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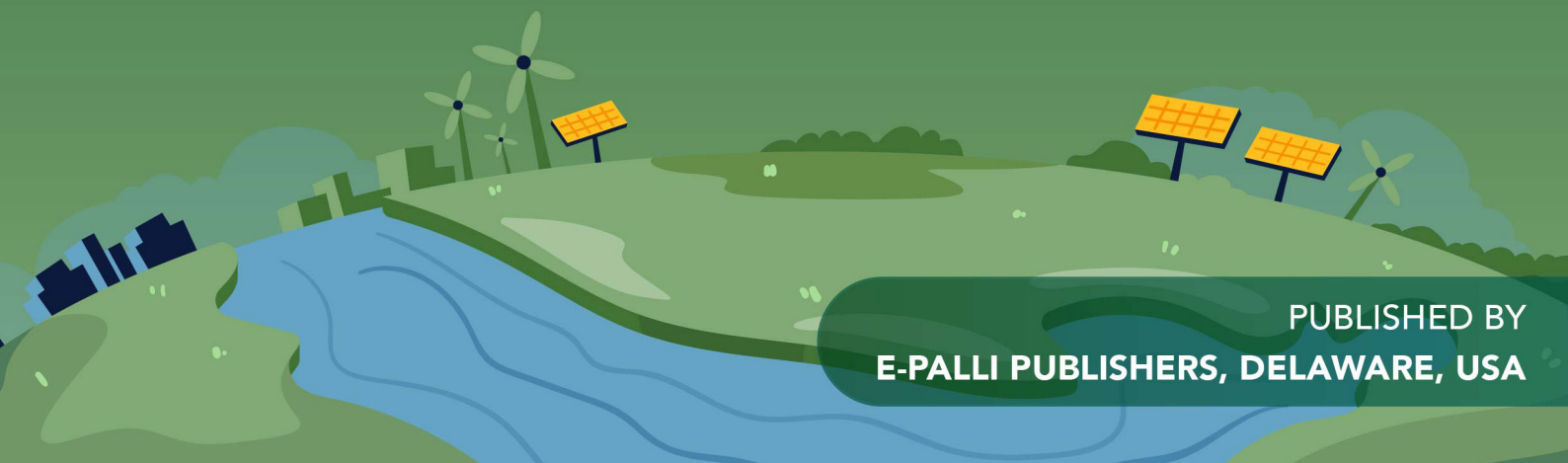

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Effect of Land Use and Land Cover Change on Soil Erosion in Alaba Sub-Watersheds of Central Rift Valley Basin, Ethiopia

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ABSTRACT

The magnitude of soil erosion rates has been accelerating in the Central Rift Valley Area of Ethiopia due to land use and land cover change (LULCC). This study aimed to analyze the trends and changes in land use and land cover dynamics and to analyze the impact of LULC change on soil erosion over the Alaba Sub-Watershed, Central Rift Valley Area of Ethiopia. This study would help to plan and use appropriate land use planning, soil, and water conservation practices, thereby reducing soil erosion in the study area. The soil loss rates were estimated using an empirical prediction model of the Revised Universal Soil Loss Equation (RUSLE) outlined in the ArcGIS environment. During the study period between 1987 and 2018, the rate of change in cultivated land and bare land was raised by 9.09% and 1.08%, respectively. On the contrary, vegetation cover and grasslands had dropped by –2.03%, and -1.42% respectively. From trends of LULC changes, cultivated land revealed an increasing trend increasing from 181.28 hectares to 351.23 hectares for the period 1987 to 2018, respectively. On the other hand, vegetation and grasslands showed a declining trend from -271.92,-22.66 hectares to -305.91, -124.63 hectares, respectively. The findings of the study generally elucidate that the LULCC has a detrimental impact on soil erosion. The estimated total annual actual soil loss in the study landscape was 25707.77 tons in 1987, 29310.71 tons in 2000, and 31769.32 tons in 2018. It was also found that the mean annual soil loss rate of the study catchment was 22.69t/ha/yr., 25.87t/ha/yr. and 28.04t/ha/yr. in 1987, 2000, and 2018 respectively. About 35% and 42% of the Sub-watershed experienced high to very severe soil erosion in 1987 and 2018, respectively. The results indicate that the estimated erosion rate for about 39 % of the sub-basin area exceeds the maximum tolerable soil erosion threshold and this shows that the erosion risk condition is deteriorating in the study landscape. The top three priority levels delineated for urgent SWC measures represent those areas within the large increase in erosion risk levels, with an area of 188 hectares and accounting for 17 % of the sub-watershed area. Therefore, further detailed investigations based on data from primary and secondary sources would be important in identifying driving socioeconomic forces and consequences of LULCCs and suggesting possible alternative options to establish sustainable resource management practices in the study area.

INTRODUCTION

Soil erosion is a complex three-phase dynamic process involving the detachment and transport of the particles or aggregate topsoil by the physical forces of wind, water, and gravity (mass movement) and immediate sediment deposition in downstream areas((UNEP, 2015; Borelli *et al.*, 2018; Uddin *et al.*, 2018; Sujatha et at., 2018). Water-induced soil erosion is indeed the most important land degradation problem worldwide (UNEP, 2015; Borelli *et al.*, 2018; Uddin *et al.*, 2018). Soil erosion has been documented as one of the greatest global problems that results in serious threats to natural resources, agriculture, and the environment (Alderman, 1994). Numerous studies have reported that the magnitude of soil erosion rates has been accelerating worldwide due to land use and land cover change (LULCC) and inappropriate land use and management practices resulting in widespread land degradation process (Rahman *et al.*, 2009).

Growing demand for agricultural, industrial, or urban areas compromises the ability of natural forests, waterbodies, and grasslands to provision for mankind (Nelson *et al.* 2009; Goldman-Benner *et al.* 2012), which causes land use and land cover changes either permanently or temporally. In recent decades, a substantial area of land use land cover (LULC) changes have been observed due to different socio-economic and biophysical drivers. Drivers of land degradation include the expansion of cultivated land for crop and timber production, overgrazing, and climate change (Scholes *et al.* 2018). Moreover, the ever-growing demand for tillable land and infrastructure as populations continue to rise exerts more pressure on land resources and accelerates LULC (Tadesse *et al.*, 2020).

Land use and land cover (LULC) changes alter the structures and functions of ecosystems and influence the supply of ecosystem services values (ESV) (Demelash *et al.*, 2022; Abera *et al.*, 2022). Though land degradation and biodiversity losses can be triggered by several factors, land use/cover (LULC) conversions have been identified as the most prominent factors in space and time (Abera, *et al.*, 2021). Conversions of natural ecosystems (i.e., natural forest, rangeland, wetlands) to modified/artificial ecosystems (i.e., agro-ecosystem, urban areas) are some

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of the most prominent and reported processes in the landscape transitions (Gezahagn and Arus, 2020; Kindu *et al*., 2013). Accordingly, varied patterns, extent, and form of change can be observed in each LULC type (Tolosa, *et al*., 2017) due to the variation of the drivers.

