shewa	Lomme	Liabo	High
10	East Shewa	Lomme	Kuncho Dalota	Medium		82	East Shewa	Lomme	Jirmi Enslale	High
11	East Shewa	Lomme	Kiltu Beja	Medium		83	East Shewa	Lomme	Birmeji Tulu Rea	High
12	East Shewa	Lomme	Jirmi Enslale	Medium		84	East Shewa	Lomme	Jegola Arfeta	High
13	East Shewa	Lomme	Dekabora Kara	Medium		85	East Shewa	Lomme	Biyu Bisqe	High
14	East Shewa	Lomme	Haro	Medium		86	East Shewa	Lomme	Shera Dibandiba	High
15	East Shewa	Lomme	Birmeji Tulu Rea	Medium		87	East Shewa	Lomme	Momo Shoke	High
16	East Shewa	Lomme	Jegola Arfeta	Medium		88	East Shewa	Lomme	Tafi Abo	High
17	East Shewa	Gimbichu	Menjeksogora	Medium		89	East Shewa	Lomme	Kurma Fatole	High
18	East Shewa	Gimbichu	Menjeksotedi	Medium		90	East Shewa	Lomme	Kolbe Gode	High
19	East Shewa	Gimbichu	Buitengego	Medium		91	East Shewa	Lomme	Muda Senkele	High
20	East Shewa	Gimbichu	Haberuseftu	Medium		92	East Shewa	Gimbichu	Beshanteno	High
21	East Shewa	Adea	Koftu Poket Land	Medium		93	East Shewa	Gimbichu	Tulufera	High
22	East Shewa	Adea	Gende Gorba	Medium		94	East Shewa	Gimbichu	Quntushelihama	High
23	East Shewa	Adea	Godino	Medium		95	East Shewa	Gimbichu	Gorotegere	High
24	East Shewa	Adea	Keteba	Medium		96	East Shewa	Gimbichu	Finchawaegeziarab	High
25	East Shewa	Adea	Anbelta	Medium		97	East Shewa	Gimbichu	Menjeksogora	High

26	East Shewa	Adea	Koftu	Medium		98	East Shewa	Gimbichu	Menjeksotedi	High
27	East Shewa	Adea	Dinsho Kebt Erbatas	Medium		99	East Shewa	Gimbichu	Buitengego	High
28	East Shewa	Lomme	Qoqa Town	Very High		100	East Shewa	Adea	Gende Gorba	High
29	East Shewa	Gimbichu	Chefedonsa Town	Very High		101	East Shewa	Adea	Godino	High
30	East Shewa	Lomme	Momo Shoke	Very High		102	East Shewa	Adea	Keteba	High
31	East Shewa	Lomme	Tafi Abo	Very High		103	East Shewa	Adea	Tulu Dimtu	High
32	East Shewa	Lomme	Muda Senkele	Very High		104	East Shewa	Adea	Kerfe	High
33	East Shewa	Lomme	Ejersa Joro	Very High		105	East Shewa	Adea	Hidi Deko	High
34	East Shewa	Lomme	Dungigi Bekele	Very High		106	East Shewa	Adea	Hidi	High
35	East Shewa	Lomme	Qoqa Negewo	Very High		107	East Shewa	Adea	Koftu	High
36	East Shewa	Gimbichu	Poket land	Very High		108	East Shewa	Adea	Kaliti	High
37	East Shewa	Gimbichu	Germamadekdeba	Very High		109	East Shewa	Adea	katila	High
38	East Shewa	Gimbichu	Kokadayou	Very High		110	East Shewa	Adea	Denkaka	High
39	East Shewa	Gimbichu	Betmetak	Very High		111	East Shewa	Adea	Ouda	High
40	East Shewa	Gimbichu	Enbosendedo	Very High		112	East Shewa	Adea	Gerbicha	High
41	East Shewa	Gimbichu	Somesakombolcha	Very High		113	East Shewa	Adea	Gicho Gerbabo	High
42	East Shewa	Gimbichu	Jegolnechdengey	Very High		114	East Shewa	Adea	Gobo Saye	High
43	East Shewa	Gimbichu	Aredabora	Very High		115	East Shewa	Adea	Dinsho Kebt Erbatas	High
44	East Shewa	Gimbichu	Webermansur	Very High		116	East Shewa	Akaki	Bili nSilto	High
45	East Shewa	Gimbichu	Burekoulaula	Very High		117	East Shewa	Akaki	Yeferabeye	High
46	East Shewa	Gimbichu	Deredagumsesa	Very High		118	East Shewa	Akaki	Mengest Den	High
47	East Shewa	Gimbichu	Dobiboset	Very High		119	East Shewa	Lomme	Deni Jateni	Low
48	East Shewa	Gimbichu	Dewetucheli	Very High		120	East Shewa	Lomme	Ardega Kordida	Low
49	East Shewa	Gimbichu	Osocheleleqaqa	Very High		121	East Shewa	Lomme	Dildila Gonbore	Low
50	East Shewa	Gimbichu	Beshanteno	Very High		122	East Shewa	Lomme	Kiltu Beja	Low
51	East Shewa	Gimbichu	Tulufera	Very High		123	East Shewa	Lomme	Liabo	Low

