**Master`s thesis**

# Effect of Land Use and Land Cover Changes on Soil Erosion:

## A Case Study of the Debre-Markos Blue Nile Basin in Ethiopia

## 토지이용 및 토지피복 변화에 따른 토양 유실량 평가:

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# Effect of Land Use and Land Cover Changes on Soil Erosion:

## A Case Study of the Debre-Markos Blue Nile Basin in Ethiopia

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# Abstract

Soil erosion has become one of the most important environmental problems in globally, particularly in Ethiopia. The past land use and land cover (LULC) changes suspected to be the main causes of soil erosion in the study area, where is the Debre-Markos Blue Nile (DMBN) basin. Therefore, the objectives of this thesis are to: (1) assess the LULC change by using ERDAS 9.2 from Landsat images (1987, 2002, and 2017) and (2) to identify the LULC changes that causes soil erosion and estimate the annual soil erosion hazard by using ArcGIS 10.1. To determine the LULC changes first, the study carried out a mapping of each LULC for 1987, 2002 and 2017 by using the Supervised Classification method of Landsat image. To improve classification accuracy and reducing misclassification, a training data was derived from Google Earth's (GE) geo-browser it has high spatial resolution images which provide opportunity for detailed LULC. The Landsat images classification for 2002 and 2017 were based on GE, while 1987 Landsat image were referenced by 2002's GE and pre-classified images, since GE images acquired from 2002 in this study area. After classification, accuracy assessment for 2017 classified image were interpreted using both digitized reference points and field varification way points. In the second place, the study estimates annual soil erosion by water using Revised Universal Soil Loss Equation (RUSLE). The LULCs map utilized for the final analysis of annual soil loss. In addition, 20 years` mean annual rainfall data from Ethiopia Metrological Agency, soil map from FAO Digital Soil Map of the World, digital elevation model (DEM) and previous reports to identify the cover management and supportive practice were used for the erosion estimation. From the achieved map the overall accuracy of 2017 was 84.5% and a Kappa coefficient of 0.81 was recorded. The LULCs change comparisen between 1987 and 2017 indicate that, from the total area about ~29% experienced with changes. The classification result showed that from 1987 to 2017 the dominant agriculture land (~44%) increased by 2% while the second and third dominant grassland (26%) and woodland (25%) had significantly decreased by 1.87% and 3.57 % of its coverage respectively. Other LULC types with small coverage such as afro-alpine, forest, agriculture, natural forest, plantation, settlements and water body experienced increased rate. Moreover, the LULC changes in DMBN-basin also affected the total soil loss. Thus, the soil erosion yield increased 3.04% (9996 tons/ $yr^{-1}$) in comparison between 1987 and 2017. As a result, the rill and inter rill soil erosion had greatest (over 95%) relation with the dominant agriculture and grasslands during 1987 - 2017. The soil erosion with respect to the agricultural lands showed an increment of 6.13% from the previous agricultural land. In other words, the annual soil loss due to grasslands became decreased by 3.93%. The study also identified the soil erosion severity level, which very slight and slight soil erosion categories (< 5tons $ha^{-1}$ $yr^{-1}$) in DMBN basin is about 76%. On the other hand, about ~23% of soil erosion rate was recorded above the tolerable limit, that categorized medium (~9%), high (~10%), severe (~2%) and very severe level (~1%). In addition, the annual soil loss rate of severe and very severe levels on the steeper slopes have decreased by a little change in vegetation coverage in 2017. However, the total soil erosion had increased due to medium slope areas, where the agricultural activities increased implementation. Overall, the LULC changes analysis and annual soil erosion estimation and mapping its distribution is important and effective for identifying natural resource prone areas. Therefore, the local experts and administrative bodies uses this information to prepare plan for those priority areas to conserve and monitor the degraded resources.

**Keywords**: Debre-Markos Blue Nile Basin, Google Earth, Landsat, Land use and land cover, RUSLE, Soil Erosion.

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# Abbreviations

| | |
|---|---|
| AOI: | Area of interest (training polygons) |
| CBPWM: | Community based Participatory Watershed Management |
| CSA: | Central Statistical Agency |
| DMBN: | Debre-Markos Blue Nile |
| DSMW: | FAO Digital Soil Map of the World |
| EMA: | Ethiopia Methodological Agency |
| ETM+/TM: | Enhanced Landsat Thematic Mapper/ Landsat Thematic Mapper |
| FAO: | World Food and Agricultural Organizations |
| GAS: | Grassland and Marshland |
| GIS: | Geographical Information System |
| Ha: | Hectare |
| Hr: | hour |
| ILRI: | International Livestock Research Institute |
| LULC: | Land Use Land Cover |
| LULCCs: | Land Use Land Cover Changes |
| MJ: | Mega Joule |
| mm: | millimetre |
| MoA: | Ministry of Agriculture |
| NRM: | Natural Resource Management |
| OPI: | Operational Land Imager |
| QGIS: | Quantum GIS |
| RS: | Remote Sensing |
| RUSLE: | Revised Universal Soil Loss Equation |
| SCRP: | Soil conservation and Research Project |

| | |
|---|---|
| SLC-off /on: | A Scan Line Corrector-off/on |
| t: | tons |
| SWC: | Soil and Water Conservation |
| USDA: | United State Department of Agriculture |
| USLE: | Universal Soil Loss Equation |
| UTM: | Universal Transverse Mercator Coordinate System |
| WGS: | World Geodetic System |

# 1. Introduction

## 1.1 The Study Backgrounds

Until today soil erosion is among the greatest environmental problems in Ethiopia. The increase desire for better living including the intensive utilization of natural resources mainly forest, grasslands, wetlands etc. have been the primary causes of soil erosion worldwide (LR, 1992; Pimentel et al., 1995). The erosion rating factors also includes poor cultivation, overgrazing and settlements. Thus, the soil loss leads to the deterioration of land resources, bounce back to minimizing agricultural production and also off-site effects including pollution and sedimentation on the adjacent catchments (Mullan, 2013; Rodrigo-Comino et al., 2017; Borrelli et al., 2018).

Although many centuries passed since serious rural landscape change and its consequences on soil erosion throughout the country have seen, it has become more serious in the second half of the 20$^{th}$ century (McCann, 1995; Hurni et al., 2005). Until 1970s soil erosion had not been broadly recognized and significant soil conservation measures started during the late 1970s (Haregeweyn et al., 2015; Demissie et al., 2017). The soil erosion studies' have been widely raised since the 1980`s and proved that very serious soil erosion severely affected the north and north-western highlands of Ethiopia (Haregeweyn et al., 2015). These areas are well known to be the densely populated areas. In addition, the overall population growth of the country for the last three decades recorded from 40 million to 90 million, of which 84% depends on subsistence agriculture activities and live in rural areas (CSA, 2015). These population growth continuing destroying and pressuring the natural resources.

Accordingly, a large number of people who depend on subsistence rain-fed agriculture make the natural resource even more scarce,  as the farmers have been going to marginal, fragile and steep slope for cultivation and grazing, thereby resulting in a cause of serious soil erosion in many parts of the country (Gelagay and Minale, 2016). The study area Debre-Markos Blue Nile (DMBN) basin found in northwest-central part of Ethiopia, which is characterized as high population area, higher to low altitudes range it leads roughed topography within a short distance and also characterized as erratic rainfall, long-term farming activities have a cause of significant land clearing, that severe soil degradation.

To alleviate such problem, currently, the Ethiopian government is motivating the communities to participate in the extension program for protecting their natural resources and conservation through mass mobilization. However, similar activities started since 1970`s by the Food and Agricultural Organization, World Food Program, the European Union etc. with government and community involvements (Hurni, 1986; Demissie et al., 2017). These practices have been focused on the rehabilitation program mainly afforestation and soil conservation practices to bring radical change (Hishe et al., 2017). Although the current methods of natural resource conservation have been grounded on community-based watershed logic, however, still today these efforts did not meet the desired and expected results (Bewket and Sterk, 2002; Demissie et al., 2017). This day activities have been intervening with the involvements of various Non-Governmental Organizations (NGOs) (e.g. Productive Safety Net Program (PSNP), Sustainable Land Management Program (SLMP), Managing Environmental Resource to Enable Transitions (MERET) etc.

The LULC changes had been the main reason for soil erosion. The depletion of natural resource, especially the depilation of Ethiopia`s forest resources, which started since many years before and it becomes the history. According to an expert discussion by Ethiopian Ministry of Agriculture and Natural Resources; these days the progress report shows that the plantation in most parts of the country has emerged on privet and communal lands. In line with the expert discussion, the previous study showed that increasing plantations, mainly the “Eucalyptus plantation”, emerging including converting agricultural lands for community energy consumption, construction purpose as well as selling its product (Bewket, 2002; Minta et al., 2018). However, the regular monitoring and evaluation of the current resources, in particular, to identify the rehabilitated progress after the implementation activities were done is still challenging.

Obviously, assessment and field measurement of a large area to identifying the resource is time-consuming and labor-intensive. To alleviate this the studies incorporating GIS and remote sensing (RS) in soil erosion estimation. This also helps us to see the spatial distribution for both the LULC changes and soil erosion for each cell by cell-based estimation and also have been being used for a long period of time (Vrieling, 2006; Rodriguez-Galiano et al., 2012), Furthermore, also officers and policymakers are interested in the use of RS and GIS techniques to estimate spatial distribution information with reasonable cost and better accuracy is important to cover big areas (Tadesse et al., 2017).

In this study, it relies on two parts: First one the LULC changes estimation within the past 30 years by taking the reference years 1987, 2002 to 2017, which the reference years are selected based on the availability of data in DMBN basin. Second, the evaluation of the LULC changes that causes annual soil loss and the estimation by using Revised Soil Loss Equation (RUSLE). The RUSLE developed from Universal Soil Loss Equation (USLE), which is widely used and a powerful tool to employ the water erosion estimation (Sun et al., 2014; Wang et al., 2016). Also, the USLE is a significant tool in soil and water conservation of the 20$^{th}$ century but has a certain limitation as it is only applicable for agricultural land with maximum 9 percent slopes and 22.13-meter slope length (Wischmeier and Smith, 1978; Laflen and Moldenhauer, 2003). Therefore, the updated RUSLE method have used in this study for estimating the erosion came from different land use categories such as rangeland, disturbed area, forest and complex topography to estimate annual raindrop erosion using computer assistance including GIS software and also RS data; applicable for wider areas within a short period of time developed by

(Renard, 1997). Due to the fact that, the study area complex train with a different land use types and land cover follows the RUSLE method.

In the case of Ethiopian, the USLE was adapted by the Soil Conservation and Research Project (SCRP) for different agro-climatic categories and reported the annual soil loss amount of 72t $ha^{-1}$ $yr^{-1}$ in north western highlands of Ethiopia (Hurni, 1985). In the current study utilize remote sensing freely available data such as Landsat, Google Earth geo-browser, Digital Elevation Model (DEM) and also the secondary data (i.e. rainfall, soil maps) as well as previous study reports in order to see the change and amount of soil erosion and LULC changes. The broader significance of this study is a quantification of resources that are important for both agricultural and livestock sector developments.

The study focuses on the following two objectives; First, to assess the LULC changes for 1987, 2002 and 2017 in DMBN-basin and secondly to identify and estimate the LULC changes that causes soil erosion for 1987 and 2017 in the DMBN-basin and categorized the soil erosion severity level.

### 1.1.1 Statement of the Problems

In the study area, the LULC changes is the long-term effect of human influence and natural processes. These LULC changes also the main cause that deteriorates other natural resources like water, soil, wildlife, biodiversity etc. As an illustration, some lists of the natural process such us runoff, volcanoes, landslides etc. The study only focuses on those influenced by humans, so-called anthropogenic processes, which is greatly aggravated LULC changes and negatively affected soil erosion.

The anthropogenic process, which is mainly the intensification of agriculture, overgrazing, urbanization and unwise utilization of natural resources, lead to the deteriorating of the vegetation, soil erosion, water quality and quantity and furthermore loss of biodiversity. In addition to this, poor farming for example badly designed and layout of the soil conservation structures and road construction intensifying these negative impacts. As a result, soil surface exposed to water and wind that aggravate the severity soil erosion.

The DMBN basin is the one largest catchment in East Gojjam administrative zone, that its water discharge to the upper Blue Nile. It has a total of 1183.59km$^2$, where the soil degraded largely by rainwater erosion. Furthermore, the soil has been washed away and transport by small tributaries. About 83 to 89% of soil erosion predicted approximately 43 to 46% of agriculture lands in the DMBN-basin. These areas are threatened by severe soil loss annually which also predicted an average of ~53 t ha$^{-1}$ yr$^{-1}$. In the basin as well as in East Gojjam part of the western highland area the sheet and rill erosion from the current traditional agricultural practice, free grazing, deforestation and the like are visible evidence. These cause a severe nutrient loss, that consequence of the decreasing agriculture production in upstream areas and sedimentation in lower catchments and reservoirs. To alleviate this quantifying the LULC changes and soil erosion with less cost per short period of time can contribute to the proper management of natural resources.

### 1.1.2 Significance of the Study

The study will be conducted in areas dominated by agriculture and grasslands and the wider agro climatic difference within a short distance. Due to this facts, the study is most important to provide information about the factors that lead to LULC changes and soil erosion within this range. This study, therefore, will help local workers, professionals and decision making bodies to track and monitor the current massive soil and water conservation and seedling plantation activities progress in the study area; and thereby helps to reclaim seriously affected or susceptible lands from further degradation by adding additional effort.

The quantification of soil erosion and LULC will be important to integrate soil erosion protection into agricultural and livestock sector to incorporate in the development plan. In this regard, the study will have a paramount contribution to the sustainable economic, environmental and social development. Therefore, this study will contribute and lay down a technical and a theoretical baseline information for policy recommendation in onsite and offsite management and planning of watershed area so as to better conserve the natural resource and improve the livelihood of the surrounding community at basin level to monitor and support from zonal/district level.

### 1.1.3 Research Hypothesis, Questions, and Theory of the Study

In this study, it has hypothesized that in Debre-Markos Blue Nile (DMBN) basin there is significant soil erosion problem, which is suspected to be the consequence of previous LULC changes. Secondly, the management practice within community mass mobilization to conserve natural resource brings significant changes for rehabilitating degraded lands and from soil and water conservation. This hypothesis tested by the following scientific questions;

- Which LULC are most prominent to change the year between 1987, 2002 and 2017?
- How much and which of the LULC changes have caused soil erosion in the study area?

The theory will be separated to answer the research questions; The time serious analysis of LULC changes by using satellite images to clearly quantifying, understanding the changes at big scales including unreachable areas. This is working on categorizing various images features by taking representative samples, which is training data and classified in specific LULC types. Second theoretical background the soil erosion is related to the detachment, transport then accumulates of soil particles in which the soil and its surface exposed to erosion agents. The loss estimated by RUSLE and identifying which factors lead to maximum soil erosion. Therefore, theoretical approaches include analyzing LULC changes, rainfall, soil types, soil length-steepness and conservation management factors.

# 2. Literature Review

## 2.1 Watershed in Ethiopia Context

In Ethiopia planning the development of community-based watershed started in 1980`s. The purpose mainly conservation of natural resource program including multidisciplinary approaches, that integrating with animal science and plant science. As an expected result this approaches has unsatisfactory result due to lack of community participation and limited sense of responsibility. Therefore, understanding participatory watershed development approach was adopted to improve the livelihood of community/households in rural Ethiopia through comprehensive and integrated natural resource development (Lakew Desta, 2005).

## 2.2 Land Use and Land Cover and its Classification

The land cover and land use are different terms but being used interchangeably. FAO define land cover is the observed bio-physical cover of the earth, whereas land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover types to produce, change or maintain it and related to land cover that the action of people in their environment (Di Gregorio, 2000; Fisher et al., 2005). This land resources also categorized under different land cover/land use which is occurred in different ecosystem either terrestrial or aquatic environment, that also founded naturally or artificially.

The term definition of LULC types found in DMBN-basin partly based on Forest Resource Assessment (FRA) definition) (FAO, 2015). Some are listed below.

Forest: Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent.

Woodland: The canopy cover of trees is less than 5 percent but the combined cover of shrubs, bushes and trees is more than 10 percent. Includes areas of shrubs and bushes where no trees are present.

Afro-alpine: With tree species that will not reach a height of at least 5 meters and with canopy greater than 10 percent or more have categorized as other woodland.

Plantation: Plantation with the primary purpose to produce wood or wood-derived products are considered as forests, not includes other goods, such as coconuts or other fruits. Furthermore, gardens, agroforestry areas and urban parks are not considered as forests.

Shrub: Woody perennial plant, generally more than 0.5 meters and less than 5 meters in height at maturity and without a definite crown.

Agriculture: Land predominantly used for cultivation including agroforestry systems when crops are grown under tree cover.

Grassland: Land opened area cover with grass and other low plants suitable for grazing, especially cattle.

Settlement: Place where peoples established for reside and develop an infrastructure such as built up, roads etc. in urban or suburban areas.

Inland water: Inland water bodies generally include major rivers, lakes and water reservoirs

The LULC changes are mainly excessive extraction forest products to meet the high demand for fuelwood, charcoal, construction, timber, fodder and other forest products and also unsustainable intensifications in smallholder agriculture, rangeland, urbanization includes built up, paved ground toward the forest and rural areas (Lambin et al., 2001). The LULC changes are also the change in the physical as well as the biological characteristics of land; it is also past and current global concern and determining the analysis of trend, causes and consequences is important for the sustainable plan, management, and development (Haregeweyn et al., 2015). The LULC changes and its causative factor is complex and dynamics mainly manipulated by natural and socioeconomic factor and common in local, regional, national and global level mostly in negative manner (Minale, 2013) and also refers the complete replacement of one land by others but does not always indicates as negative manner (Bewket, 2002; Lambin et al., 2003). In most cases, the agriculture in rural and built-up near to urban areas are intensively accelerated (Mather and Needle, 2000). This leads to severe soil erosion, land degradation, destruction of biodiversity, vegetation loss etc.

For LULC analysis most studies are utilizing aerial photo and satellite images. In Ethiopian condition such studies are at micro level specifically at watershed base. To mention few Bewket (2002) and Teferi et al. (2013) analysis the LULC trend for half decades by using aerial photos, multispectral spot images and Landsat. Such kind of study are the base to similar studies in the country. In addition, researches showed that agricultural and settlement increases related with population growth (Bewket, 2002; Hurni et al., 2005). Ariti et al. (2015) and Demissie et al. (2017) also stated the common drivers of LULC changes are population growth, drought, civil unrest, governmental change and land tenure policy. Lack of institution coordination, lack of information on best practice, poverty, less alternative livelihood incomes and illiteracy causes LULC changes (Ariti et al. (2015). In addition to that, in arid and semiarid area of the country, the environmental degradation such as drought causes to declining the rangelands, that influenced the livelihood of the community (Kassahun et al., 2008). Therefore, the local level LULC dynamics studies can help to design more effective land management strategy in the future, if it will be incorporated with local administrative bodies.

Remote sensing is efficiently used technology for mapping LULC changes or change detection study less cost and relatively within a short period of time. There is no conventional methods through ground survey because it could not impossible to implemented for inaccessible areas or wider range (Kindu et al., 2013; Demissie et al., 2017). In LULC classification also there is no logical reason to expect that one detail inventory should be adequate within a short period of time, that the LULC pattern changes keeping the demanding of a natural resource. So the need for mapping and classifying by remote sensing is important (Anderson, 1976). Such study starts since in mid-1940`s Francis J. Marschner began mapping major land use association for the entire US, using aerial photographs taken during late of 1930`s and the early 1940`s. and also in 1969 and 1970 start using computer manipulation to aerial photograph analysis. The USGS has been the core of LULC historical research and mapping application since 1960`s (https://landcover.usgs.gov/).

In LULC change detection approach have different methods includes traditional post-classification cross-tabulation method called Unsupervised Classification, cross-correlation analysis, a neutral network which working on mainly training data and Supervised Classification and image segmentation and/or object orientated classification. These different methods of using satellite images with computer-assisted result comparison that there appears to be no single best way in which to perform estimate the change (Civco et al., 2002).

