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THESIS

Effects of land use land cover changes on soil erosion risk in Beshilo sub basin and the influence on Tebi dam, north eastern highlands of Ethiopia

Submitted by: Andarge Getachew

ID NO: PGIDEK/003/09

Advisor: Tewodros Tesfay (PhD)

Co-Advisor: Teshale Tadesse (Msc)

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Name of Internal Examiner	Signature	Date
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DECLARATION

I, Andarge Getachew, hereby declare that this thesis entitled "Effects of land use land cover changes on soil erosion risk in Beshilo sub basin and the influence on Tebi dam, north eastern highlands of Ethiopia'' submitted for the partial fulfilment of the requirements for the Masters of Technology in Irrigation and Drainage Engineering, is the original work done by me under the supervision of Dr. Tewodros Tesfay and Mr. Teshale Tadesse and this thesis has not been published or submitted elsewhere for the requirement of a degree program to the best of my knowledge and belief. All materials or ideas of other authors used in this thesis have been duly acknowledged and references are listed at the end of the main text.

Name: Andarge Getachew

Signature: ____________________

Date: ________________________

ABBREVIATIONS/ACRONYMS/

ANRS	Amhara National Regional State
CSA	Central Statistical Agency
DA	Development Agent
DEM	Digital Elevation Model
ERDAS	Earth Resources Data Analysis System
ESRI	Environmental Science Research Institute
ETM+	Enhanced Thematic Mapper plus
GCPs	Ground control points
GEF	Global Environment Facility
GIS	Geographic Information System
IDW	Inverse Distance Weight overlay
LULC	Land Use Land Cover
LULCC	Land use land covers Change
LULUCF	Land Use, Land Use Change Forestry
NME	National Metrology Agency
OLI	Operational Land Imagery
RUSLE	Revised Universal Soil Loss Equation
SRTM	Shuttle Radar Topographic Mission
SWC	Soil and Water Conservation
USGS	United State Geological Survey
USLE	Universal soil loss Equation
WGS	World Geodetic Survey
UTM	Universal Transverse Mercator

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EFFECTS OF LAND USE LAND COVER CHANGES ON SOIL EROSION RISK IN BESHILO SUB BASIN

Andarge Getachew (andargeg09@gmail.com)

ABSTRACT

Continuous increase of world's population and demand for food and staple production poses a major challenge for agriculture in the short and medium period. In the current study area, soil loss information and evaluation of risk of potential of soil erosion was not assessed. So, the aim of these study is to assess and analyze the impact of land use land cover change on soil erosion risk using remote sensing and GIS techniques in the upper bushilo sub-basin northern-eastern highland of Ethiopia between 1990 and 2020. Primary materials and tools used are ArcGIS 10.8 software, ENVI 5.3 software, Landsat satellite image of 1990, 2000, 2010, and 2020, ASTER DEM /DEM 30X30 was downloaded from USGS earth explore, Google earth pro as use for base map that also were downloaded for the four study periods. GPS, Camera, Internet access, and computer software were used for data processing and GIS analysis. the watershed's computed soil loss ranged from zero in plain areas and water courses to large over 68.7t ha^{-1} yr^{-1}. In very degraded sloping regions and at specific spots of steep slopes of the watershed, gross soil loss rate ranged to 79.65 t/ha. It shows a larger spatial variation of soil loss over the watershed. It is mainly caused by the difference in soil, rainfall, slope, land cover, and improper land management. The estimated mean annual gross soil loss from 1990-2020 under the entire watershed is about a 9.94 t/ha/yr. Within the study period (1990-2020), 41723.8 ton soil has transported to Tebi dam. The GIS-based RUSLE model can assist decision-makers in effective planning for erosion control studies on risky areas.

Key Words: *Beshilo sub basin, GIS, LULC, soil erosion, Tebi dam*

1. INTRODUCTION

1.1. Back Ground of the Study

Land cover change is a major component of global change with an impact greater than that of climate change. Land cover changes lie on a scale of severity that ranges from no alteration through modifications of variable intensity to a full transformation or conversion of class membership (Prakasam et al., 2012, Prakasam, 2010).

Land use land cover defined as the observed physical layer including natural and planted vegetation and human constructions. The reduction of vegetation cover can increase soil erosion. This relationship is the reason why vegetation cover and land use have been widely included in soil erosion studies (Foody, 2001).

Particularly, continuous increase of world's population and demand for food and staple production poses a major challenge for agriculture in the short and medium period. It requires an integrated and systemic approach to face food insecurity and natural resources loss threats. To address sustainable use and management of natural resources toward development and adoption of farming technology and management practices capable to ensure food availability and agricultural livelihoods, meaningful comparison of potentially arable land with presently cultivated land requires that, within the potential arable land, nonagricultural land uses are accounted for. Land cover and land cover change is recognized as the precursor of land use and land use change (Vinciková et al. 2010).

Assessment on land degradation hazard is therefore believed essential for soil conservation plans in the basin for sustainable development (Watson and Zakri, 1978).

Soil erosion is one of the most vital land degradation problems through the water and critical environmental hazard in the modern time at worldwide. Soil erosion and associated degradation of land resources are highly significant the spatiotemporal phenomena in many countries. Soil erosion normally related to farming practices in tropical country, lead to a decline in soil productiveness, obtain a series of negative impact of environmental problem and also risk to sustainable devolvement of agricultural production and water quality in this region (Leh, Bajwa, and Chaubey 2011). In Ethiopia, soil erosion has a major effect for agricultural land, degradation of the soils and siltation in reservoir etc. formed in the nation.

As one of the most important basic natural resource, land relates to almost all the human activities directly or indirectly, and is crucial for sustaining livelihoods in many Sub Saharan African (SSA) countries like Ethiopia. Rational utilization of the land resource has been treated as the key factor in the development pathways of many SSA countries (Jiang 2013).

This has happened as a result of rapidly growing demand on natural resources (Watson and Zakri 1978). It has caused in ruin of the natural ecosystem functioning. Thus, to recognize land cover and land use change process and its implication for environmental, it is important to recognize the services provided by the natural environments, and to come up with a sustainable land use plan (Thompson et al., 2011).

The basic decision that emerges from this fact is whether to use deterministic or empirical approaches for the context at hand (Vinciková et al., 2010).

LULC changes pattern in the watersheds has direct implication on hydrological yield. It was an important characteristic in the runoff processes, that, affects the infiltration, soil erosion, and evapotranspiration extended. Deforestation, urbanization, and other LULC activities can significantly alter the seasonal and annual distribution of soil loss and surface runoff (Manandhar, Odeh, and Ancev 2009).

climate change, land cover patterns and the fundamental properties of a soil, which makes the soil particles more prone to erosion (Hurni ,2016). Due to inappropriate land use, erosion has become one of the most dangerous forms of soil degradation leading to significant reduction of soil fertility and crop yields (Sotiropoulou et al., 2011).

Land use change detection is therefore a serious requirement for the valuation of potential environmental impacts and developing effective land management and planning strategies. Soil erosion directly affected by land use change. Therefore, the modeling of land use change is important with respect to the prediction of soil erosion and degradation (Watson and Zakri 1978).

These changes and their repercussions require careful consideration by local and regional land managers and policy makers in order to make informed decisions that effectively balance the positive aspects of development and its negative impacts in order to preserve environmental resources and increase socioeconomic welfare (Yuan et al., 2005). Understanding of land cover and land use change process and its implication for environmental condition and ecosystem functioning, it is essential to identify and recognize the services provided by the ecosystem (Inca, 2009).

1.2. Statement of the Problem

It estimated that the human footprint has affected 83% of the global terrestrial land surface and has degraded about 60% of the ecosystems services in the past 50 years alone LULCC has been the most visible indicator of the human footprint and the most important driver of loss of biodiversity and other forms of land degradation (Ephraim *et al.* 2012). Information regards to impact of LULC change on soil loss is therefore essential to plan and prioritize treatments of the sub watershed, and to understand the erosion process and their interaction. Soil erosion evaluation and mapping of soil loss susceptible area also helps to understand soil conservation and ecosystem management mechanisms in the sub watershed, LULCC has become a fundamental part in existing strategies for handling natural resources and inspection environmental changes. Observing the Earth from space is now vital to understand human's activities on his natural resource base over time. In circumstances of rapid and habitually unrecorded land use change, observations of the Earth from space provide objective information of anthropoid utilization of the landscape. To attain optimal utilization of resources, the study undertaken to find alternative land use options in the sub watershed by visual interpretation techniques using GIS.

This study is carried out in the Upper Beshilo sub watershed on Tebi dam of the north eastern part of Ethiopia, an agrarian, rural settlement and urban built-up watershed under an intense land use, which is largely modifying the natural land cover and having several impacts on the local ecosystem functioning. The urban and suburban growth and the agricultural and livestock practices in steep slopes have a strong impact to soil erosion increasing sediment load to water streams. Sediment was a major disturbance;

high sedimentation rate and amount determine the performance and life of reservoirs, canals, drainage channels etc. Sediment accumulation also contributes to risk of flooding.

The upper Beshilo sub watershed, several projects have been executed. While millions of Ethiopian Birr have been invested for river canalization, training, water cleaning and flood control but due to the rapid infrastructure deterioration because of sediment accumulation and urban drainage discharge into the river, intense storm runoffs, flooding and silt accumulation, stream erosion and the problem did not solved. As (Mekedela Woreda Agriculture Office 2007) less productivity in watershed due to catchment were degraded 25 ha of cultivated of annual and perennial crop land of downstream lost and ,irrigation canal, water harvesting structures ,water way ,cut off drain silted up by sedimentation and destruction, the gabion construction for river training every years displaced and disappeared by stream erosion.

Thus, community encompassed prior benefit also woredas development office, researchers and other development partner access and use as base line. With the impact of LULCC and erosion, resulted the land used for cultivation is also decreasing per household size. However, at the same time land under cultivation area is cumulative increasing. Recently the functioning of the increased population, people and property promoters are bringing a serious disaster to forest area and agricultural land. This is an unhealthy situation of land management. Such constraints hope fully averting by such study.

1.3. Objective of the Study

1.3.1. General Objective

To assess and analyze the impact of land use land cover change on soil erosion risk using remote sensing and GIS techniques in the upper beshilo sub-basin northern-eastern highland of Ethiopia between 1990 and 2020.

1.3.2. Specific Objectives

- To analyze LULC dynamics of upper Beshilo sub watershed.
- To quantify the rate of soil loss, within the sub watershed.
- To interpret and identify hotspot areas for sustainable land managements
- To examine and analyze the impacts of LULCC on soil erosion.