Recent research has shown that cropland conversion, urbanization, and deforestation have led to the loss of carbon sequestration, reduction in biodiversity, decline in water quality, changes in the local hydrology and land degradation, and a significant decline in ESV. In sub-Saharan Africa, some studies have been conducted to estimate ES in the context of LULC changes (Arowolo *et al.* 2018; Kindu *et al.* 2016; Tolessa *et al.* 2017). Most of these studies indicate that this region is under critical challenges of degradation, with significant response to rural livelihoods (Abera *et al.* 2018). For illustration, it is estimated that about 1.5 billion tons of topsoil are eroded per annum from the Ethiopian highlands (Gebreselassie *et al*., 2016); soil fertility of the country has diminished by 122, 13, and 82 kg ha-1 yr-1 of N, P, and K, respectively. (Haileslassie *et al*., 2005) Meanwhile, crop production has dropped by 32% (Mesfin., 2020) and forest cover of the country has been reduced by 140 thousand ha-1 yr-1 (on average 1.0–1.5%) since 1990 (Gebreselassie *et al*., 2016). These dynamics have led to an estimated overall environmental loss cost of about $4.6 billion yr-1 (FAO, 2020). Inside Ethiopia, the Central Rift Valley (CRV) is immeasurably affected.

The study watershed, one of the sub-watersheds under the Central Rift Valley basin, is facing the above challenges. Deforestation is a day-to-day activity for people living in and around the watershed due to increasing demand for charcoal, construction, domestic needs, and expansion of arable land, and grazing areas (Degelo 2007). The basin has serious soil erosion, desertification, and extensive land degradation. These are, in part, the moment of LULC trade-offs related to policies in approval of agricultural production and expansion (Brhanu, 2020; Efrem *et al*., 2009). Because of population growth, climate change and anthropogenic activities in the watershed have significantly altered natural landscapes. Thus, understanding the pattern of these LULC changes is important for efficient watershed management. Though efforts have been made to restrain land degradation, there leftovers a shortage of information on the dynamics of landscape transformations and connected ES value. Several studies on LULC change analysis have been led in various parts of Ethiopia (Feyissa and Gebremariam, 2018; Tolessa *et al*., 2017). However, very minute is known about the impact of the state and magnitude of LULC change on soil erosion in the study Sub- -watershed of Alaba Ethiopia.

In Ethiopia, water erosion is the leading cause of degradation of the soil capital and the environment. It affects, with varying intensities, about 1.9 billion tons of topsoil from the highlands by soil erosion and losses of an estimated USD 1 billion y-1 of land in Ethiopia (Addis & Klik, 2015; Atoma *et al*., 2020; FAO, 1984; Sonneveld, 2002). This amount of soil could have added about 1.5 million tons of grain to the country's annual harvest (Lulseged & Vlek, 2008). Soil erosion is a severe threat to food security and directly impacts livelihoods among rural communities in Ethiopia (Berhan *et al*., 2014; Samuel *et al*., 2016). There is a wide range of estimates on the annual rate of soil erosion by water is the dominant degradation process and occurs particularly on cropland, with annual soil loss rates on average of 42 ton ha-1 y-1 for croplands, and up to 300 ton ha-1 y -1 in extreme cases (Tamrie, 1995; Tesfaye *et al*., 2013). Temporal patterns of LULC changes, especially in areas susceptible to accelerated soil erosion, provide further reason to reevaluate former qualitative approaches, considering the worldwide increase in croplands by 279 million hectares during 1985 - 2013 (Gebreegziabher *et al*., 2021). Therefore, in recent years, local authorities increasingly concerned about the issue of soil fertility and have funded several research projects aimed at the conservation of water resources and the limitation of soil erosion.

Land use change has multiple environmental impacts by negatively affecting the water supply, reservoir storage capacity, agricultural productivity, and freshwater ecology of the region (Mesfin *et al*., 2020). The accuracy of estimating soil erosion at a given watershed scale is influenced by the complexity of the soil erosion process and the availability of data describing soil erosion in the last decade. In addition, it is also influenced by the regional and national level assessments of soil erosion carried out using different approaches ranging from indicator or factor-based approaches to process-based models (Gobin*et al*., 2004). Numerous studies in Ethiopia (e.g., Mengistu *et al.* 2015; Taye *et al.* 2018; Tadesse *et al.* 2017; Haregeweyn *et al.* 2017; Gelagay and Minale 2016; Molla and Sisheber 2017; Hassen and Assen 2018; Miheretu and Yimer 2018; Anache *et al.* 2018; Ebabu *et al.* 2019; Berihun *et al*., 2019; Kidane *et al.* 2019; Aneseyee *et al.* 2020) reported that changes in LULC could significantly affect the intensity of soil erosion at various spatiotemporal scales. For instance, Mengistu *et al.* (2015) reported the influence of temperature and precipitation on biomass production and soil organic carbon, thereby increasing soil erosion in the Abay River basin. An increase in precipitation levels and intensity will lead to intensified erosion (Field and Barros 2014). To curb such problems, assessment, planning, and implementation of locally acceptable and effective soil conservation practices are urgently needed (Sonneveld & Keyzer, 2003). Most of the studies focused on the study was intended to assess the magnitudes of LULCC in different parts of the country. Although some research was conducted on the land-use changes in soil erosion, the context is not yet well understood particularly in the study sub-watershed of the Central Rift Valley Basin. In addition, the environmental impact of future LULC is still a contentious issue and unresolved problem and requires further research (Simane *et al.* 2013; Demessie 2015). Hence, predicting the impact of LULC changes on

soil erosion is very important to design appropriate land use planning and adaptation and mitigation measures under local and regional scales.

Thus, to better understand the effects of LULC change on soil erosion at a watershed level, a holistic and multidisciplinary approach is required. The effects of change in LULC on soil erosion can be investigated by associating field measurements of soil erosion variables with different LULC class data (Adugna and Abegaz 2016; Ebabu *et al.* 2019). However, measurement of soil erosion is often not possible over the required temporal and spatial scale. Thus, field studies have to be complemented by soil erosion model simulation (Giri *et al.* 2015; Woznicki *et al.* 2016). Furthermore, results from soil erosion models have been used to predict the impacts of climate and LULC changes on soil erosion and as a scientific basis for soil erosion control and management at different scales (Addis and Klik 2015; Serpa *et al.* 2015; Woldesenbet *et al.* 2018; Anache *et al.* 2018). A wide range of models was developed to assess the rate of soil erosion. Model simulations are the basic methods for soil erosion prediction. The prediction of rates of soil erosion typically involves the use of empirical models (Leh *et al.*, 2013), thus the empirical models are still widely used for soil erosion assessment both on the watershed and regional scale. Of all the empirical models, the Universal Soil Loss Equation (USLE; Wischmeier & Smith, 1978) and the Revised Universal Soil Loss Equation (RUSLE) are probably the most widely used empirical models for water erosion assessment and water conservation plans worldwide (Kinnel, 2010; Renard *et al.*, 1997; Oliveira *et al.*, 2011). Therefore, this study aimed to analyze the trends and changes in land use and land cover dynamics and to analyze the impact of LULC change on soil erosion with the help of RUSLE over the Alaba Sub-Watershed, Central Rift Valley Area of Ethiopia. This study would help to plan and use appropriate land use planning, soil, and water conservation practices, decision-making, and policy development, thereby reducing soil erosion in the study area and watersheds with similar settings.