For environmental planning and management strategies accurate information of LULC is basic (Demissie et al., 2017). For such studies Landsat freely available data frequently used to analyzing the LULC changes. Few other examples for similar studies are MODIS, Sentinel for LULC and DEM for erosion estimation, which freely provided by sources such as USGS, NASA, NOAA, SRTM, Global Land Cover etc. It is also possible for regular monitoring the earth but certain limitations on getting higher resolution images for different time serious.

However, the compensation between getting higher resolution images with minimum cost was still difficult. The current study uses Landsat i.e. medium spatial resolution but higher spectral resolution and the primary training data sources was GE geo-browser, that has higher spatial resolution but lower spectral values for better final result of the Landsat images.

This LULC classification tells us the quality of life of population and its growth, the agriculture expansion and urbanization, which impact on natural resources (Coulter et al., 2016) and this LULC map further important for analyzing the level of soil erosion, landslides, land use and urban planning, carbon and ecosystem value estimation etc. (Reis, 2008).

## 2.3 Google Earth Base Classification

"Google Earth (GE) is a geo-browser that offers satellite and aerial imagery, ocean bathymetry, and other geographic data over the internet to represent the Earth as a three-dimensional globe (Google-Earth, 2007). It has free to access, easy to navigate, is distributed across the region and valid source of data in LULC mapping and similar study (Jaafari and Nazarisamani, 2013). The source of images are mostly cover by Digital Globe images which is from Quick Bird satellites launched on October 18, 2001, which is Digital Globe's primary satellite until early 2015 (https://en.wikipedia.org/wiki/Digital Globe.). The other advantage of using GE provides it is possible to use historical imagery can be a very useful tool when utilized in the right circumstance and it enables to analyze the change in the landscape over time (David G.Jones, 2016).

As many studies stated GE is higher spatial but less temporal resolution. (Hu et al., 2013; Malarvizhi et al., 2016) stated that for GE earth is direct data source and used for heterogeneous landscape. GE for appropriate training data collection from each LULC (Ishihara and Tadono, 2017). In other hands (Hu et al., 2013) compares Quick Bird (QB) satellite images with GE imagery and they found slighter lower accuracy with QB. In addition, Potere (2008) comparing GE image with Landsat image by using 436 control points in 109 cities in developed and developing countries all over the world and found that the estimate in horizontal position accuracy of Ortho-rectified Landsat Geo-Cover is less than 50 meters' root mean square error (RMSE). The control points derived from satellite images have an accuracy of 22.8 RMSE and the GE is 39.7-meter RMSE and aerial photo that has the RMSE 41.3 meter. Thereby the GE help to collect polygons/control points of the planned areas (Potere, 2008).

Lu et al. (2015) used the GE as validate the unchanged points (no change pixels) were taken from MODIS. The points collected from among the long-term serious images for different years of MODIS have used for LULC classification. However, to solve this coursed values they used GE to screen out and verification of no change points those previously taken. The final training points obtained from screening result to minimize generalization used for Landsat classification with good Kappa coefficient.

To say few, GE earth is useful tools for urban area change detection studies by direct screen digitizing (Malarvizhi et al., 2016, Wibowo, 2016 #56); it also, the higher resolution of GE is important to have an accuracy assessment of classified images when impossible to take ground truthing (Tilahun and Teferie, 2015), it is also for LULC classification (Jaafari and Nazarisamani, 2013; Lu et al., 2015), for soil erosion mapping (Boardman, 2016) and others similar studies. In addition, the study uses GE as primary training data sources that are compensation some limitation such as lack of image availability (e.g. blurred images) from GE.

The few list of limitation of Google Earth is the one different temporal frequency and other is impossible to obtain multispectral band data that includes limited to get pixel number and the brightness or reflectance values and have limitation to Supervised or Unsupervised Classification (Malarvizhi et al., 2016). It is also limited to downloading big area image and a serious of images will be time taking during image geo-referencing and less accurate between the mosaicking images.

Therefore, for this study able to see alternative method of LULC training data collection using GE because high spatial resolution characteristics. The flowchart presented in Figure 4 have shown the steps forward to superviessed classification.

## 2.4 Soil Erosion by Water

The process of soil erosion by water is the detachment of soil particles by raindrop, transport and then flowing water until it accumulates during losses its energy (Wischmeier and Smith, 1978). The deterioration of the soil as a result of human intervention and recognized a serious widespread problem and their spatial distribution is only known roughly (LR, 1992). This soil erosion is a cause of land degradation is amongst the leading environmental problem in various time scale from single storm to many decades (Le Roux et al., 2007). Increasing the rate of soil erosion that aggravate the loss of nutrient and its final consequences of decreasing the productivity of the area. As an illustration the soil organic carbon is a part of soil nutrient and also the adversely affect the soil productivity and environmental quality (Flügel et al., 2003; Lal, 2004) and also surface water pollution and downstream siltation and sedimentation (Mullan, 2013; Rodrigo-Comino et al., 2017; Borrelli et al., 2018).

In addition, the soil erosion also an implication to climate changes as the soil carbon is 3.3 times the size of the atmospheric pool (760Gt) and 4.5 times the size of the biotic pool (560Gt.). However, the conversion of natural ecosystem to agricultural ecosystem causes depletion of the soil organic carbon pool by as much as 60% in temperate and & 75% or more in tropical regions. Therefore, soil organic carbon also removed by mainly water and wind soil erosion. Some are redistributed others are deposited in depression site or aquatic ecosystem the rest emitted to the atmosphere (Lal, 2004).

The past study showed 1.5 billion tons of topsoil have been annually lost from the highland of Ethiopia (Braimoh and Vlek, 2008). As a base of population growth demand of forest increment and about 20 thousand hectares of forest are harvested annually in the Amhara region without replaced adequately, soils are exposed to high intensity of rainfall and the replacing and conservation interest of community in most parts country has been willing to planting only Eucalyptus for their consumption (Desta et al., 2000).

In General, the net consequence national soil loss rate as moderate to high which estimates 20 to 100 t/ha/yr with annual productivity loss on cropland 0.1% to 2% of the total production and have an economic implication. In addition to this, in Amhara regional state the soil loss rate was estimated about 58% of coverage of the national soil loss rate but accounts one-sixth of the nation as cited and reviewed by ILRI (Kappel, 1996; Desta et al., 2000). Therefore, the soil loss from this region is very high due to higher rainfall, and very thick agriculture activities and very deep and loosen types of soil in most part of the region.

Land cover is one of the major factors that determine the rate of soil loss implication for soil degradation, hydrological balance by water retention, flooding and sedimentation (Bewket, 2002; Wang et al., 2016). The population growth exaggerated the use of marginal and fragile land such processes aggravate soil erosion (Gelagay and Minale, 2016).

According to USDA the average rate of soil loss each feasible alternatives combination of crop system and management practice in association with specific soil types, rainfall pattern and topography. From this it is possible to estimated soil loss by universal soil loss equation (USLE) (Wischmeier and Smith, 1978). The method was later developed in to Revised Universal Soil Loss Equation (RUSLE) framed with wider range for different cover types and complex topography assisted by computer system (Moore and Wilson, 1992; Renard, 1997). GIS and RS techniques of estimating the mean annual soil loss with relatively large data, within a short period of time (Seutloali et al., 2017) but the RUSLE by GIS and RS is still limited to estimate the gully erosion due to less spatial and temporal resolution (Le Roux et al., 2007; Gelagay and Minale, 2016).

Eventually, Hurni (1985) adopted USLE in Ethiopian condition for different cover types, management activities and slope ranges. Therefore, recent many studies also using RUSLE for a wider range soil erosion estimation, that includes from single to grouped micro watershed study. The GIS and RS environment also predict the measurements cell by cell-based estimation. The current study similarly employed RUSLE at basin scales, that included different micro-watersheds.

# 3. Methodology

## 3.1 Study Area

The study area, the DMBN-basin in East Gojjam, Ethiopia is presented in Figure 1. A country located in eastern Africa and DMBN-basin approximately located longitude and latitude ranges from 37° 16' 38" to 37° 53' 07"E and 10° 00' 15" to 10° 38' 42"N respectively, which is central part of north-west of Ethiopia, that far from 300 km north west of the capital city, Addis Ababa.

The basin delineated from the Digital Elevation Model (DEM) based on East Gojjam administrative boundary. Identified as one of the basin in East Gojjam, which is part of bigger Blue Nile Basin. The upper catchment, that started from "Chokey Mountain" ecosystem. DMBN-basin includes "*Chemoga*" and "*Weterene*" main rivers watershed. The climate varies significantly along with altitude gradient but generally characterize wet during summer, with heterogeneous land features ranges from 3960 m.a.s.l "Chokey" (afro-alpine) ecosystem to 880 m.a.s.l Blue-Nile Gorge (Semi-dry area). The estimated shortest flight distance 78km. The landscape divided into rugged topography to relatively flat terrain. This basin covers a total of 1183.59 sq.km (118,359 hectares) including Debre-Markos town at the center and parts of different rural districts namely Gozamen, Senane, Basoliben, Debay-Tilatgen, Andede and small parts of Awebel.

The area mainly has three agro-climatic zones, which is moist "Dega" (colder) with the main agroecosystem is afro-alpine habitat, "Woyna-Dega" (medium temperature) and "Kola" (relatively hot) that characterized by relatively low rainfall, which is higher, middle and lower altitudes respectively. These ecosystems have no clear boundary transition from one zone to other (Simane et al., 2013). The estimated population is 212, 912 from population density shapefile of CSA-Ethiopia. The mean monthly temperature is ranges from 14 to 18°C (Weatherbase, 2017) and average mean annual precipitation is about 1421mm from nearest surrounding eight station (EMA) and the area main rain season in "*Meher*" season range from the June to the mid of September. In addition, this area is also upper part of Blue-Nile basin, which is the majority of water source for the Nile river.

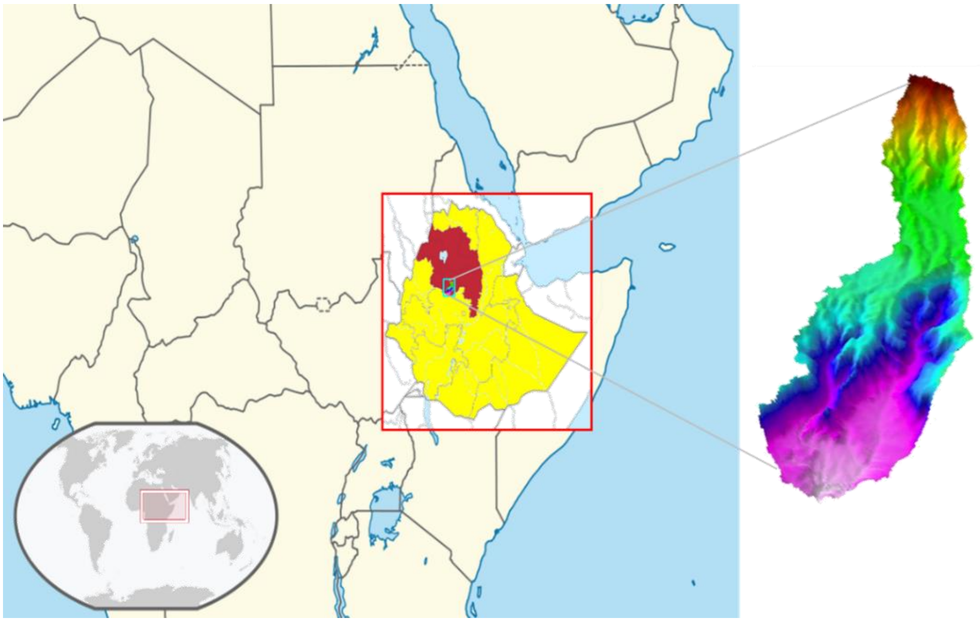


Figure 1. Geographical location of the study area. a) Ethiopia; b) Amhara regional state; and c) DMBN basin

## 3.2 Land Use and Land Cover Classification

### 3.2.1 Data Collection

The data collection was compiled for both LULC changes analysis and soil erosion identification and estimation. It has collected tiff files of Landsat TM 5 for 1987, Landsat 7 ETM+ of 2002 and Landsat 8 OLI for 2017 for LULC classification, the data acquisition month was January and February, which is dry season in the area. The Landsat and DEM resolution/cell size is 30*30 and its data source was (USGS.gov, 2017). The acquired Landsat image with cloud cover less than 10% for all images. Also, software used for analysis was ArcGIS 10.1 and ERDAS Imagine 9.2.

The novelty of this work to perform mapping relatively heterogeneous LULC classification in the basin by using Google Earth (GE) geo-browser, rather than Landsat standalone classification. GE helps in the first steps of taking samples polygons or areas of interest (AOI) to train latter the Landsat images. The polygons created in GE was similar to GPS ground truthing points for pre-image classification. Totally 218 unchanged points were collected. The unchanged points were the same LULC types in 2004 (validated later by 2002 Landsat) and 2017 from GE geo-browser. The collected points from GE have used to train 2002 and 2017 Landsat image.

The validation was the cross-checked done by identifying inappropriately fallen points to Landsat such as fall into different pixel from pervious GE or due to a clouded pixel in Landsat were excluded. Whereas, for 1987 Landsat image it has not been used GE due to unavailability during that time period. Based on the functional points with few additional training points are also taken directly from Landsat to improve the accuracy of the primary classification and then reclassified final outputs of both 2002 and 2017. The added and minimized training dataset are as presented in Table 1.

In primary data collection, it was included 165 GPS field verification waypoints from July to August 2017 utilized for accuracy check. These points are independent of those used as training points from GE. All the data from different sources was georeferenced to map projection UTM Zone 37N, WGS 1984 datum and ellipsoid then image subset, a radiometric correction such as image enhancement and noise reduction was done for Landsat images. Also, for 1987 and 2002 accuracy check a total of 96 and 105 respective randomly generated reference points from the original Landsat images that representing each LULC class using GIS 10.1 were produced. This is an alternative way which the time being the ground truth data is impossible to collect (Howdy, 2016). This because of lack of data access and references for back years 1987 and 2002.

Table 1. Training points collected from GE and Landsat for each LULC types

| LULC | 1987 | Google Earth Based Classification | | | | |
|---|---|---|---|---|---|---|
| | | GE-unchanged points | 2002 | | 2017 | |
| | | | Used | Added/ minimize | Used | Added/ minimize |
| Afro-alpine | 9 | 22 | 11 | -11 | 11 | -11 |
| Agriculture | 20 | 50 | 49 | -1 | 49 | -1 |
| Forest | 15 | 40 | 36 | -4 | 41 | 1 |
| Grassland | 33 | 50 | 50 | 53 | 50 | 1 |
| Plantation | 16 | 30 | 26 | -4 | 30 | 13 |
| Shrubs | - | 10 | - | -10 | - | -10 |
| Water | 3 | 6 | 6 | 0 | 8 | 2 |
| Woodland | 10 | 10 | 10 | 0 | 10 | 0 |
| Total | 106 | 218 | 188 | | 199 | |

In the second part, for annual soil erosion analysis the data collection includes secondary data such us twenty years (1995-2015) mean annual rainfall data of eight stations as presented in Table 9 and appendices 4 its sources was EMA, Soil map from Digital Soil Map of the World (DSMW) (FAO, 2007), and also each cover factor and management practice factor adapted from the previous literature.

### 3.2.2 LULC Classification Analysis.

Image classification and detecting the change of LULC by using Landsat images. Pre-training data, collected previously from GE were used for a pixel-based Landsat supervised image classification. The step by step flow chart has presented in Figure 4. The collected training data from GE projected to UTM zone WGS 1984 37N and exported as vector format to train Landsat image of the year 2002 and 2017 for final implementing Supervised Classification.

In the part of pre-classification, the higher spatial resolution GE geo-browser was functional for to clearly seen each LULC. From the distinguishing features of the GE such as; 3D viewing helps to see in different direction especially area hilly or gorge areas similarly hidden LULC types. Also the site-specific altitude on GE using to partly differentiate specific vegetation ecosystem where which kind of specious grown in that area. The overall GE easily identify natural or artificial LULC types as presented in figure 2 and 3. Generally, that enables us identifying relatively diverse features than Landsat. In addition to that, it could easily identify the shape, color, and textures of each LULCs from GE. This helps to extract higher confident training data for final classification.

As an illustration, in relation to altitude difference, it enables to identify the woodland better identified from afro-alpine, forest, and plantation. For example, afro-alpine in higher altitudes different ecosystem with woodland in lower altitudes was good examples in the basin (Figure 3 c and d). Woodland is found below 1500 m.a.s.l commonly acacia species. In other hand, afro-alpine found above 3500 altitudes and it was clearly seen from GE. Whereas, natural forest and plantation is different texture, shape and also a little difference in color with woodland. GE is recommended for distinguished sound features for training points. Such training point collection techniques useful for areas to extracted fragmented LULC of the DMBN basin.

Before scientific LULC classification, it was also seen some changes by visual interpretation from the GE features. For examples, agricultural lands change to plantation woodlots, this commonly near to residential areas and roadsides. In addition to this, it has seen the burnt area in the lower elevation, that was the lower part of the basin. The fire occurrence in the lower part of the study site has been more frequent and it was possibly identified from both from GE as well as Landsat. Furthermore, in order to quantify its area coverage, the image analysis was needed using available resources.