1.4. Research Questions

What is the long-term LULC change of Beshilo River sub watershed at Tebi dam in the Northeast Ethiopia?

How much was soil loss within the study area?

Where is the most vulnerable soil erosion spot of study area?

What is the impact of LULCC on the soil erosion Potential in study period?

1.5. Significance of the Study

The land use and land cover change within the study area has scientific and developmental importance for the future. Mostly, such information is fundamental for comparing the past and present condition LULC change and identifying the most hotspot area of erosion and scaling up such method of protecting the soil degradation and expanding such techniques to South Wollo Zone in the Amhara National Regional

State (ANRS). Agricultural information are relevant to variety of people, agencies etc. for decision-making. Among these users are both government and non-governmental agencies. Some of these potential users are development partners and country planners, statisticians, environmental agencies, landowners etc.

1.6. Limitation of the Study

There were great challenges for getting high resolution of satellite images even free licensed released especially for the years 1989 and 2003. This research study is also restricted on using high-resolution satellite data for producing a more realistic estimated LULC change of the past years. Most of the studies developing on the land use either mapping of hill tracks, based on primary data or using Land Sat images. It is not always possible to collect the primary data and using real land sat images are very expensive. Although few land sat images are available freely now but they lack sufficient resolution to work on. Besides error in selecting, downloading, processing and analyzing remote sensing datasets may additionally result in inappropriate recommendations and conclusions. The challenges had made to fulfill the missed data in order to obtain the mean annual rainfall amount**.** Due to the unavailable full monthly rainfall data stations inside the sub watershed, thus forced to use IDW interpolation of the monthly rainfall data for the stations located near the watershed used.

2. LITERATURE REVIEW

2.1. Land Use Land Cover Change

Timely and accurate change detection of Earth's surface features provides the foundation for better understanding relationships and interactions between human and natural phenomena to better manage and use resources (Xiaodong, Jianya, and Deren 2000). Therefore, it usefully applied to the various fields, such as environmental inspection, rural planning, forest policy, updating of geographical information and the land use usage. In general, change detection involves the application of multi temporal datasets quantitatively analyze the temporal effects of the phenomenon.

The degradation of worldwide natural resources ecosystems as a result of accelerated human population growth accompanied by agricultural, industrial, settlements and urban development justifies a strong need to find efficient ways to manage and protect these sensitive environments (Yang and Liu, 2005). Previously and now, no authors have been involved in an interdisciplinary research project aiming to develop environmental indicators for integrated natural recourses ecosystem assessment in this study area. As part of this project, a study will conducted to characterize land use and land cover changes of the different trend of the area.

As Global Environment Facility Land Use, Land Use Change Forestry (LULUCF) Activities; GEF: Washington DC, USA, 2012 explained that much of the direct change is a consequence of land use, and today about 40% of the land surface is used for agriculture (crops and pasture) (Hailemariam, Soromessa, and Teketay 2016). It obviously knew and supported by various scientists in addition to cropland, tree plantations, urbanization in order to produce food, timber, housing and other commodities have resulted in the reduction of many ecosystem services, including biodiversity.

As (Berresaw.M, 2016) studied that based on the 1984 and 2004 data; lands devoted to agricultural uses have increased at an average annual rate of 1.02 percent, employing the average annual growth rate (geometric) formula. The estimated opening stock was at 33.1 million hectares in 1995; it rose to 36.3 million hectares in 2000, indicating an average additional stock of about 3.1 million hectares (on average about 630,000 hectares per year), whereas in the next five years (2000 to 2005), the additional stock was 3.4 million hectares (on average about 690,000 hectares per year). The relative increase in the additional stock during the last five years could explained by the fact that more land were brought to agriculture due to population growth and expansion of large-scale commercial farms and new settlement programs. Agriculture led industrial development policy of the government coupled with better price for agricultural produces being the drive behind.

The changes in the extent of agricultural land are attributed to conversion of other land uses (forest and grassland) to agriculture, conversion of agricultural land to urban centers and bare land (assumed as a result of erosion), and expansion of villages extent.

Land must change to meet new demands yet change brings new conflicts between competing uses of the land and the interests of individual land users and the common good. Land taken for towns and industry is no longer available for farming; likewise, the development of new farmland competes with forestry, water supplies and wildlife (Resources and Service 1996).

Natural Resource Management, Planning and Monitoring programs depend on accurate information about the land cover in a region. The growing of population and the increasing of socio economic had create pressure on land use/land cover which lead to unplanned and uncontrolled changes in LULC (NOR ASHIFAH 2011). Available data on LULC changes can provide critical input to decision making of environment management and planning the future better. Common understanding of the causes of land use and land cover change is dominated by simplifications which, in turn, underlie many environment development policies (Lambin et al. 2001).

Decision-making problems are the process of finding the best option from all of the feasible alternatives. In almost all such problems, the multiplicity of criteria for judging the alternatives is pervasive. That is, for many such problems, the decision maker wants to solve a multiple criteria decision making (MCDM) problem (Chen 2000).Thus providing accurate information on LULC significantly help officials for suitable and sustainable development. LULC change lends the need of knowing the type of change, when and where they occur with their extent and rates. Hence, effective information regarding the environmental responses of land use land cover changes are important to hydrologists, land use planners, watershed management and decision makers to formulate and implement effective and appropriate response strategies to minimize the undesirable effects of future land use land cover change (Takala, Adugna, and Tamam 2016).

LULCC has been an important research field and it is one of the most sensitive indicators of the interactions between human activities and natural environment. It is associated with climatic and geomorphologic conditions of the area have an accelerating impact on the land degradation. Natural as well as human induced LULCC has significant impacts on regional soil degradation, including soil erosion, soil acidification, nutrient leaching, and organic matter depletion. In recent years, the number of studies carried out to estimate the potential effects of LULCC on soil erosion at different spatio-temporal scales. These include the scale of small watersheds (Cebecaauer and Hofierka 2008) and global scale. Similarly, effects of LULCC have been studied at temporal scale of few years to number of decades (Szilassi et al. 2006). All these studies identified a strong influence of land use changes on soil erosion and sediment transport rates (Alkharabsheh et al. 2013).

2.2. Use of Remote Sensing and GIS in LULC Change Analyzing

The satellite remote sensing, GPS and GIS technology helped to overcome the limitations of manual system. This technique has been useful to supply temporal and synoptic data of high quality in advance of land use, land cover mapping (Haroun et al. 2013). This has also helped to monitor natural calamities as floods and drought for appropriate planning.

Satellite data conveniently supplies terrestrial information, and as the technologies for acquiring and processing this information are continuously improving, they have huge potential in landscape monitoring (Vinciková et al. 2010). In connection with GIS, remote sensing may be a useful tool for classifying land cover (Vinciková et al. 2010).

Remotely sensed data together with GIS increase the capability to analyze the human impact on the environment in quantitative, qualitative and spatial form (Inca 2009). As the main goal of this study, was to generate the LCLU, multi temporal information map, to quantify and analyze the LCLU change and shows its impact on climate change and productivity yield regulation services. In addition, to identify the main driving force and the relation between the upper and downstream relationship on sediment control as agro ecological zone.

Preserving the environmental resources while maintaining or enhancing the economic and social benefits from their use is a present day challenge. For this reason, there is a need to understand the pattern and trends of LULC changes on the local, regional and global scales. Advances in remote sensing science and associated technologies have made it possible to obtain valuable spatiotemporal information on LULC. The search for methods used for producing accurate LULC and determining LULC change over time has been an important component of remote sensing research within the last two decades or so. However, classifying a remote sensing imagery still remains a challenge that depends on many factors such as complexity of landscape in a study area, the choice of remote sensing data, and image processing and classification approaches etc. (Manandhar, Odeh, and Ancev 2009).

2.3. Soil Erosion

The average annual soil loss in Awash catchments is in the order of 200-300 t/ha or 20,000-30,000 t/km^2 (Taddese, Sonder, and Peden 1995). Removal of vegetation cover through deforestation and overgrazing, repeated tilling of the soil to prepare fine seedbed and lack of adequate soil and water conservation is causing the dam to silt up. Inflow to the reservoir was heavily laden with sediments and this lowered the water volume from the designed live storage capacity of 1,667 m^3 to 1,186 m^3 at present (i.e., loss of 481 m^3), which was loss of 30 % of the total storage volume of the reservoir as Ethiopia electric power corporation 2002 cited by (Taddese, Sonder, and Peden 1995).

Soil erosion is a major factor in land degradation and has severe effects on soil functions. Water and wind erosion, respectively, account for 46% and 38% of all the degradation (Yengoh et al. 2011). Soil erosion in the area and the subsequent deposition of sediment by highest inundation and damages in the downstream infrastructure are of great concern with loss of alluvial rich fertile cultivated land in the site, the reduction and destruction water harvesting capacity, the deterioration of downstream.

Land is the most vital and heavily threatened natural resource globally. Land degradation due to soil erosion is of concern mainly because of its consequences for agriculture. Continued soil erosion seriously affects peoples' livelihood in most watersheds of the country (Udayakumara, Shrestha, and Samarakoon 2011).

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 (Kinnell 2017); (Taddese, Sonder, and Peden 1995); (Sreenivasulu et al. 2014). These highlands account 43 % of the countries and dominated by high soil fertility that covers 95 percent of the cultivated land. The impact of this loss of fertile soil in Ethiopia is multifaceted. It is still affecting 50 percent of the agricultural area and 88 percent of the total population of the country (Review 2012).

2.4. Soil Erosion and its Extent

Soil erosion is one of the most serious environmental problems in the world today, as it threatens agricultural and natural environment (Vrieling, 2006). As sources cited by Deore (2005), study on global soil loss has indicated that soil loss rate in the United

States is 16 t/ha/yr. in Europe it ranges between 10 – 20 t/ha/yr. while in Asia, Africa and South America between 20 and 40 tons/ha/yr.

In general, Soil erosion is one of the major factors causing severe land degradation problem in Ethiopia, which in turn is threatening the agricultural productivity and the very survival of the overwhelming majority of the rural population. The rate of soil loss, depletion of soil organic matter and nutrients as a result is so high and much faster than they can be replaced. The Ethiopian Highland Reclamation Study FAO (1986) estimated that water erosion moves nearly 1.9 billion tons of fertile soil from highlands annually.

According to Hurni (1988) and Tamire (1995), rates of soil erosion, documented in Ethiopia, ranges from 16–300 ton ha^{-1} yr^{-1}. Hurni (1988) and Hurni *et al.* (2008) predicted soil loss from cultivated fields in Ethiopia and its amount to about 42 metric tons $ha^{-1}yr^{-1}$. The amount of annual soil movement (loss) by erosion is estimated to range from 1,248 to 23,400 million ton yr^{-1} from 78 million ha of pasture and rangelands and cultivated fields throughout Ethiopia Tamire (1995). Bobe (2004) estimated soil loss in different Zones of East and west Hararghe Zone, of Ethiopia found that soil loss in both Zones varied from 1.74-135 t/ha/yr.