MATERIALS AND METHODS

Description of the Study Area

The study Sub - watershed is situated in the Halaba Zone of Southern Nations, Nationalities, and People's Regional State, Ethiopia. It is located in the Central Rift Valley, about 310 km from Addis Ababa, the Capital of Ethiopia. It covers an area of 1133 hectares and the sub-watershed is one of the main streams draining into Rift Valley basins. The watershed is geographically located at 380 6' 0" to 380 9' 0" East and 70 21'0"to to 70 23' 0" North coordinates (Fig.1). The altitude ranges from 1800 to 2000 meters above sea level. The slope of the study watershed ranges from flat (0-2%) to very steep (>20%). According to the FAO Classification system, the major soils of the sub-watershed are Vertic Andosols, Luvic Phaeozems, and Chromic Luvisols. Vertic Andosols are found in most areas of the watershed. Agro-ecologically, the sub-watershed is characterized by sub-humid climatic conditions having a mean precipitation of 1035 mm per year and an average annual temperature value of 21OC, mean temperatures also vary from 15 OC to 29 OC. The study area receives a bimodal rainfall where the small rains are between March and April while the main rains are from July to September. The major crops produced under rain-fed agriculture include maize, teff, pepper, haricot bean, sorghum, and millet. Rainfall during the main rains is erratic most of the time crops fail due to an uneven distribution of rainfall over the growing period.

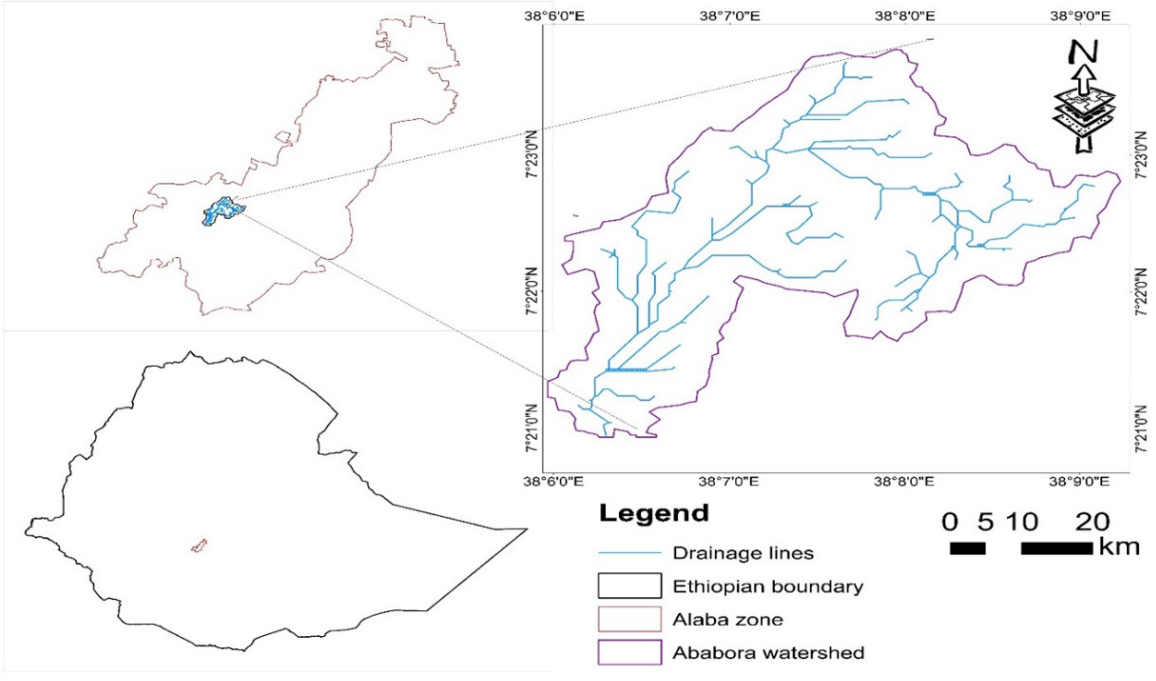

Figure 1: Map of the study area

Data Acquisition and Processing

The biophysical baseline was characterized to identify detailed information on topography and landforms, present land use, soil erosion status, vegetation, climate, and water resources. It was supported by remote sensing technology, especially with the availability of high spatial and temporal resolution satellite data, aided by Geographic Information System (GIS) tools. Using these biophysical information and feedback obtained from farmers and other stakeholders constraints and opportunities were identified and prioritized for intervention planning. Different types of data were acquired from various sources. Three-time series Landsat satellite images and a digital elevation model (DEM) with 30 m resolution were obtained from the United States Geological Survey (USGS https://earthexplorer.usgs.gov/ (accessed on 1 March 2020)). Landsat of Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and Operational Land Imager (OLI) were obtained for the 1987, 2000, and 2018 study periods, respectively. These cloud-free Landsat images were acquired in January and February. The path and raw of these Landsat data were 169/54&55. All spatial data were prepared to the same reference systems (WGS_1984_UTM_Zone_37N) and then cropped to fit the study landscape in order to use and proceed with further process. Distance from road, river, and market were prepared using DEM and corresponding features in ArcGIS environment. Similarly, altitude and slope classes were prepared using contour and DEM. Ground trothing data and information were undertaken using participatory field observation, interviews, and GPS ground control points. Google Earth imagery of corresponding study periods was also used as an ancillary information provider.

LULC Classification, Accuracy Assessment, and Change Detection

Model Builder of ArcGIS software was used to make composite bands and mosaicked images of 1987, 2000, and 2018. Geo-referencing and rectification were done to adjust distortion using ground points and road networks using ArcGIS. Following correction, atmospheric corrections were performed to remove the haze and nose from images using ERDAS Imagine 15 software. Images were then resampled using the study area boundary. Then, a supervised classification procedure was conducted for image classification. The training points that were proportionally distributed to each cover type were taken based on field observations, GPS ground points, and Google Earth images. A maximum likelihood classifier was used in a supervised classification procedure to classify the images independently in ERDAS Imagine 15 software. In order to assess the accuracy of image classification, reference data points were used to ensure that all four LULC classes were adequately represented based on their proportional area. The reference ground truth data was chosen in such a way that it appear in both the Landsat images for the respective periods of 1987, 2000, and 2018 and the Google Earth map. The pattern and transitions of LULC classes that are described in the watershed were determined and detected over the studied years. The percent and rate of changes were also calculated to elucidate observed LULC transitions. LULC changes were calculated for three different time periods between 1987 and 2018 as methods applied by different studies (Kindu *et al.* 2016; Shiferaw *et al.* 2019) and calculating percent changes for each LULC type over time (Gashaw *et al.* 2018; Kindu *et al.* 2016) (equation 1).

Percent of changes= ((A2-A1)/A1)*100 (1)

Where A1 is the area of land use and land cover type (ha) in year 1, A2 is the area of land use and land cover type (ha) in year 2.