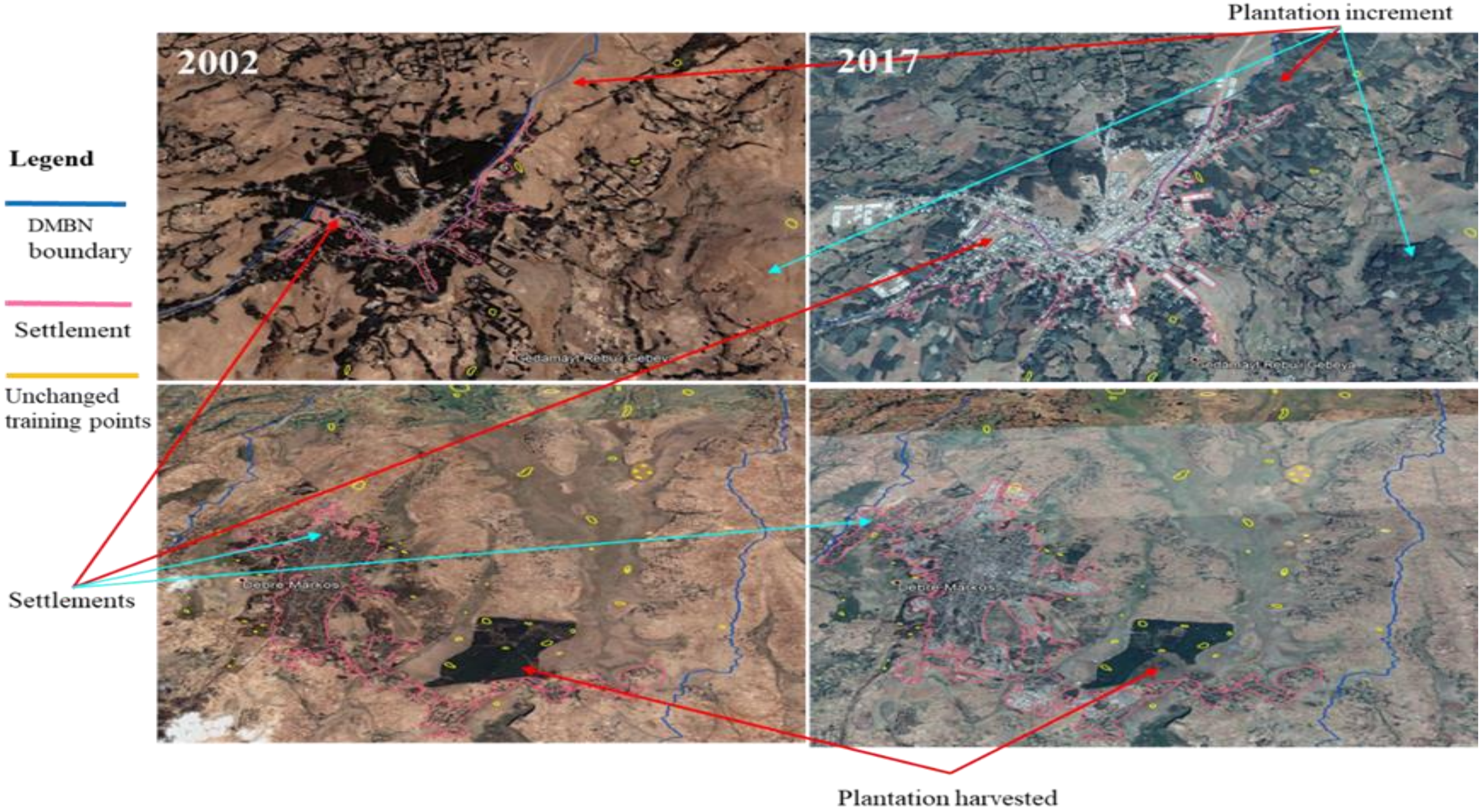



Figure 2. GE unchanging points and some LULC changes comparison

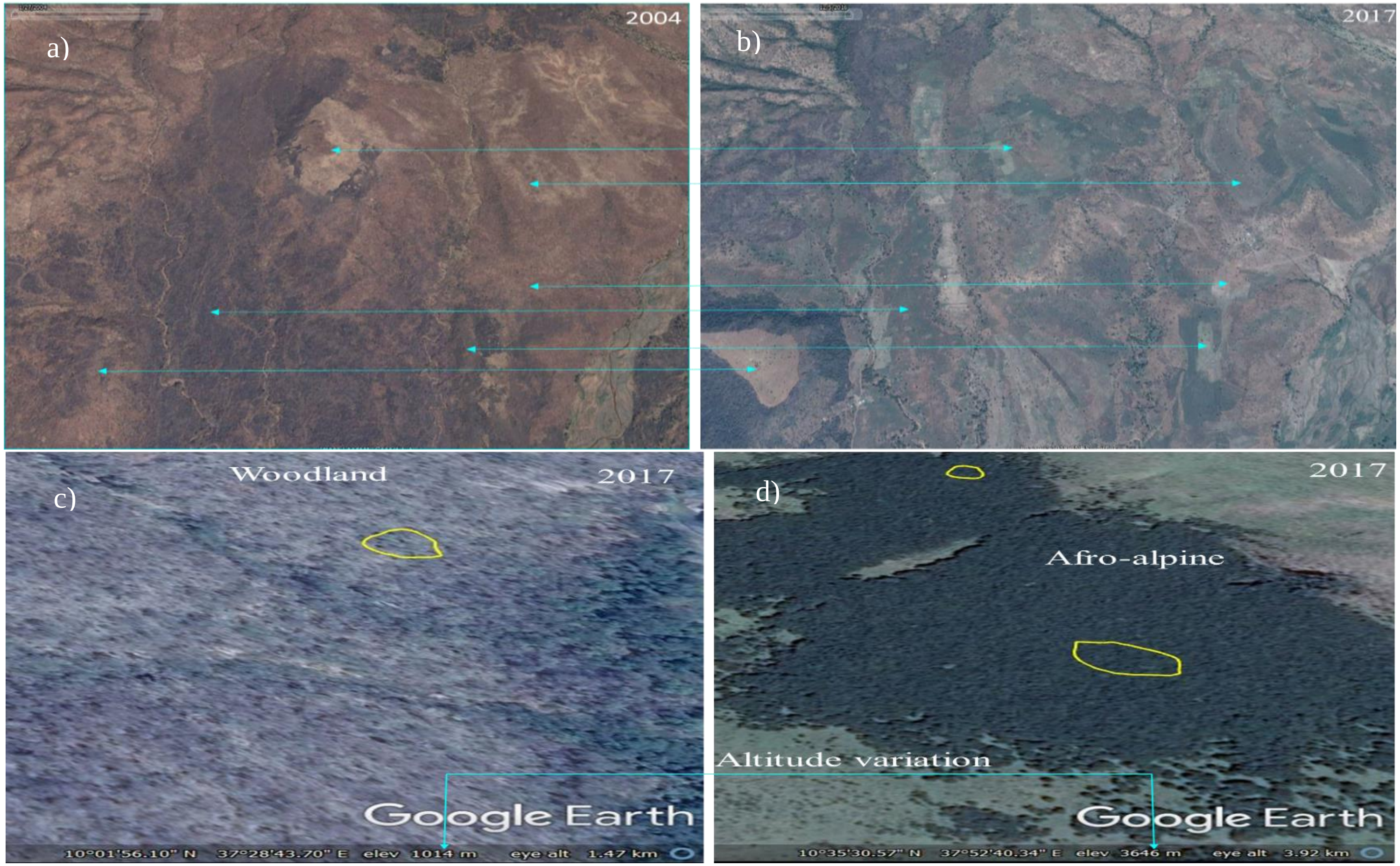



Figure 3. The LULC change GE pictures (a) to (b) and altitudes difference (c) woodland and (d) Afro-alpine

The study considered 2004 GE collected training data for later classification of 2002 Landsat image. This is because on GE of 2002 was fully blurred and not available for the time being. Thus in the current analysis, the training data of 2004 for 2002 are validated and cross-checked. From the total unchanged training points for both year (2002 and 2017), 86% were functional for the year 2002. Its percentage of functionality was decreased with relative to 2017, which have been used 91% of them. The main reason to choose 2002 due to SLC-off of Landsat 7 ETM+ image for the image year 2004. The primary result on 2004 Landsat was less accurate, even if the gap-filling techniques were implemented. Therefore, we chose 2002 Landsat with 2004 GE training points for latter crosschecked. However, due to unavailability of GE-geo-browser for the year 1987, which was used only Landsat image by referring the recent GE (after 2004) and the classified map of 2002 and 2017.

The GE also used for direct digitizing for settlement areas. The fact that the similar reflectance value of the settlement to various LULC such as agriculture, bare lands and grassland, it will lead confusion in the final classification. To minimize this errors, we digitize part of settlements/urban areas directly from GE. This enables decreasing the confusion between urban/settlement with other LULC for better LULC mapping.

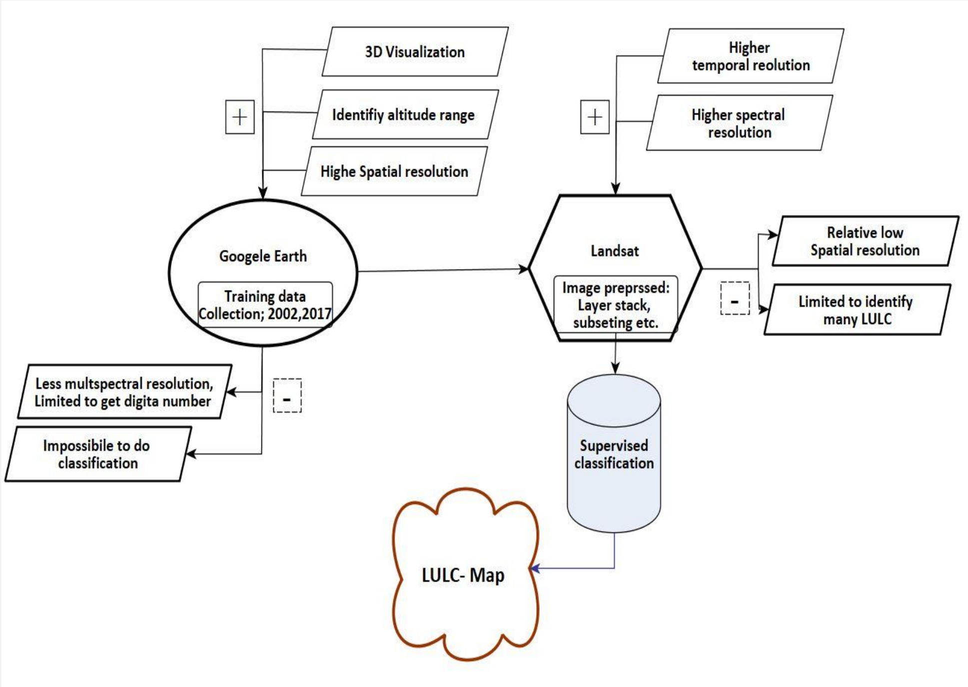



Figure 4. Classification flow chart

### 3.2.3 Accuracy Assessments Samples

The accuracy assessments were done by two different methods. For the accuracy assessment of the year 2017, totally 165 field verification points were collected during July to August 2017. These points have independent of those used as training samples for Landsat classification. These ground-truthing way points were used only for 2017 classification accuracy assessment. For others 2002 and 1987 classification we produce various points from the original Landsat images that representing each LULC class using GIS 10.1. This is an alternative way whereas the time being the ground truth data is impossible to collect, thus reference points randomly generated using Arc GIS by point screen digitizing from original Landsat image (Howdy, 2016). Because of lack of data access for years 1987 and 2002, the classification accuracy of the map was estimated by taking representative samples points from original Landsat image using Arc GIS 10.1 by point screen digitizing methods. These representative points used for accuracy check, other than training points were 96 and 105 for the year 1987 and 2002, respectively. Thus accuracy of the map was done accordingly for 1987 and 2002.

## 3.3 Revised Soil Loss Equation (RUSLE)

The USDA developed the main reference for soil conservation called Universal Soil Loss Equation (USLE). This method is very practical, widely used and powerful, primarily designed the long-term average soil loss caused by rill and inter-rill erosion (Wischmeier and Smith, 1978). The USLE have certain limitation with specific sites for agriculture land and flat train, it did not account spatial dynamics of erosion processes but later developed to Revised Universal Soil Loss Equation (RUSLE) which formulated to computerized based algorithm for raster grid cell estimation for various land use and topography (Renard et al., 1991; Renard, 1997; Lu et al., 2004). The estimate annual soil loss by GIS and Remote Sensing techniques enables us to conduct cell by cell calculation and possibly identifying the major area soil risks and important for taking measures (Gelagay and Minale, 2016). The model quantitatively estimates by the following empirical equation developed by (Wischmeier and Smith, 1978) will be used. The USLE also revised to RUSLE developed for a various wider range of heterogeneous area computed by computer-based estimation (Renard et al., 1991).

$$A = RKLSCP \qquad \text{Equation 1}$$

Where: - A is estimated annual soil loss (t $ha^{-1}$ $yr^{-1}$), R (MJ.mm $ha^{-1}$ $hr^{-1}$ $yr^{-1}$) is rainfall erosivity factor from mean annual rainfall and K (t-ha-hr $ha^{-1}$ $MJ^{-1}$ $mm^{-1}$) is soil erodibility from soil map and the other factors LS is slope length & steepness factor drives from DEM, C is the cover factor and P is supportive practice factor adapted from the previous study. LS, C and P; are unitless.

The diagram in figure 5 shows the illustration workflow and direction of annual soil loss.  This work flow shows the steps of each five factor estimation and mapping to rich the final annual soil loss estimation by an empirical formula Equation 1. This model estimating annual soil loss with less cost and within short time period. Whereas, relative field experimental methods are much more expensive, laborious, need much follow up and not always possible to acquire field measurement especially in large areas. It helps for experts and decision makers to understand each factor to take measures and plan.

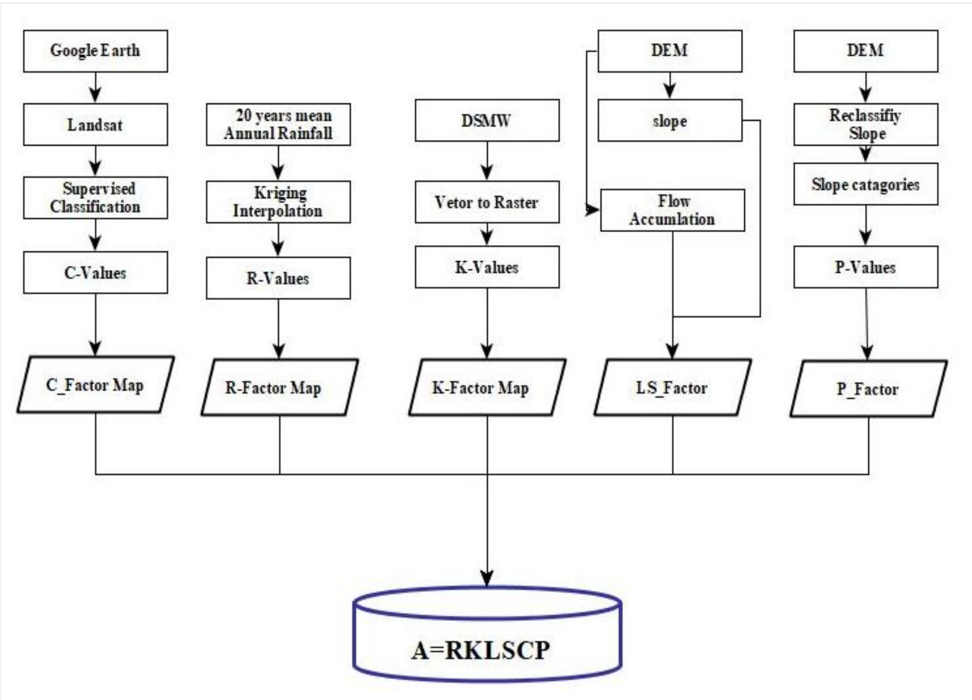



Figure 5. Annual soil loss model diagram.

### 3.3.1 Rainfall Erositivity (R) Factor

The rainfall factors (R) that determine the average annual soil loss is must include the cumulative effect of many moderate size storms, which equals to total storm energy (E) within 30-minute intensity ($I_{30}$) (Wischmeier and Smith, 1978). Therefore, the main determinant is the intensity of rainfall that higher amount of rainfall within a short period of time or erratic rainfall is higher impacts than with much volume with a long period. The USLE developed by Wischmeier and Smith (1978) is adopted in Ethiopian condition through soil conservation research project (SCRP) by composed about 30 individual storms per year on average, and reported the measured and predicted with USLE remarkable higher linear correlation function (Hurni, 1985) expressed by Equation 2. and the current study finally used the following formula.

$$R = -8.12 + 0.562P \qquad \text{Equation 2}$$

Where R is rainfall erositivity factor, P is mean annual precipitation of the different station as listed in Table 7. The rainfall data used are the mean annual rainfall of 20 years' data collected from Ethiopia methodological Agency (EMA) inside and nearest neigbouring to the DMBN basin from 1995 to 2015. The erositivity computed by raster interpolation, which was kriging interpolation function from eight stations recommended by (Mair and Fares, 2010; Mahalingam et al., 2015). The final erositivity values computed each cell and resample into 30m*30m as the same as all other parameters.

### 3.3.2 Soil Erodibility (K) Factor

Soil erodibility is the physical isolation of soil particles by water, wind and any other agents. The soil water erodibility (K-factors) depend on the sand, silt, clay and organic carbon component of the soil. And also the erodibility depends on the physical and chemical properties of the soil that is inherent resistance from erosion (Wischmeier and Smith, 1978). Soil classification based on texture classes reflect the relative proportions of clay (fraction less than 0.002mm), silt (0.002 - 0.05mm) and sand (0.05 - 2mm) in the soil (Sharpley and Williams, 1990). According to these three textural classes are recognized, the first classes are under coarse soil categories such as sands, loamy sands and sandy loams with less than 18 percent clay and more than 65 percent sand. Second, the medium soil texture are sandy loams, loams, sandy clay loams, silt loams, silt, silty clay loams and clay loams, which has less than 35 percent clay and less than 65 percent sand; the sand fraction sometimes be as high as 82 percent if a minimum of 18 percent clay is present; and finally the fine categories under clay, silty clays, sandy clays, clay loams, with more than 35 percent clay content (FAO., 2007).

As shown in many studies for erodibility analysis it is only considering the topsoil because of the soil vulnerable to water erosion and transport is the main part of the topsoil. For this analysis the soil data source from FAO-DSMW (FAO., 2007). The formula used for to get each soil types K values by Equation 3 to 7 recommended by (Sharpley and Williams, 1990; Wiliams, 2002) and this formula was tested suitable for indirect K factor estimation (Wawer et al., 2005; Anache et al., 2016). The data also vector format was changed to raster format after calculating K factor in Arc GIS tools.

$$K = A * B * C * D * 0.1317 \qquad \text{Equation 3}$$

Where A is the first factor that gives low soil erodibility is soil with coarser sand contents and high values of soil with little sand; B the second factor that gives low soil erodibility factors soils with high clay to silt ratios. The next factor C that reduces soil erodibility that the soils with high organic carbon contents and The final, D factor that reduces soil erodibility for soil with extremely high sand contents mostly sands greater than 70% (Sharpley and Williams, 1990). The A, B, C and D was evaluated by the following equations separately.

$$A = 0.2 + 0.3 * \exp\left(-0.0256 * SAN * \left(1 - \frac{SIL}{100}\right)\right) \qquad \text{Equation 4}$$

$$B = \left(\frac{SIL}{(CLA + SIL)}\right)^{0.3} \qquad \text{Equation 5}$$

$$C = \left[1 - \frac{0.25 * OC}{OC + \exp(3.72 - 2.95 * OC)}\right] \quad \text{Equation 6}$$

$$D = \left(1 - \frac{0.7 * SN1}{SN1 + \exp(-5.51 - 22.9 * SN1)}\right) \quad \text{Equation 7}$$

Where K USLE -factor is finally multiplied by 0.1317 to get real K that is conversion factor real SI unit and to get final erodibility by t-ha-hr $ha^{-1}MJ^{-1}mm^{-1}$ recommended by Wischmeier and Smith (1978). Whereas, SAN, SIL, CLA, and OC are the sand, silt, clay and organic carbon contents of the soil in percent and SN1 a shortened form of 1-SAN/100.

### 3.3.3 Slope Length Steepness (LS) Factors

The LS-factor is the "topography factors", a combination of two factors, which is slope length (L) and slope steepens (S). The L is the distance between the source to the slope gradient decreases (deposition started) or runoff become concentrated in the defined channel (Wischmeier and Smith, 1978). Also, S reflects the influence of slope gradient on erosion (Renard, 1997). The slope length and steepens substantially affecting the development of sheet and rill erosion (Lee et al., 2017). For calculating both the LS-factor there are various formula has been used to because it is more sensitive than all other factors (Meshesha et al., 2012b).

In areas for three-dimensional terrains based on the stream power theory, the LS-factor is a measure of the sediment transport capacity or runoff from the landscape, which includes the upslope contributing area per unit width (Moore and Burch, 1986). The total of all contributing area is the summing of upslope grid cell which is driven from DEM that drain into, it is called flow accumulation (Mitasova and Mitas, 1999). In RUSLE the LS-factor including complex train and different land cover categories that estimates rill and inter-rill (sheet) erosion for specific sites rely on computer-based estimation (Blanco-

Canqui and Lal, 2010). Erosion also more sensitive to slope steepens than slope length. For both LS-factor mapping, the effect of hydrology and 3D natural train should be included and also considered in flow divergence and convergence of upper slope contributing area (Moore and Wilson, 1992; Mitasova and Mitas, 1999). Therefore, the current study employed Equation 8 suggested by (Moore and Wilson, 1992; Mitasova and Mitas, 1999).

$$LS = (A/22.13\ )\ \text{^}m\ * (\sin(t)/0.09)\ \text{^}n * (m+1) \qquad \text{Equation 8}$$

Where A = upslope area/per unit contour width; 22.13m is slope length of the RUSLE experimental unit plot; m is the slop length exponent, i.e. m is ranges from 0.4 to 0.6 (m = 0.4 was used mostly recommended when the dominant land is rangeland and agriculture); n is the experimental slope angle 9% of RUSLE, i.e. n is ranges from 1.2 to 1.3. (Moore and Wilson, 1992; Renard, 1997) and (http://gis4geomorphology.com/ls-factor-in-rusle), m+1 for a multiplication values to prediction erosion at a point recommended by (Griffin et al., 1988; Moore and Wilson, 1992).