2.5. Factors Affecting Soil Erosion

Soil erosion and transport is a complex process that is influenced by climate, soil type, topography, and land use.

2.5.1. Climatic factors

Climate includes drop size distribution and intensity of rain, amount and frequency of rainfall, runoff amount and velocity. Soil loss is closely related to rainfall partly through the detaching power of raindrops striking the soil surface and partly through the contribution of rain to runoff (Morgan, 1995). If rainfall intensity is less than the infiltration capacity of the soil, no surface runoff occurs and the infiltration rate equals the rainfall intensity (Horton, 1945) as cited by (Morgan, 1995). If the rainfall intensity exceeds the infiltration capacity, the infiltration rate equals the infiltration capacity and the excess rainfall forms surface runoff.

Potential ability of rain to cause erosion is known as erosivity (R) factor (Renard *et al*., 1997). Raindrops while falling acquire kinetic energy and on impact, the kinetic energy is used up in detaching the soil particles. Energy is required to break the soil aggregates, splashing them and subsequently carrying them with runoff (Saavedra, 2005).

2.5.2. Soil factors

The susceptibility of soil to erosion agents is generally referred to as soil erodibility (Renard*et al*., 1997). Soils differ in their resistance to erosion, which is a function of a range of soil properties such as texture, structure, soil moisture, roughness, and organic matter content (Deore, 2005).

Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Soils high in clay have low K values, because they are resistant to detachment. Coarse textured soils, such as sandy soils also have low K values, because of low runoff even though these soils are easily detachable. Medium textured soils, such as silts loam soils, have a moderate K value, because they are moderately susceptible to detachment and they produce moderate runoff. Soils having high silt content are the most erodible of all soils as they cause a decrease in infiltration (Saavedra, 2005).

2.5.3. Topographic factors

The slope factors (LS) refer to topographic and/or relief factor. Erosion would normally be expected to increase with increase in slope steepness and slope length as a result of respective increases in velocity and volume of surface runoff (Doere, 2005). However, soil loss is much less sensitive to changes in slope length than to changes in slope steepness (McCool *et al.,* 1987 as cited in Remortel*et al*., 2001). Steeper terrain slopes cause higher runoff velocities, more splashes downhill and faster flow and therefore contributes greater soil erosion. Erosion only doubled for a steepness change from 2-20% and the erosion rate tends to level off (Remortel*et al*., 2001). A slight increase in detachment rate probably occurs as the raindrops strike at a greater angle, but this effect should not cause a major change in total splash detachment.

2.5.4. Ground cover factor

Vegetation cover is one of the most crucial factors in reducing soil erosion. Vegetation reduces soil erosion by protecting the soil against the action of falling raindrops, increasing the degree of infiltration of water into the soil, reducing the speed of the surface runoff, binding the soil mechanically, maintaining the roughness of the soil surface, and improving the physical; chemical and biological properties of the soil (De Asis and Omasa, 2007).

Differences in erosion rates are commonly related to land use in areas where soil, climate, and topography are similar, for example, in Malaysia, the rate of soil erosion increased from 0.24 ton/ha/yr. under natural forest to 4.9 ton/ha/yr. in areas of mature coffee, to 7.32 ton/ha/yr. in areas with cultivated vegetable crops (Lal, 1990). In Puerto Rico, soil erosion in coffee plantations without ground cover was ten times greater than from adjacent areas of coffee with natural ground cover (Smith and Abruna, 1955 as cited in Lopez *et al*., 1998).

To account for the effect of vegetation in erosion assessments, a cover and management factor (C-factor) has often been used. The C-factor is defined as the ratio of soil loss from land cropped under specified conditions to the corresponding clean-tilled continuous fallow (Wischmeier and Smith, 1978).

2.5.5. Conservation practice factor

Especially in agricultural areas, conservation practices such as contouring, strip cropping, or terracing, reduce soil losses. For instance, in areas where there is terracing, runoff speed could be reduced with increased infiltration, ultimately resulting in lower soil loss and sediment delivery. The effectiveness of such practices is often analyzed with a support practice factor (P-factor) which is defined as the ratio of soil loss with the practice applied and up- and down slope cultivation (Wischmeier and Smith, 1978; Renard*et al*., 1997).

2.6. RUSLE Model

Soil erosion over Earth is a quite frequent problem, thus modeling and quantitative estimation of erosion processes for its impact assessment is required. Models have developed for fine study scale (field or catchment scale) along with assistance of Remote Sensing (RS) and GIS techniques like USLE, Modified Universal Soil Loss Equation (MUSLE) or RUSLE. They relate erosion to catchment properties, including drainage area, topography, climate, and soil and vegetation characteristics as cited by (Garima and Rohit 2011).

The RUSLE is an erosion model , is used to estimate average soil loss that would generally result from splash, sheet and rill erosion from agricultural plots (Miller and Hobbs 2007). The USLE was first developed in the 1960s by Wischmeier and Smith of the United States Department of Agriculture as a field scale model (Bowling 2004). It was later revised in 1997 in an effort to better estimate the values of the various parameters in the USLE (Darbyshire, Lamb, and Umer 2003).

Six major factors existed that are used for calculate the soil loss for a given site. Each parameter is the arithmetic estimate of a specific condition that affects the severity of soil erosion at a particular location. The calculated erosion values reflected by this model can vary significantly due to fluctuating weather conditions (Darbyshire, Lamb, and Umer 2003).Thus, the erosion values obtained from the RUSLE more accurately represents long term averages.

The RUSLE uses the simple equation $A = R \times K \times LS \times C \times P$ (Group 2002).

Where _A' is the average annual potential soil loss in tons/ha/year, _R' is the rainfall-runoff erosivity factor, _K' is the soil erodability factor, _LS' is the slope length and degree, _C' is the land-cover management factor and _P' is the conservation practice factor (Darbyshire, Lamb, and Umer 2003). Use of RUSLE has been extended as a useful tool predicting soil losses and planning control practices in agricultural watersheds by the effective integration of the GIS-based procedures to estimate the factor values in a grid cell basis (Darbyshire, Lamb, and Umer 2003).

The soil erosion, hazard classes in 1992 and 2009 compared where the “high and very high" soil loss classes are decreased and the "low" and "moderate" soil loss classes increased in 2009. This could interpreted due to the change in the land use land cover in the study area from agricultural land to uncultivated lands which reduced the agricultural practices in these areas and decreased the soil loss. Another reason may be due to the differences in acquired time of the satellite images that used to derive the NDVI, the image of 1992 acquired on May 31 first and the 2009 image acquired on the May 1. With difference in these times the plant coverage could have big changes which affect the C factor and finally the soil loss in the study area (Kavian, Sabet, and Solaimani 2016).There for such problem of interpretation and other related gaps critically getting attention for this study.

As studied by (Hurni and Centre 2016) the spatial distribution of annual soil loss estimates using RUSLE model that ranges from 12.1 t ha−1 at the outlet to 456.2 t ha/yr. at the upper part of the study area for 2015. High soil loss rates observed at the upper parts of the study area and along the sides of rivers. Soil loss rates from these areas were above 50 t ha/yr. The statistical values in revealed that the rate of soil loss has a significant correlation with the slope conditions in the area.

As shown in (Ayalew et al. 2015), Based on the analysis, the mean and total annual soil loss potential the study watershed was 9.10 and 57,750.15 tons year^{-1} respectively. About 78.31 % (4969.63 ha) of watershed was categorized none to slight class which under SLT values ranging from 5 to 11 tons ha^{-1} year $^{-1}$ and. The remaining 21.69 % (1376.48 ha) of land was estimated classified under moderate to high class about several 11 of times the maximum tolerable soil loss (11 tons ha/yr. (Zerihun et al. 2018), Estimated average soil loss the croplands in the highlands of Ethiopia as a whole at 100 metric tons ha^{-1} year^{-1}. In the highlands of Ethiopia under and Eritrea soil losses are extremely high with an estimated average of 20 metric tons ha^{-1} year^{-1} (Hurni 2016) and measured amounts of more than 300 metric tons ha^{-1} $year^{-1}$ on specific plots. (Hurni and Centre 2016) Estimated mean soil loss from cultivated fields as 42 metric tons ha^{-1} yr-^{1}. The average annual soil loss estimated by RUSLE from Zingin soil watershed was 24.95 tons ha^{-1} $year^{-1}$. Thus, the estimated soil loss rate was generally realistic, compared to results from previous studies. However, all in tolerable range as fit to Ethiopian condition but various in the amount all, so this study try to concerning on the average of all to get accurate and reasonable value.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Geographical Location

Tebi Watershed (Figure 1) in which Tebi reservoir was constructed, is located 14 km far on the west side of Masha Town. The dam out let point is 11°13′36.17 "N latitude and 39°0′.40.17" E longitude. The watershed is in Beshilo sub basin having an area of 1000.28 ha. It approximately lies between 11^{0}5′30"N-11^{0}13′30"N and 38^{0}5′40"E-39^{0}10′0"E latitude and longitude respectively (Fig1). Tebi earth dam project was constructed by Co-SAERAR in 1998 G.C and being to harvest water in 1999 G.C. The project was implemented to irrigate 161 ha of land but now it irrigates only 67.6 ha due to shortage of water (Wereda agriculture office report). The project was expected to fulfill the food self-sufficiency of the local community by using irrigation. The reservoir harvests water from Tebi stream and its watershed, which is seasonal river. The dam has 16m height; 25.99 ha reservoir area and 560m dam axis length at elevation range from 2763 m to 2779 m above sea level excluding free board.

