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Estimating Soil Loss for Soil Conservation Planning In AFA River Watershed of Upper Blue Nile Basin, North West Ethiopia

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ABSTRACT: Soil erosion is a worldwide problem that cause environmental degradation. The problem is severe in African countries including Ethiopia. Afa river watershed is also the victim of this problem. This study was aimed to estimate soil loss in the watershed by GIS based USLE model, and prioritize sub watersheds for soil conservation planning. Rainfall erosive effect, soil erodibility, topographic effect, land use land cover and supportive conservation practice factors were used as an input for the model to determine the amount of soil loss from the watershed. A combination of GIS application, Remote Sensing technique, and USLE model were used for soil loss estimation and the result showed that the annual soil loss from the watershed was in the range of 0 to 129.58 ton $ha^{-1}year^{-1}$ with mean soil loss of 20.04 ton ha^{-1} $year^{-1}$. The mean soil loss was greater than soil loss tolerance of 11ton ha^{-1} $year^{-1}$. Based on mean annual soil loss and erosion risk area coverage, erosion 'hot spot' areas were identified and prioritized for conservation planning. Accordingly, SW5, SW 15, SW 17, SW 14, SW 13, SW 6, SW 2, SW 10, SW 7, SW 11, SW 8, SW 18, SW 19, SW 1, SW 4, SW 9, SW 16, SW 3 and SW12 got 1 up to 19 priority level respectively. This study recommended that soil and water conservation measures should be planned for impelimentation, starting from SW5 to SW12 based on the capacity of logistics, time, budget and skill availability.
Keywords: Afa watershed, Soil loss, Upper Blue Nile Basin, Ethiopia

I. INTRODUCTION

Soil erosion is worldwide environmental problem that threatens the lives of most small holder farmers [1]. Soil erosion is a major cause of land degradation that affects the physical and chemical properties of soils and resulting in on-site nutrient loss and off-site sedimentation of hydraulic structures in the world and as well as in Ethiopia. World population livelihood is closely linked to soil, and soil contributes of food, clean water, clean air, and are a major carrier for biodiversity [2]. Most of the people in the world, especially farmers remain heavily dependent on soil resources as their main livelihood source that lead to high soil erosion. Soil erosion is also a natural phenomena and modified by biophysical environment comprising soil, climate, terrain, ground cover and interactions between them. The high erosion rates are affecting mainly the developing countries due to intensive cultivation, deforestation, ploughing of marginal lands and extreme climate hazards [3]. Soil erosion rates beyond the tolerable limit changes in the hydrological, biological, erosion and geochemical cycles, which result in lack of the services that the soil offers to the human beings [4]. In Ethiopia, soil erosion and nutrient depletion has been one of the most important environmental problems [5]. It is also most serious form of land degradation, in which its on-site and off-site effects threaten the food security and the national economy of the country [6]. According to the Ethiopian highland reclamation study [7] in mid-1980's 27 million hectare or almost 50% of the highland area was significantly eroded,14 million hectare seriously eroded and over 2 million hectare beyond reclamation. Whereas the Blue Nile basin lost fertile soils with a rate of 131 million ton yr^{-1} [8]. Lack of appropriate soil conservation measures and poor land use management have played a great role for serious soil erosion problems in the country. The main cause of soil erosion that can aggravate land degradation in any watershed is removal of land cover. Thus, there is need for appropriate interventions to combat the prevailing constraints using suitable technologies for improved and sustainable agricultural production [9].

To undertake corrective measures and prevent further degradation of the watershed, timely information on the extent and spatial distribution of erosion areas is of paramount importance. Many soil erosion models were developed over the last four decades to assess soil erosion risk at different levels of single slope, catchment, regional and global scales [10]. Most current erosion modeling researches are focused on using process-based erosion models. Soil erosion models are useful to estimate soil loss and runoff rates from agricultural land, to plan land use strategies, to provide relative soil loss indices and to guide government policy and strategy on soil and water conservation. The universal soil loss equation (USLE), is one of the most popular empirical models to predict the long- term average annual rate of soil loss. Under these circumstances, Remote Sensing (RS) and Geographical Information System (GIS) in combination with USLE become valuable tools to achieve more satisfactory results in the assessment of soil erosion in the watershed. Remote sensing will be used to identify and map eroded areas [11]. GIS will make a tremendous impact in many fields of application, because it allows ease of data update, data management and data presentation in forms most suited to user requirements. At the same time, GIS allows for vast amounts of information on different themes and from different sources to be integrated [12].

In the study area watershed crop cultivation and human inhabitation has taken place from a long period of time leading to expansion of farming activities, and increasing population settlements. Due to its physical feature and human intervention in clearing the forest covered areas for cultivation as well as deforestation for fuel, charcoal and construction purposes the area has exposed to severe soil erosion which leads to land degradation and declined crop production. The main aim of this study was estimation of annual soil loss and prioritization of erosion hotspot areas for conservation planning to bring sustainable land and water resource management in the watershed.

II. MATERIALS AND METHODS

The study was conducted at Afa river watershed in the upper Blue Nile River Basin north west Ethiopia (Figure 1).The watershed is located at 661 km north west of Addis Ababa bounded by the geographical location of 9º 59' 14.3"N to 10º 32' 21.2"N latitude and from 34º 32'4.2"E to 34º 49' 26" E longitude. The watershed area covers Assosa and Bambasi woreda in Assosa zone, Benishangul- Gumuz regional state, Ethiopia.