To calculate the LS factor, the study use ASTER Global DEM (GDEM). The first steps were DEM-fill for producing depression less DEM and then flow direction for deriving flow accumulation. The slope also calculated separately from DEM. All computed by using Arc GIS extension tool, which was Arc Hydro tool. The final LS-factor computed by the GIS map algebra tool the expression Equation 9 derived from Equation 8 suggested by (Van Remortel et al., 2004; Ashiagbor et al., 2013; Gelagay and Minale, 2016) we produced final LS-map.

$$LS = \text{Power}\left(\text{flowacc} * \frac{\text{DEM resolution}}{22.1}, 0.4\right) * \text{power}\left(\frac{\sin\,(\text{slope} * 0.01745)}{0.09}, 1.4\right) * 1.4 \qquad \text{Equation 9}$$

### 3.3.4 Cover Management (C) Factor

The cover management factor (C-factor) is the ratio of soil loss from the specific vegetation cover or types of fallow (Wischmeier and Smith, 1978). In Ethiopian condition, the C-factor developed by SCRP in 6 part of the country through adopting USLE. In this study, the LULC classified into two eight categories which mainly natural forest, afro-alpine, plantation, woodlands and shrubs, grasslands, cultivated lands, settlements and water body. The LULC-map previously produced in Supervised Classification of Landsat images combine and adapted its C-value to SCRP (Hurni, 1985). The steps also include change raster to vector to calculate each LULC cover C-factor value.

Table 2. The C-factors values of different LULC.

| Classified LULC | C-factor | References |
|---|---|---|
| Forest, plantation and afro-alpine | 0.001 | (Hurni, 1985) adapted to Ethiopian |
| Woodland and shrubs | 0.01 | |
| Degraded grassland (overgrazed) | 0.05 | |
| Agriculture | 0.6 | |
| Settlement | 0.09 | (Erdogan et al., 2007; Ganasri and Gowda, 2016) |
| Waterbody | 0 | (Qaryouti et al., 2014) |

### 3.3.5 Supportive Practice (P) Factor

The conservation or supportive management (P) factors include mainly the physical SWC and farming management practices. These activities could be either contouring, contour strip cropping, terracing, or a combination of contouring, strip-cropping, and terracing on agricultural lands and other supportive practice in degraded areas such as hillside terracing, bench terracing, water harvesting structures etc. The selection of these activities highly dependent on each LULC class. The P values in RUSLE also estimated considering slope length and steepness, ridge height, soil deposition, soil infiltration, cover and roughness conditions (Blanco-Canqui and Lal, 2010). The supportive practice could be categorized in to biological and physical conservation. However, the biological conservations have included in C-factor estimation.

In recent success stories in SWC activities in Ethiopia, only 18% of cultivated land rainfed croplands are so far treated by soil conservation physical structure like terracing (Hurni et al., 2016). In most studies shows the farmers believed the soil erosion is common and they use a range of practice of countering and traditional drainage ditches. For this, a best example listed in (Amsalu and de Graaff, 2006) stated that in the north-west highlands 83% of the farmer implement contour plowing. In other cases the traditional drainage ditches have control excess surface runoff and reduce soil erosion as the same time, its proposed P values have 0.9, if it integrated with contouring its value increased by two time which is 0.81 (Subhatu et al., 2017).

From the above statement we assume in the study area at list a minimum requirement contouring have been implemented but still have a limitation on conservation. Also the traditional drainage ditches known as "*Feses*" have been implemented (Bewket and Teferi, 2009). Due to this reason for close estimation the current study adapt the minimum P values from table 3, which is at list countering have been implemented in agriculture fields. The P values for agriculture also depend on slope and for all other LULC the assume there is no supportive practice and $P = \mathbf{1}$, because the current conservation implementation practice is not enough and not sustainable on those area and also suggested by (Wischmeier and Smith, 1978). Therefore, in this study we estimate the P values using LULC cover classification of the year 1987 and 2017 and the P value regularly change by LULC changes.

Table 3. Soil conservation management (P) factor

| Land use types | Slope percent | Farm Planning | | Terracing | |
|---|---|---|---|---|---|
| | | Contour factor | Strip-crop factor | Graded Channels sod outlets | Steep back slope underground outlets |
| Agriculture | 1 to 3 | 0.6 | 0.3 | 0.12 | 0.05 |
| | 3 to 8 | 0.5 | 0.25 | 0.1 | 0.05 |
| | 8 to 12 | 0.6 | 0.3 | 0.12 | 0.05 |
| | 12 to 16 | 0.7 | 0.35 | 0.14 | 0.05 |
| | 16 to 20 | 0.8 | 0.4 | 0.16 | 0.06 |
| | 20 to 25 | 0.9 | 0.45 | 0.18 | 0.06 |
| All others | | 1 | | - | - |

Adapted from (Wischmeier and Smith, 1978)

# 4. Result and Discussion

## 4.1 Accuracy Assessment for LULC Classification

The LULC classification map was prepared for the year 1987, 2002 and 2017 presented in figure 6. The detail explanation of the error matrices is presented in Table 4 for year 2017. It includes the Producer`s, User`s, Overall accuracy and Kappa coefficient. First, the Overall accuracy telling us, out of all reference sites how proportions are accurately mapped. Second, Producer`s accuracy, that the real feature on the ground correctly shown on the classified map and similarly the User`s accuracy is essentially telling us how often the class on the map will actually be present on the ground. Thirdly, the Kappa coefficient is evaluating how well the classification performed as compared to from randomly assigning values and it ranges -1 to 1, that a value close to one indicates significantly better than random (Congalton, 1991).

From the final 2017 classified map, the accuracy was estimated from 165 field verification GPS point, the overall accuracy was found 84.5% with Kappa statistics of 0.81. The minimum value of producer`s accuracy recorded in agriculture and forest areas, which accounts 62.9% and 63.13% respectively. In User`s accuracy the minimum values of 75% seen in forest and woodland and shrubs. In addition to this for 1987 and 2002, the accuracy checked by 96 and 105 points respective randomly generated reference points from the Landsat. For this, the overall accuracy showed that 89.5% and 86.5% have accurately classified for 1987 and 2002 maps respectively. However, the error matrices of 1987 and 2017 value was not fully utilized because these points might lead to bias due to personal judgment of taking samples from Landsat during pre-classification and accuracy checks after classification. The detail explanation for 1987 and 2002 accuracy was presented in Appendices 2 and 3.

In the second place, the accuracy checks also produced by change matrices. The LULC changed matrices analysis will also tell us from which majority of LULC from

1987 shifted during 2017 as presented in Table 5. Within 30 years a total of 28.8% of the DMBN basin lands have been experienced with changes. For example, 30,871.42ha of grassland in 1987 only 16,568.97ha (54%) remaining unchanged. Similarly, only 22,860 ha (74%) of woodlands are unchanged. In addition to this, the coverage of afro-alpine, water and plantation have been a small amount, on the other hand, it shows drastic changes while agriculture and settlement seem constant and have higher coverage of unchanged pixels/areas. In the present study, the complex LULC change system makes the change matrices also more complicated. From field visit the farming community widening their farmland toward neighboring communal land with few meters. Also, the vegetation decreasing and increasing in a fragmented way and this makes the estimation with 30-meter resolution more complex. Generally, the percentage change in an area which is the lower matrices value in a plantation that showed drastic change. In other words, 19% of the plantation coverage of year 1987 was found in 2017. Whereas the settlement (96.56%) and agriculture (81.06%) areas, which was maximum no change have recorded from the previous year.

Table 4. Accuracy assessment of 2017 classified images

| | | Ground truth | | | | | | | | Users |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Afro-alpine | Agriculture | Forest | Grassland | Plantation | Water | Woodlands and Shrubs | Total | Accuracy % |
| **Classification** | Afro-alpine | 8 | | 2 | | | | | 10 | 80 |
| | Agriculture | | 17 | | | | | | 17 | 100 |
| | Forest | | 1 | 12 | 1 | 2 | | | 16 | 75 |
| | Grassland | | 5 | 2 | 60 | | | | 67 | 89.55 |
| | Plantation | | 4 | 3 | 3 | 38 | | | 48 | 79.17 |
| | Water | | | | | | 3 | | 3 | 100 |
| | Woodlands and Shrubs | | | | 1 | | | 3 | 4 | 75 |
| | Total | 8 | 27 | 19 | 65 | 40 | 3 | 3 | 165 | |
| | Producers Accuracy % | 100 | 62.96 | 63.16 | 92.31 | 95 | 100 | 100 | | |
| Overall Accuracy 84.5 % and Kappa coefficient = 0.8096 | | | | | | | | | | |

Table 5. The change matrices of 1987 to 2017

| | | 2017 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Afro-alpine | Agriculture | Forest | Grassland | Plantation | Settlement | Water | Woodland and Shrubs | Unchanged area % |
| | Afro-alpine | **29.53** | 8.50 | 9.66 | 49.56 | 1.89 | 0 | 0 | 0 | 29.79 |
| | Agriculture | 0 | **42458.90** | 1904.84 | 5023.55 | 1344.62 | 579.52 | 7.69 | 1058.38 | 81.06 |
| | Forest | 0.40 | 1056.42 | **1642.30** | 455.98 | 268.26 | 69.72 | 0.90 | 239.10 | 43.99 |
| | Grassland | 80.57 | 9797.03 | 1043.22 | **16568.97** | 1109.97 | 413.32 | 32.67 | 1445.93 | 54.34 |
| 1987 | Plantation | 0.37 | 315.53 | 271.45 | 316.11 | **260.33** | 202.97 | 0.33 | 0.90 | 19.03 |
| | Settlement | 0 | 9.74 | 0.42 | 1.00 | 4.45 | **438.37** | 0 | 0 | 96.56 |
| | Water | 0 | 0.30 | 0 | 0 | 0 | 0 | **0.21** | 0.04 | 38.18 |
| | Woodland and Shrubs | | 1191.21 | 184.50 | 5539.32 | 6.95 | 1.49 | 0.12 | **22860.21** | 76.75 |

NB: - The unchanged area between two periods have written in bold

## 4.2 Land Use and Land Cover Change Analysis

The study showed that, the LULCC of the DMBN-basin for the past 30 years, which is between 1987 and 2017. A summary of the extent of the area associated with each class for the reference years 1987, 2002 and 2017 have described in Table 6 and their maps are presented in Figure 6. It was possibly categorized into eight main types of LULCs in DMBN basin. The main LULCs in the basin includes; afro-alpine, agriculture, forests, grasslands and marsh areas (grasslands), plantations, woodlands and shrubs, water, and settlements. For our purpose, different forest types are also categorized separately under; natural forest, afro-alpine forest, and plantation because they found in the different ecosystem and different management system.

Each LULC identified based on GE geo-browser historical data from 2017 back to 2004 and possibly seen and identified different LULC easily. In the upper part of the study area, the afro-alpine species were identified. This Afro-alpine ecosystem includes Giant Lobelia (Lobelia synchopetala), lady's mantle (Alchemilla humania), Guassa grass (Festuca spp.) and other grasses and woody plant cover includes Asta (Erica arborea) and Amijja (Hypericum revolutum) (Simane et al., 2013). From the result map of woody vegetation in this area classified as afro-alpine forest and other are categorized under grassland, which dominated by afro-alpine grass species. In final map showed the afro-alpine forest have seen some irregular and inconstant variation, it increases from 1987 to 2002 by 47.28 then decrease between 2002 and 2017. The overall afro-alpine increasing by 7.38ha between 1987 to 2017.

In DMBN-basin the most dominate LULC type is agriculture. It increases from 43.96% to 44.95 and 45.94%, that shows approximately 1% increasing rates every fifteen years. This percentage increase in agriculture land is bigger in hectare than other types of LULC in related to large percentage coverage. From change matrices Table 5, much of shift of grasslands and woodlands are shifted to agriculture areas. Previous study Bewket (2002) stated that the population growth leads the land reform at the national level in 1975 E.C., in addition to that during in 1997 the Amhara regional state redistributed land, which was allocated much of the grazing lands to those peasants did not have any cultivation field. During the field survey, informal discussion with the farm community and experts support that the most agricultural lands came from grasslands. The current study also locates much of agricultural lands are came from grassland, woodland, and forest, that its coverage 9797.03, 1193.21 and 1056.42 hectare of lands respectively as presented in Table 5. The tendency of previous allocating lands also continues converting to agricultural land by illegal means. Most the changes are specifically grasslands near to rivers for irrigation and It also changed to settlements mainly those areas near to urban. Other studies showed also agriculture has been increasing or riches at maximum threshold (Bewket, 2002; Hurni et al., 2005; Ariti et al., 2015; Demissie et al., 2017).

The cumulative natural forest change by 1248.41ha within 30 years. The overall forest percentage riched 4.28% from 3.28% in DMBN basin. The study finding present forest conservation, protection of the natural forest was in good progress that agree on the government current strategies mainly enclosure activities. However, the change area still showed inconsistency in the second fifteen years, which showed decreasing experience by 609.49ha (~0.52%). Similar studies in a different part of the country showed, the LULC trend the natural forests are decreasing, especially places have relatively higher coverages (Meshesha et al., 2012a; Kindu et al., 2013; Demissie et al., 2017). The remnant forests are mostly found in sloppy and mountainous areas in a fragmented manner and deforesting these areas are accelerating the vulnerable to soil erosion (Kindu et al., 2013).

For our purpose, due to similar reflectance value with grassland, the wetland categorized under grasslands. The grassland showed continuous decline rate throughout the study period including wetlands. The wetlands commonly follow the rivers in the DMBN basin and due to Landsat acquisition date of the dry season and the wetland characterized as majurity becaome dry and grouped under grassland. Within in the first 15 years as well as 30 years' ranges of grassland continues decreased by 2216.73, which is 26.08% to 24.21%. In the study time period, the grassland and woodlands showed continuous declination and most susceptible to change, commonly change to agriculture and settlement areas. Also, an adjacent study by Teferi et al. (2013) stated that farmers subsequently changing grasslands to agriculture lands. In different areas also reported grasslands are changing (Meshesha et al., 2012a; Kindu et al., 2013; Demissie et al., 2017). However, in the study suspect that the transitional change for the past decades was forest to shrubs then grasslands. Because the remnant shrubs are found in the sloppy area and its understory is commonly grasslands. In addition to that, the shrubs lands have more often functional for grazing purpose. The recent time the farming community prefers changing grasslands to agriculture rather than going to the far natural forest.

In related to the Plantation progress in DMBN basin constantly increasing from total coverage of 1.23%, 2.53% to 2.57% in prospective periods. It has been noticed that the most planted areas are in middle and upper catchments. In this areas, the dominant trees species preferred by the community and seen practically was Eucalyptus globulus. The plantation mostly those areas near to residences and roadsides. In related to planting Eucalyptus, it also includes the farmer`s intention to changing their agricultural lands. The intention is due to the demand of attractive price of Eucalyptus related to the population growth, urbanization and road development are main drivers increasing plantation forest (Teferi et al., 2013). The farmers benefited widely from Eucalyptus for selling construction materials like poles to neighboring big cities as well as it has been the main energy source in the local community.

The water body, small sized ponds are clearly seen only during in 2002 and in 2017. These ponds basically for two reasons i.e. created for irrigation purpose and during road construction. Ponds created by road constructions was during the preparation of gravel pit cites then for water accumulation and subsequently, the community might change for their own purpose. However, Meshesha et al. (2012a). proved that, the continuous drastic changes have been seen in natural lakes in central rift value of Ethiopia. Generally, the water body in the study are counted small coverage and also due the Landsat acquisition date are dry season and all seasonal rivers have not been identified in the map.

Due to similar reflectance values of woodlands and shrubs from Landsat, the current study categories into one group, Also, Bewket (2002) reported these two LULC categories have shown similar patterns. Within the first past first 15 years, the woodlands and shrubs decreased by 4402.90ha. These drastic change related to large coverage of areas have been seen a little improvement by 171ha between 2002 and 2017. However, the past 30 years' the ranges of woodlands and shrubs are decreased by 4231.44 ha which accounts 3.57%. This drastic change in low land woody species, this might be because of the fire occurrence, which is relatively dry characteristics of the lower altitude area are more frequent. The fire also clearly seen by visual interpretation directly from the GE as well as Landsat before analysis was done. In another perspective, from the change matrices Table 5., locate the majority of woodland shifted to agriculture and grasslands.

The settlements, which is characterized urban areas identified in one places are directly delineated from GE by screen digitizing recommended by (Malarvizhi et al., 2016). Eventually, the urban signature reflectance value is similar with various LULC for instance with agriculture and degraded grassland and the values make the map less accurate. Yuan et al. (2005) also reported the spectral similarities of certain classes such as urban/settlements with agriculture, agriculture with bare lands causes to produce a less accurate map. As a result, for smaller areas that placed in one area like settlements in the study area, it's better directly digitized from GE. As a result, the dense settlement areas, drastically increase from 474.73 to 1236.19ha. Other small villages placed in scattered manner are not digitized in this study because it has been dominated commonly by neighboring LULC types mostly by agriculture land.

Table 6. Each LULCs of 1987, 2002 and 2017 and their changes

| LULC types | 1987 | | 2002 | | 2017 | | LULC changes (ha) | | |
|---|---|---|---|---|---|---|---|---|---|
| | area-ha | % | area-ha | % | area-ha | % | 1987 to 2002 | 2002 to 2017 | 1987 to 2017 |
| Afro alpine | 103.49 | 0.09 | 150.77 | 0.13 | 110.88 | 0.09 | 47.28 | -39.90 | 7.38 |
| Agriculture | 52031.36 | 43.96 | 53207.57 | 44.95 | 54368.56 | 45.94 | 1176.21 | 1160.99 | 2337.20 |
| Forest | 3819.95 | 3.23 | 5678.53 | 4.80 | 5068.36 | 4.28 | 1858.58 | -610.17 | 1248.41 |
| Grassland | 30871.42 | 26.08 | 30182.88 | 25.50 | 28654.69 | 24.21 | -688.54 | -1528.19 | -2216.73 |
| Plantation | 1459.78 | 1.23 | 2996.43 | 2.53 | 3037.01 | 2.57 | 1536.65 | 40.57 | 1577.23 |
| Water | 0.90 | 0.00 | 38.19 | 0.03 | 42.66 | 0.04 | 37.29 | 4.47 | 41.76 |
| Woodland | 29597.36 | 25.01 | 25194.46 | 21.29 | 25365.92 | 21.43 | -4402.90 | 171.46 | -4231.44 |
| Settlements | 474.73 | 0.40 | 910.17 | 0.77 | 1710.93 | 1.45 | 435.43 | 800.76 | 1236.19 |

NB: - Some Land Use and Land Cover features photos have presented in Appendix 5.

In addition, the continuous declination has seen on grasslands because most grassland in this area susceptible to change for agriculture and residence areas. At the same time, the grassland quality is degraded by intensive free grazing system. Similar studies in Blue Nile basin proved that the past three to four decades' settlement, forest are agriculture are increasing while grassland decline. For this, an illustration studies by Teferi et al. (2013) reported in Jedeb watershed and Meshesha et al. (2016) in Beressa watershed, the listed LULC have shown continues changes. Moreover, the increasing agriculture land and settlements commonly from grasslands in close border to cultivated and residential areas. Agriculture lands at high and mid altitudes also change to Eucalyptus woodlots. In the present study, the plantation land was mostly adjacent to settlement and road paths for easily accesses. This species preferred by the community because of fast-growing characteristics and basic sources for poles, construction and fuel wood than other tree species and known as commercial forest crop but limited to soil conservation (Bewket and Sterk, 2003). But this species is minimizing the huge dependency to natural forest.