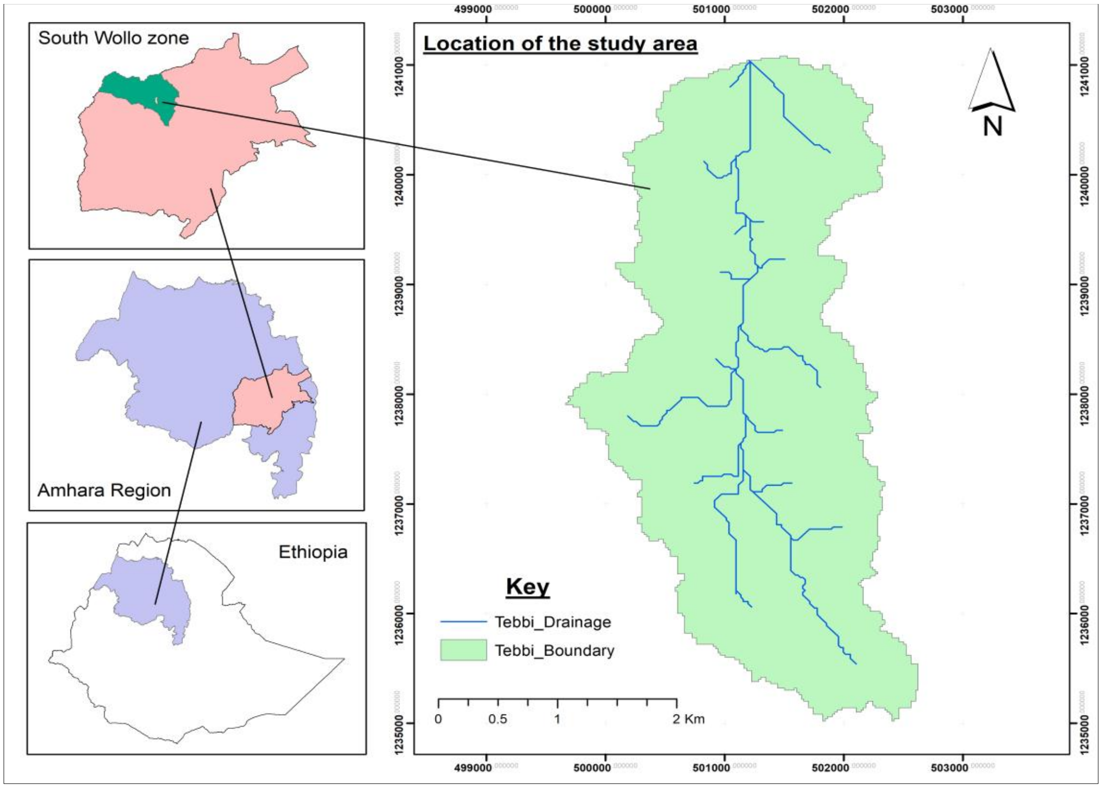

Figure 1: Location Mapp of study area

3.1.2. Climate

The area is characterized by a sub-humid tropical climate of bimodal rainfall pattern, with a mean annual rainfall of 1141 mm and mean annual temperature of 18.2 °C. (Yesuf *et.al,* 2012). There are two rainy seasons, these are Kiremt (July to September) which is the long rainy season and Belg (February & March), the short rainy season.

3.1.3. Soil

The major soil types are Vertic Cambisols, Eutric Leptosols, Eutric Regosols and Eutric Cambisols, which cover an area of 41.12%, 22.91%, 5.89% and 4.53% of the catchment, respectively (FAO 1998). The remaining area (25.5%) represents the water surface area.

3.1.4. Agricultural practice

The area is dominantly hilly and intensively cultivated. In the area both rain fed and irrigation activities are occurred, the source of water for irrigation is the reservoir water. Major crops-planted in the study area are Wheat, Teff, bean, pea, lentil, etc. vegetable and fruits are the dominant cultivated commercial plants in the study area

3.2. Methods

3.2.1. Materials and Tools

Primary materials and tools used are ArcGIS 10.8 software, ENVI 5.3 software, Landsat Satellite image 0f 1990, 2000, 2010, and 2020, ASTER DEM /DEM 30X30 was downloaded from USGS earth explore, Google earth pro as use for base map that also wear downloaded for the four study periods. GPS, Camera, Internet access, and computer software were used for data processing and GIS analysis .

Furthermore, secondary data like FAO Digital soil map2013; 30 years mean annual rainfall data for three rain gage stations that were acquired from NMA of kombolicha branch to extract the R-map through arc map spatial analysis tools of interpolation IDW. Also shape file and thematic map of study areas to national level to extract study areas infrastructures that were accessed from training of various years by Bureau and Ministry of agriculture .Moreover, models are the most effective ways to predict soil erosion processes and their effects by using GIS and remote sensing RS tools (Solomon 2005). GIS and RS analysis could help examine land degradation mainly soil erosion in immediate and accurate way. Through processing these sources and building geo-database, integration, analysis and modeling works were carried out using RS and GIS software's such as ERDAS Imagine 15, ArcGIS10.8 and RUSLE model (Kebede 2018).

3.2.2 Research Design

Approaches of the research was used both quantitative and qualitative methods. The research that was suited for LULC changes from various studies that descriptive and explanatory type was used for describing and summarizing LULC changes and soil erosion risk that were took place in the study site. As cited by (Al-doski et al. 2013), this is considered an important process in monitoring LULCC because it provides quantitative analysis of the spatial distribution of the population of interest and this makes LULC changes study a topic of interest in remote sensing application. Primarily the study uses both qualitative and quantitative approaches for data gathering and analysis. Based on the research objective and questions, quantitative and qualitative which focuses on the examination of LULCC and its impact on soil erosion risk to exploring mitigation strategies and describing and explain the magnitude of change and with rate of impact.

3.2.3. Data Collection and Sampling

3.2.4. Data Collection and Source

Different digital and non-digital data set including rainfall data, soil data, Digital Elevation Model (DEM), and satellite image data were collected from different sources. The land sate images are acquired and downloaded for the 4 epochs, 1990, 2000 ,2010 and 2020. The images that downloaded from USGS earth explorer of path 168 and row52. The images acquired from the period January–February, as this is a clear sky season in the region, reducing atmospheric, radiometric and penology effects. DEM, digital soil

Map of FAO 2013 and different GIS maps, thematic map and other related and secondary data from different development office to the study area were collected.

In order to detect areas that was changed because of the expansion of the specific land use or others. The area of inters (AOI) of the study areas are selected, demarcated and delineated by Arc GIS 10.8 Spatial Analyst Tools of hydrology method by taking outlet coordinate point by GPS. Field observation to observe an actual current land features and collect GCP by GPS. This is to get an accurate and actual reading for ground truth samples for validate accuracy assessment of the year 2021. The ground survey carried out with together quantitative and qualitative information to assist and superior understand, elucidate, and interpret the LULCC and its impact on soil, which was the heart issue of this study. The ground reference pointes were collected through extensive field visits (2021/22) by handheld GPS and Google earth for accuracy comparing and validating reference data.

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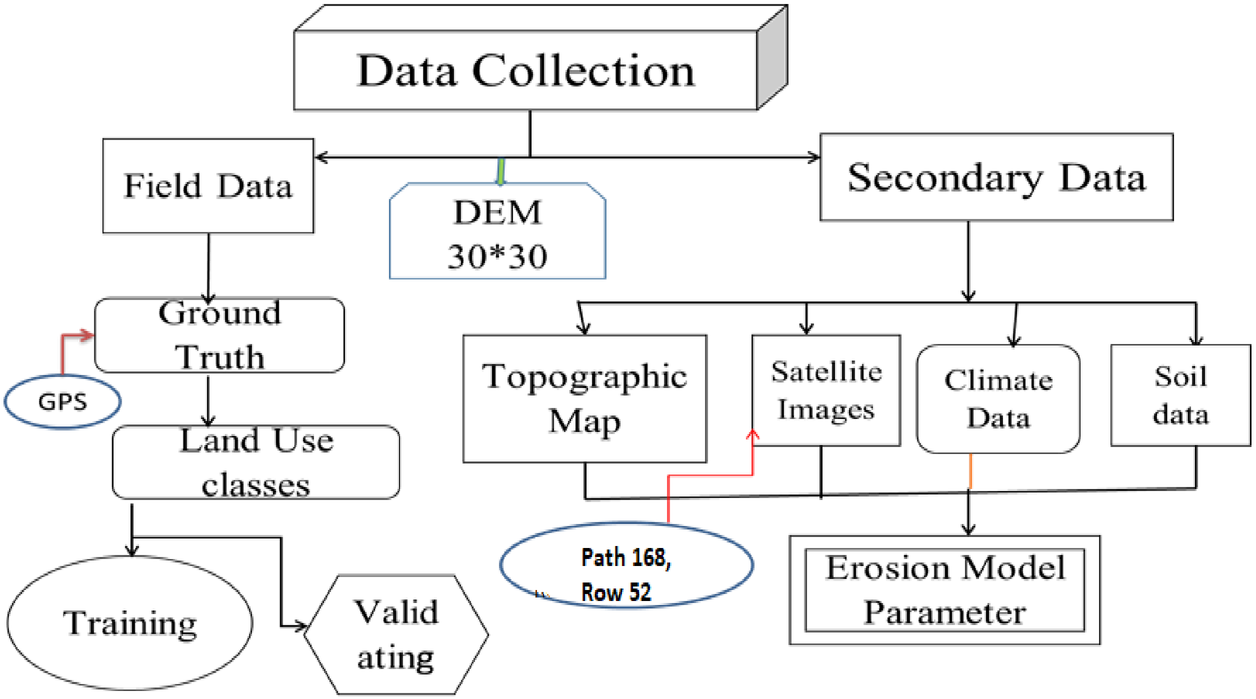

Figure 2: Data collection method

3.2.5. Land Use Land Cover Changes

The primary tools used in the study of LULCC are ArcGIS10.8 and ENVI 5.3 after getting the row satellite image data from United States Geological Survey (USGS) official website. The satellite imageries are used for classification of land covers for different applications. Multi-temporal analysis of satellite imagery is effective for change detection only because there is high correlation between spectral variation in the imagery and land-cover change (Green, Kempka, and Lackey 1994). (Al-doski *et al*. 2013) also showed the importance of the multi-temporal images for land classification.

Table 1. Satellite images used for the study

No	Satellite Sensor	Path-Row	Date of Acquisition	Spatial Resolution (m)
1	L5_TM	168-52	07/01/1990	30 x 30
2	L7_ETM	168-52	27/01/2000	30 x 30
3	L5_TM	168-52	14/01/2010	30 x 30
4	L8_OLI_TIRS	168-52	27/02/2020	30 x 30

For each year of the study period, blue, green, red, and Near Infrared (NIR) bands has been composited and classified. Supervised classification under ENVI 5.3 environment is recruited to have the raster and vector outputs of land cover for each study periods. In the classification process, four (4) regions of interests (ROI) have been selected for each class to give the training pixels for supervised classification. A pixel based supervised image classification with maximum likelihood algorithm is used to classify the images. Supervised image classification is recommended classification approach to yield good results when satisfactory training data and detailed information about the study area is available (Wolde Yohannes *et al.*, 2018).

Accuracy assessment has been undertaken by using the same image for that there was unable to have field data for historical images. Three ROIs has selected on a clearly visible and known areas of the image to validate the classified thematic layer.