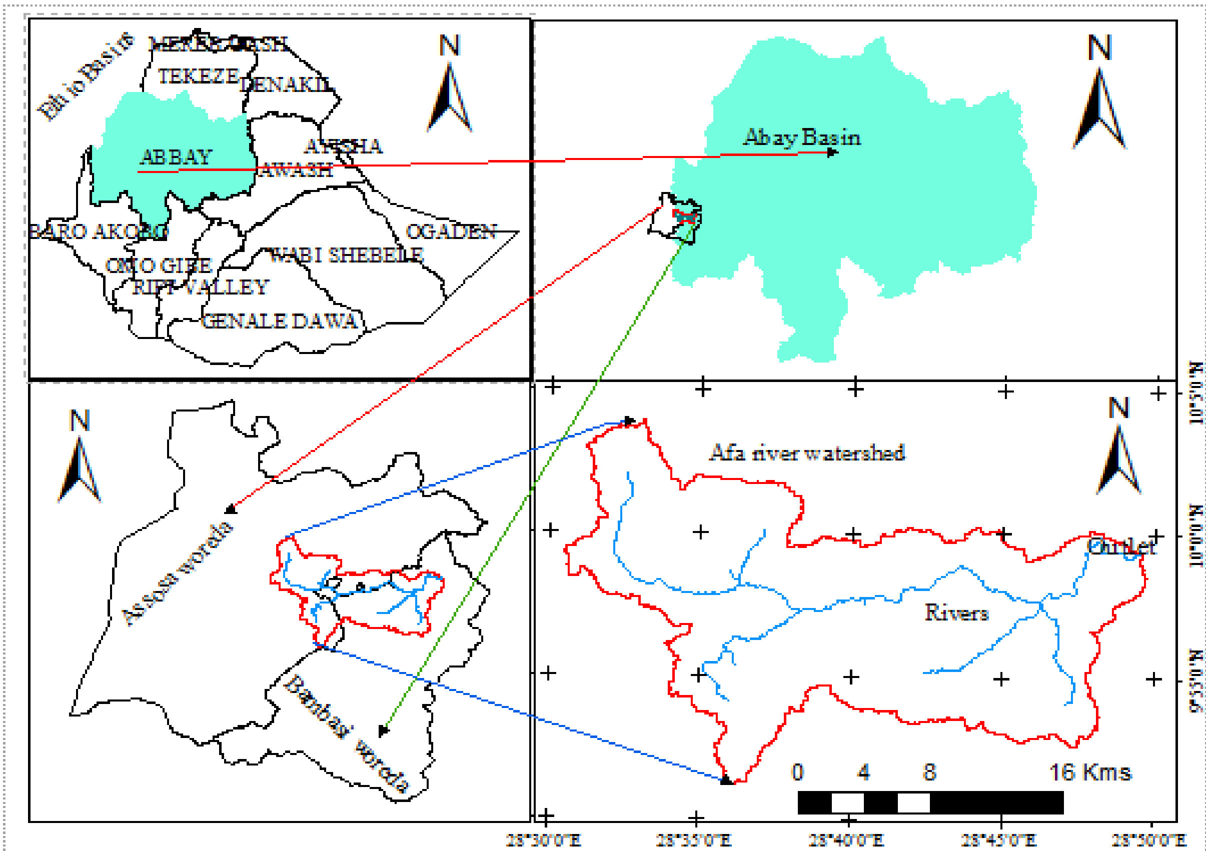


Figure 1. Location map of the study area

Source and method of data collection

Land sat image covering the study area and digital elevation model (DEM) were downloaded from earth explorer website for analysis. The main characteristics of Land Sat image and DEM of the study area are presented in Table 1 below.

Table 1. Characteristics of land sat image and DEM of the study area

Sensors	Landsat image	Acquisition date	Path/Row	Spatial resolution	Spectral resolution
ETM+	8OLI/TIRS C1	19 Feb 2018	171/53	30m*30m	8bit
SRTM	DEM	5 Jan 2018	171/53	30m*30m	16 bit

Source : *https://earthexplorer.usgs.gov (2018)*

Rainfall data was collected based on monthly record. Accordingly, monthly annual rainfall of 22 years,1996 to 2017, for six meteorological stations located in and around the watershed were gathered from Ethiopian National Meteorological Agency. Soil data was taken in the field. Twenty five soil samples were taken from 0 to 20cm soil depth using soil auger. Amount of soil samples were determined based on area coverage of the major soil types in the watershed and visual observation of soil color and nature of topography existed in the watershed. The major soil types of the watershed were obtained from Ministry of Water, Irrigation and Electricity. The coordinate point of 9º 59' 14.3"N latitude and 34º 49' 26" E longitude was taken to fix the outlet of the watershed using GPS on the ground. Then, thirty meters (30m x 30m) pixel resolution Digital Elevation Model (DEM) was filled in sinks of areas of internal drainage so as to create depression less elevation grid. From filled DEM, flow direction and flow accumulation were generated. Finally, the watershed boundary and sub- watersheds were delineated using Arc-SWAT automatically in ArcGIS10.3.

Methods of Data Analysis

The estimation of missing values is often desirable prior to the use of any hydrologic data. In this study, the years, that had inadequate annual records of rainfall data for the selected station were identified and considered to be missed. Hence, they were needed for reconstruction to make them at least relatively complete by the estimation of missed data. The normal ratio method is used if any surrounding gauges of normal annual precipitation exceeding 10% of the considered gauges [13]. So, the missed data were estimated and reconstructed by the normal ratio method because the normal annual precipitation of the meteorological station of the study area was exceeding by 10%.The method is given as:

$$\mathbf{Px} = \frac{\mathbf{Ax}}{\mathbf{M}}\left(\frac{\mathbf{P1}}{\mathbf{A1}} + \frac{\mathbf{P2}}{\mathbf{A2}} + \frac{\mathbf{P3}}{\mathbf{A3}} + - - - + \frac{\mathbf{Pi}}{\mathbf{Ai}}\right) \quad (1)$$

where: Px = is normal annual precipitation at guage X to be estimated, Ax = is annual precipitation at guage X, M = total number of stations (N) other than station X (N-1) and, P_i/A_i = ratio of normal annual precipitation to annual precipitation of each stations. The consistency of the data set of the given station was checked using double mass-curve method within reference to their group stations. The double mass curve was plotted by using the annual cumulative total rainfall of the each stations as ordinate and the average annual cumulative total of group stations as abscissa. For inconsistent rainfall stations the data was adjusted using:

$$\mathbf{pa} = \left(\frac{\mathbf{ba}}{\mathbf{bo}}\right) \mathbf{x\ po} \quad (2)$$

where: Pa = adjusted precipitation; Po = observed precipitation; ba = slope of graph to which records are adjusted; bo = slope of graph at time Po was observed. Besides homogeneity of annual rainfall was tested using RAINBOW software [14].

Estimation of Soil Erosion Factors for USLE

Soil loss computation was conducted by USLE model in a raster GIS environment (grid-based approach). Individual GIS files were built for the rainfall erosivity, soil erodibility, topography, land use/land cover, and conservation practice factor (denoted by RKSLCP) in the USLE and combined by cell grid modeling procedures in GIS software to predict soil loss in a spatial domain. Average annual soil erosion expected on the field slopes were estimated using [15] equation.

$$\mathbf{A = R\ x\ K\ x\ LS\ x\ C\ x\ P} \quad (3)$$

where: A = the computed spatial and temporal average soil loss per unit area (ton ha^{-1} $year^{-1}$), R = the rainfall erosivity factor (MJ mm/(ha h year)), K= the soil erodibility factor (ton ha h/(ha MJ mm)), L= the slope-length factor, S = the slope steepness factor, C = the cover management factor and P = the conservation support practice factor. L, S, C, and P are all dimensionless.