As a summary of the GE based image classification is too intensive and take the large number of AOI. It has the advantage to possibly identify additional LULC such us wetlands, shrubs, and settlements from GE. On the contrary, when increasing the number LULC types to classify the Landsat showed a confusion and less accurate result and intermixed each other. For example, it is found to be shrubs mixed with forest, sometimes with grassland because of its less dense texture, which is most shrubs have lower grass understory. Wetlands also considered under grassland because it differs only during the rainy season and more probably wider in the wet season.

Therefore, even if it was possibly identifying more LULC types from GE the final classification on Landsat is still limited during adding many LULC types. Especially, areas like in DMBN-basin, the LULC characteristics is very fragmented within a short distance.

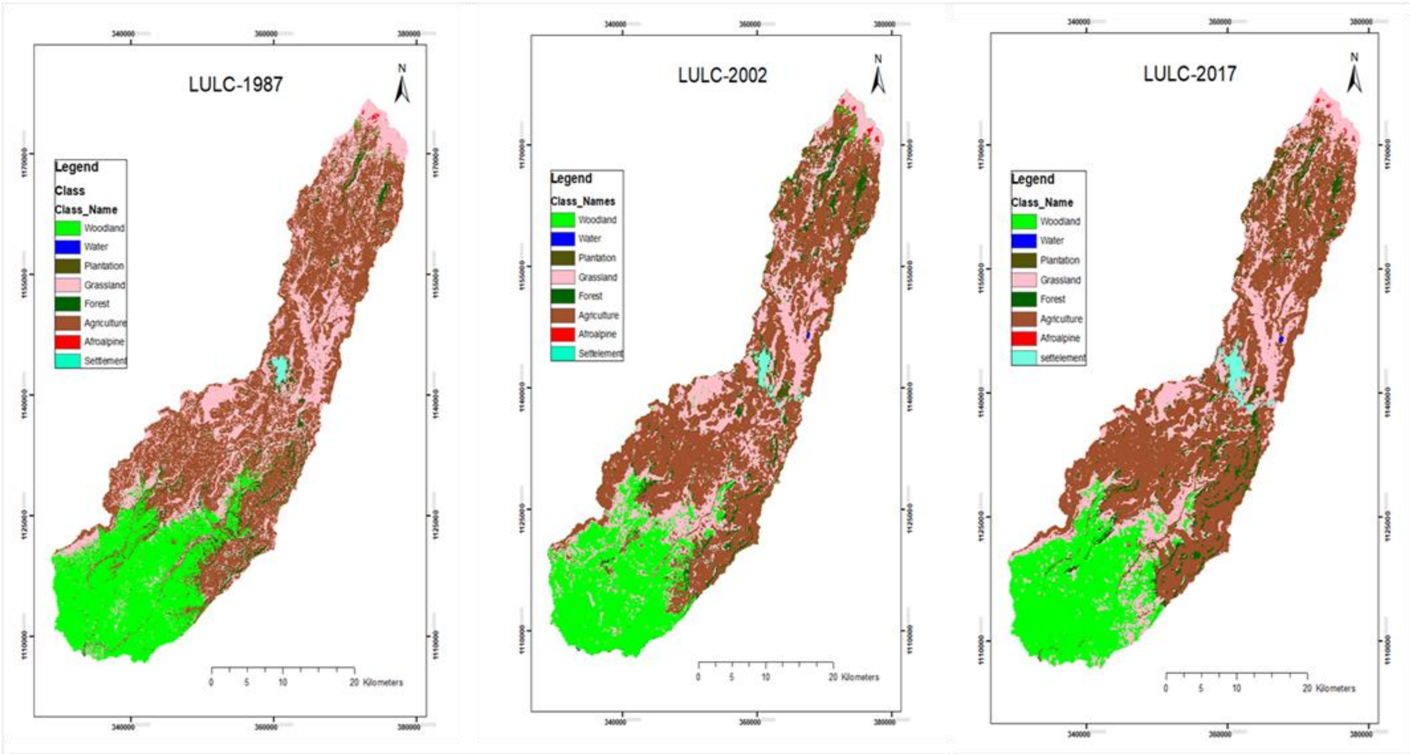



Figure 6. LULC- Map of 1987, 2002 and 2017

## 4.3 Soil Loss Factors Maps

### 4.3.1 Cover (C) Factor Map

The cover factors (C-factor) mainly derived from the LULC types of the specific area. The produced LULC from Landsat image with GE aid Supervised Classification. We have selected the reference year 1987 and 2017 of LULC map to estimate C-factor values that affect the annual soil loss of both years. In this study area, the dominant lands are agriculture, grasslands and woodlands account 91% of the total and the remaining part are categorized under afro-alpine, natural-forest, plantation, settlement, and water body. This raster LULC information converted to vector for assigning corresponding cover management factor value obtained from Hurni (1985).

Finally, the in the raster map we produced of each cell ranges minimum values from zero i.e. water body to the maximum of 0.6 agriculture as shown in Figure 7 a) and b). In C-factor estimation, we have taken each LULC C-factor from the previous literature mentioned in Table 2. in the methodology chapter. Generally, the values of the forest, plantation, and afro-alpine have higher protection ability from water erosion and its value is 0.001 relatively minimum than other, which means less erosion in this areas. In other cases, the grassland areas assumed as a degraded, because it has been affected by overgrazed throughout the year. However, lowering the density of grassland, the greater the decreasing trend of C-factor on grassland (Sun et al., 2014). Although the cover managements have the power to determine the erosion risk brings all erosion factors at minimal, if it managed well. The cover factor also artificially modified factors except those areas occurred naturally such as natural vegetation.

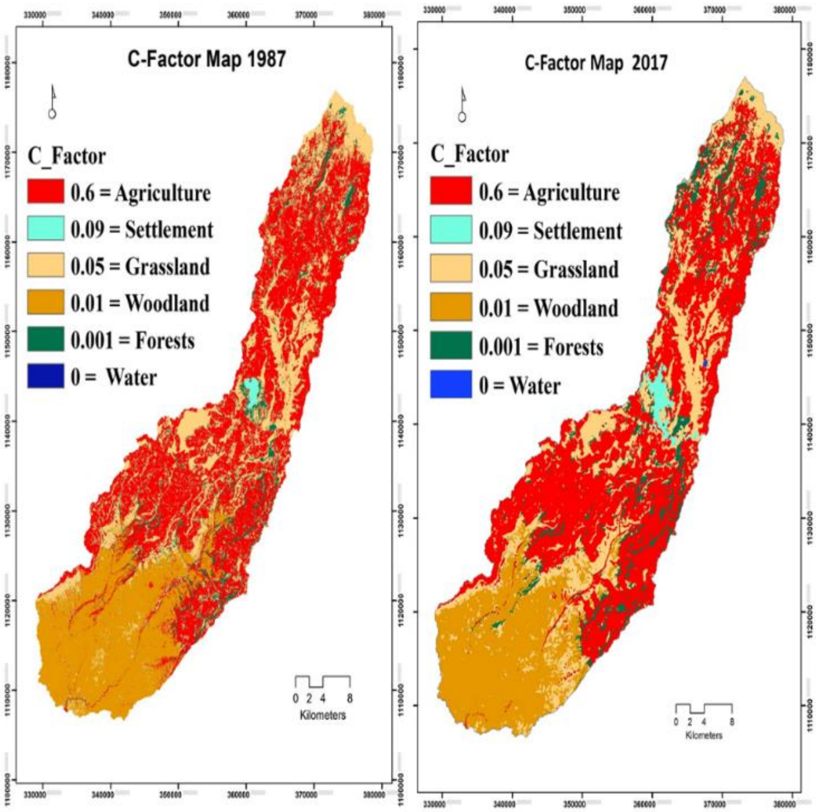



Figure 7. C-Factor map of a) 1987 and b) 2017

### 4.3.2 Rainfall Erositivity (R) Map

The rainfall erositivity factor calculated by using mean annual rainfall of 20-years of EMA metrological data. The study area and the nearby eight stations mean annual rainfall ranges from 1182.42mm Yejubey station to 1445.51mm of Combolcha stations as shown in Table 7. In DMBN-basin and nearby station after computed by Equation 2, the erositivity (R-Factor) rates, ranges from 600.20 to 804.256. The higher rainfall recorded influences the erositivity as that much rate. The erositivity values also much greater than other four factors (K, LS, C, and P) and it has been greater weight since we are studying soil erosion by water.

Thereby, the rainfall erositivity factor of each grid cell produced by raster calculator geo-processing tools, by Kriging methods recommended by (Mair and Fares, 2010; Mahalingam et al., 2015). From these eight stations, the produced uninterrupted interpolated R-factor map by using two inside and surrounding nearest six station to DMBN-basin, taking over all spatial arrangement of each station values. The final map presented in Figure 8-a. The erositivity each pixel values of R-factor map have ranges minimum of 647.46 to maximum 679.56 MJ.mm $ha^{-1}hr^{-1}yr^{-1}$, which have 32.1 MJ.mm $ha^{-1}hr^{-1}yr^{-1}$ differences.

Table 7. Mean annual rainfall erositivity of each stations

| Name of Stations | Latitude | Longitudes | Elevation | Mean annual rainfall | R-factor |
|---|---|---|---|---|---|
| Debre-Markos | 10.325700 | 37.7392 | 2446 | 1109.87 | 615.63 |
| Yejube | 10.153300 | 37.7488 | 2322 | 1082.42 | 600.20 |
| Rob_Gebeya | 10.550000 | 37.8700 | 2940 | 1186.81 | 658.867 |
| Amanueal | 10.432483 | 37.5630 | 2386 | 1197.72 | 664.998 |
| Gebete | 9.383800 | 37.4092 | 2287 | 1219.03 | 676.974 |
| Digua Tsion | 10.854000 | 37.7416 | 2782 | 1224.00 | 679.768 |
| Combolcha | 9.502300 | 37.4727 | 2341 | 1445.51 | 804.256 |
| Dejen | 10.171150 | 38.1507 | 2448 | 1180.82 | 655.501 |

The rainfall erositivity interpolated result also determined by the quality of rainfall data recorded in each station and the closeness of between stations. In addition to that the rainfall affected by topography and elevations. The higher altitudes we have seen the higher amount of precipitation but most part the lower elevation of the basin got relatively lower rainfall. Due to the limited station on lower part DMBN-basin that the expected result might affected by higher rainfall recorded from Combolcha and Gebete station in the lower/south side of basin.

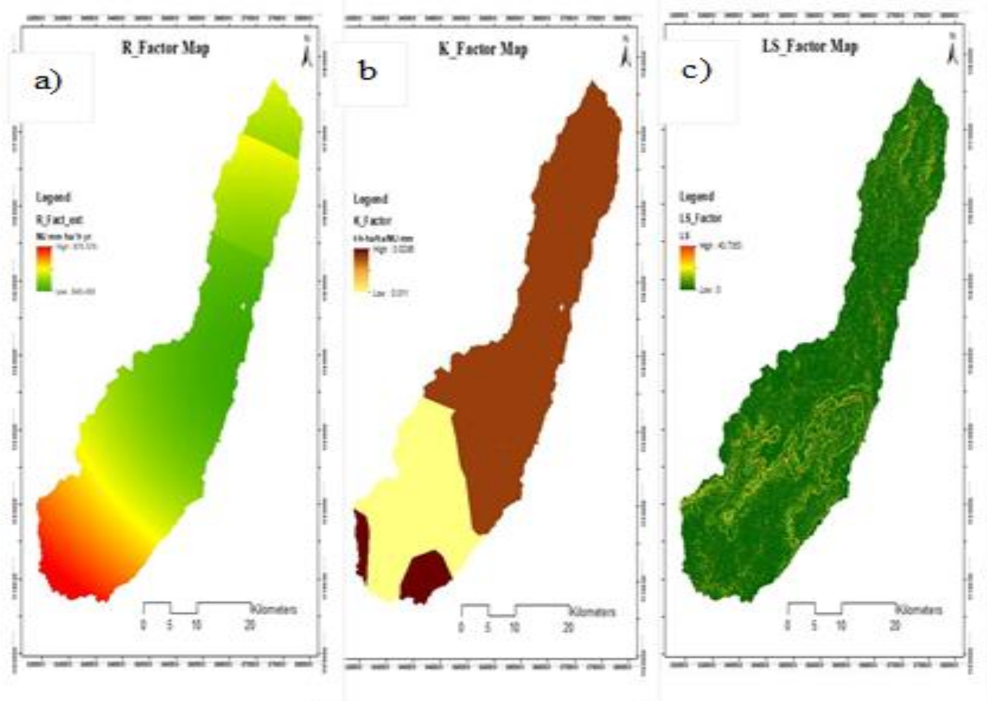



Figure 8. Erosion each factor maps; a) R-factor map; b) K-factor map c) LS-Factor map.

### 4.3.3 Soil Erodibility (K) Factor Map

The soil erodibility (K-factor) influenced by the inherent characteristics of the parent materials, that is the percentage of sand, silt, clay and organic matter ratio of the existing soil types. In the basin, there are three soil types based on dominant characteristics of soil under FAO classification. These three types of soil distributed in the basin, such as Eutric Nitosols (NE) its characteristics sandy clay loam; Dystric Cambisol (BD) its textures are clay loam and Cambic Arenosols (Qc) with coarse texture (FAO., 2007). The coverage of NE, Qc and BD have 64.89%, 29.46% and 5.35% respectively.

The erodibility of this soil calculated from (Equation 3 to 7) and multiplied by 0.1317 to get real K-factor recommended by (Neitsch et al., 2002; Anache et al., 2016). In the detail erodibility factor presented in Table 8., showed the courser texture is more tolerable or less erodible than finest soil texture and related to inherent characteristics of the soil. Therefore, Dystric Cambisol are higher erodible but relatively small percentage area and Cambic Arenosols have less erodibility. The erodibility of in the study ranges from 0.011 to 0.0286t $hr^{-1}$ $ha^{-1}$ $hr^{-1}$ MJ $mm^{-1}$ and the final erodibility map presented in figure 8-b. Its respective erodibility impact percentage of NE, QC and BD would be 76.05%, 16.32and 7.6%, were Qc relatively minim erodibility relative to its coverage.

Table 8. The soil erodibility factor of each soil types

| Soil unit | sand | silt | clay | OC | A | B | C | D | $K_{usle}$ | K-factor |
|---|---|---|---|---|---|---|---|---|---|---|
| NE | 68.4 | 10.5 | 21.2 | 0.6 | 0.2626 | 0.7179 | 0.9803 | 0.9661 | 0.1785 | 0.0235 |
| BD | 32.7 | 30.3 | 37.1 | 3.28 | 0.3674 | 0.7867 | 0.7502 | 1.0000 | 0.2168 | 0.0286 |
| Qc | 91.9 | 3.2 | 5 | 0.23 | 0.2308 | 0.7541 | 0.9973 | 0.4826 | 0.0837 | 0.0110 |

Where $K_{usle}$ is erodibility value, OC=organic carbon and A, B, C, D discussed in Equation 3. Part 2.

### 4.3.4 Slope Length-Steepens (LS) Factor Map

The topographic parameter of RUSLE computed by Equation 7 suggested by (Moore and Wilson, 1992) and map algebra expression of this equation for single and multiple watershed study areas by Equation 8 (Van Remortel et al., 2004; Gelagay and Minale, 2016). The final LS-factor map presented in figure 8-c. The LS-factor is the most determinant factor in water erosion and its value bigger next to rainfall erositivity. The soil loss variation by LS-factor ranges 0 to 43.7, that has wider variation from the lower zero values to higher ranges 43.7.

The areas with higher LS values were located on the steep slope, gully and river bank regions, these areas were sensitive to erosion. This factor also naturally occurred factor. However, it is possibly improving and change its impacts by supportive management practice and cover management.

### 4.3.5 Supportive Practice (P) Factor Map

The P-factor is the management (supportive) practice of the area basically soils and water conservation (SWC) activities including different agricultural management system. For the present study, we have used the LULC of 1987 and 2017 shapefile and slope categories of agriculture to determine the P values because the supportive practice commonly determined by the LULC types. Finally, the final result P-factor values using LULC map presented in Figure 9 a) and b). Considering the agriculture categorized into seven slopes as listed in Table 3. The final P-factor values from the map, it ranges from minimum 0.5 (good conservation areas) to maximum 1 per each cell. The maximum cell recorded in higher slope areas of agriculture and those not have any supportive practices were implemented. In other hands, the P values other LULC types is maximum $P=1$, because no measurement have been taken in those area.

The total P values of agriculture lands about 30 to 34 % recorded. From these the slope between 3 to 8 % have maximum coverage. This might because of these area agricultural land came from grasslands and increases between 1987 to 2017, which accounts P values 9.32% and 11.05% for the respective year. Due to the grassland and woodland covers larger areas next to agriculture, their rates P have maximum. The total P values for grassland is 31.09% and 29.34% for the respective year 1987 and 2017. Also, the total P values of woodland account 29.81% and 25.97% for the year 1987 and 2017 respectively as presented in Table 9.

Table 9. P- factor difference of 1987 and 2017

| LULC | Slope % | 1987 | | | 2017 | | |
|---|---|---|---|---|---|---|---|
| | | Area % | Total-P Values | % of P | Area % | Total P Values | % of P |
| Agriculture | 0-3 | 3.52 | 2713.2 | 2.49 | 4.05 | 2872.2 | 2.96 |
| Agriculture | 3-8 | 15.82 | 10163.5 | 9.32 | 18.16 | 10733.5 | 11.05 |
| Agriculture | 8-12 | 5.51 | 4246.8 | 3.89 | 11 | 7801.2 | 8.03 |
| Agriculture | 12-16 | 9.59 | 8626.8 | 7.91 | 6.3 | 5217.1 | 5.37 |
| Agriculture | 16-20 | 2.74 | 2820 | 2.59 | 3.14 | 2968 | 3.05 |
| Agriculture | 20-25 | 1.61 | 1863 | 1.71 | 1.82 | 1941.3 | 2.00 |
| Agriculture | >25 | 1.97 | 2527 | 2.32 | 1.86 | 2196 | 2.26 |
| Afro-alpine | All | 0.09 | 99 | 0.1 | 0.09 | 111 | 0.11 |
| Forest | All | 3.23 | 3737 | 3.85 | 4.28 | 5057 | 5.9 |
| Grassland | All | 26.08 | 30581 | 31.09 | 24.22 | 27960 | 29.34 |
| Plantation | All | 1.23 | 1373 | 1.47 | 2.57 | 2997 | 3.11 |
| Woodland | All | 25.01 | 39836 | 29.81 | 21.44 | 25606 | 25.97 |
| Settlement | All | 0.4 | 455 | 0.48 | 1.45 | 1706 | 1.75 |
| | | 100 | 109041.3 | 100 | 100 | 97166.3 | 100 |

The other LULC types including afro-alpine, forest, plantation and settlement areas have P values was one but their coverage was a small and small percentage of P total values. Therefore, The P value agricultural land with slope between 12-16% and > 25%, grassland and woodland have significantly decreased.