Annual change rates were calculated for each LULC type following, i.e., the rate of change for a specific class was calculated by dividing the class-specific changes between two-time intervals by the number of years between these two observed points in time (Tewabe and Fentahun, 2020). (Equation 2).

Rate of changes= (A2-A1)/Z (2)

Where A2 is the recent area of the land use and A1 is the area of the previous land use and Z refers to the time interval between the studies periods considered for analysis.

Table 1: Description of each land use/cover type in the study area

Land use/cover classes	Description of each land use class
Vegetation	Area covered by plantation as well as natural forest trees and land covered with shrubs and thorn bushes plants
Grassland	Places covered in small trees and bushes combined with grasses
Cultivated land	Areas allotted to rainfed crop cultivation both annuals and perennials, mostly of cereals in subsistence farming within the cultivated fields
Bare land	areas with sparse and stunted vegetation, as well as wastelands and badlands with exposed rocks

Model Selection and Parameterization

RUSLE model was used to estimate and map soil loss rates in the study watershed, however, it includes numerous improvements, such as factors and incorporation of the influence of surface. Improved empirical equations were used for the computation of rainfall erosivity (R), eroded factor (K), and crop management (C) factor. Moreover, some parameters of the model have been adjusted for

Ethiopian situations (Hurni, 1985). Today computed in a raster-based GIS, the model provides information on potential water erosion on a cell-by-cell basis. Annual soil loss is a function of five factors described by the expression (Renard *et al.*, 1997):

$$A = R \times K \times LS \times C \times P \quad (3)$$

Where R is the rainfall-runoff erosivity factor (MJ mm ha^{-1} h^{-1} y^{-1}), K is soil erodibility (t ha h ha^{-1} MJ^{-1} mm $^{-1}$), LS is slope length-steepness, C is land-use and land-cover; and P is the erosion control (conservation support) practices factor (dimensionless, ranging between zero and 1).

Rainfall Erosivity Factor (R)

The R-factor is defined as the product of kinetic energy and the maximum 30-minute intensity and shows the erosivity of rainfall events (Wischmeier and Smith, 1978). However, in this study, to determine the value of the R-factor, the average of annual historic rainfall event (30-years) was collected from a meteorological station located at near distance from the watershed. Then the R value was calculated according to the equation given by Hurni (1985) which is derived from a spatial regression analysis (Hellden, 1987) for Ethiopian conditions. It is based on the available mean annual rainfall data.

$$R = -8.12 + (0.562*P) \quad (4)$$

Where P is the mean annual rainfall in mm

Soil Erodability Factor (K)

Soil Erodability Factor (K) is defined as the mean annual rainfall soil loss per unit of R for a standard condition of bare soil, recently tilled up-and-down with slope with no conservation practices and on a slope of 50 and 22 m length (Morgan, 1994). Hellden (1987) developed a USLE for the Ethiopian condition by adapting different sources and proposed the K values of the soil based on their color. Thus, soil color was determined from 20 points in the watershed and assigned K values as their soil color (see Table 2).

Table 2: Soil Erodability factor Hellden, 1987

Soil color	Black	Brown	Red	S Yellow	Grey	White
K factor	0.15	0.2	0.25	0.3	0.35	0.40

Slope Length and Slope Steepness (LS)

SL is the topographic factor expressed as the expected ratio of soil loss per unit area from a field slope to that from a unit plot under otherwise identical conditions. The slope length and slope steepness can be used in a single index, which expresses the ratio of soil loss as defined by (Wischmeier and Smith 1978). Slope length and slope gradients factors was recorded using meter tape and clinometers, respectively, in the watershed on different landform and land uses.

$$LS = (X/22.1)\ m\ (0.065 + 0.045\ S + 0.0065\ S2) \quad (5)$$

Where X = slope length (m) and S = slope gradient (%)

m = an exponent depending upon the slope. The exponent n is given by:

m = 0.3 for slope ≤ 3 percent

m = 0.4 for slope = 4 percent

m = 0.5 for slope ≥ 5 percent

Crop Management Factor (C)

The C-factor is defined as the ratio of soil loss from land with specific vegetation to the corresponding soil loss from continuous fallow (Wischmeier and Smith, 1978). The land use land covers of the three years (1987, 2000, and 2018) were used to determine the c-value. Assessment of the type of land use-cover was made separately for each land unit and the corresponding land cover was obtained from Hurni (1985) which was developed to Ethiopia condition.

Erosion Management Practice Factor (P-value)

The P-factor gives the ratio between the soil losses expected in soil conservation Practice to that with up- and down-slope plowing (Wischmeier and Smith, 1978). Values for this factor were assigned considering local management practices and based on values suggested in Hurni, (1985).

Table 3: Conservation support practice (P) factor values

Land Use Type	Slope (%)	p Values
Agricultural land use	0–5	0.1
	5–10	0.12
	10–20	0.14
	20–30	0.19
	30–50	0.25
	50–100	0.33
Nonagricultural land use	0-100	1.00