To assign C factor value of this study, the Landsat based LULC classes created for the study periods of the watershed was employed. For this end, the watershed was categorized in to the required LULC classes of each year and the C-factor values were determined from these LULC cover maps of the watershed. Then, the raster map was converted to vector format to assign the corresponding C factor value of each land cover class based on available literature recommendations in the Highlands of Ethiopia.

3.2.6. Determination of USLE Factors

USLE is an empirically based model, which has been developed for both natural and simulated runoff plots. Its simplicity and statistical relationship between input and output variables make it adaptable to other environment (Morgan, R.P.C. 1986), (Soil and Water Conservation Society. 1994). The general equation for USLE is (Foster, G.R., Yoder, D.C., Weesies, G.A., McCool, D.K., McGregor, K.C. and Bingner, R.L. 2002):

$$\mathbf{A = R*K*L*S*C*P} \quad \mathbf{(1)}$$

Where A is the computed soil loss, R is the rainfall runoff erosivity factor, K is the soil erodibility factor, L is the slope length factor, Sis the slope steepness factor, C is the cover management factor, and P is the supporting practices factor. These empirically based equation, derived from a large mass of field data; computes combined inter rill and rill erosion using values representing the four major factors affecting erosion. These factors are climatic erosivity represented by R, soil erodibility represented by K, topography represented by LS, and land use and management represented by C and P (Hall and Foster 2000).

3.2.6.1. Rain fall erosivity (R) factor

The R factor refers to the erosive force of a specific rainfall at a specific period (Prasannakumar et al., 2012; Alexakis et al., 2013). In order to calculate erosivity factor (R), the total amount of rainfall intensity, and seasonal distribution of rainfall are considered Tadesse and Abebe, 2014). The erosivity factor of rainfall (R) is the product of kinetic energy of the rain drop and the 30-minute maximum rainfall intensity.

In Tebi watershed, 30-minute rainfall intensity data is not available and therefore, the erosivity factor R that was adapted for Ethiopian conditions based on the easily available mean annual rainfall P were used in this study.

$$R = -8.12+0.562*P \quad (2)$$

30 year (1990-2020) rainfall data for three stations (Amba-Mariam, Saint Adjibar and Akesta) around the watershed were taken from Ethiopian National Meteorological Agency and checked for missing data, homogeneity and consistency before using it for further analysis. As indicated in the figure below (Figure 3), R-factor value was calculated for each station and spatial distribution of Rainfall runoff factor (R) was interpolated using IDW method in spatial analysis tool in Arc GIS environment. The table below (Table 2) shows the erosive factors of all station.

Table 2. Average annual rainfall and erosivity factor (R) value of the three stations

Station	Latitude	Longitude	Altitude	Mean annual rainfall (mm) (1995-2020)	Erosivity (R)
Amba Mariam	524472	1238256	2991	1030.6	571.1
Saint Adjibar	475640	1219169	2851	1093.3	622.6
Akesta	519304	1201213	3091	939.2	535.9

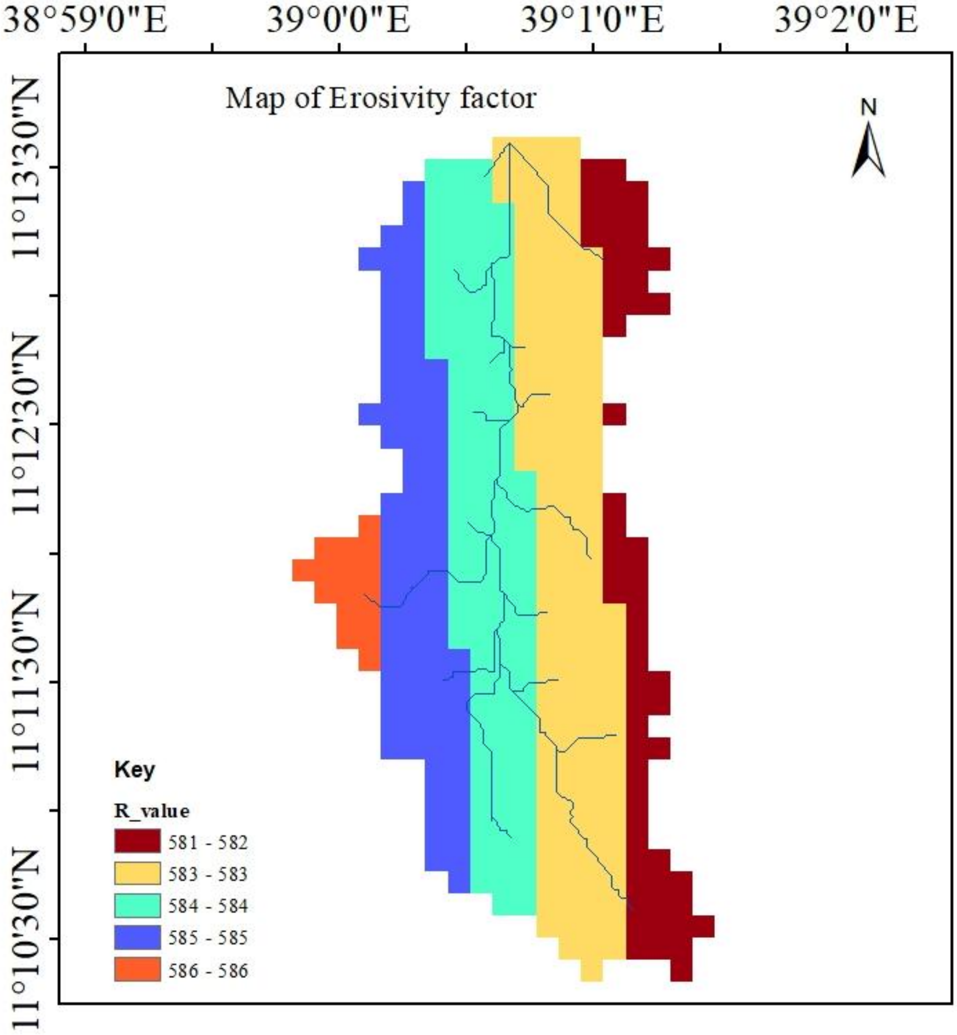

Figure 3: Erosivity factor map of the study area

3.3.1. Soil erodibility factor (K factor)

The soil erodebility factor (K factor) is based on the soil texture, structure, organic matter and probability. Accordingly , soil survey was conducted in the watershed on the bases of slope steepness, Slope aspect and soil color, and a total of 36 soil samples were collected randomly and composited into 22 composite soil samples. These soil samples were analyzed for soil textural class (hydrometer method) and organic matter (walkley black method) at Dessie Regional soil lab, Soil and plant tissue analysis laboratory.

Therefore, using the equation developed by (*Foster GR et al*., 1991) soil erodibility factor (K-value) for each soil sample were calculated and soil erodebility map was generated (Figure 4) as a raster data through interpolation by invers distance weight (IDW) method

$K = [2.1\ M\ 1.4 \times 10-4(12 - a) + 3.25(b - 2) + 2.5(c - 3)]/100$ ……………(3)

where, M particle Size parameter; (percent silt + percent very fine sand) (100−percent clay), a = percent organic matter, b = permeability class, c = soil structure code used in soil classification.

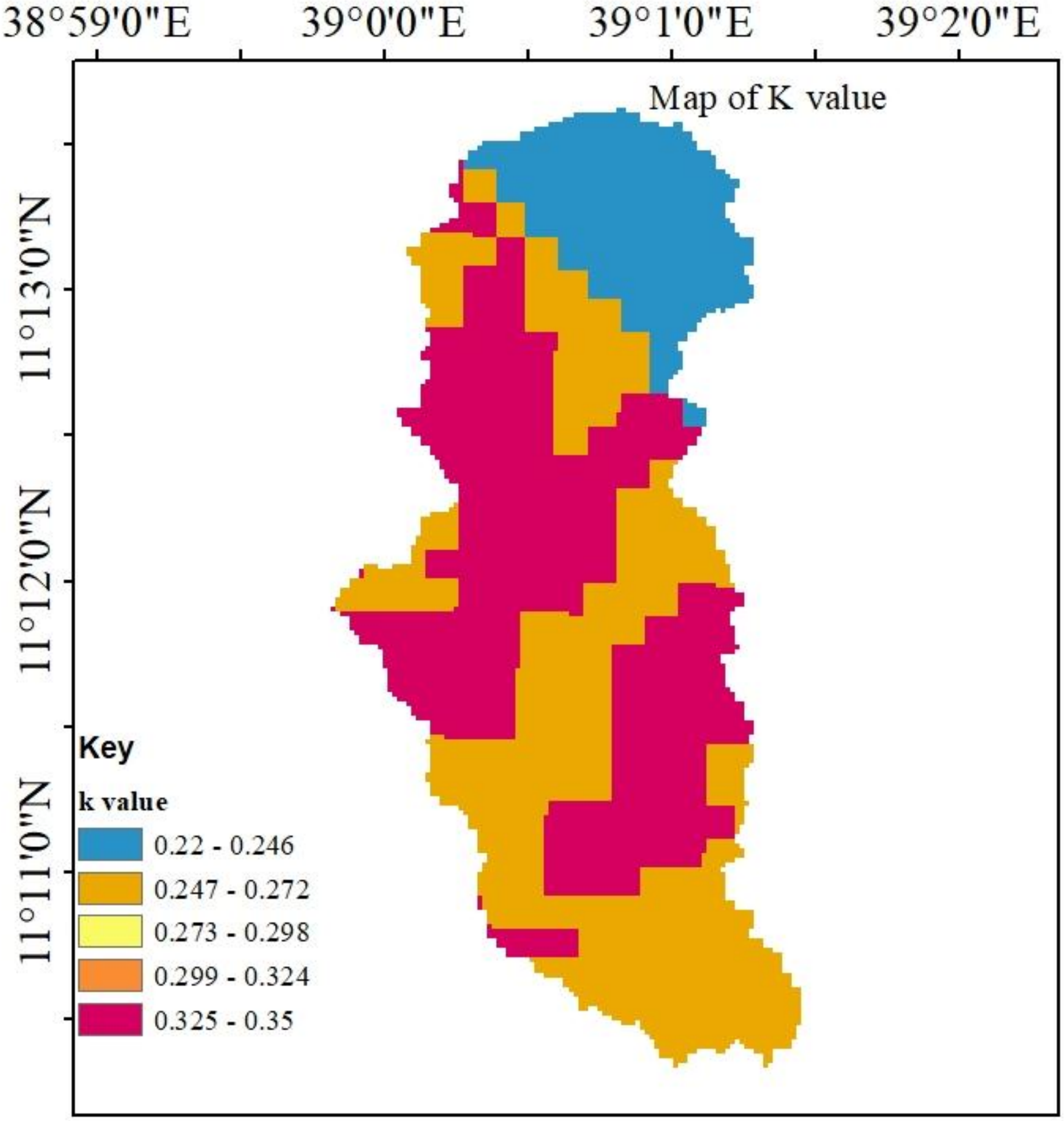

Figure 4: Map of soil erodibility factor of the study area

3.3.2. Slope length (LS factor)

The L and S factors represent the effects of slope length (L) and slope steepness (S) on soil erosion. LS- factor was calculated by unit stream power erosion and deposition (USPED) method, which uses the raster calculation flow accumulation and slope of watershed, (Pelton et al., 2012). The following equation was used:

LS = power (“flow accumulation” *[cell resolution]/22.1, 0.4) *Power (Sin (“slope in degree” *0.01745))/0.09, 1.4) *1.4………………. (4)

Landsat image was taken in 2021 and was pre-processed and classified for land use land cover by the help of both ArcGIS 10.8 and ERDAS IMAGINE 2021 through supervise classification system.