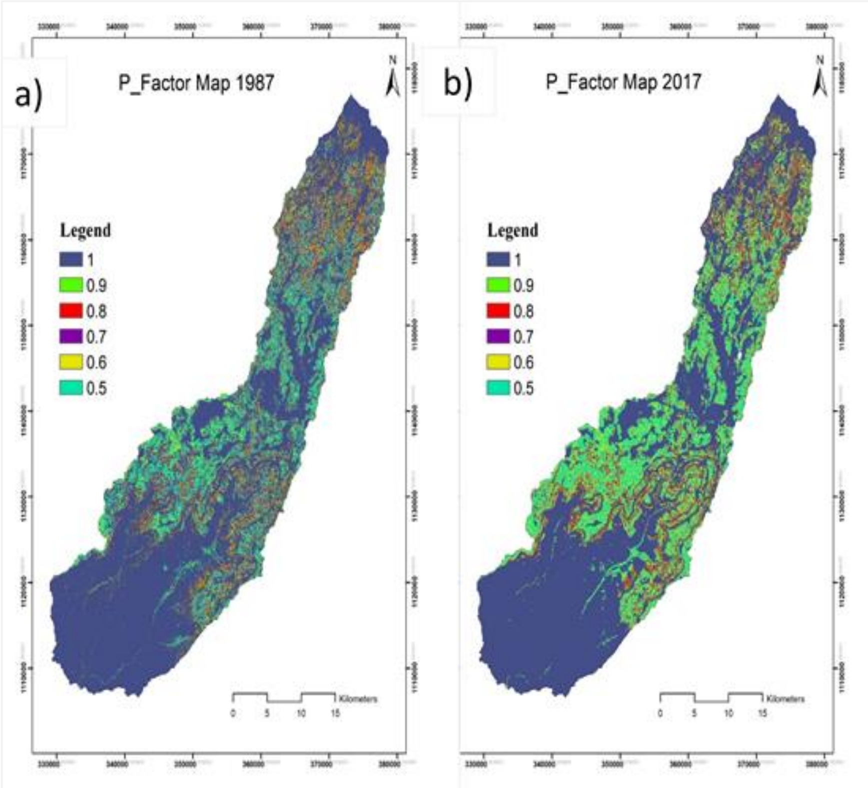



Figure 9. P-Factor Map a) 1987 and b) 2017

## 4.4 Annual Soil Loss

The estimated annual soil loss by RUSLE, that is the overlay result of all five factors, which produced by Equation 1. These five factors have been discussed separately in the previous section including; rainfall erositivity, soil erodibility, topographic factors, cover management factors and supportive practice factors. The estimated result by the empirical formula in map algebra Arc GIS expression gave an idea from which topographic arrangement and LULC of the prone to soil erosion and where the spatial distribution have been located. The spatial expression of soil erosion also presented in Figure 14. Therefore, the sum of annual soil loss from this area recorded 336,234 t $yr^{-1}$ for 1987 and 346,230 t $yr^{-1}$ for 2017 were recorded.

The soil erosion factors most of them are occurred by the natural environment which includes rainfall erositivity, soil erodibility, and slope length and steepens. Whereas, the cover management factor and supportive practice factors are regularly influenced or modified by human activities. Thus, R and LS have significantly bigger cell values and both have a wider range. For example, the LS ranges from zero of gentle slope to 43 on a steep slope in DMBN-basin. In other cases, R and K factor more or less not modified factors or it takes longer time. Meanwhile, LS factor has naturally occurred, it could be modified by cover management and supportive practice.

Therefore, from natural factor the LS have maximum effect, could be modify by minimizing the slope steepens and length by managing rainwater to drain slowly, which is included in supportive practice. Also, the cover management protect the direct contact of water to the soil. The cover management simountaniously improving soil organic content that have adverse effect on soil erodibility. These all activities included in physical SWC activities or the improvement of vegetation management measures. Therefore, it is possible to minimizing the biger erosin values of R and LS as the same time K. The soil erosion severity of basin, the LULC and topographic effect on soil erosion also discussed in next three section.

### 4.4.1 Land Use and Land Cover Effects on Soil Erosion

Identifying soil loss based on LULC and slope categories is essential for selection and implementation of appropriate SWC measures, vegetation restoration (Meshesha et al., 2012b; Sun et al., 2014). The final result from the current study, which shows the annual soil loss per each LULC soil loss is presented in Table 10 and Figure 10.

In the present study, while there has been a gradual decrease in soil erosion came from afro-alpine, forest, grassland, and woodland. Whereas, soil erosion was showing an increasing trend in agriculture, plantation and settlement areas. The soil erosion came from plantation was increased, because of the increase in the total area coverage and sometimes it might be planted for the purpose for rehabilitation the degraded areas and hilly areas, which would have expected to be increased. But, the reverse is true in afro-alpine and forest, that increasing area coverage resulted in decreasing the amount of soil erosion.

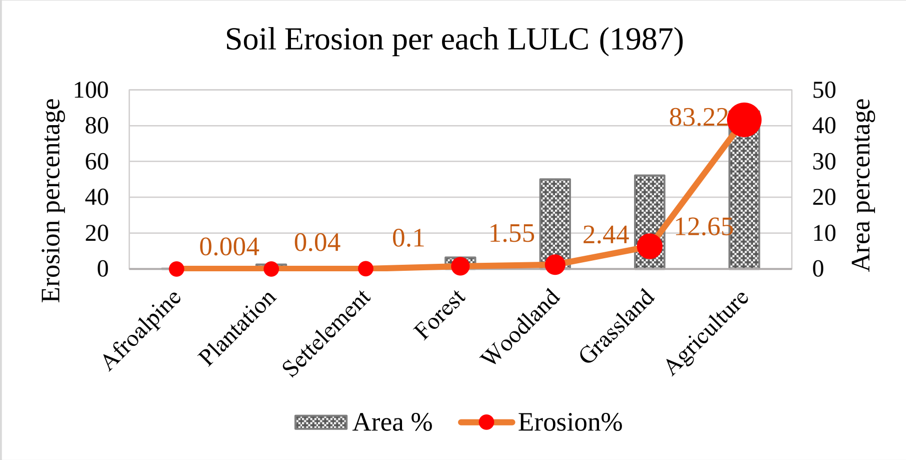
In the study area, agricultural land displayed a greater impact on soil erosion. The erosion coming from agriculture was 279,798 t $yr^{-1}$ in 1987 and 309,550 t $yr^{-1}$ in 2017. There was only 2% increase in area coverage in agricultural land within these years. This increase in the agricultural area coverage resulted in an increase in soil erosion by 6.13%. The erosion impact came from grassland was the second priority in DMBN-basin. Its` erosion value was 12.65 % in 1987 and 8.72% in 2017. Between these years the erosion came from grassland effects was decreased by 3.93% related with to decreasing area coverage.

In other cases, the huge degradation of woodland resulted adverse effect on soil erosion protection. From 1987 to 2017 the erosion came from woodlands are decreased by 8193.07 to 3400.46 t $yr^{-1}$ this is due to the woodland coverage decreased. Thus much of change of woodland areas to grasslands or agriculture should expect to be increasing the soil erosion. Overall, the total soil erosion from all LULC in DMBN basin increased by 3.04% (9996 t $yr^{-1}$) between the years 1987 and 2017.

Table 10. Soil erosion per each LULC types for the year 1987 and 2017

| LULC-type | Annual Soil loss | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1987 | | | | 2017 | | | |
| | Area (ha) | Area% | tone/yr | Erosion % | Area (ha) | Area% | tone/yr | Erosion % |
| Afro-alpine | 103.49 | 0.09 | 11.85 | 0.004 | 110.88 | 0.09 | 5.33 | 0.002 |
| Agriculture | 52031.36 | 43.96 | 279798 | 83.22 | 54368.56 | 45.95 | 309550 | 89.35 |
| Forest | 3819.95 | 3.23 | 5219.74 | 1.55 | 5068.36 | 4.28 | 1477.12 | 0.43 |
| Grassland | 30871.42 | 26.08 | 42528.5 | 12.65 | 28654.69 | 24.22 | 30202.3 | 8.72 |
| Plantation | 1459.78 | 1.23 | 130.25 | 0.04 | 3037.01 | 2.57 | 342.34 | 0.1 |
| Settlement | 474.73 | 0.40 | 336.43 | 0.1 | 1710.93 | 1.45 | 1479.39 | 0.43 |
| Woodland | 29597.36 | 25.01 | 8193.07 | 2.44 | 25365.92 | 21.44 | 3400.46 | 0.98 |
| Water | 0.90 | 0.0 | 0.0 | 0.0 | 42.66 | 0.036 | 0.0 | 0.0 |

Generally, the soil erosion that came from the dominant LULCs, including the agricultural area that covered a total 45.95% and grassland covering 24.22%, which accounted for the total 70.17% of LULC coverage, and 98.07% of soil loss for the year 2017 (Table 10). In the year 1987, the coverage of agriculture and grassland were 43.96%, and 26.08%, respectively. The total soil loss coming from these two LULCs was 95.87% for the year 1987 (Table 10). Therefore, while agriculture shows an increasing trend in affecting soil erosion, grassland resulted in the decrease of the annual soil loss in the study area. The comparison of each soil erosion per LULC have presented in Figure 10.



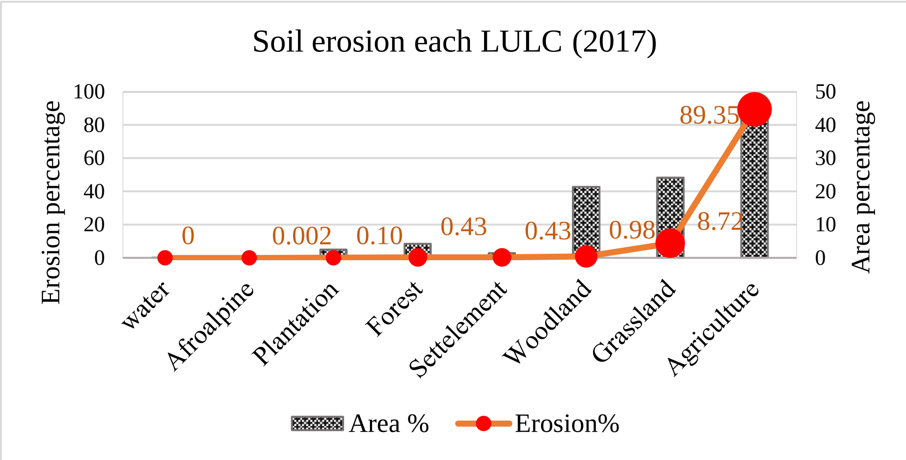




Figure 10. Erosion change per each LULCs in 1987 to 2017

The third maximum soil erosion was observed on woodland areas, which might be associated directly to a steep slope. Similarly, the remnant natural forests are placed at steep slopes in which people can not access. Similarly, Kindu et al. (2013) have reported that natural forests are situated on steep and very steep slopes. However, deforestation on those remaining forest in steep slopes will worsen the soil erosion, that might be greater than other areas. The other LULC such as afro-alpine, plantation, settlements and water bodies have seen significant protective effects on soil erosion and minimum amount of erosion recorded in the current study. The LULC comparison presented in Figure 11-a and also the LULC decreasing and increasing rate in Figure 11-b. In other figure the comparison the soil erosion of two year presented in Figure 12-a and its decreasing and increasing per each LULC also presented in Figure 12-b.

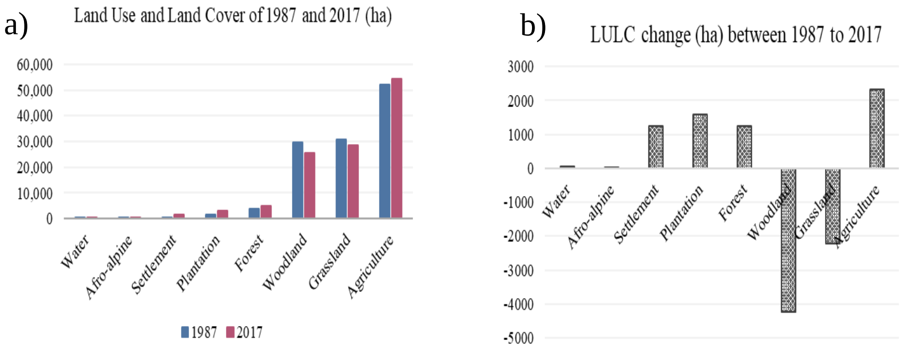



Figure 11. Graphs of LULC types comparison (a) and LULC change graphs (b)

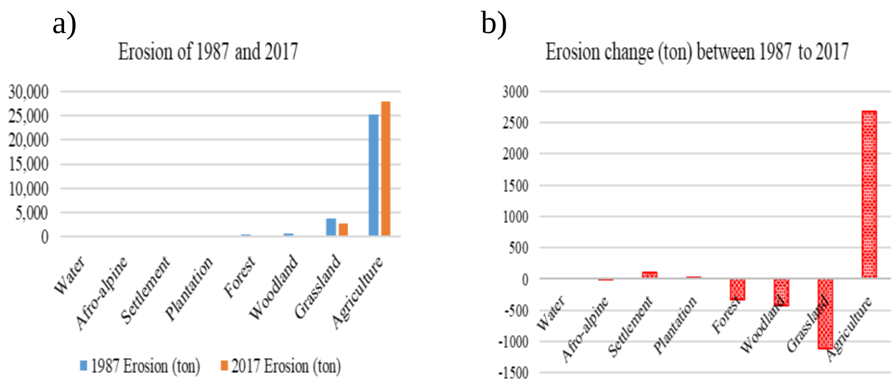



Figure 12. Erosion year 1987 and 2017 (a)and The erosion difference (b)

### 4.4.2 The Slope Effect on Soil Erosion:

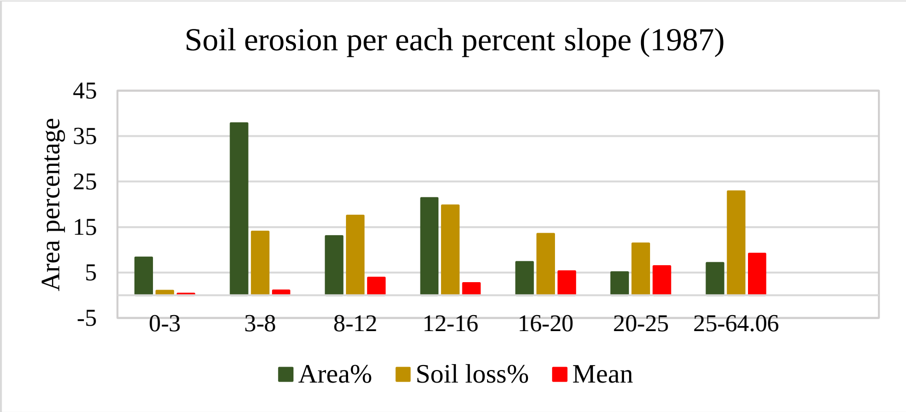
Topography has the greatest effect on soil erosion. During the increment of slope steepness and slope length, the soil loss came from steep areas are increases significantly, soil erosion per each slope categories are presented in Table 11. From the overall result soil erosion coming from the steeper slopes, those with slope >20%, that covering only 12.19% area was 34.23% for 1987 and 32.98% for 2017. The soil loss found in this areas was three-fold as compared to the area coverage. Similarly, the higher soil erosion rate recorded in steep slope agriculture fields also reported in other studies (Meshesha et al., 2012b; Sun et al., 2014). These areas call the attention to a priority for conservation measures.

The soil loss between 1987 and 2017 on a slope greater than 25% has decreased from 22.82% to 20.33%, which also presented in Figure 14. From this we understand that from very small intervention in higher slope areas the soil erosion trend became decrease, this also might be because of related to plantation and forest coverage increment in these slope categories. Sun et al. (2014) reported forest, shrub, and dense grassland reduced soil loss from slope land more than moderate and sparse grassland and woodland in lower slope areas. However, to support the current study further studies on the specific site in relation to topography change by vegetation coverage and other conservation measures are still required.

Table 11. Soil erosion per each slope categories of 1987 and 2017

| Slope range | 1987 | | | | 2017 | | | |
|---|---|---|---|---|---|---|---|---|
| | Area-ha | % area | Soil loss tone/yr | % of rosion | Area-ha | % area | Soil loss tone/yr | % of erosion |
| 0-3% | 9816.63 | 8.29 | 3379.23 | 1.01 | 9814.94 | 8.30 | 3565.49 | 1.03 |
| 3-8% | 44764.84 | 37.82 | 46971.3 | 13.97 | 44749.73 | 37.82 | 47496.5 | 13.71 |
| 8-12% | 15351.33 | 12.97 | 58931.2 | 17.53 | 15345.03 | 12.97 | 65208.7 | 18.82 |
| 12-16% | 25322.89 | 21.39 | 66497.2 | 19.78 | 25310.26 | 21.39 | 65566.9 | 18.93 |
| 16-20% | 8670.72 | 7.33 | 45347.2 | 13.49 | 8665.76 | 7.32 | 50365.8 | 14.54 |
| 20-25% | 6004.49 | 5.07 | 38373.5 | 11.41 | 6002.54 | 5.07 | 43825.4 | 12.65 |
| > 25 % | 8428.06 | 7.12 | 76731.1 | 22.82 | 8428.73 | 7.12 | 70422.6 | 20.33 |

From slope categories, most of the soil erosion came from the medium slope areas 0-12% and 16-25% showed increasing rate. Due to the fact that majority of these areas covered by agricultural lands in 1987 and 2017. Also implicates that, it needs to be considered recommended conservation measures on these areas. Data on the relative area coverage and amount of erosion per each slope percentage categories presented in Table 11. Also, the study proved that in all slope categories the agricultural lands is increased, except those slopes between 12-16% and slope >25% have also presented in Table 9, which soil erosion also in this slope categories have not increased. In other case the mean soil erosion increases when slope increases and Figure 13 represent similar things. Therefore, the soil erosion mainly depends on slope and agriculture activities.



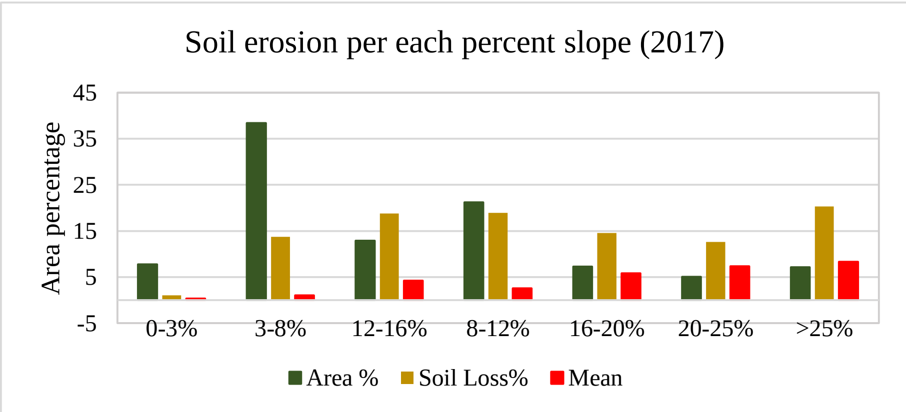




Figure 13. The soil loss per each slope and area of 1987 (a) and 2017 (b).

The smaller area variation by conservation in higher slope areas are minimizing the soil loss significantly change the presented Figure 14. The erosion decreasing in this slope categories it might be because of the conservation measure. In other word with a small consevation measures even if it costs maximum expense and a little successful history and sustainable activities would protect noticeable soil loss.

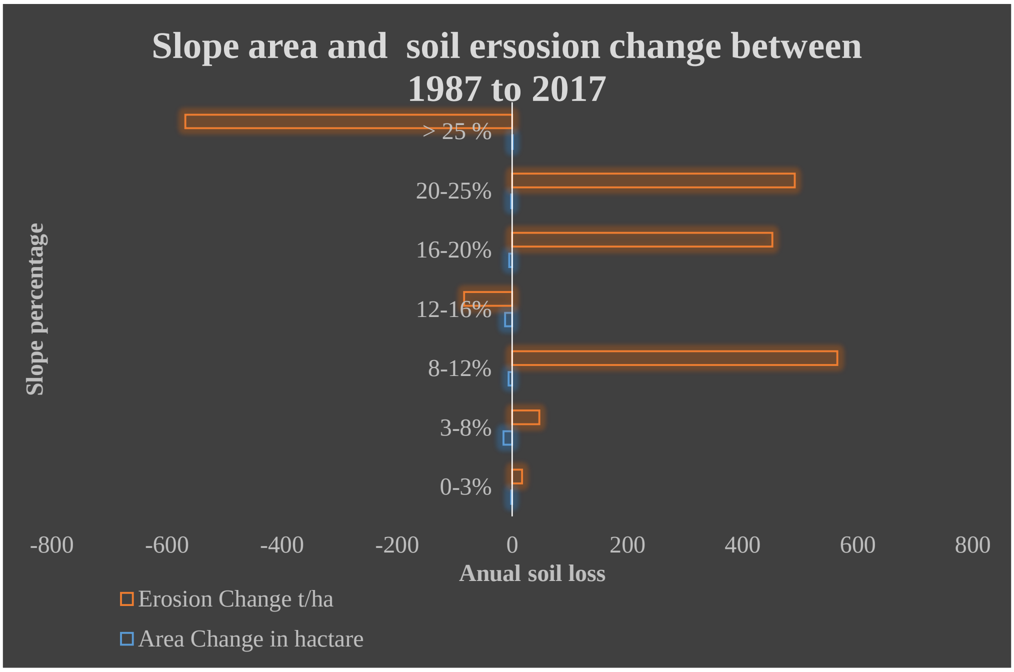



Figure 14. Erosion change with relative small topographic and vegetation variation

### 4.4.3 Soil Erosion Severity and Mean Annual Soil Loss

The estimation of soil loss is important for identifying; the severity level, the source of pollution on down streams or reservoirs and for future conservation planning. The severity of soil loss was categorized into six groups, its ranges from very slight, slight, moderate, high, Severe and very severe. This classification based on Morgan (2009) soil loss severity classification. The total annual soil loss of the year 1987 and 2017 were 336,234 t ha $^{-1}$ and 346,456 t ha $^{-1}$ respectively.