R-factor

R-factor was computed by using the regression equation developed by [16] for Oromia region, Ethiopia (i.e. Nejo, Kiltu-karra and Mendi areas which were found in Dabus sub basin of upper Blue Nile (Abay) river basin the same to the study area). The equation developed for the R factor was:

$$\mathbf{R = 0.67P^{1.19}} \tag{4}$$

where, R is the rainfall-runoff erosive factor(MJ-mm/ha. h. year) and P is the mean annual rainfall (mm).Using 22 years mean annual precipitation of six stations (Menge, Amba-10, Assosa, Amba-16, Bambasi and Oda Bildinglu). Rainfall erosive factor value was calculated for each station and mapped by the help of raster calculator tool in GIS, and R-factor map was generated as a raster data. Spatial distribution of rainfall factor (R) was interpolated using 'Kriging' technique in spatial analysis tool.

Kriging technique is an advanced geo-statistical procedure that generates an estimated surface from a scattered set of points with Z-values. Kriging is a multistep process; it includes exploratory statistical analysis of the data, variogram modeling, creating the surface, and (optionally) exploring a variance surface. The general formula for kriging is a weighted sum of the given data.

$$Z_{(s_o)} = \sum_{i=1}^{N} \lambda_i Z(s_i) \tag{5}$$

where: $Z(s_i)$ = the measured value at the i^{th} location, λ_i = an unknown weight for the measured value at the i^{th} location, s_0 = the prediction location, N = the number of measured values.

K-factor

Soil erodibility factor was obtained from physicochemical properties of soils in the watershed. The soil samples were analyzed for soil texture (% sand, % silt and % clay), soil structure, organic matter content and permeability of soil in laboratory. However percent of very fine sand was obtained using the RUSLE2 mathematical equation which was developed by [17].

$$Pvfs = [\,0.74 - (\frac{0.62Psd}{100})\,] * Psd \tag{6}$$

where, *Pvfs* = Percent of very fine sand, *Psd* = percent of sand. Soil structure was identified at field observation and determined by soil visual descriptors methods suggested by [18] on the field during soil survey. Based on the result of soil properties obtained, soil erodibility factor (K-value) for soil samples were calculated empirically using the equation developed for soil erodibility factor by [19] given as:

$$\mathrm{K} = \frac{[2.1\mathrm{M}^{1.14} \times 10^{-4}(12 - a) + 3.25(b\ - 2) + 2.5(c\ - 3)]}{100} \tag{7}$$

where, M = particle size parameter; M = [% silt + % very fine sand] × [100 - % clay], *a* = percent organic matter, *b* = soil structure code used in soil classification; (very fine granular = 1, fine granular = 2, medium or coarse granular = 3, blocky, platy or massive= 4) and *c* = soil permeability class; (rapid = 1, moderate to rapid = 2, moderate = 3, slow to moderate = 4, slow = 5, very slow = 6). Finally, spatial soil erodibility map was generated as a raster data through interpolation by Kriging method in Arc toolbox (Interpolation) of ArcGIS10.3.

LS-factors

The effects of topography on soil erosion are estimated by the slope length (L) and slope steepness (S). Slope length is defined as the horizontal distance from the origin of overland flow to the point where deposition begins or where runoff flows into a defined channel [20]. Using spatial analysis tool in ArcGIS10.3 value of LS was calculated in the following steps: (1) using patched DEM of the watershed in spatial analysis tool, slope (in degree) of the watershed was analyzed, (2) then flow direction was generated, (3) from flow direction flow accumulation was generated, (4) finally, the LS-factor was calculated in raster calculator using:

$$\mathbf{LS = Power\left(''Flowacc'' * \frac{Resolution}{22.13, 0.4}\right) * power\ [sin\ (''Slope\ of\ DEM''0.01745) / \ 0.0896, 1.4] * 1.4)} \tag{8}$$

where, Flowacc = flow accumulation and Resolution = resolution level of DEM used which was 30m.

C-factor

Classification process and analysis of the different LULC classes were done using Landsat satellite image covering the Landsat 8OLI/TIRS C1 acquired on 19 February 2018 with path 171, rows 53) (Table 2). The Landsat image was down-loaded from United States Geological (USGS) Earth Explorer (https://earthexplorer.usgs.gov/). The Landsat was geo-referenced to the WGS_84 datum and Universal Transverse Mercator Zone 36 North coordinate system. An intensive pre-processing such as geo-referencing, mosaic, and layer-stacking were carried out in order to Ortho-rectify the satellite image. The image was then processed in ERDAS IMAGINE 2015 software. The satellite image of each band was stacked in ERDAS Hexagon within interpreter main icon utility with layer stacked function. Then, from the stacked satellite image the study area image was extracted by clipping the study area using Arc-GIS 10.3 software. For this study, only supervised classification was performed. In supervised classification the user develops the spectral signatures of known categories, such as settlement, cultivated land and etc, and then the software assigns each pixel in the image to the cover type to which its signature is most comparable. Supervised classification is the process most frequently used for quantitative analyses of remote sensing image data. The supervised classification was applied after defined area of interest (AOI) which is called training classes. More than one training area was used to represent a particular class. The training sites were selected in agreement with the Land sat image, Google Earth and Google map. The basic sequence operation followed on supervised classification was; (i) Defining of training sites; the first step in undertaking a supervised classification was to define the areas that will be used as training sites for each land cover class. This is usually done by using the onscreen digitized features. The created features were called Area of Interest (AOI).The selection of the training sites was based on those areas clearly identified in all sources of images. In this study, fifty training sites were been identified. (ii) Extraction of signatures; after the training site (AOI) being digitized, the next step was to create statistical characterizations of each information. These are called signatures editors in ERDAS Imagine 2015. In this step, the goal was to create a signal (SIG) file for every informational class.