52	East Shewa	Gimbichu	Gorotegere	Very High		124	East Shewa	Gimbichu	Quntushelihama	Low
53	East Shewa	Gimbichu	Finchawaegeziarab	Very High		125	East Shewa	Gimbichu	Edadoejire	Low
54	East Shewa	Gimbichu	Geremiborchota	Very High		126	East Shewa	Gimbichu	Gorotegere	Low
55	East Shewa	Gimbichu	Lemelemchefi	Very High		127	East Shewa	Adea	Kerfe	Low
56	East Shewa	Gimbichu	Adadigole	Very High		128	East Shewa	Adea	Hidi Deko	Low
57	East Shewa	Gimbichu	Menjeksogora	Very High		129	East Shewa	Adea	Hidi	Low
58	East Shewa	Gimbichu	Haberuseftu	Very High		130	East Shewa	Adea	katila	Low
59	East Shewa	Adea	Godino	Very High		131	East Shewa	Bishoftu Town	Bishoftu Town	Very low
60	East Shewa	Adea	Keteba	Very High		132	East Shewa	Lomme	Liabo	Very low
61	East Shewa	Adea	Anbelta	Very High		133	East Shewa	Adea	Gende Gorba	Very low
62	East Shewa	Adea	Tulu Dimtu	Very High		134	East Shewa	Adea	Godino	Very low
63	East Shewa	Adea	Kerfe	Very High		135	East Shewa	Adea	Kerfe	Very low
64	East Shewa	Adea	Koftu	Very High		136	East Shewa	Adea	Hidi	Very low
65	East Shewa	Adea	Golbo	Very High		137	East Shewa	Adea	Koftu	Very low
66	East Shewa	Adea	Gicho Gerbabo	Very High		138	East Shewa	Adea	Kaliti	Very low
67	East Shewa	Adea	Gobo Saye	Very High		139	East Shewa	Adea	katila	Very low
68	East Shewa	Liben	Jara Goro	Very High		140	East Shewa	Adea	Denkaka	Very low
69	East Shewa	Liben	Golole Huluka	Very High		141	East Shewa	Adea	Ouda	Very low
70	East Shewa	Liben	Jalo Chancho	Very High		142	East Shewa	Adea	Gerbicha	Very low
71	East Shewa	Liben	Gongo	Very High		143	East Shewa	Adea	Kajimana Dibayou	Very low
72	East Shewa	Liben	Goditi Goro	Very High		144	East Shewa	Adea	Dinsho Kebt Erbatas	Very low

Annex B prioritized sub watershed rural kebele map