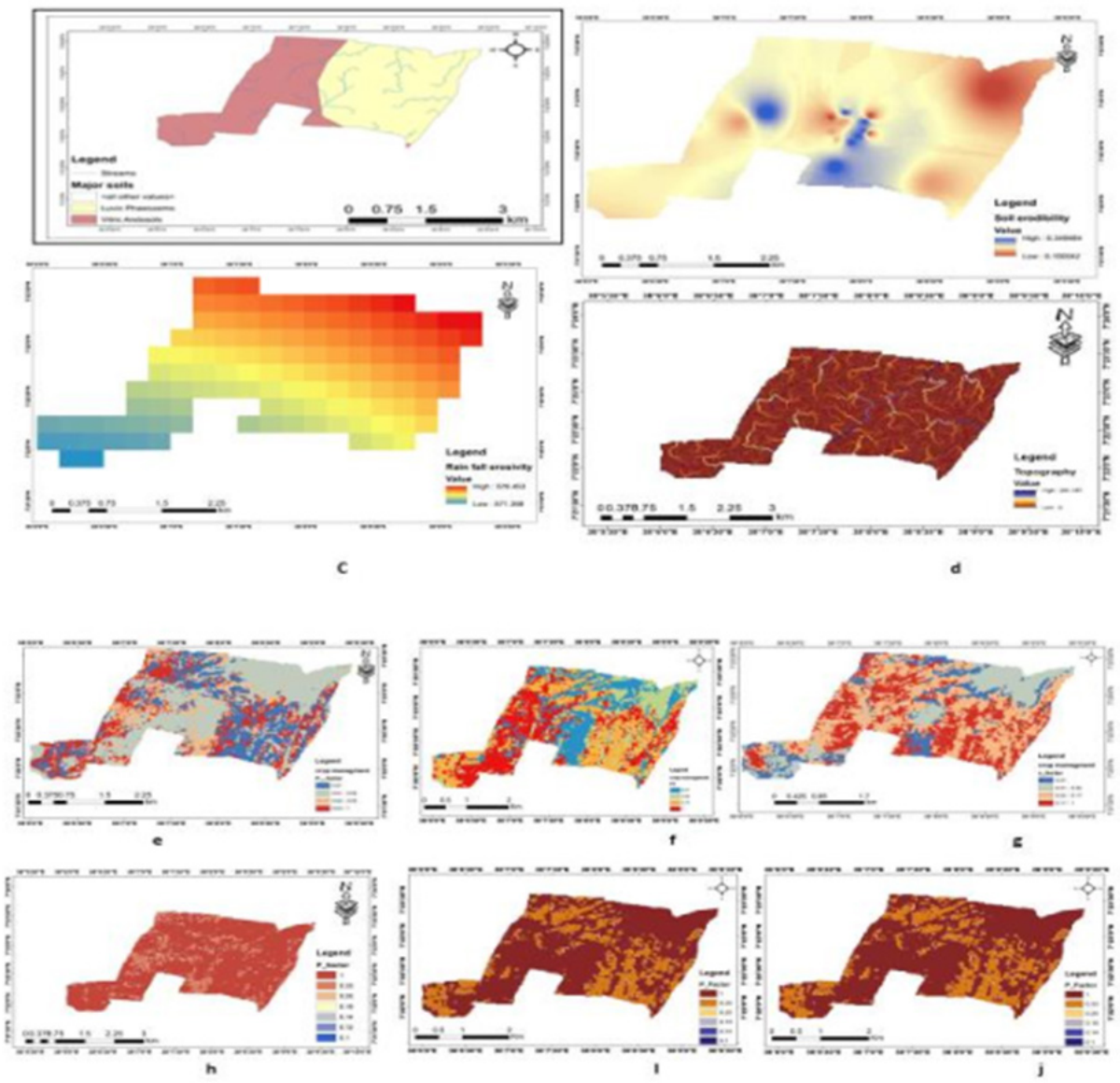

Figure 2: Soil type (a), Soil erodibility (K) factor (b), Rainfall-erosivity (R) factor (c), Topographic (LS) factor (d), Cover management (C) factor in 1987 (e), 2000 (f) and 2018 (g); Support practice (P) factor in 1987 (h), 2000 (i) and 2018 (j) in the sub watershed, Alaba Rift Valley Basin, Ethiopia.

RESULTS AND DISCUSSION

LULC Classification

Examination of the satellite-derived thematic maps and field survey revealed a varying degree of changes in the composition of LULC categories in the study areas over a span of three decades. Four LULC classes identified in the Alaba Sub-watershed were classified for the years 1987, 2000, and 2018, as shown in Table 2 and Figure 2. This includes vegetation, grassland, cultivated land, and bare land, with a proportion of each LULC class in 1987 contributing 43 %, 25 %, 11 %, and 21 % of the total study area, respectively. Each LULC class in 2000 accounts for 19 %, 23 %, 27 %, and 31 % of the total study area, respectively. On the other hand, the share of vegetation, grassland, cultivated land, and bare land is 16 %, 14 %, 42 %, and 28 % of the total study area in 2018, respectively (Table 4). Of all LULC classes, cultivated land greatly and persistently increased in the years between 1987 and 2018. On the contrary, forest, grazing land, and shrub-bush-woodland were significantly decreased (Table 4). Similarly, Badasa *et al.* (2022) indicated that the coverage of agricultural land is higher than other LULC classes in the Geba watershed, western Ethiopia from 1990 to 2020. LULC of forests is being converted into cultivated land settlements, due to the high population increase in the Geba watershed (Mekuriaw, 2019). Previous research in various parts of Ethiopia also found similar results (Abebe *et al.*, 2022; Dibaba *et al.*, 2020; Galata, 2020; Gashaw *et al.*, 2017; Shiferaw and Singh, 2015).

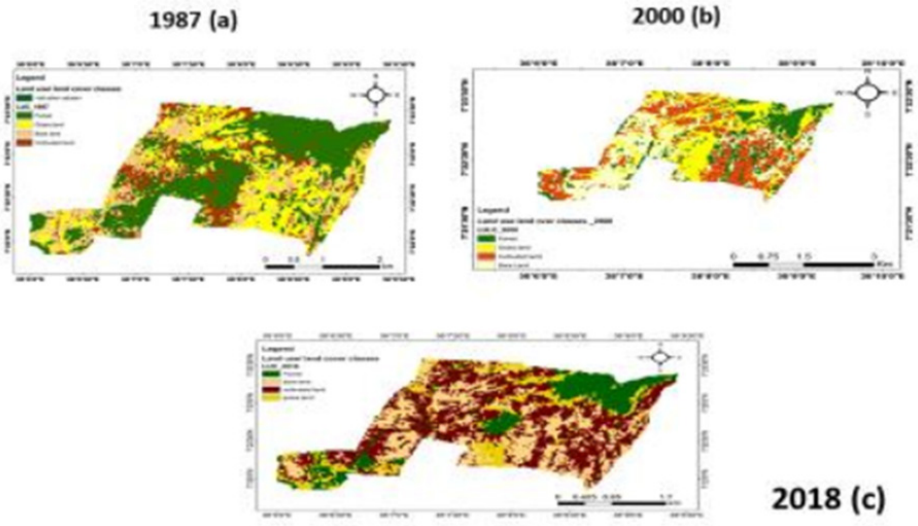

Figure 3: Land use and land cover (LULC) map of the watershed, Alaba Rift Valley Basin, Ethiopia., Ethiopia; 1987 (a), 2000 (b) and 2018 (c).

Table 4: The area coverage and percentage of LULC classes for 1987, 2000, and 2018

Land Use/Cover Types	1987		2000		2018	
	Area (ha)	Cover (%)	Area (ha)	Cover (%)	Area (ha)	Cover (%)
Vegetation	487.19	43	215.27	19	181.28	16
Grassland	283.25	25	260.59	23	158.62	14
Cultivated land	124.63	11	305.91	27	475.86	42
Bare land	237.93	21	351.23	31	317.24	28
Total	**1133**	**100**	**1133**	**100**	**1133**	**100**

The Extent and Rate of LULC Change

LULCC is closely related to human decisions and complex interactions among multiple activities, working at a location. Up-to-date information about the dynamics of LULCC and its drivers is an increasingly important issue in the examination of environmental change for identifying the current resource situation and designing sustainable resource management measures (Meshesha *et al*., 2014). The present study found a substantial LULCC in the Central Rift Valley Sub-Basin, which is located in the Alaba Zone. We found that LULC in the area was variable throughout the study period. For three periods, the extent and rates of changes for each LULC were summarized below 1987, 2000, and 2018 (Tables 5). Cultivated land and bare land increased by 145.45% and 47.62%, respectively between 1987 and 2000. Contrarily, Vegetation, and grassland both showed a decreased trend of -55.81% and – 8.00% respectively in the same period (Table 5). Cultivated land and bare land had an increasing LULC change arrangement, while Vegetation and grassland had a decreasing trend between 1987 and 2000. From 1987 to 2000, agricultural land and bare land have grown at a rate of 11.19 % and 3.66%, respectively. Contrarily, Vegetation and grassland both throw down at a rate of -4.29% and - 0.62%, respectively. The findings show that forest cover, bushland, and grassland in the study watershed have been decreasing, which is reliable with preceding research (Demelash *et al*., 2022; Negassa *et al*., 2020; Abera *et al*., 2022). The results showed accelerated landscape change with an observed reduction in natural ecosystems, especially wetlands, grazing lands, and forests, while cultivated, built-up areas and barren lands increased over time (Table 5). These patterns could be attributed to competition for agricultural and settlement land. Previous studies conducted in Ethiopia (e.g., Moisa *et al*., 2022; Abera *et al*., 2022; Kindu *et al*., 2015) reported similar results.