The topographic (LS) factors represent the effect of both slop length (L) and slop steepness (S) on soil erosion. The slop steepness influences the flow velocity, while the slop length describes the distances from where the orogion of erosion to the point where deposition occurs (Bekele and Gemi, 2021). To remove the depression, the original 30m x30m cell resolution DEM where filled, flow direction, flow accumulation and slop in degree was computed in ArcGIS environment.

$$LS = (\frac{AS}{22.13})^{0.6(\mathrm{SinB}/0.0896)1.3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(5)}$$

Where, LS is slope steepness-length factor, AS is a specific catchment area, i.e. the upslope contributing area per unit width and B is the slope angle. LS factor was computed in ArcGIS raster calculator using the map algebra expression in Eq. (1) as suggested by Simms et al. (2003)

LS value showed variations, hence, the Central and South Western part of the watershed has relatively sloppy, having greater LS value than the other part (Figure 5).

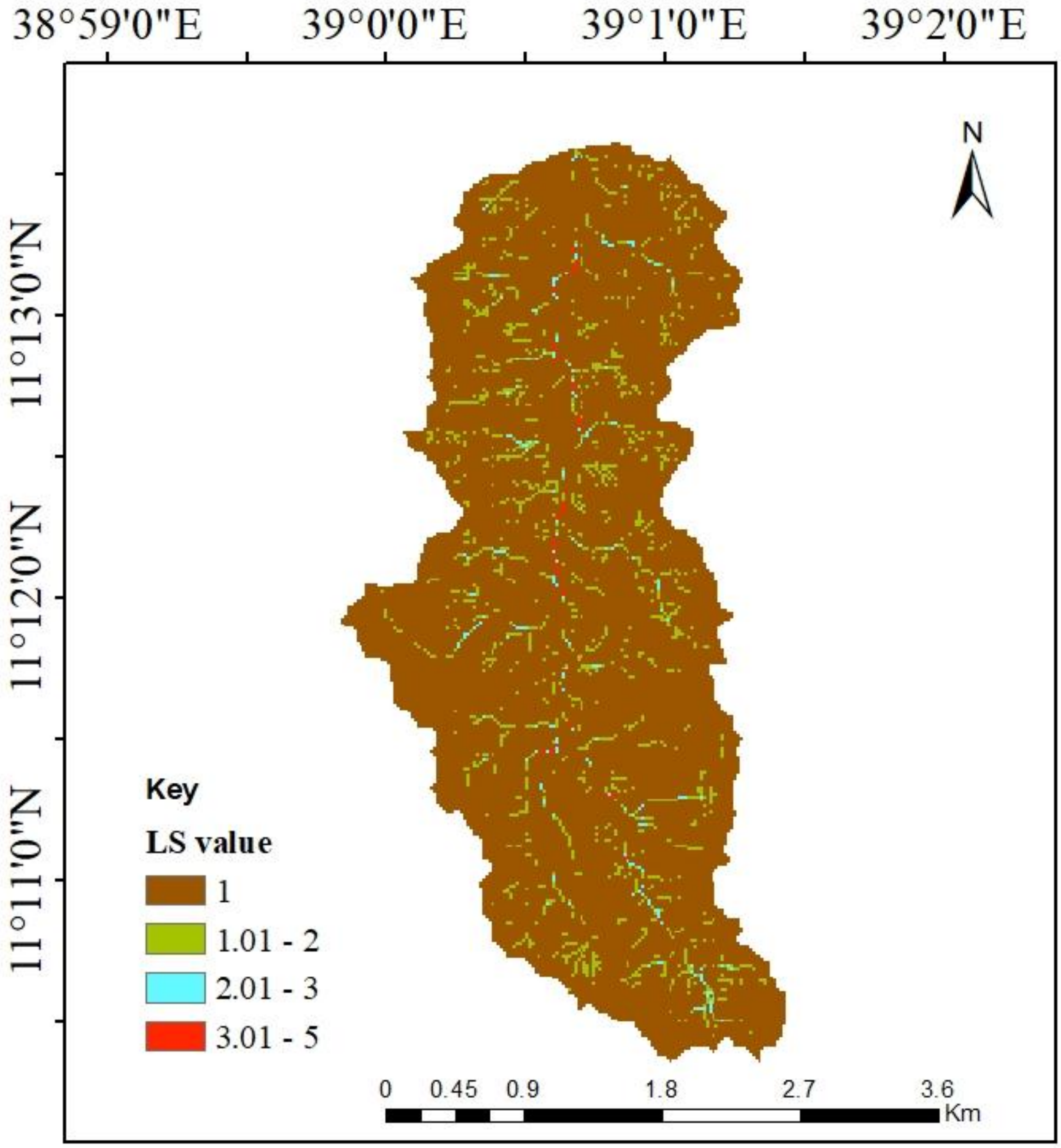

Figure 5: LS value of the study area

3.3.3. Cover and management (C) factor

The C-factor is used to reflect the effect of cropping and management practices on erosion rates. It is the factor used most to compare the relative impacts of management options on conservation plans. The C-factor indicates how the conservation plan were affect the average annual soil loss and how that soil loss potential was distributed in time during construction activities, crop rotations or other management schemes.

The watershed was classified into different major land use classes. C-values given by different scholars for different land use classes were used to map and estimate the weighted C-values of the catchment, which was used in the USLE model. The support practice affects erosion primarily by modifying the flow pattern, grade and direction of surface runoff and by reducing runoff amount and rate (Schulze R.E. 1995). The C factor values adapted for Ethiopian condition by (Nyssen J., 2009) was used for this study to determine C-value. Based on the estimated C-value was given for different land uses support practice factor map was generated by reclassifying land use type map by the help of spatial analysis tools in ArcGIS. The watershed was divided into different sub- watersheds on the bases of hydrological response were generated and prioritized on the bases of mean annual soil loss rate of each sub-watershed, and first priority given for sub-watershed having high mean soil loss rate while last priority was given for sub-watershed with low soil loss rate. Erosion severity class was also done using mean annual soil loss recorded in sub-watersheds. Tolerable soil loss rate is known as 11 ton ha^{-1} year^{-1} (Morgan and Duzant, 2008).

On the bases of this the sub-watersheds of Tebi were categorized under five classes as mean annual soil loss ranging from 0–5 ton/ha^{-1} year^{-1} (very slight), 5–15 ton/ha^{-1} year^{-1} (slight), 15–30 ton ha^{-1} year^{-1} (moderate), 30–50 ton ha^{-1} year^{-1} (high) and > 50 ton ha^{-1} year^{-1} (very high), illustrated in Table 5.

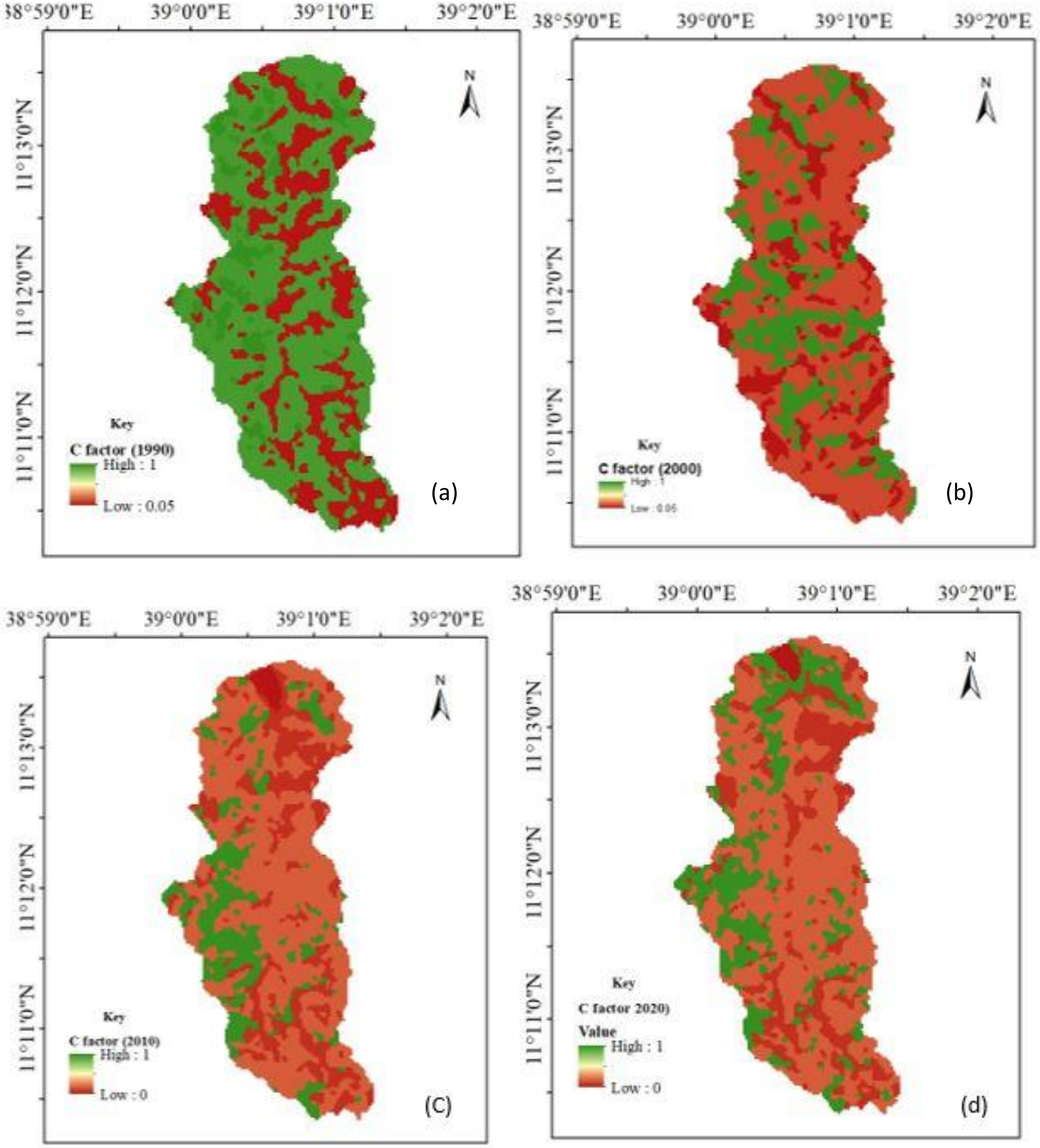

Figure 6: Cover and management (C) factor value map (a, b, c and d) of the study area