The erosion rate classification in DMBN basin, very slight and slight soil loss categories are covered the majority of areas. Therefore, in our soil loss severity classification very slit means almost zero erosion and it covers almost 55%. Wischmeier and Smith (1978) shown as the other tolerable soil erosion ranges from 2 to 5 t ha$^{-1}$ yr$^{-1}$.

In this study severity classification category, it is under slight and a covers approximately 21%. Thus, this RUSLE estimations only considering the rill and inter-rill erosion.

The overall erosion severity those areas greater than the tolerable soil loss limit rate, which is greater than 5 t $ha^{-1}yr^{-1}$ were recording 23.03% to 23.64 % of the DMBN-basin. This limit includes moderate to very sever erosion level. The detail list presented in Table 12. Also, the soil erosion above the tolerable limit should be under threatened in the basin still larger coverage. Similarly Gelagay and Minale (2016) reported 23.95% greater than 7 t $ha^{-1}yr^{-1}$.

The soil erosion rate between 1987 and 2017 which shows that decreasing and increasing severity level. For instance, very severe and severe soil loss severity categorize shows decreasing rate. Whereas, very slight, slight, moderate and high zones are decreases presented in Figure 15. This implicates with a little improvement of the vegetation and conservation measures in sloppy area make the rill and inter-rill soil erosion level decreases significantly. In case of deforestation, if it will be on the remnant forests on the steep slope could worsen erosion than other LULC by the cumulative effect of vegetation clearing (C-factor), that exposed the soil to water and topography (LS-factor) leads soil erosion to the maximum level.

Table 12. Overall soil loss severity rate classification of 1987 and 2017

| | | 1987 | | | 2017 | | |
|---|---|---|---|---|---|---|---|
| | | Tone/yr | area (ha) | Severity % | Tone/yr | area (ha) | Severity % |
| Very slight | <2 | 186219.50 | 65551.70 | 55.38 | 190485.20 | 65074.97 | 54.98 |
| Slight | 2-5 | 72574.30 | 25547.10 | 21.58 | 74078.70 | 25307.32 | 21.38 |
| Moderate | 5-10 | 30329.50 | 10676.38 | 9.02 | 33153.93 | 11326.29 | 9.57 |
| High | 10-50 | 33513.59 | 11797.22 | 9.97 | 37808.45 | 12916.40 | 10.91 |
| Severe | 50-100 | 8860.06 | 3118.86 | 2.64 | 7316.74 | 2499.60 | 2.11 |
| Very-Severe | 100-248 | 4737.73 | 1667.74 | 1.41 | 3613.33 | 1234.41 | 1.04 |

| | | |
|---|---|---|
| Sum | 336234.67 | 346456.35 |

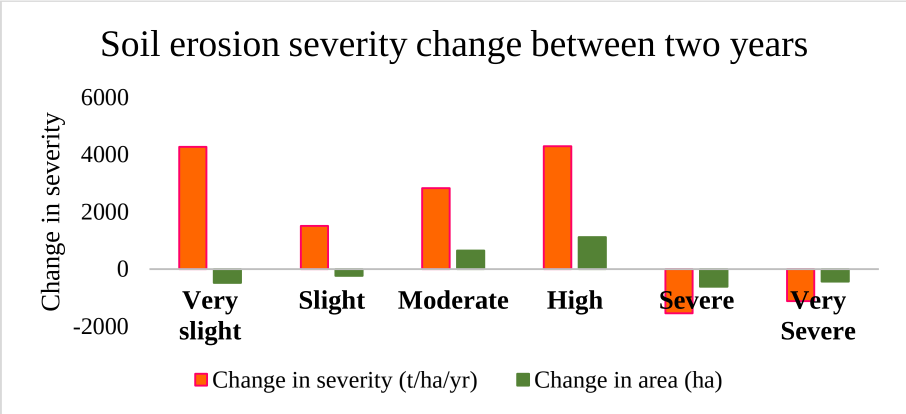



Figure 15. Annual soil loss severity increase and decreasing rate

Thus, the final map that shows the potential annual soil loss of the watershed was produced in Figure 16 a) and b) for 1987 and 2017 respectively. Each cell value was ranged from minimum values of zero for both years to maximum 268 in 1987 and 248 in 2017 t $ha^{-1}yr^{-1}$. A similar study by Gelagay and Minale (2016) showed in Koga watershed that the value of each cell values ranged from zero to 265 t $ha^{-1}yr^{-1}$ with a mean value of is 47.4 t $ha^{-1}yr^{-1}$, which is close to current estimation. The estimated average annual soil loss value of each cell for 1987 and 2017 are 53.63 and 53.82 t $ha^{-1}yr^{-1}$ respectively.

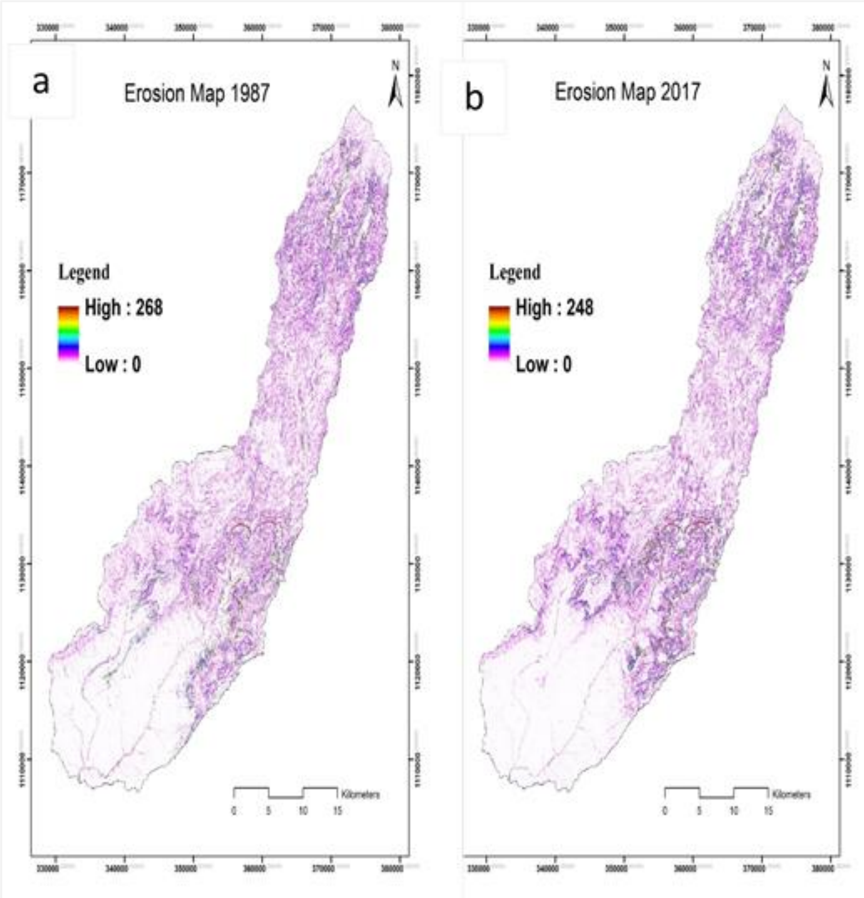



Figure 16. Annual Soil Loss Map of 1987 and 2017

For mean annual soil loss calculation the study considered the sum of all pixel counts of cell. From primarily produced map by spatial analysis tool after the float map changed to raster by integer arc tool function then produced zonal statics as table, which give the sum soil erosion pear each erosion level values. Therefore, according to USDA the tolerable limits ranges from 2 to 5 t $ha^{-1}yr^{-}$(Wischmeier and Smith, 1978). Also, the erosion very slight categories erosion is negligible in soil erosion and less than this tolerable limit. Therefore, we exclude the very slight erosion categories in mean annual soil calculation and the final mean annual soil loss from the total cell count have been 53.63 to 53.82 t $ha^{-1}yr^{-1}$ for 1987 and 2017 respectively.

### 4.4.4 Comparison and Summary with Other Studies

The well-known study SCRP estimated soil erosion in six geographical location of Ethiopia for several years. In this six areas Hurni (1985) estimated an average of 72 t $ha^{-1}yr^{-1}$ of soil loss in six geographical locations with a correction of sediment delivery ratio factor. In part of this well-known study SCRP by Grounder and Herweg 1991 as cited in Desta et al. (2000), the soil erosion in Anjeni research unit in Gojjam is similar to the current study area, which soil erosion was ranged from 14.4 to 210.6 with an average of 146.28 t $ha^{-1}yr^{-1}$ in 1987. According to the same authors the soil loss due to water erosion measured range from 1.6 to 199.2t $ha^{-1}yr^{-1}$ in 1988 was significantly reduced to the average value of 78.65 t $ha^{-1}yr^{-1}$.

Different study methods in Kechemo and Eren watershed, which is part of the study areas. In these two micro watershed using survey methodology in Kechemo and Erene showed average of 14.85 and 67.1t $ha^{-1}yr^{-1}$ from rill erosion and 19.8 and 86.9 t $ha^{-1}yr^{-1}$ from inter-rill erosion recorded only in two rainy seasons (Bewket and Sterk, 2003). In addition to that by using USLE method of estimation in Chemoga watershed about 110t/ha/yr soil have been eroded annually (Bewket and Teferi, 2009). And also RUSLE estimation weighted mean of annual soil loss Hafety watershed in South Gonder about 84 t $ha^{-1}yr^{-1}$ loss annually (Selassie and Belay, 2013).

The current study also was found to be comparable result with 47 t $ha^{-1}yr^{-1}$ soil loss in Koga watershed (Gelagay and Minale, 2016) and 45 t $ha^{-1}yr^{-1}$ in northern Ethiopia three catchment by (Tamene et al., 2017), such estimation is less than the present study. In the reference study the annual soil loss showed is inconsistency but it gives an idea soil erosion is severe in this areas. The current study proved that soil erosion is very severe for both reference periods. The soil erosion rate by different methods in different study areas of north and north-western part of the country have presented in Figure 17.

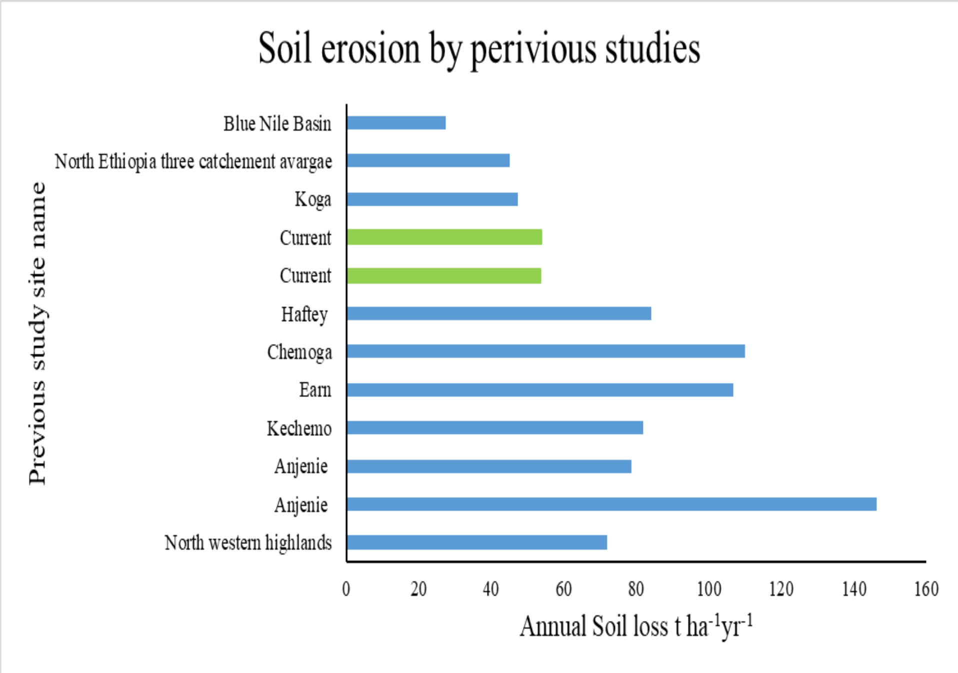



Figure 17. Soil erosion rate comparison with different study by various method.

For future scenario as an illustration, Meshesha et al. (2012b) stated that by putting different scenario treating hotspot areas by business as usual to vegetation improvement, installing physical SWC structures, enclosures or by integration decreases soil loss from 12.6 % to 87.8% protection, whereas, the deforestation increases up to 66% soil erosion. Lee et al. (2017) reported future projection scenario agroforestry and reforestation on denude land decreases 41% and 60% the erosion level respectively and agroforestry is a more recommended intervention for sustainability. Similarly, Subhatu et al. (2017) reported from practical intervention in Minchet catchment in North Ethiopian highlands, which shows from 54% to 74% of soil erosion deposited seen in well spacing terrace areas and the soil conservation structures combat soil erosion level.

# 5. Conclusions and Recommendations

## 5.1 Conclusions

Supervised LULC classification is based on ground trothing point, which is popular to map LULC. However, it is not always possible to acquire field verified data in a real-life situation. The GE have multiple advantages such as; to freely access geo-browser, higher spatial resolution, to sees three-dimensional land features, to see the altitude of the specific ecosystem, to see the shape and textures of LULC than the Landsat. Using these all from the GE are important for collecting exact training data, mainly those are less separable each other for better accurate classifying images. Therefore, training data collection from GE is the best and an alternative method during a barrier to do ground-truthing, such as inaccessible areas, limited time, labour and other resources. Especially in areas like DMBN-basin and those also fragmented and heterogeneous landscape within a short distance, which have a difficulty to identify each LULC types from medium or coarser resolution images and GE is important. However, the study enables us to understand the DMBN basin LULC trend from the GE aid Landsat Supervised Classified map with comparable kappa coefficient.

Even though we had collected relatively higher/diverse number of LULC types from GE, the Landsat still limited due to similar reflectance value of few LULC types. For instance, settlements/urban with agriculture, marshland with grassland, agriculture with bare land etc. The classification result of those have similar reflectance values and had been less accurate, which intermixed during classification. Thus, the GE is better to identify and minimizing the error that came from the settlement by directly screens digitizing.

As Civco et al. (2002) stated that there have been no accurate single methods. Therefore, the integration Landsat and GE is the quantification of LULC improve accuracy, as shown in the map accuracy assessment. Indeed, the large area by spatial distribution analysis with remote sensing mapping is important. This estimation is valuable in the past as well more in the future to give information for experts and decision makers to plan activities including protection and conservation natural ecosystem.

Further investigation of accurate LULC mapping is also important for other related studies. Including, monitoring the resource where it is allocated, identifying the problem, intervening conservation and management options. In the study, the 30 years LULC analysis at the same time enables to see the annual soil loss variation. The spatial distribution of soil loss computed from RUSLE method of GIS and RS analysis intermediate in DMBN-basin is important for evaluating within a short time, where the ground-based experiment is difficult.

We noticed that more than 83% of the rill and inter rill erosion came from agricultural lands. Also considering topography, the steeper slope greater than 20% that only cover 12.25% of the total land of the study area and can be estimated to be about 32.98 to 34.23% of soil loss came from this steeper slope lands. Therefore, erosion exceeds the tolerable limit as per the analysis using RUSLE estimation on the narrow steeper slope and agricultural land of the basin. The combined effect that farming on steeper slope aggravates the soil loss. In brief, the conservation farming areas on the steeper slope, greater than 20% were identified areas considered the priority for conservation.

The RUSLE methods is the best for wider area application with less cost and labour. However, such method has also a certain limitation including under and over annual soil loss estimation. The accurate RUSLE estimation of annual soil loss is also subjective to error produced by uncertainty of quality data such as rainfall measurement and spatial distribution of the rainfall stations, resolution and accuracy of DEM and satellite images and site-specific supportive practice recorded values from the previous studies/reference are determinant to get the close estimation. Thus, all data need special attention while acquiring. Also, RUSLE needs updated field experiments to further developed to site-specific and different agro-climatic condition. Basically, P and C factor are frequently changed by different tradition and experience in a different part of the country. In general, the analysis shows that the most determinant factor for soil erosion by water is found to be the topography and this can be mitigated by modifying the land cover with vegetation as well as by practicing the physical soil and water conservations.

## 5.2 Recommendations

In this study, we suggested that the GE could be a better and a more useful tool as a data sources for identifying each LULC. Such method is as important as the ground truthing based classification. It is a helpful tool instead of using leave alone medium or courser resolution image for training data collection, which extracts relatively much more LULC types because more confusing to identify LULC pixels of similar reflectance values from the courser image. Furthermore, it is also important when higher resolution image and ground truthing data is difficult to acquire practically. As a result, Landsat has still limited capacity to classify many LULC at once, even if we brought many LULCs from GE. To improve this, it is better to take some land features, for instance, settlement and bare land directly by screen digitizing from GE as a shapefile.

In near recent years the GE geo-browser has been providing more clear images than the previous years and also becomes higher temporal resolution free of blurred images. Therefore, the increasing availability of GE geo-browser in recent years as well as in future is important for future similar studies. Also, hopefully GE will continue to upload more temporal data.

This study is also show how to practice of mapping LULC changes and annual soil loss estimation at zone and district expert level for micro or macro watershed studies. They can also use available data for estimation of LULC changes and soil loss. The ultimate function is important for identifying the problems at the local level, that are useful for plan preparation and to give priority to those that are needed prior to SWC measures as well as monitoring the changes. Therefore, the local level analysis will have higher spatial information because it also includes local knowledge.

RUSLE is empirical, alternative methods based on remote sensing and GIS analysis to estimate annual soil loss, in which field measures are limited and when it is necessary to estimate for wider areas. During implementation, it includes data such as vegetation coverage, slope steepness, and length, soil types and depth. For final analysis of the annual soil loss, it also needs different areas of expertise are needed. The integration of expertise to work on each factor and bring together would lead accurate result. For instance, the rainfall, soil, slope, cover and supportive/conservation practice are characterized separately by its own field expert for aproximate final output.

Of the natural factor causing soil loss, higher intensity of rainfall and steep relied are the major factor. The impact of the raindrop with higher energy on unprotected bare land, which causes a splash the soil pores get plugged with the fine particles followed by sheet and rill erosion (Desta et al., 2000). As a result, working on supportive (P) factor that minimizes the slope length and steeper slopes. Also working on the cover (C) factors that protect the earth surface from direct intact of the raindrop, roots bind the soil together and litter regulates soil water movement. The two factors are the key determinants and artificially modified factors, that possibly improve all other factors, even if the R and LS have a higher impact on soil erosion.

Some examples are managing slope length and steepness could be terracing, bench terrace, hillside terracing, hilside water harvesting structures. These improve groundwater recharge whilst decreasing the time of the flood concentration and sedimentation in lower catchment etc. In addition, it also increases the soil organic content and structure of the soil, which decrease soil erosion by increasing cohesive power of soil particle from rill and inter-rill erosion. Also Ariti et al. (2015) reported that almost all farmers, institutions and businessmen have a perception on the present land degradation, whereas, there is the limitation on adaptation measures due to a lack of information on best practices, a lack of skills and technical know-how, a shortage of financial resources, and a limited infrastructure. To improve these, working closely with the community to grounded the listed conservation activities is mandatory.