The extent and rate of change in LULC between 2000 and 2018 as presented in (Table 5), only cultivated land has increased by 55.56 % and cultivated land also has a growth rate of 3.09 %. In contrast, vegetation, bare land and grassland had decreased by -15.59 %, -9.68% and -39.63 respectively (Table 5). Vegetation, bare land and grassland, on the other hand, fell at rates of -0.88%, -0.54 % and -2.17%, respectively. The Cultivated land expansion increased to produce more crops at the expenditure of forest, grassland and bushlands, which leads to land and soil degradation (Kindu *et al*., 20132; Abebe *et al*., 2022). The extent of changes varied among the LULC classes during the period between 1987 and 2018. During the study period, areas covered by forestland, shrub land and grassland showed a considerable reduction (Table 5). The vegetation cover converted during the period of the assessment totaled which is about 168.75% of the total area that covered in 1987. Likewise, grassland cover has decreased in the study landscape by 68.57% of the total

area. On the contrary, cultivated land and bare land LULC classes have increased by 73.81% and 25%, respectively. The rate of change in cultivated land and bare land was also raised by 9.09% and 1.08%, respectively. Vegetation cover and grasslands had also dropped by –2.03%, and -1.42% respectively (Table 5). LULC change was caused due to deforestation of woods for fuel and construction purposes, and the removal of shrubs and grasses to meet the growing demand for cultivated land that resulted due to rapid population growth and climatic variability. As a result, the cover of cultivated land, bare land, and built-up showed an increasing pattern from year to year. However, woodland, shrub land, and grassland showed a shrinking change (Zemede and Tewedrose, 2023). (Demelash *et al.*, 2022) concluded that agricultural land, built-up areas, and water bodies have increased, while forestland, rangeland, and grazing areas have decreased over the last three decades from 1987 to 2017.

Table 5: Rate of LULC changes during 1987-2000, 2000-2018 and 1987-2018 in percentage.

Land Use/ Cover Types	1987		2000		2018		Rate of changes (%)		
	Area (ha)	Cover (%)	Area (ha)	Cover (%)	Area (ha)	Cover (%)	1987-2000	2000-2018	1987-2018
Vegetation	487.19	43	215.27	19	181.28	16	-4.29	-0.88	-2.03
Grassland	283.25	25	260.59	23	158.62	14	-0.62	-2.17	-1.42
Cultivated land	124.63	11	305.91	27	475.86	42	11.19	3.09	9.09
Bare land	237.93	21	351.23	31	317.24	28	3.66	-0.54	1.08
Total	**1133**	**100**	**1133**	**100**	**1133**	**100**			

Trend and Magnitude of LULC Dynamics

The cultivated land revealed an increasing trend increasing from 181.28 hectare to 351.23 hectare for the period 1987 to 2018, respectively. On the other hand, vegetation and grasslands showed a declining trend from -271.92,-22.66 hectare to -305.91, -124.63 hectare, respectively (Fig.4). Agricultural and settlement classes are growing in the advances of bushland, forest, and grasslands LULC types. This indicates that there is a reduction of bushland and grassland and an increasing trend of agriculture and settlements in the study period. The population has recently grown and environmental consequences have been detrimental. From the evidence of the study area, the primary cause of natural resource depletion is population growth, cultivation of marginal and steep slope areas, mostly sharing grazing and bushland areas with landless youth, timber production, charcoal production, fuel wood, and construction material collections. This finding is in line with previous research (Bufebo and Elias, 2021; Ogato *et al.*, 2021). For example, Bufebo and Elias (2021) reported that understanding the scope of land use change, its driving force, and its consequences are critical for proper land resource management over the Shenkolla watershed, in south-central Ethiopia. The findings of this study were consistent with numerous studies' findings in other parts in Ethiopia (Zemede and Tewedrose, 2023; Demelash *et al.*, 2022; Gezahagn and Arus, 2020; Kindu *et al.*, 2013) and elsewhere in the world (Uddin *et al.*, 2018; Sharma *et al.*, 2011). These studies have revealed a heterogeneity in the spatial and temporal extent of LULCCs.

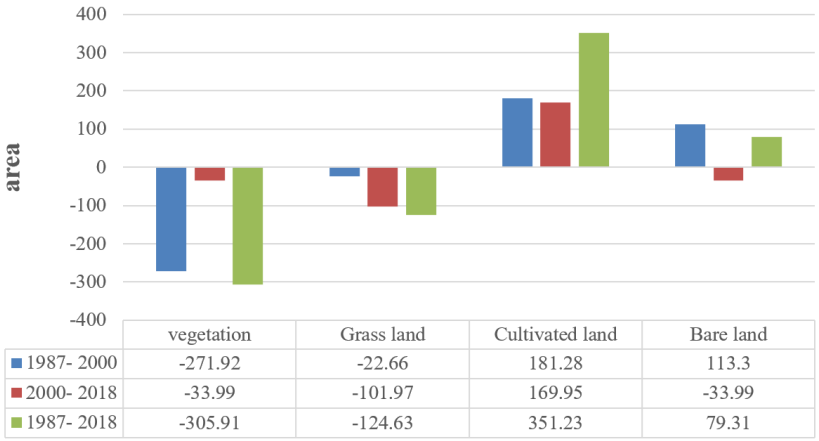

Figure 4: Trends of LULC changes in the Alaba sub-watershed

Soil Erosion Rate under Different LULC Change

After all the six layers were combined and multiplied using a raster calculator in ArcGIS from all existing surface information based on the relationship defined by the RUSLE model, the result (output) layer of the three years was generated which gives the rate of annual soil loss by erosion at a pixel level in a raster format (Figure 5). From the result of the analysis of the soil loss rate in the study

area using the RUSLE model, the estimated total annual actual soil loss in the study landscape was 25707.77 tons in 1987, 29310.71 tons in 2000 and 31769.32 tons in 2018. Our estimate of soil loss falls within the range of the previous findings that estimated the soil loss rate in the Central Rift Valley of Ethiopia from 23096 to 118776.3 tons and in the Highland areas of Ethiopia from 1248 to 23,400 million tons, respectively (FAO, 1998; Wolka *et al.*, 2015).

As can be observed from Table 6, it was also found that the mean annual soil loss rate of the study catchment was 22.69t/ha/yr., 25.87t/ha/yr. and 28.04t/ha/yr.