3.3.4. Erosion management (support) practice (P) factor

As described by different scholars like (Wischmeier and Smith, 1978); (Meshesha et al., 2012), P-factor indicates the ratio of soil loss afterward applying conservation practice to soil loss from straight row cultivation running up and down slope. Supporting conservation practices; such as contour farming, strip cropping, and terracing principally affect water erosion by modifying the flow amount, pattern, grade , or direction of surface runoff, reducing the volume and rate of runoff (Renard, 1997). The P-factor ranges from 0 to 1 (Ganasri and Ramesh, 2016); the value approaching 0 indicates good conservation practice, and the value approaching 1 indicates poor conservation practice. In this study area (Figure 7), the watershed is not preserved with improved soil and water conservation measures. The land management practices in the watershed are poor, and it is not reasonable to use the existing conservation practices for evaluating soil loss. The watershed was categorized into five erosion management classes as adopted by (Ganasri and Ramesh, 2016).

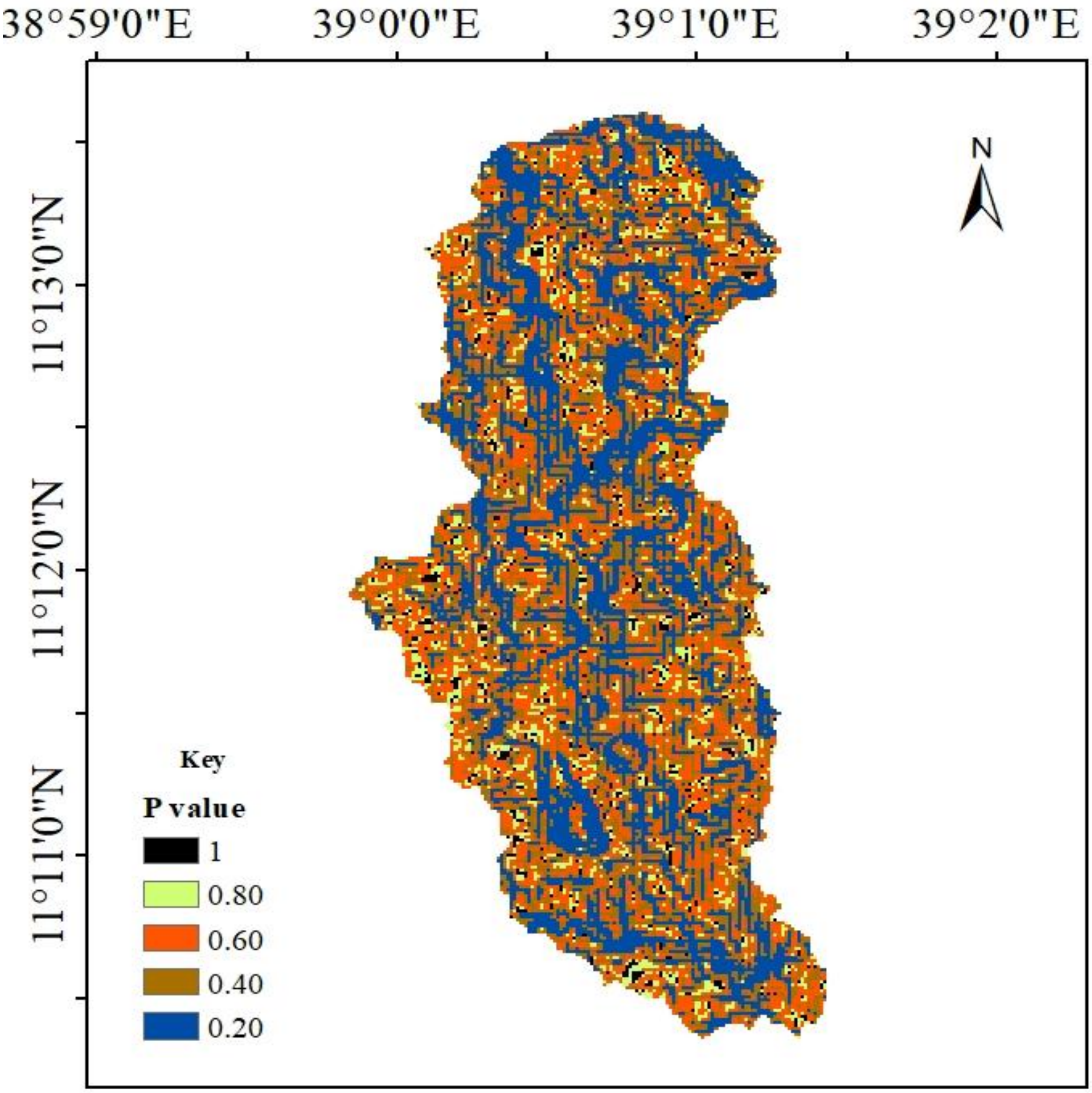

Figure 7: Erosion management practice (P) factor value of the study area

4. Result and Discussion

4.1. Land use land cover change and its impact of soil erosion

The impact of land use land cover (LULC) change on soil resource is getting global attention. Soil erosion is one of the critical environmental problems worldwide with high severity in developing countries like Ethiopia. Soil erosion severity is influenced by land use land cover (LULC) type and cumulative effects of Lu and management (Moisa et al., 2021) . For this study soil erosion is measured using the Revised Universal Soil Loss (RUSLE) model with geographical information system (GIS).

Using the Landsat image, the study area was classified into four major LULC classes for the years 1990 and 2000, and five classes for the years 2010 and 2020, i.e., bare land, cultivated land, grass land, shrub and bush land, and water body (Table 3). The result claims that cultivated land covers higher area for all the study years. As the watershed is intensively cultivated for subsistence farming, bare land is also a major threat with increasing trend. This will have an effect on the value of sediment loss to increase with high C value compared to other land use land covers.

Table 3. Land use Land Cover History of the Watershed

Land use Class	Year							
	1990		2000		2010		2020	
	Area (ha)	% Cover-age	Area (ha)	% Cover-age	Area (ha)	% Cover-age	Area (ha)	% Cover-age
Bare Land	97	9.2	268	25.5	203	19.3	235	22.4
Cultivated Land	630	60.0	595	56.7	602	57.3	584	55.6
Grass Land	205	19.5	98	9.3	112	10.7	98	9.3
Shrub and Bush Land	118	11.2	89	8.5	115	11.0	119	11.3
Water Body		0.0		0.0	18	1.7	14	1.3
Total	1050	100	1050	100	1050	100	1050	100

The spatial extent of different land use land cover is presented in Figure 8 below (1990-2020). The LULC of the area was classified in to five major classes: Bare land, cultivated land, Grass land, shrub and bush land and water body. From which classified land uses cultivated land covers the largest portion, which is about 630 ha (60.0%), 595 ha (56.7%), 602 ha (57.3%) and 584 ha (55.6%) in 1990, 2000, 2010 and 2020, respectively. The land use land cover analysis shows that cultivated land spatial coverage is fluctuating over time. Moreover, bare land is increasing over time. It increases from 97 ha (9.2%), 268 ha (25.5%), 203 ha (19.3%), 235 ha (22.4%) in 1990, 2000, 2010 and 2020, respectively. Grass land shows the decreasing trends in the study period. The declining trends of grassland in the study resulted in land degradation predominantly soil erosion. Reduction of grassland area resulted in an increase in surface runoff (Shang et al., 2019).

It was valid to use the classified satellite images for further analysis for that it has been checked for accuracy assessment and kappa coefficient. As shown on Table 4, all land cover classification validation techniques are met better which indicates that all the classified thematic layers are valid for further analysis.

Table 4. Accuracy Assessment Results

Study Years	Overall accuracy	Kappa Coefficient	Remark
1990	93.1 %	0.9082	
2000	94.1 %	0.9207	
2010	98.1 %	0.9743	
2020	97.7%	0.9708	