The SIG files contain a variety of information about the land cover classes described. After the entire signature have been created, then the SIG file saved as dialog.(iii) classification of the image using supervised classification; the supervised classification has been applied after defined training classes. One or more than one training area was used to represent a particular class. During the supervised classification process, the entire signature editor was selected in order to be used on the classification process. Then the classify was selected and the selected similar images were merged together for each land use/land cover class and named by each LULC class. (iv) classification accuracy assessment, one of the most important final step at image classification process is accuracy assessment. The aim of accuracy assessment is to quantitatively assess how effectively the pixels were sampled into the correct land cover classes. Moreover the key emphasis for accuracy assessment pixel selection was on areas that could be clearly identified on the Land sat high resolution image, Google earth and Google Map. The relationship between ground truth data and the corresponding classified data obtained was checked by overall classification accuracy and KAPPA analysis. The overall classification accuracy = No. of correct points/total number of points. KAPPA analysis a discrete multivariate technique used in accuracy assessments. KAPPA analysis (an estimate of KAPPA) that is a measure of agreement or accuracy.

$$KAPPA_{coficient} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{r=1}^{r}(x_{i} + x_{x+i})}{N^{2} - \sum_{i=1}^{r}(x_{ii} x_{x+i})} \quad (9)$$

where; r = number of rows and columns in error matrix, N = total number of observations (pixels) Xii = observation in row i and column i, Xi+ = marginal total of row i, and X_{X+i} = marginal total of column i. Then, based on values presented in Table 2 the LULC value (C-value) for each LULC class were assigned using spatial analysis tool by reclass method in Arc-GIS 10.3 software and the C-factor map was generated.

Table 2. C-values for the Land use/land covers

Land use/cover	C-value	References
Cultivated Land	0.17	Hurni, 1988
Settlement	0.03	SWCS, 2003
Woodland	0.06	FAO, 1986
Grazing land	0.15	Wischmier and Smith, 1978
Shrub land	0.014	Wischmier and Smith, 1978

P-factor

The support conservation practice factor represents the effects of those practices such as contouring, strip cropping, terracing, etc., that help to prevent soil from erosion by reducing the rate of water runoff. The P-value ranges from 0 to 1 where, 0 represents very good manmade erosion resistance facility and 1 represents no man made erosion resistance facility. In the study area there was no well organized supporting conservation practices except contouring. Contouring was implemented by the farmers. So, a corresponding P- value of contouring based on slopes given by [21]was assigned to cultivated land (Table 3).

Table 3. Conservation practice factor for cultivated land

Slope (%)	Contouring
0.0 - 7.0	0.55
7.0 - 11.3	0.60
11.3 - 17.6	0.80
17.6 - 26.8	0.90
>26.8	1.00

However, since there were no any supporting conservation practice on the other land uses in the watershed, P-value was assigned based on values given by [22] which was 1.0 in any slope steepness. Finally, P-values were assigned for each land use classes and analyzed using spatial analyst tool by reclass method in Arc-GIS 10.3, and the P-factor map was generated.

III. RESULTS AND DISCUSSION

Watershed Delineation

To delineate the watershed, the geographical location of the outlet point (9º 59' 14.3"N latitude and 34º 49' 26" E longitude) and Digital Elevation Model with a range of 1171m.asl to 2062m.asl was used. The delineation result showed that the total area of Afa river watershed was 397.7km^2 .

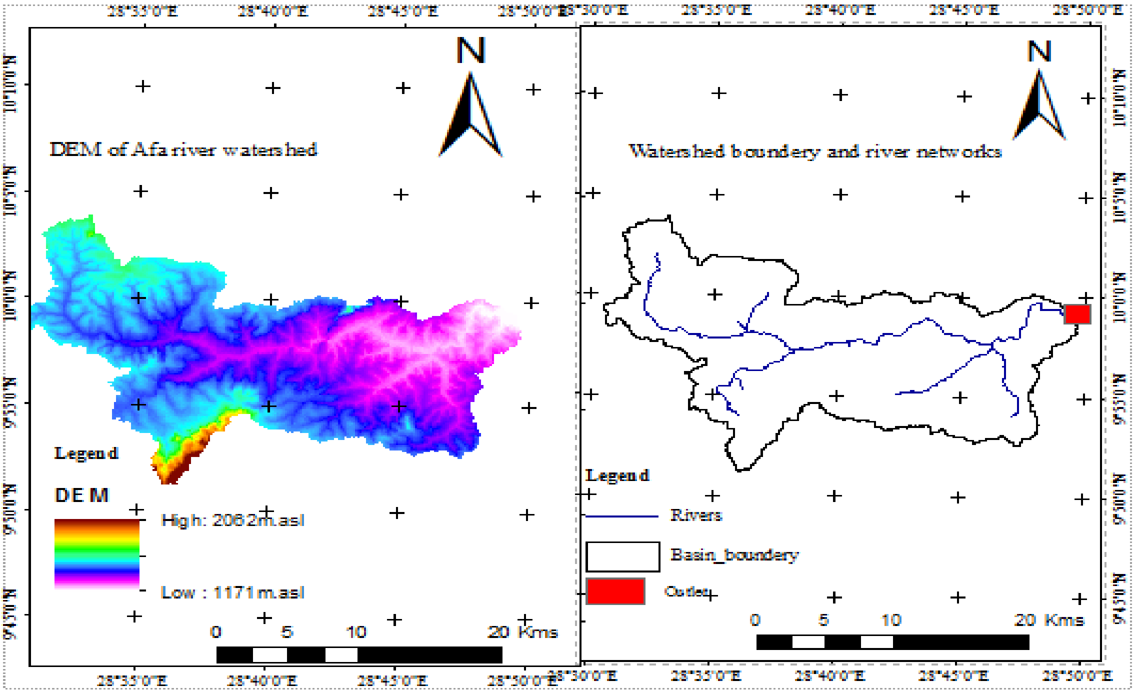


Figure 2. Afa river DEM and watershed map

Missed data estimation, consistency and homogeneity test of rainfall data

Stations having inadequate annual records of rainfall were identified and considered missed. The stations with missed annual records were Oda-Bildinglu for the year of 1996,1997 and 2009, Menge for the year 1999 and 2007 and Amba-10 for the year of 2011 and completed using equation 3. Double mass curve was used to plot annual cumulative total rainfall of each individual station with the average annual cumulative rainfall of all group stations to test consistency of rainfall data. All the rainfall stations were consistent with R^2 values of 0.96,0.97,0.98,0.98,0.99 and 0.97 for station Oda-bildinglu, Amba-10, Bambasi, Assosa ,Amba-16 and Menge respectively. The graph of the double mass curve plot was founded linear for meteorological stations. This implies that the rainfall data was consistent over the considered period. The result of the homogeneity test for the rainfall data showed that the collected data were homogeneous. When the deviation crosses one of the horizontal lines the homogeneity of the data set was rejected with respectively 90%, 95% and 99% probability but, for this study, no cumulative deviation crossed horizontal lines and the restriction of homogeneity assured that the observation of all stations were from the same population.