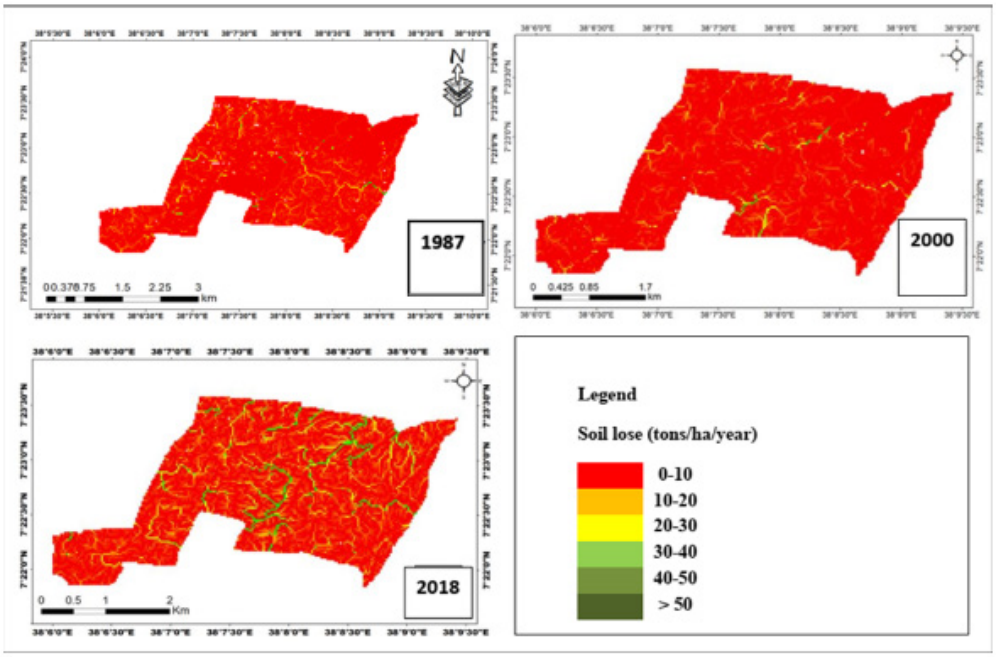

Figure 5: Estimated annual soil loss map of the study area in 1987, 2000, and 2018

in 1987, 2000, and 2018 respectively. Compared to the proposed tolerable range by Hurni (1985) for different agro-ecological regions of Ethiopia i.e. 2t/ha/yr-18t/ha/yr. and formation rate of 2 - 22 t ha-1 y-1) for Ethiopia, the amounts of the mean annual soil losses of the study catchment for the three study years (1987, 2000 and 2018) are much greater. Present results are in conformity with Asmamaw and Mohammed (2019) demonstrated that it varied from less than 10 to over 80 t ha -1 y-1 in Ethiopia. Consequently, the estimated rate of soil loss and the spatial patterns are generally realistic as compared with the findings in the field and from the results of previous studies (Hurni 1983a, b, 1985; Bewket and Teferi 2009; Mengistu *et al.* 2015).

Table 6: The mean annual Soil losses per hectare for the three study years

Year	Mean soil loss (ton/ha/year)	Annual Soil loss (ton/year)
1987	22.69	25707.77
2000	25.87	29310.71
2018	28.04	31769.32

The calculated soil erosion rate is categorized into six major severity classes namely: very severe, severe, very high, high, moderate, and low following previous studies (Haregeweyn *et al.*, 2017; Hurni, 2022; Moisa *et al.*, 2022). The proportion of the area at low risk covered a larger part of the sub-basin area accounts for about 65 %, 60% and 58% of the total study area in 1987, 2000, and 2018, respectively. From the total area, about 1.75, 3.80, and 4.50% are exposed to severe erosion risk in the years 1987, 2000, and 2018, respectively (Table 7; Figure 4). In the year 1987, about 30.53% was exposed to low soil erosion. In 2000, about 28.64% of the study area was categorized under low, 31.16% moderate, 22.84% high, 3.80% severe, and 1.68% very severe soil erosion risk. By the year 2018, about 28.02% is categorized as a low soil erosion risk, which is lower than the results of 1987, and 2000. About 35% and 42% of the Sub-basin experienced high to very severe soil erosion in 1987 and 2018, respectively. The area at high, very high, severe, and extremely severe risk of soil erosion increased from 21.84%. 10.30%, 1.75%, and 1.08% in 1987 to 22.50%, 12.33%, 4.50%, and 2.38% respectively, in 2018. The results indicate that the estimated erosion rate for about 39 % of the sub-basin area exceeds the maximum tolerable soil erosion threshold (Hurni, 1985). Present results are in conformity with Gezahagn and Arus, (2020) demonstrate that the estimated erosion rate for about 39 % of the sub-basin area exceeds the maximum tolerable soil erosion threshold. Similarly, FAO (2019) showed that the threshold soil loss value is between 4.5 − 11.2 ton

ha−1 y−1 established by USDA and a range for threshold soil loss between 1 t ha−1 y−1 for shallow sandy soils and 5 t ha−1 y-1 on deeper and well-developed soils set by the European Environment Agency.

Table 7: Erosion severity classes and area of soil loss in the Alaba Sub-watershed.

Land Use/Cover Types		1987		2000		2018	
	Soil Erosion Rate (ton/ha/year)	Area (ha)	(%)	Area (ha)	Cover (%)	Area (ha)	Cover (%)
Low	0-10	345.86	30.53	324.45	28.64	317.51	28.02
Moderate	10-20	390.84	34.50	352.99	31.16	342.75	30.25
High	20-30	247.5	21.84	258.81	22.84	254.95	22.50
Very high	30-40	116.75	10.30	134.60	11.88	139.74	12.33
Severe	40-50	19.8	1.75	43.09	3.80	51.04	4.50
Very severe	> 50	12.25	1.08	19.06	1.68	27.02	2.38
Total		**1133**	**100**	**1133**	**100**	**1133**	**100**

Since the C factor in the RUSLE model directly depends on land use/land cover, the change of land use type had a significant influence on soil loss potential. The observed considerable change in LULC is likely to influence and expose the watershed to soil erosion. The first effect results from overall compositional change of LULC categories, which has direct bearing on spatial distribution of the C factor. The second effect arises from redistribution of individual patches of LULC categories, which would alter the association of particular LULC category with terrain slope and soil properties. This is of significance because a particular LULC category will have a different erosion potential for a different slope and soil. Thus in the present study, special emphases were given for the different associations of LULC with terrain and soil to explore and reveal the underlying mechanism for changed erosion pattern of the study site. Therefore, the high reduction of forest and shrub land areas and substituted predominantly by cultivation lands over 1987-2018 periods which reduced the protective function of the land, have led the dramatic increase of soil loss in the watershed which can negatively influence to the soil productivity. Among all LULC, cultivated land is experiencing an increasing trend in soil loss, i.e., the soil loss is increased from the year 1987 to, 2000 and 2018, respectively. During 1987 and 2018, the minimum amount of soil loss was expected in vegetation. Understanding the dynamics in LULCCs and consequent changes in the distribution of soil erosion risk can provide a spatial decision support tool for conservation planners to develop an appropriate SWC measures. Ample studies have been reported that LULC change and type significantly influence soil erosion (Borrelli *et al.*, 2013; Uddin *et al.*, 2018; Weldu and Edo, 2020; Sintayehu *et al.*, 2018). The present study's findings agree with those of the recent study by Weldemariam *et al.*, (2018) who indicated that the situation of soil loss risk in the Gobele watershed has been worsening due to increases in the proportion of erosion risk areas by 19.67% of the total watershed area between 2000 and 2016. Gezahagn and Arus, (2020) also demonstrate that cropland, bare land, and settlement had become the main causes of soil erosion in the study landscape, as the estimated mean soil loss rate for the three LULC classes have increased 11.88, 6.80, and 2.44 t ha-1 yr-1 of the total watershed area between 2000 and 2018.

