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# Soil Loss Mapping and Severity Analysis by Using Revised Universal Soil Loss Equation (RUSLE) Modeling: A Case Study of Dijo River Watershed, Central Rift Valley Basin of Ethiopia

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***Abstract***: ***Background***: *Soil loss is one of the main forms of soil and environmental degradation. Soil degradation due to erosion contributes to loss of ecological and aesthetic values of environment, socio-economic local community, and agricultural land productivity. The study aimed to evaluate the spatial variability of erosion occurring at Dijo river watershed in central rift valley basin of Ethiopia RUSLE model.*
***Methodology***: *30 m by 30 m DEM, thirty four years' rainfall data measured at 5 rain gauge stations across the watershed, soil and land use maps, published literature review were used as inputs to analyze the model.*

***Results***: *The computed mean annual soil loss rate of the watershed was found to be 48.4 ton ha$^{-1}$ yr$^{-1}$, which is more than three times higher as compared to the maximum tolerable soil loss value (16 ton ha$^{-1}$ yr$^{-1}$) and the annual erosion rates range from 0 to above 947 ton ha$^{-1}$ yr$^{-1}$. The mean annual soil loss values below 5 ton ha$^{-1}$ yr$^{-1}$ were rated as very slight, while those above 50 ton ha$^{-1}$ yr$^{-1}$ were categorized as very severe soil erosion risk. About 25% of the areas (35533.96 ha) in the watershed were identified with moderate to high severity erosion class (>50 ton ha$^{-1}$ yr$^{-1}$) which needs immediate measures to reclaim soil erosion.*

***Conclusions***: *The quantitative soil loss computation results indicated that soil loss has still continued substantial problems in the watershed. The results underline the urgent need for appropriate land use management practices in the watershed.*

***Keywords***: *Dijo river watershed, Erodibility factor, Erosivity factor, RUSLE, Soil loss*

**Abbreviations**

| | |
|---|---|
| ATVETC | Agricultural Technical Vocational Education Training College |
| DEM | Digital Elevation Model |
| E | East |
| GIS | Geographic Information Systems |
| ha | hectare |
| km | kilometer |
| IDW | Inverse Distance Weighted |
| Lat | Latitude |
| Long | Longitude |
| m | meter |
| mm | millimeter |
| MoWIE | Ministry of Water Irrigation and Energy |
| N | North |
| NMA | National Meteorological Agency |
| RUSLE | Revised Universal Soil Loss Equation |
| SNNP | Southern Nation Nationality People |
| USLE | Universal Soil Loss Equation |
| yr | year |
| % | Percentage |

# I. Introduction

Soil loss is currently one of the main environmental problems for degrading soil and water resources (Carvalho et al. 2014).In addition, it poses a risk to food security and represents a serious challenge to sustainable development. Carvalho et al. (2014); Yesuph and Dagnew (2019); Kidane et al. (2019) they stated that soil use management in watersheds, especially predictive models, are important to reduce erosive processes. Empirical and conceptual models were developed to compute soil loss based on physical processes (Aksoy & Kavvas, 2005; Kinnell, 2010). Empirical models such as the universal soil loss equation (USLE) developed by Wischmeier & Smith (1978) and its revised version, RUSLE was developed by Renard et al. (1997), are used worldwide in varying climatic, geologic and land use scenarios. The model provides useful information to support soil and water conservation plans (Kinnell, 2010; Oliveira et al., 2011).

Revised universal soil loss equation (RULSE) is a simplified and extended tools that has been used with different scale e.g. low data requirements by Sonneveld and Keyzer ( 2003), large data requirements Lu et al. (2001), and global data requirements (Hootsmans et al., 2001). It was adapted to different landscape and watershed scales combined with Geographic Information Systems (GIS) tools Amsalu and Mengaw (2014); Wischmeier and Smith (1965) in soil loss assessments. A number of research were investigated on the highlands part of Ethiopian to the peril of soil loss using GIS based RUSLE at various spatial and temporal scales (Hurni, 1993; Amsalu et al., 2007; Amare 2007; Haregeweyn et al., 2017; (Yesuph and Dagnew, 2019; Kidane et al. 2019). All these underlined that soil loss caused land degradations are the major problems, which divest soil's capacity to holding water, soil's fertility, and its biodiversity. But, the magnitude and extent differs from one part of the country to another depending on the agriculture practices, population growth, nature and vulnerability of the soils to loss, local microclimate, land scape, and agro-ecological variations of the area (Tebebu et al., 2010; Monsieurs et al., 2015). All this finding indicates that location specific annual soil loss studies are still generous in Ethiopia for striking the problem of soil erosion.