Estimated USLE model parameters

The parameters used in USLE were rainfall erosivity, soil erodiblity, topographic factor, land use land cover factor and supportive conservation practice factor with the range 1884.26 MJ mm ha^{-1} hr^{-1} yr^{-1} to 2551.18 MJ mm ha^{-1} hr^{-1} yr^{-1}, 0.08 ton ha h ha^{-1} MJ^{-1} mm $^{-1}$ to 0.20 ton ha h ha^{-1} MJ^{-1} mm^{-1}, 0.03 to 38.07, 0.014 to 0.17 and 0.55 to 1.0 respectively (Figures 3,4,5,6,7).

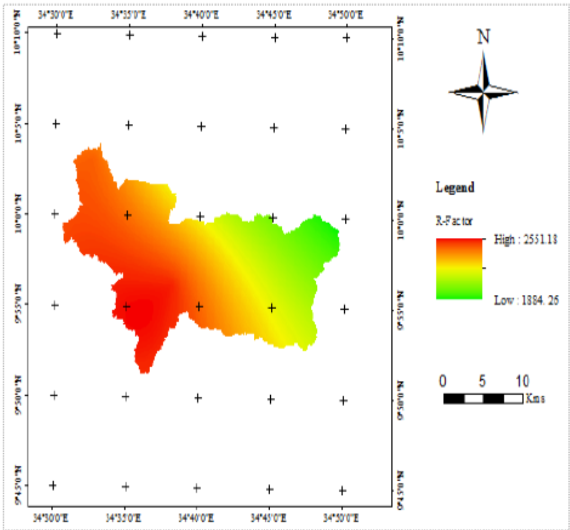


Figure 3. Rainfall erosivity factor map

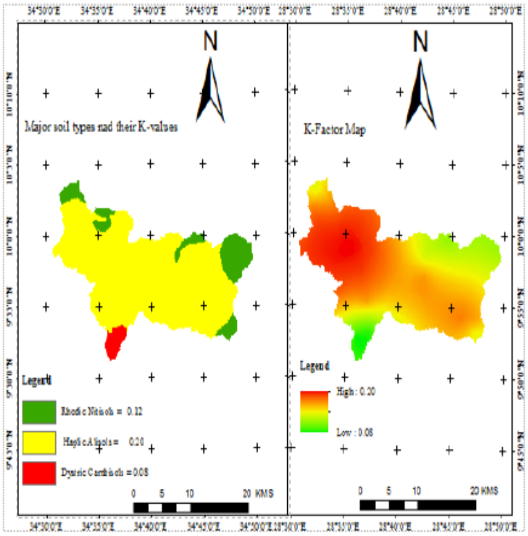
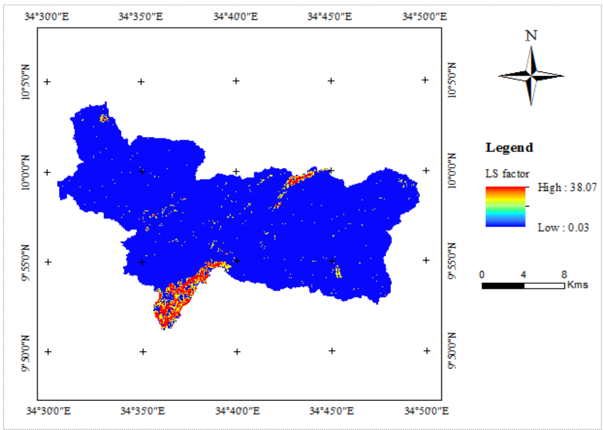