The government policy supports the soil and water conservation and afforestation by the community mass mobilization throughout the country. In the current study, the SWC practice implementation by public mobilization showed as hint good progress. For saying this, some areas like in the DMBN-basin showed some of the vegetation coverage improvement in the higher and mid-altitude. However, it also necessary works on a recommended specious in addition to Eucalyptus. Although the current implementation on SWC and afforestation are vast, that working on sustainability after implemented are limited and need to be considered once after implementation. In addition, it is important to note that even a small increment of agricultural land categories has disproportional increment on the soil erosion amount. Thereby the vegetation coverage increases in the mid and higher altitudes of DMBN-basin and also in steeper slope. However, these increments have not solved the overall erosion level because due to decreasing the lowland woodlands still affects the soil erosion level. Protection of clearing the current wood vegetation and modification of overgrazing would be a great addition too. Especially those are under communal lands are susceptible to change. Therefore, the implementation of the current policy on natural resource conservation, community bylaws must be practiced for functionality and must pass beyond the written document.

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# Appendices

## Appendixes 1) Ground truthing points

| Number | Elevation | Longitude | Latitude | Number | Elevatio | Longitude | Latitude |
|---|---|---|---|---|---|---|---|
| 1 | 3732.30 | 37.84 | 10.63 | 37 | 2397.70 | 37.71 | 10.33 |
| 2 | 3725.19 | 37.84 | 10.63 | 38 | 2400.86 | 37.71 | 10.32 |
| 3 | 3722.08 | 37.84 | 10.63 | 39 | 2219.51 | 37.64 | 10.26 |
| 4 | 3722.75 | 37.84 | 10.63 | 40 | 2221.05 | 37.64 | 10.26 |
| 5 | 3715.84 | 37.84 | 10.63 | 41 | 2220.47 | 37.64 | 10.27 |
| 6 | 3714.65 | 37.84 | 10.63 | 42 | 2428.83 | 37.77 | 10.31 |
| 7 | 3709.13 | 37.84 | 10.63 | 43 | 2417.48 | 37.72 | 10.31 |
| 8 | 3727.11 | 37.84 | 10.63 | 44 | 2400.42 | 37.72 | 10.31 |
| 9 | 3728.06 | 37.84 | 10.63 | 45 | 2398.97 | 37.72 | 10.31 |
| 10 | 3732.45 | 37.84 | 10.63 | 46 | 3518.15 | 37.82 | 10.60 |
| 11 | 2449.78 | 37.75 | 10.30 | 47 | 3543.32 | 37.82 | 10.60 |
| 12 | 2450.10 | 37.75 | 10.30 | 48 | 3547.51 | 37.82 | 10.60 |
| 13 | 2160.00 | 37.66 | 10.26 | 49 | 3729.16 | 37.83 | 10.63 |
| 14 | 2252.54 | 37.65 | 10.26 | 50 | 3738.47 | 37.83 | 10.63 |
| 15 | 2469.64 | 37.72 | 10.31 | 51 | 3745.57 | 37.83 | 10.63 |
| 16 | 2470.25 | 37.72 | 10.31 | 52 | 3725.19 | 37.83 | 10.63 |
| 17 | 2460.75 | 37.72 | 10.31 | 53 | 3722.08 | 37.83 | 10.63 |
| 18 | 2437.10 | 37.71 | 10.30 | 54 | 3722.75 | 37.83 | 10.63 |
| 19 | 2437.97 | 37.71 | 10.30 | 55 | 3715.84 | 37.84 | 10.63 |
| 20 | 2474.14 | 37.74 | 10.38 | 56 | 3714.65 | 37.84 | 10.63 |
| 21 | 2504.86 | 37.74 | 10.39 | 57 | 3709.13 | 37.84 | 10.63 |
| 22 | 2475.22 | 37.74 | 10.38 | 58 | 3727.11 | 37.84 | 10.63 |
| 23 | 2230.32 | 37.65 | 10.26 | 59 | 3728.06 | 37.84 | 10.63 |
| 24 | 2472.83 | 37.79 | 10.33 | 60 | 3732.45 | 37.84 | 10.63 |
| 25 | 3501.20 | 37.81 | 10.60 | 61 | 2458.49 | 37.79 | 10.33 |
| 26 | 3496.29 | 37.81 | 10.60 | 62 | 2406.40 | 37.75 | 10.30 |
| 27 | 2461.61 | 37.79 | 10.33 | 63 | 2403.43 | 37.75 | 10.30 |
| 28 | 3501.20 | 37.81 | 10.60 | 64 | 2405.62 | 37.75 | 10.30 |
| 29 | 3496.29 | 37.81 | 10.60 | 65 | 2405.81 | 37.75 | 10.30 |
| 30 | 2221.60 | 37.64 | 10.26 | 66 | 2405.04 | 37.74 | 10.30 |
| 31 | 2221.52 | 37.64 | 10.26 | 67 | 2400.19 | 37.74 | 10.30 |
| 32 | 2218.12 | 37.64 | 10.26 | 68 | 2399.86 | 37.74 | 10.30 |
| 33 | 2390.07 | 37.71 | 10.32 | 69 | 2488.54 | 37.74 | 10.39 |
| 34 | 2392.66 | 37.71 | 10.32 | 70 | 2486.85 | 37.74 | 10.39 |
| 35 | 2400.10 | 37.71 | 10.33 | 71 | 2504.40 | 37.74 | 10.40 |
| 36 | 2396.08 | 37.71 | 10.33 | 72 | 2506.62 | 37.74 | 10.40 |
| 73 | 2506.55 | 37.74 | 10.40 | 109 | 2222.0 | 37.65 | 10.26 |
| 74 | 2507.48 | 37.74 | 10.41 | 110 | 3518.1 | 37.82 | 10.60 |
| 75 | 2504.24 | 37.74 | 10.41 | 111 | 3543.3 | 37.82 | 10.60 |
| 76 | 2511.31 | 37.74 | 10.41 | 112 | 3547.5 | 37.82 | 10.60 |

| Number | Elevation | Longitude | Latitude | Number | Elevatio | Longitude | Latitude |
|---|---|---|---|---|---|---|---|
| 77 | 2377.58 | 37.72 | 10.33 | 113 | 2301.9 | 37.76 | 10.30 |
| 78 | 2380.38 | 37.72 | 10.33 | 114 | 2300.2 | 37.72 | 10.32 |
| 79 | 2457.10 | 37.79 | 10.33 | 115 | 2438.1 | 37.75 | 10.30 |
| 80 | 2453.59 | 37.79 | 10.33 | 116 | 2431.7 | 37.75 | 10.30 |
| 81 | 2788.28 | 37.77 | 10.54 | 117 | 2429.3 | 37.75 | 10.30 |
| 82 | 3749.96 | 37.83 | 10.63 | 118 | 2788.7 | 37.77 | 10.54 |
| 83 | 2430.20 | 37.76 | 10.30 | 119 | 2424.6 | 37.75 | 10.30 |
| 84 | 2431.18 | 37.76 | 10.30 | 120 | 2422.7 | 37.75 | 10.30 |
| 85 | 2429.32 | 37.76 | 10.30 | 121 | 2447.5 | 37.75 | 10.30 |
| 86 | 2434.00 | 37.76 | 10.30 | 122 | 2415.3 | 37.75 | 10.30 |
| 87 | 2434.22 | 37.76 | 10.30 | 123 | 2406.4 | 37.75 | 10.30 |
| 88 | 2434.89 | 37.76 | 10.30 | 124 | 2414.6 | 37.75 | 10.30 |
| 89 | 2444.84 | 37.76 | 10.31 | 125 | 2511.7 | 37.74 | 10.39 |
| 90 | 2445.11 | 37.76 | 10.31 | 126 | 2437.2 | 37.72 | 10.32 |
| 91 | 3729.16 | 37.83 | 10.63 | 127 | 2438.8 | 37.72 | 10.32 |
| 92 | 3738.47 | 37.83 | 10.63 | 128 | 2501.7 | 37.74 | 10.40 |
| 93 | 3745.57 | 37.83 | 10.63 | 129 | 2500.5 | 37.74 | 10.40 |
| 94 | 3732.30 | 37.83 | 10.63 | 130 | 2506.5 | 37.74 | 10.40 |
| 95 | 3749.96 | 37.83 | 10.63 | 131 | 2435.2 | 37.72 | 10.32 |
| 96 | 2442.69 | 37.72 | 10.30 | 132 | 2405.5 | 37.72 | 10.33 |
| 97 | 2249.54 | 37.65 | 10.26 | 133 | 2406.7 | 37.72 | 10.33 |
| 98 | 2227.93 | 37.65 | 10.26 | 134 | 2410.6 | 37.72 | 10.33 |
| 99 | 2439.68 | 37.72 | 10.30 | 135 | 2393.1 | 37.72 | 10.32 |
| 100 | 2230.44 | 37.64 | 10.26 | 136 | 2399.7 | 37.72 | 10.32 |
| 101 | 2377.08 | 37.72 | 10.33 | 137 | 2437.7 | 37.72 | 10.32 |
| 102 | 2216.33 | 37.64 | 10.26 | 138 | 2493.3 | 37.80 | 10.33 |
| 103 | 2368.98 | 37.72 | 10.33 | 139 | 2506.4 | 37.80 | 10.33 |
| 104 | 2215.58 | 37.64 | 10.26 | 140 | 2513.4 | 37.80 | 10.33 |
| 105 | 2235.95 | 37.64 | 10.26 | 141 | 2437.1 | 37.72 | 10.32 |
| 106 | 2411.99 | 37.76 | 10.30 | 142 | 2970.4 | 37.77 | 10.55 |
| 107 | 2412.44 | 37.77 | 10.31 | 143 | 2962.0 | 37.77 | 10.55 |
| 108 | 2229.51 | 37.64 | 10.26 | 144 | 2423.0 | 37.76 | 10.30 |
| 145 | 2427.48 | 37.76 | 10.30 | 158 | 2402.5 | 37.74 | 10.30 |
| 146 | 2433.06 | 37.75 | 10.30 | 159 | 2403.9 | 37.73 | 10.31 |
| 147 | 2824.57 | 37.77 | 10.55 | 160 | 2414.1 | 37.73 | 10.31 |
| 148 | 2456.55 | 37.73 | 10.35 | 161 | 2413.8 | 37.73 | 10.31 |
| 149 | 2474.42 | 37.73 | 10.34 | 162 | 2418.8 | 37.73 | 10.32 |
| 150 | 2477.59 | 37.73 | 10.34 | 163 | 2338.4 | 37.73 | 10.34 |

| Number | Elevation | Longitude | Latitude | Number | Elevatio | Longitude | Latitude |
|---|---|---|---|---|---|---|---|
| 151 | 2478.23 | 37.73 | 10.34 | 164 | 2420.1 | 37.77 | 10.31 |
| 152 | 2479.29 | 37.73 | 10.35 | 165 | 2403.2 | 37.77 | 10.31 |
| 153 | 2468.89 | 37.73 | 10.35 | 166 | 2402.2 | 37.77 | 10.31 |
| 154 | 2979.30 | 37.77 | 10.55 | 167 | 2413.5 | 37.67 | 10.20 |
| 155 | 2948.23 | 37.77 | 10.54 | 168 | 2414.4 | 37.67 | 10.20 |
| 156 | 2960.35 | 37.77 | 10.54 | 169 | 2424.7 | 37.67 | 10.19 |
| 157 | 2966.34 | 37.77 | 10.55 | 170 | 2427.4 | 37.68 | 10.20 |

**Appendixes 2) Accuracy assessment of the LULC classification of the year 2002**

| 2002 | | Ground truth | | | | | | | | Users |
|---|---|---|---|---|---|---|---|---|---|---|
| | | AF | A | F | GM | P | W | WS | Total | Accuracy |
| Classified | AF | 10 | | | | | | 1 | 11 | 90.91 |
| | A | 1 | 20 | | | | | | 21 | 95.24 |
| | F | | | 15 | | 2 | | | 17 | 88.24 |
| | GM | | | 1 | 20 | | | 4 | 25 | 80 |
| | P | | | 2 | | 11 | | | 13 | 84.62 |
| | W | | | | | | 7 | | 7 | 100 |
| | WS | | | | | | | 11 | 11 | 100 |
| | Total | 11 | 20 | 18 | 20 | 13 | 7 | 16 | 105 | |
| | Producers | 90.91 | 100 | 83.33 | 100 | 84.62 | 100 | 68.75 | | |

Overall accuracy 89.5 % and kappa coefficient = 0.877

**Appendixes 3) Accuracy assessment of the LULC classification of the year 1987.**

| 1987 | | Ground truth | | | | | | | | Users |
|---|---|---|---|---|---|---|---|---|---|---|
| | | AF | A | F | GM | P | W | WS | Total | Accuracy |
| Classified | AF | 10 | | | | | | | 10 | 100 |
| | A | | 18 | | 2 | 1 | | | 21 | 85.71 |
| | F | 1 | | 12 | 2 | | | | 15 | 80 |
| | GM | | 2 | 1 | 20 | | | | 23 | 86.96 |
| | P | | | 2 | | 8 | | | 10 | 80 |
| | W | | | | | | 3 | | 3 | 100 |
| | WS | | 1 | | 1 | | | 12 | 14 | 85.71 |
| | Total | 11 | 21 | 15 | 25 | 9 | 3 | 12 | 96 | |
| | Producers | 90.91 | 85.71 | 80 | 80 | 88.89 | 100 | 100 | | |

Overall Accuracy 86.45% and Kappa coefficient = 0.936

Where AF = Afro alpine, A = Agriculture, F = Forest, GS = Grassland and Marshland, P = Plantation, W = Water and WS = Wood and Shrubs used also in the next tables.

**Appendixes 4) Mean monthly rainfall from 1995 to 2015 (Source: Ethiopia Metrological Agency)**

| Stations | Aneded | Yejubey | Debre-Markos | Dejen | Digo-Tsion | Gebete | Combolca | Amanuel |
|---|---|---|---|---|---|---|---|---|
| Jan | 5.48 | 4.87 | 12.12 | 7.82 | 8.16 | 22.53 | 7.56 | 6.59 |
| Feb | 8.06 | 6.86 | 8.69 | 10.46 | 3.60 | 7.89 | 5.81 | 5.81 |
| Mar | 46.77 | 33.48 | 45.63 | 59.74 | 34.38 | 64.14 | 41.02 | 45.10 |
| Apr | 50.40 | 54.39 | 63.55 | 71.56 | 43.19 | 53.29 | 43.79 | 45.28 |
| May | 95.47 | 91.07 | 106.27 | 94.24 | 168.69 | 138.97 | 159.69 | 149.43 |
| Jun | 182.02 | 188.02 | 167.03 | 163.70 | 167.61 | 294.59 | 278.01 | 193.13 |
| Jul | 297.77 | 323.14 | 268.24 | 360.96 | 352.21 | 333.09 | 436.31 | 296.74 |
| Aug | 275.36 | 309.77 | 302.25 | 346.68 | 363.23 | 277.94 | 395.74 | 311.20 |
| Sep | 157.14 | 187.85 | 227.83 | 172.19 | 175.72 | 160.40 | 228.41 | 270.90 |
| Oct | 66.84 | 74.41 | 85.54 | 88.95 | 92.64 | 64.77 | 79.38 | 69.24 |
| Nov | 20.22 | 19.31 | 26.29 | 33.74 | 34.55 | 30.09 | 45.56 | 37.43 |
| Dec | 15.14 | 7.95 | 18.41 | 6.96 | 24.81 | 15.13 | 13.34 | 6.43 |
| Annual | 1220.64 | 1301.09 | 1331.85 | 1416.98 | 1468.80 | 1462.83 | 1734.61 | 1437.28 |

**Appendixes 5) Pictures of few Land use and Land Cover types**

A) Agriculture

B) Grassland

C) Natural Forest

D) Afro-alpine Forest

E) Plantation

F) Woodland

# Abstract (In Korean)

토양유실 위험성은 토지이용 및 토지피복 변화 (Land use and land cover change, LULCC)와 밀접한 관련이 있으며, 이로 인하여 전 세계적으로 사회적, 경제적, 환경적 문제가 발생되고 있다. 최근 에티오피아 데브레 마르코스 블루 나일(DMBN: Debre-Markos Blue Nile) 유역에서 토양침식이 급격하게 증가되고 있으며, 이는 토지이용 및 토지피복 변화의 원인으로 발생된다고 보고되고 있다. 따라서 본 연구에서는 Landsat TM, Landsat 7 ETM+(Enhanced TM), Landsat 8 OLI(Operational Land Imager) 영상을 이용하여 30 년 간의 토지이용 및 토지피복 변화를 파악하고, 이로부터 구축된 1987, 2002, 2017 년의 토지이용 자료를 기반으로 RUSLE(Revised Universal Soil Loss Equation) 모델을 이용하여 토양유실량 변화와 위험성을 평가하였다.

첫째, 토지이용 및 토지피복 변화를 정량적으로 분석하기 위하여 2002 년과 2017 년의 Landsat 위성영상은 고화질의 구글어스(Google Earth) 영상에서 획득한 훈련지역을 이용하여 감독분류를 실시한 반면, 1987 년의 구글어스 영상을 획득하는데 어려움 있어 2002 년의 훈련지역을 이용하여 감독분류를 진행하였다. 구글어스 영상에 의한 토지 이용 분류 정확도는 85%를 나타내었으며, 훈련지역과 현장데이터의 일치정도를 나타내는 지수인 Kappa 계수는 0.81 로 높은 정확도를 보였다. 분석결과, 2017 년 기준으로 44%의 농경지역으로 이루어져 있으며 1987 년에 비해 30 년간 29%의 토지이용 및 토지피복 변화가 나타났다. 특히, 연구대상 유역의 토지이용 변화는 아프로알파인(afro-alpine), 교목림(forest), 농경지, 천연림, 농장(plantation), 정착지(settlements), 수역이 증가한 반면, 관목림(woodland)와 초원지역(grassland)은 각각 4%과 2%가 감소하는 것으로 나타났다.

둘째, 기 구축된 토지이용 및 토지피복 주제도를 이용하여 이에 따른 연간 토양유실량을 RUSLE 를 이용하여 평가하였다. 1987 년부터 2017 년까지의 강우에너지인자, 토양침식인자, 사면길이인자, 사면경사인자 값은 동일하다고 가정한 반면, 토지피복인자와 토양보존대책인자는 인공위성영상 분류 결과 자료를 기초로 1987, 2002, 2017 의 인자 값을 다르게 적용하였다. 그 결과, 2017 년 기준으로 연간 토양유실량은 346,230 톤/년으로 1987 년에 비해 3%(9,996 톤/년)이 증가하였으며, 총 토양침식량의 95% 이상이 농경지와 초원지역에서 발생되는 것을 알 수 있었다. 특히, 전체 DMBN 유역내 토양침식 위험성은 급경사지역에 분포하고 있는 농경지가 이외의 토지이용 및 피복 지역에 비해 높은 것으로 평가되었다.

본 논문 결과를 종합해볼 때, Landsat 위성영상과 고화질의 구글어스영상과의 접목을 통해 직접적인 접근이 어려운 지역의 토지이용 및 토지피복 변화를 평가하는데 효율적으로 이용될 수 있을 것으로 판단되었다. 또한 RUSLE 모델의 토지피복 관련 매개변수를 수정 및 추정하는 과정을 통하여 토지이용 및 토지피복 변화에 따른 토양유실 위험지역을 합리적으로 평가하였다고 사료된다.

**주요어:** 데브레 마르코스 블루 나일(DMBN) 유역, 토지 이용 및 토지 피복 변화(LULCC)), Landsat 위성영상, 구글어스(Google Earth), RUSLE

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