Determination of Conservation Priority Levels

Six SWC priority areas were identified at the sub-watershed scale revealed that the top three priority levels delineated for urgent SWC measures represent those areas within a higher soil loss rate and the large increase in erosion risk levels, with an area of 188 hectare and accounts for 17 % of the sub-watershed area. These sub-watersheds are found in the upstream, steep slope landscape and in the hilly parts of the study watershed. Relatively low, mean annual soil loss rate (< 20 t/ha/yr.) are observed in Sub-watershed- VI and Sub-watershed-V, which are located in the lower reach (gentle part) of the watershed. About 50% of the sub-watersheds fall in below the annual average soil loss of the entire watershed.

Table 8: Area of the conservation priority level of the study area.

Priority Level	Average soil loss ($t\ ha^{-1}\ yr^{-1}$)	Area (ha)	Percentage (%)
VI	0-10	329.27	29.06
V	10-20	362.19	31.97
IV	20-30	253.75	22.39
III	30-40	130.36	11.50
II	40-50	37.98	3.35
I	> 50	19.44	1.71

Several previous studies highlighted the positive outcome of SWC measures for mitigating erosion risk, restoration of the degraded land while improving the soil fertility and land productivity (Gezahagn and Arus, 2020; Kindu *et al.*, 2013). In view of the fact that the distributions of soil erosion risk have shown a spatial variation within the sub-watershed, we identified and mapped areas with a higher soil erosion rate as priority areas for SWC measures (Zhang *et al.*, 2010). Similarly, based on annual soil losses, sub-watersheds III, II and I were found to be the highest soil erosion risk areas in the watershed. The portion of the sub-watershed area with high soil loss and increases in erosion risk grades were delineated in upper most conservation priority levels (Table 9).

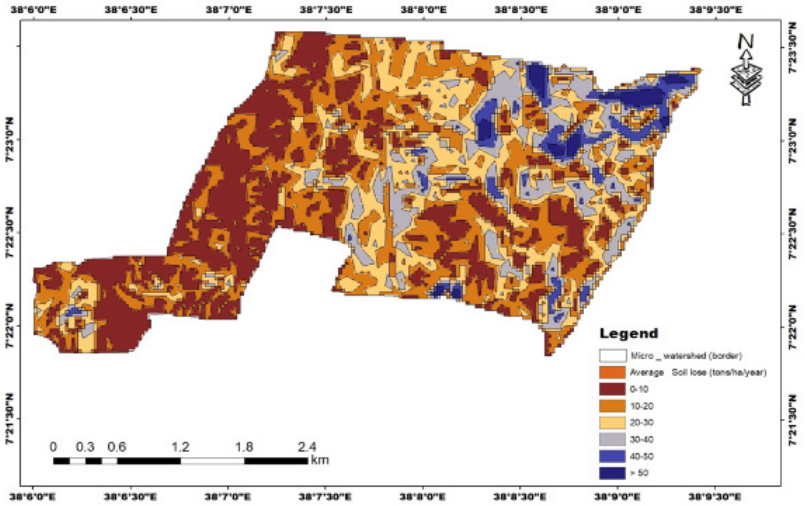

Figure 6: Conservation Priority Levels of the Medo Watershed

CONCLUSIONS

The study was intended to analyze the trends and changes in land use and land cover dynamics and to analyze the impact of LULC change on soil erosion over the Alaba Sub-Watershed, Central Rift Valley Area of Ethiopia. The LULCC was examined based on multispectral Landsat satellite images acquired in 1987, 2000 and 2018. Assessment of soil erosion using the RUSLE model developed in the ArcGIS environment successfully provided a set of spatially different management approaches to stop erosion in the study area. The observed cultivated land and bare land showed an increasing trend, while vegetation cover and grassland revealed a decreasing trend over the study period. During the study period between 1987 and 2018, the rate of change in cultivated land and bare land was raised by 9.09% and 1.08%, respectively. On the contrary, vegetation cover and grasslands had dropped by –2.03%, and -1.42% respectively. From trends of LULC changes, cultivated land revealed an increasing trend increasing from 181.28 hectare to 351.23 hectare for the period 1987 to 2018, respectively. On the other hand, vegetation and grasslands showed a declining trend from -271.92,-22.66 hectare to -305.91, -124.63 hectare, respectively. This study demonstrated that the present observed LULC changes are primarily related to population growth and the resulting demand for natural resources through deforestation for various purposes in the Alaba Sub - Watershed. The bare land and cropland expansion were found to be the major drivers of LULCC contributing to high soil loss rates. The findings of the study generally elucidate that the LULCC have a detrimental impact on soil erosion. The estimated total annual actual soil loss in the study landscape was 25707.77 tons in 1987, 29310.71 tons in 2000 and 31769.32 tons in 2018. It was also found that the mean annual soil loss rate of the study catchment was 22.69t/ha/yr., 25.87t/ha/yr. and 28.04t/ha/yr. in 1987, 2000, and 2018 respectively. The calculated soil erosion rate is categorized into six major severity classes namely: very severe, severe, very high, high, moderate, and low. About 35% and 42% of the Sub-basin experienced high to very severe soil erosion in 1987 and 2018, respectively. The area at high, very high, severe, and extremely severe risk of soil erosion increased from 21.84%. 10.30%, 1.75%, and 1.08% in 1987 to 22.50%, 12.33%, 4.50%, and 2.38% respectively, in 2018. The results indicate that the estimated erosion rate for about 39 % of the sub-basin area exceeds the maximum tolerable soil erosion threshold and this shows that the erosion risk condition is deteriorating in the study landscape. Six SWC priority areas were identified at the sub-watershed scale revealed that the top three priority levels delineated for urgent SWC measures represent those areas within a higher soil loss rate and the large increase in erosion risk levels, with an area of 188 hectare and accounts for 17 % of the sub-watershed area. Similarly, based on annual soil losses, sub-watersheds III, II and I were found to be the highest soil erosion risk areas in the watershed. The portion of the sub-watershed area with high soil loss and increases in erosion risk grades were delineated in upper most conservation priority levels. The outcome of this investigation would be imperative in the decision and implementation of appropriate soil and water conservation methods and

within the study area and for deducing the changes in the future. Likewise, local and regional government agencies, developers and policymakers to diminish the rate of soil loss in the study watershed can use the results obtained from this study. Further detailed investigations based on data from primary and secondary sources would be important in identifying driving socioeconomic forces and consequences of LULCCs and suggest possible alternative options to establish sustainable resource management practices in the study area.

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