Figure 4. Soil erodibility factor map



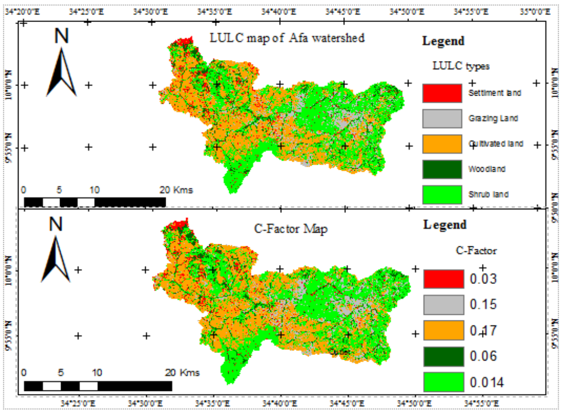


Figure 5. Topographic factor map Figure 6. Land use/land cover factor map

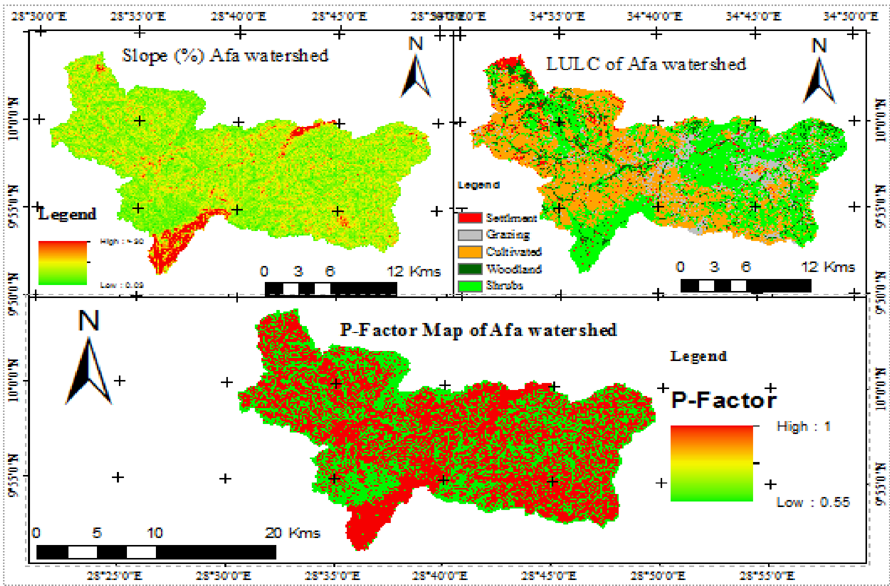


Figure 7. Supportive conservation factor map

Estimated soil loss by USLE Model

After completing data input procedure and preparation of the appropriate maps of USLE factors with 30 m x 30 m pixel size raster data layers, they were combined and analyzed in raster calculator of ArcGIS10.3, to provide a estimate of the annual soil loss map. The computed annual soil loss of the watershed was found in a range of 0 to 1,439 at a cell level. Thus, by multiplying with pixel size (0.09ha), the annual soil loss rate from the watershed were in the range of 0 to 129.578 ton ha^{-1} $year^{-1}$ with mean soil loss of 20.039 ton ha^{-1} $year^{-1}$.The study result, soil loss range of 0 to 129.578 ton ha^{-1} $year^{-1}$ and mean soil loss of 20.039 ton ha^{-1} $year^{-1}$, was in agreement with the findings of previous studies done in upper Blue Nile river basin and also in different parts of Ethiopia. [23] have found mean annual soil loss ranging from 7 to 243 ton ha^{-1} $year^{-1}$ for a catchment in the Blue Nile basin and [24] found the annual soil loss of Ethiopian highlands ranges from 16-300 ton ha^{-1} $year^{-1}$ from pasture and cultivated fields. Research conducted by [25] in Mojo river basin found that an annual soil loss of ranging from 8.57 to 134.46 ton ha^{-1} yr^{-1} with a mean value of 21.2 ton ha^{-1} yr^{-1}. A study done at somodo watershed in Abay River Basin, south west Ethiopia showed mean annual soil loss 18.699 ton ha^{-1} $year^{-1}$, which was ranging from 0 to 131.21 ton ha^{-1} $year^{-1}$ [26]. [27] estimated soil loss in different zones of East and West Hararghe Zone, of Ethiopia found that soil loss in both zones varied from 1.74 to135 tons $ha^{-1}year^{-1}$.The mean soil loss, 20.039 ton ha^{-1} $year^{-1}$, was greater than 11 ton ha^{-1} $year^{-1}$ which is the critical soil loss level in a watershed as suggested in [22]. Therefore, soil loss priority areas were evaluated based on 11 ton ha^{-1} $year^{-1}$ as a bench mark or standard.

Prioritization of sub watersheds

The soil loss severity in the watershed were categorized as (0 to 10) ton ha^{-1} $year^{-1}$ as low, (10 to 20) ton ha^{-1} $year^{-1}$, as moderate (20 to 30) ton ha^{-1} $year^{-1}$ as high, (30 to 45) ton ha^{-1} $year^{-1}$ as very high, (45 to 60) ton ha^{-1} $year^{-1}$ as severe,(60 to 80) ton ha^{-1} $year^{-1}$ as very severe, and greater than 80 ton ha^{-1} $year^{-1}$ as extreme [22]. Accordingly, the watershed area was covered, 49.5 % low,18.0 % moderate,13.5 % high, 6.0 % very high, 5.3 % severe 4.7 % very severe and 3.0 % extremely severe (Table 4). It was obtained that about 19, 643.5 ha area (49.5 %) of the watershed was under low soil loss class while 20, 063.5 ha (50.5%) of the watershed was under moderate to extremely severe soil loss class. Generally, the 50.5% of the watershed area have soil loss greater than tolerable level, which is 11 ton $ha^{-1}year^{-1}$.The soil loss severity classes map were presented as low, moderate, high, very high, severe very severe and Extremely severe (Figure 8). Low soil loss was mostly found in the areas of minimum slope and also in areas of better land covers were located (i.e. area covered with shrubs, woodland) while moderate to extremely severe soil loss was found in areas of high slope and also poor land covers were located (i.e. cultivated land and degraded grazing land).

Table 4. Soil loss severity class of Afa river watershed

Soil loss rates (ton ha^{-1} yr^{-1})	Severity class	Area (ha)	Area (%)
0 to 10	Low	19643.50	49.5
10 to 20	Moderate	7142.23	18.0
20 to 30	High	5378.71	13.5
30 to 45	Very high	2373.33	6.0
40 to 60	Severe	2100.54	5.3
60 to 80	Very Severe	1868.24	4.7
>80	Extremely severe	1200.45	3.0
Total		39707.00	100.0

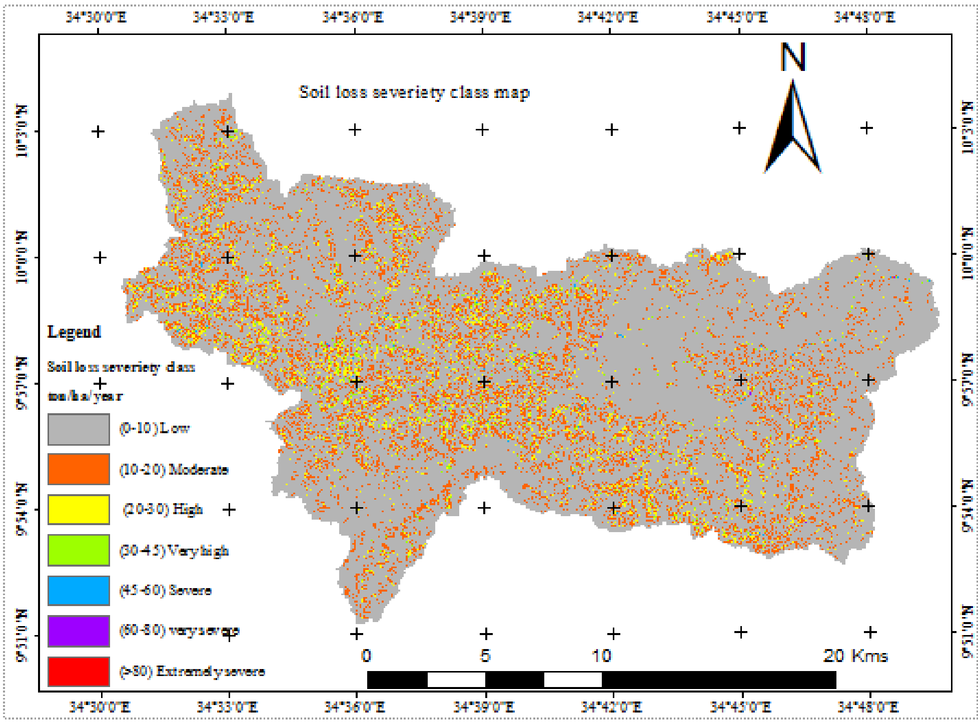


Figure 8: Soil loss severity class of Afa river watershed

Based on mean soil loss obtained in the sub watersheds and erosion risk area coverage the sub watersheds were ranked for conservation planning (Table 5). Accordingly SW3 has got rank 1 based on mean soil loss and got rank 18 based on area affected. On the other hand, SW5 has got rank 1 based on erosion risk area coverage but has got rank 2 based on mean soil loss. Generally, the important sub watershed prioritization was when erosion risk area coverage (area affected and could out of production because of the soil erosion continuum) had been considered. So, the priority was; SW5 to SW12 had got the first and last rank respectively.