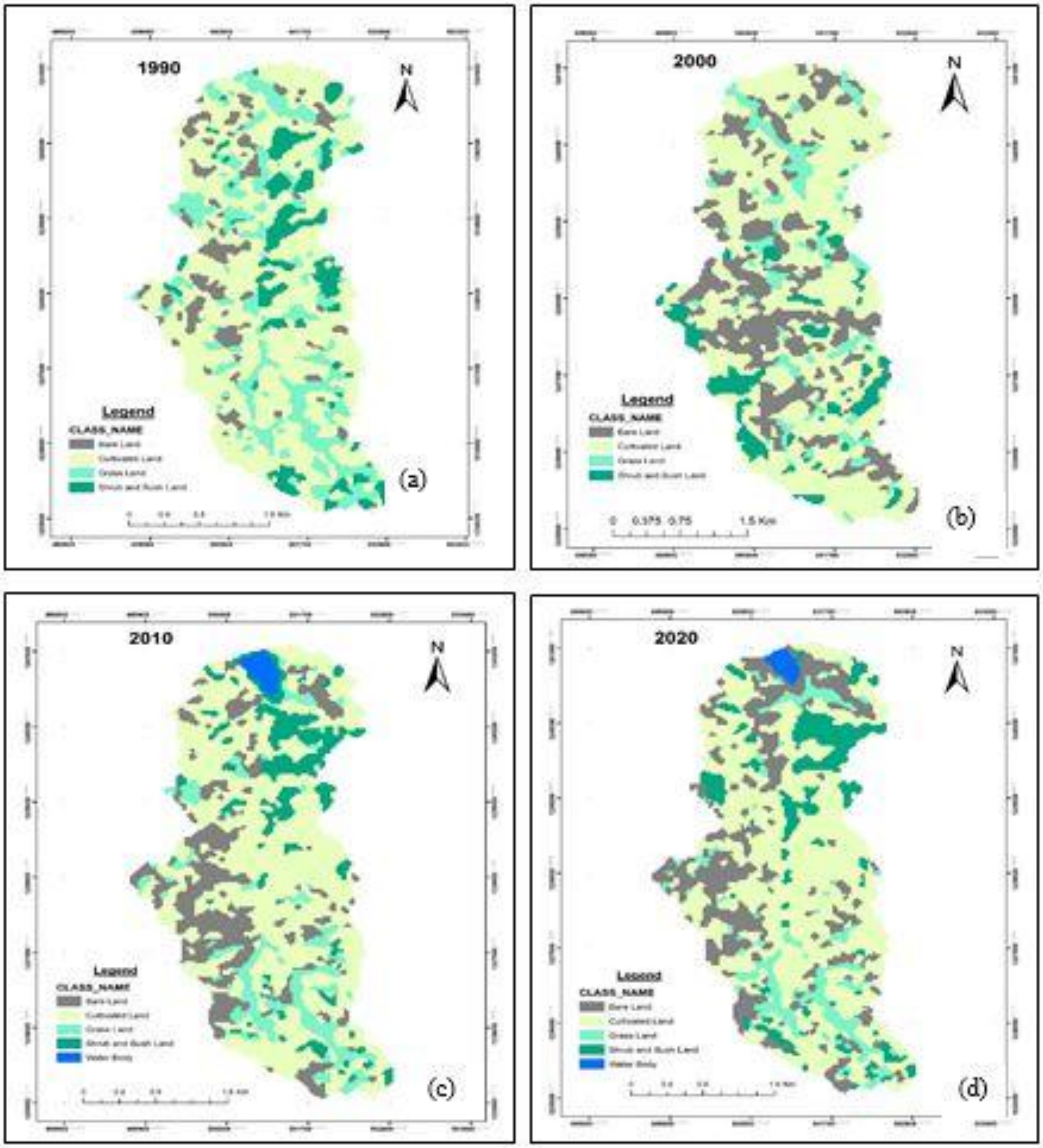

Figure 8: Land use Land Cover Historical map of the Watershed ,1990(a), 2000(b) 2010(c),2020(d)

4.2.1. Estimation of soil erosion potentials

The possible soil erosion maps were generated for 1990, 2000, 2010 and 2020 years in the ArcGIS environment using Eq. 1. And shown in Figure 9 below. As indicated in the Table 5 below, the watershed's computed soil loss ranged from zero in plain areas and water courses to large over 68.7t ha^{-1} yr^{-1}. In very degraded sloping regions and at specific spots of steep slopes of the watershed, gross soil loss rate ranged to 79.65 t/ha. It shows a larger spatial variation of soil loss over the watershed. It is mainly caused by the difference in soil, rainfall, slope, land cover, and improper land management.

Table 5. Soil loss severity of the study area (1990-2020)

Soil loss severity	soil loss t/ha/yr	1990			2000			2010			2020		
		Area in ha	Area in %	Total soil loss(t/yr)	Area in ha	Area in %	Total soil loss(t/yr)	Area in ha	Area in %	Total soil loss(t/yr)	Area in ha	Area in %	Total soil loss (t/yr)
Very low	0-5	595.35	56.7	2100.47	597.35	56.9	2198.6	599.55	57.1	2199.21	622.3	59.3	2465.2
Low	5-15t	340.2	32.4	4762.8	340.3	32.4	4779.8	340.2	32.4	5034.96	342.5	32.6	5095.3
Moderate	15-30	75.55	7.2	1078	75.35	7.2	1096	76.65	7.30	1127.11	45.7	4.4	1320.7
High	30-50	27	2.6	1323	26	2.5	1318	22.05	2.1	1326.22	27.9	2.7	1361.5
Very high	>50	11.9	1.1	788.8	11	1.0	765.6	11.55	1.1	793.65	11.6	1.1	788.8
	Total	1050	100	10053.07	1050	100	10158	1050	100	10481.15	1050	100	11031.6

The estimated mean annual gross soil loss from 1990-2020 under the entire watershed is about a 9.94 t/ha/yr. Within the study period (1990-2020), 41723.8 ton soil has transported to Tebi dam. As observed from the mean value, the largest soil loss rate exceeding 68.7 t ha^{-1} yr^{-1} accounts for only a small amount of the total soil loss, and this huge rate comes from a small proportion of watershed areas (Table 5).

This study is comparable with the other studies like, (Ayalew, 2015) estimated a mean annual soil loss rate of 9.1 t ha^{-1} yr^{-1} in the Zingin watershed in the highlands of Ethiopia. (Bewket and Teferi, 2009) estimated an average soil loss of 93 t ha-1 yr-1 for the Chemoga watershed. In Ethiopia, rift valley (Wolka et al., 2015) estimated average soil loss of 45 t ha^{-1} yr^{-1}, (Mohammed *et al*., 2020) in Central Rift valley basin of Tikur Wuha watershed estimated 16.4 t $ha^{-1}yr^{-1}$.

4.2.2. Spatial variation of soil erosion in the watershed

The spatial pattern of soil erosion is showed in Figure 9 below. The estimated mean annual gross soil loss is about 41723.8 tons. The watershed has been classified into five erosion severity classes. Soil loss and severity classification were made based on soil erosion literature on Upper Blue Nile Basin (Haregeweyn et al., 2017). Accordingly, average areas categorized as having very low (below 5 t ha^{-1} yr^{-1}) erosion severity class represent 54.4% of the Beshilo sub basin area coverage. Average Areas classified as having low (5–15 t ha^{-1} yr^{-1}) and moderate (15–30 t ha^{-1} yr^{-1}) erosion severity class accounted for 32.5% and 6.5% of the total area coverage. The watershed parts classified as having high (30–50 t ha^{-1} yr^{-1}) and very high (above 50 t ha^{-1} yr^{-1}) soil erosion severity class signify 2.5 and 1.1% of the total area coverage, respectively.

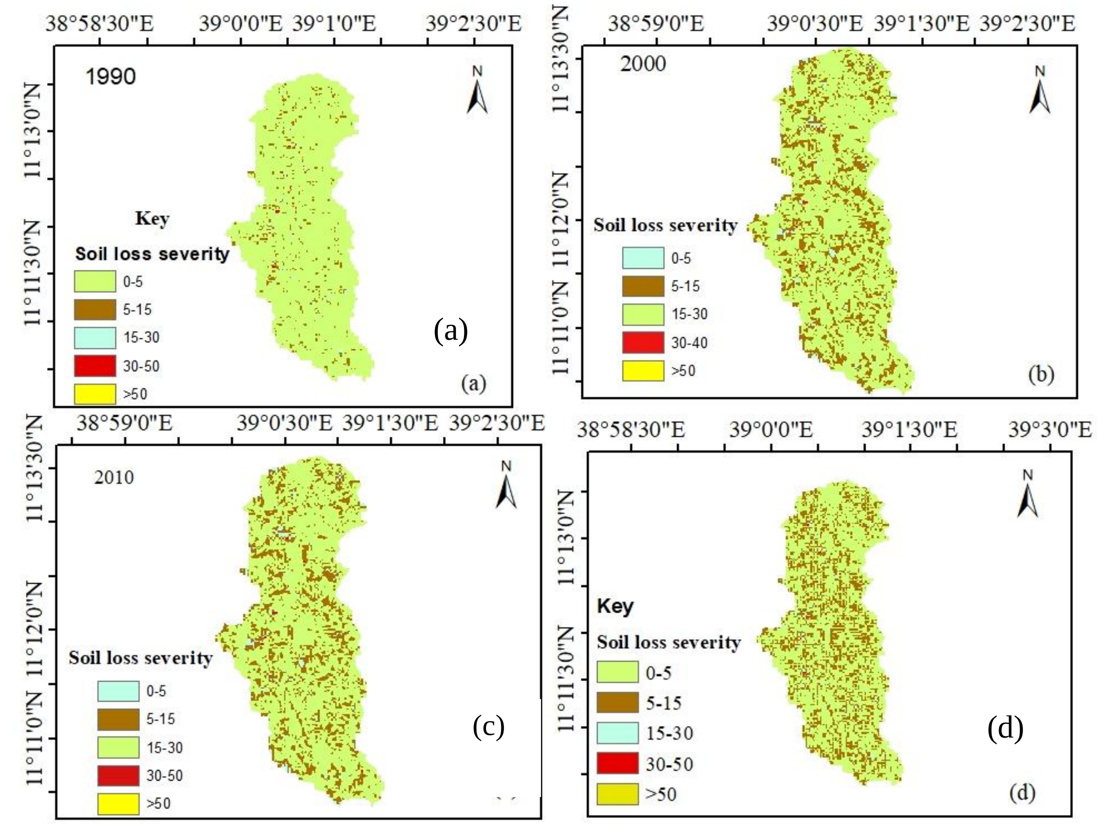

Figure 9. Soil loss severity t/ha/yr and distribution in the study period (1990 (a), 2000 (b), 2010 (c) and 2020 (d)).

5. Conclusion and Recommendation

This study investigated the effects of land use/cover change on soil erosion potential in Beshilo sub basin between 1990 and 2020. The results revealed that human-induced activities in the basin caused a considerable land use changes which had negative effects on soil erosion potential in the last three decades. The erosion risk in the watershed increased from 10053.07 to 11031.06 tons within the last 30 years. These indicates a huge amount of soil transported to the Tebi dam. The increment of soil loss related to disturbance of Shrub and bush land and also grass land on the high sloppy areas in the Southern and South Western part of the watershed. In general ,land conversion in the watershed are the most detrimental land changes and caused an increase in soil erosion. However, cultivated land reduced in the watershed despite the intensive anthropogenic activities increases soil erosion loses in the watershed. Moreover, erosion potential can be reduced by ensuring the quality and protection of the vegetation cover in the basin. This study provided the first basic data of the sub basin for erosion models for future intervention. The results also confirmed the effectiveness of spatial analysis tools in mapping the spatial distribution of soil erosion potential.

Physical soil and water conservation strategies have been practiced by local communities in the study area. But, the soil and water conservation measures in the watershed are very poor , some mechanical and biological soil and water conservation measures have been implemented by the local community. During field observation for the validation of RUSLE results, confirmed that the participation of local community in biological soil and water conservation practices is considerably lower. This is the major factor that aggravated the problem of soil erosions in the Beshilo watershed, which requires further intervention by the government as well as the public.

The GIS-based RUSLE model can assist decision-makers in effective planning for erosion control studies on risky areas. Policy makers, agricultural development office and other stockholders should give more attention for the sustainability of Tebi dam which is currently have high sedimentation problems transported from the upper part of the watershed.

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