Table 5. Ranked Subwatersheds for soil conservation planning

Sub watersheds	Area (ha)	Area (%)	Mean soilloss (ton ha^{-1} $year^{-1}$)	Rank (priority) Based on mean soil loss	Rank (priority) Based on Area affected
SW1	1077.4	2.71	8.12	12	14
SW2	2606.32	6.56	12.40	11	7
SW3	23.59	0.06	81.14	1	18
SW4	1010.17	2.54	7.42	13	15
SW5***	4665.16	11.75	62.01	2	1
SW6	1012.6	2.55	33.70	4	6
SW7	1198.63	3.02	25.81	6	9
SW8	3621.16	9.12	4.66	15	11
SW9	2913.31	7.34	2.16	19	16
SW10	1932.76	4.87	16.10	9	8
SW11	1039.51	2.62	21.42	8	10
SW12	16.03	0.04	3.98	17	19
SW13	1230.58	3.1	32.11	5	5
SW14	2187.37	5.51	22.70	7	4
SW15**	2305.9	5.81	53.06	3	2
SW16	1105.12	2.78	5.32	14	17
SW17*	5599.9	14.1	12.89	10	3

SW18	2761.75	6.96	4.50	16	12
SW19	3399.67	8.56	3.60	18	13

Based on FAO (1986) the Sub watersheds were also categorized under different soil loss severity class using their mean soil lossobtained (Figure 9).

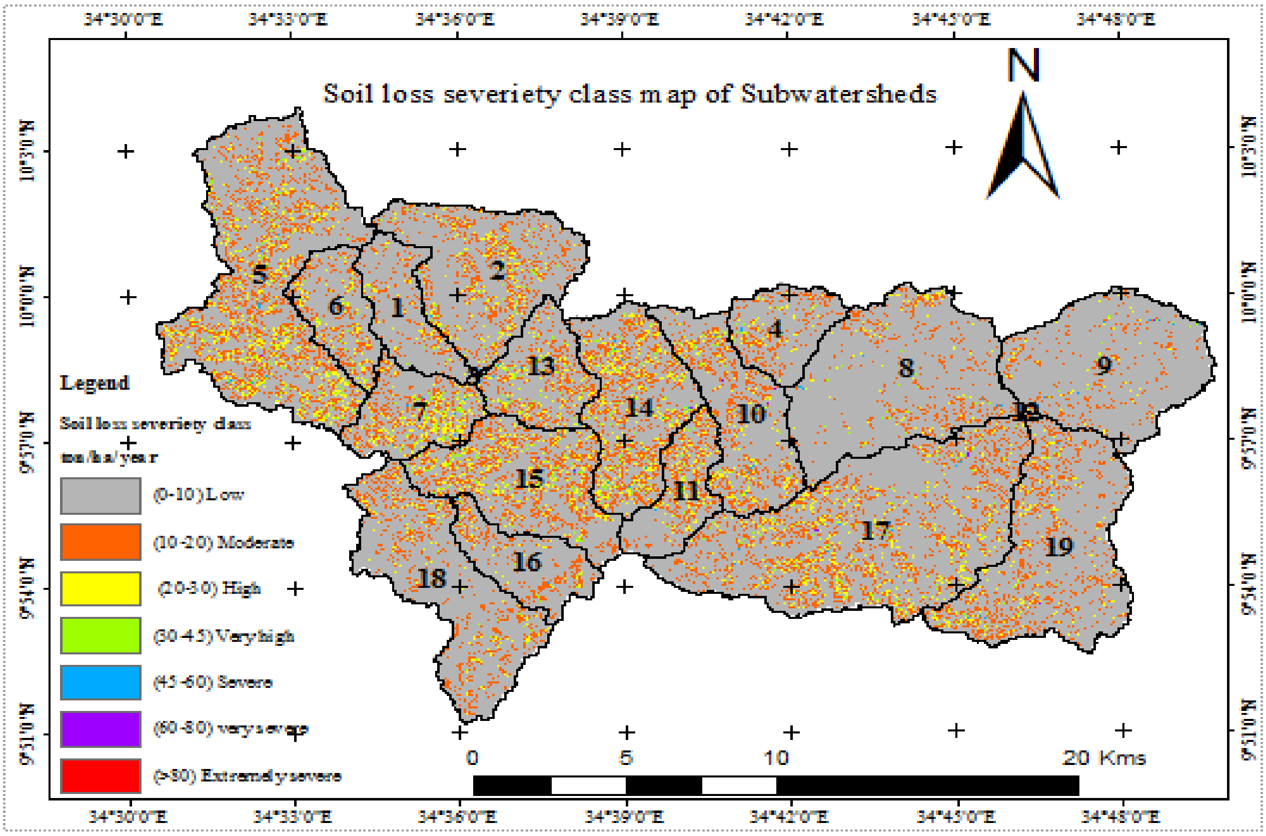


Figure 9. Soil loss severity class of sub-watersheds

IV. CONCLUSION

Annual soil loss obtained in the watershed was in the range of 0 ton ha^{-1} $year^{-1}$ to 129.578 ton ha^{-1} $year^{-1}$ with mean soil loss of 20.039 ton ha^{-1} $year^{-1}$.The mean soil loss obtained in the watershed was greater than the tolerable soil loss level of 11 ton ha^{-1} $year^{-1}$. About 49.5 % of the watershed have a soil loss less than tolerable erosion level and about 50.5 % of the watershed had a soil loss greater than tolerable soil loss level 18%, 13.5%, 6.0%, 5.3%, 4.7% and 3.0% of the watershed have soil loss severity class of moderate, high, very high, severe, very severe and extremely severe respectively. Based on mean annual soil loss and erosion risk area coverage, erosion 'hot spot' areas were identified and prioritized for conservation planning. Accordingly, SW5, SW 15, SW 17, SW 14, SW 13, SW 6, SW 2, SW 10, SW 7, SW 11, SW 8, SW 18, SW19, SW 1, SW 4, SW 9, SW 16, SW 3 and SW12 got 1 up to 19 priority level respectively.

REFERENCES

[1]. Gessesse, B., Bewket, W., and Bräuning, A 2015.: Model-based characterization and monitoring of runoff and soil erosion in response to land use/land cover changes in the Modjo watershed, Ethiopia, Land Degrad. Dev., 26, 711-724,

[2]. Keesstra, S., Pereira, P., Novara, A., Brevik, E. C., Azorin- Molina, C., Parras-Alcántara, L., Jordán, A., and Cerdà, A. 2016.

[3]. Effects of soil management techniques on soil water erosion in apricot orchards, Sci. Total Environ., 551, 357–366,

[4]. Biswas, H., Raizada, A., Mandal, D., Kumar, S., Srinivas, S. and Mishra P. K. 2015. Identification of areas vulnerable to soil erosion risk in India using GIS methods. Solid Earth, 6 (4), pp. 1247-1257. DOI: 10. 5194/se-6-1247.

[5]. Smith, P., Cotrufo, M. F., Rumpel, C., Paustian, K., Kuikman, P. J., Elliott, J. A., McDowell, R., Griffiths, R. I., Asakawa, S., Bustamante, M., House, J. I., Sobocká, J., Harper, R., Pan, G., West, P. C.,

Gerber, J. S., Clark, J. M., Adhya, T., Scholes, R. J., and Scholes, M. C.: 2015. Biogeochemical cycles and biodiversity as key drivers of ecosystem services provided by soils, SOIL, 1, 665– 685, doi:10.5194.

[6]. Nyssen J., W., Clymans K., Descheemaeker J., Poesen I., Vandecasteele M., Vanmaercke A., Zenebe M., Van Camp M., Haile N., Haregeweyn J., Moeyersons K., Martens T., Gebreyohannes, Deckers J., Walraevens K., 2010. Impact of soil and water conservation measures on catchment hydrological response a case in north Ethiopia. Hydrol. Processes, 24(13): 1880-1895.

[7]. Hurni H.,1993. Land degradation, famine, and land resource scenarios in Ethiopia. [7]FAO.1984. Ethiopian Highland reclamation Study (EHRS). Final Report, Volume 1-2. Rome.

[8]. Betrie, G.D., Mohamed, Y.A., van Griensven, A., Srinivasan, R., 2011. Sediment management modelling in the Blue Nile Basin using SWAT model. Hydrol. Earth Syst. Sci. 15, 807–818.

[9]. Tadesse, M., and Belay Taddese, 2004. Factors Influencing Adoption of Soil Conservation Measures in Southern Ethiopia: The case of Gununno area. Agric. and Rural Develop.105:49- 62.

[10]. Prasannakumar V.,Vijith H., Geetha N. and Shiny R., 2012. Regional Scale Erosion Assessment of a Sub-Tropical High land Segment in the Western Ghats of Kerala, South India, Water Resources Management, Vol. 25, No. 14, pp. 3715-3727 http://dx.doi.org/10.1007/s11269-011-9878-y.

[11]. De Asis, A.M. and Omsa, K. 2007. Estimation of vegetation parameter for modeling soil erosion using linear Spectral Mixture Analysis of Land sat ETM data. ISPRS Journal of Photogrammetric and Remote Sensing62, 309–324.

[12]. Shi, Z.H., Cai, C.F., Ding, S.W., Li, Z.X., Wang, T.W. and Sun, Z.C. 2004. Assessment of Erosion Risk with the RUSLE and GIS in the Middle and Lower Reaches of Hanjiang River. Assessment of Erosion Risk.

[13]. Samuel, L.M. 2014. Prediction of Runoff and Sediment Yield Using AnnAGNPS Model: Case of Erer-Guda Cachment, East Hararghe, Ethiopia. *Journal of Science and Technology. Vol. 4, No. 10.*

[14]. Raes, D., Willems, P. and Baguidi, F. 2006. RAINBOW a software package for analyzing data and testing the homogeneity of historical data sets. *Proceedings of the 4th InternationalWorkshop on 'Sustainable management of marginal drylands'*. Island, Pakistan, 27-31 January.

[15]. Zelalem B. 2006. Estimation of Rainfall Erosion Potential and Development of Iso-Erodent Map of Oromia Regional state Based on Daily Rainfall Amount. M.Sc. Thesis Presented to the school of Graduate Studies of Haramaya University. P95.

[16]. Wischmeier, W.H. and Smith, D. 1978. Predicting rainfall erosion losses: a guide to conservation planning. USDA-ARS Agriculture Handbook Number, 537, Washington, DC.

[17]. Foster G.R., McCool D.K., Renard K.G. and Moldenhauer W.C., 1991. Conversion of the USLE to SI metric units. *Journal of Soil and Water Conservation* 36: 355–369.

[18]. USDA- Agricultural Research paper, 2008.

[19]. Shepherd, G. 2000.Visual Soil Assessment Volume 1 Field guide for cropping and grazing on flat to rolling country. Horizons andLand care Research. Palmerson North, New Zealand. P84.

[20]. Renard K.G., Foster G., Weesies G., McCool D., and Yoder D., 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). *Agricultural Handbook 703, USDA-ARS* .

[21]. Shin K 1999.The soil loss analysis using GSIS in watershed. Dissertation, Kangwon National University, South Korea.

[22]. FAO.1986. Ethiopia Highlands Reclamation Study. *Final Report*, *Volume 1*. FAO, Rome, Italy.

[23]. Bewket W, Teferi E., 2009. Assessment of soil erosion hazard and prioritization for treatment at the watershed level: case study in the Chemoga watershed, Blue Nile basin, Ethiopia. *Land Degrad Dev* 20:609-622.

[24]. Hawando T., 1995. The Survey of the Soil and Water Resources of Ethiopia. UNU/Toko.

[25]. Kiflu G. 2010. RUSLE with GIS Conservation Priority Area Identification on Mojo River, Ethiopia. M.Sc. Thesis Presented to theschool of Graduate Studies of Addis Ababa University.

[26]. Gizaw. T, Yalemtsehay. D, Kalkidan. F., 2018 Soil Erosion Risk Assessment Using GIS Based USLE Model for Soil and Water Conservation Planning in Somodo Watershed, South West Ethiopia. *International Journal of Environmental & Agriculture Research (IJOEAR)*; ISSN:[2454-1850] [Vol-4, Issue-5, May- 2018].

[27]. Bobe B., 2004. Evaluation of soil erosion in Harerge region of Ethiopia using soil loss models, rainfall simulation and field trials. Submitted in partial fulfillment of the requirements for degree Doctor of Philosophy, University of Pretoria. 191p.