The current inquiry was undertaken in relatively little known but highly susceptible and fragile areas of the Dijo river watershed, where soil loss is the main challenges and common phenomenon, conversely such studies are rare. The watershed is more susceptible to water provoked soil loss and related soil degradation due to numerous causal factors including, but not limited to, the nature of landforms which is manifested by steep slopes, uneven topographies, complex gorge networks, erosive rainfall after long period of dry seasons; inappropriate land use practices and intrinsic soil properties; and other anthropogenic activities. It is debated that earlier appraisal of the spatial distribution of soil loss is important for successful sustainable planning land management program.

Therefore, assessment of soil loss rates and identification of susceptible loss areas in such an ignored place is very substantial to conserve the area from additional damage. Furthermore, fruitful protection planning and related land management policies needs site-specific, precise and comprehensive environmental and socio-economic information supplement by land users and experts. Therefore, this study aims to estimate the average and total annual soil loss and spatial distribution in the Dijo River watershed using the revised empirical equation in combination with an ArcGIS and develop soil loss map using remote sensing data. It provides an outline for decision-makers for planning activities to control loss and contributes toward filling a gap of soil loss information of a particular area.

# II. Materials and Methods

1.1. Location of the study area.

The Dijo river watershed (1,426 km$^2$) is located in the southwestern part of the central rift valley basin of Ethiopia. The river length is about 75 km long and extends from 7° 28' 40'' and 7° 59' 40'' N and 37° 51' 40'' to 38° 53' 40'' E (Figure 1). The Dijo river starts in the central hills of the country at an altitude of 3,250 m above sea level and runs into the Shalla Lake near to Bulbula town. The upstream area of the watershed is higher in gradient while downstream area of the watershed is gentle gradient, more or less at and elevation varied from 1620 m (Figure 3C &D).

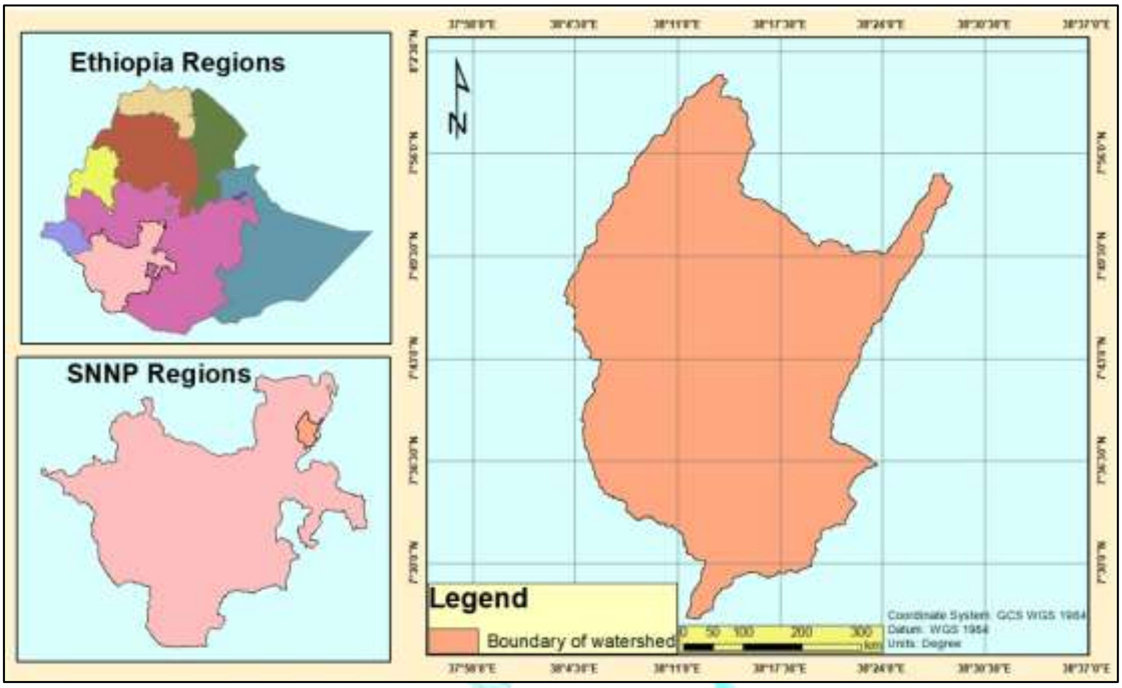


**Figure 1**. Location map of Dijo river watershed

Annual average rainfall is about 950 mm and the annual water flow is about 1700 million $m^3$. Average annual rainfall variation of the watershed is shown in (Figure 2). The maximum rainfall value of 1350 mm was recorded in Werabe and the lowest average annual rainfall value of 650 mm rainfall of Bulbula, this river watershed receives medium rainfall.

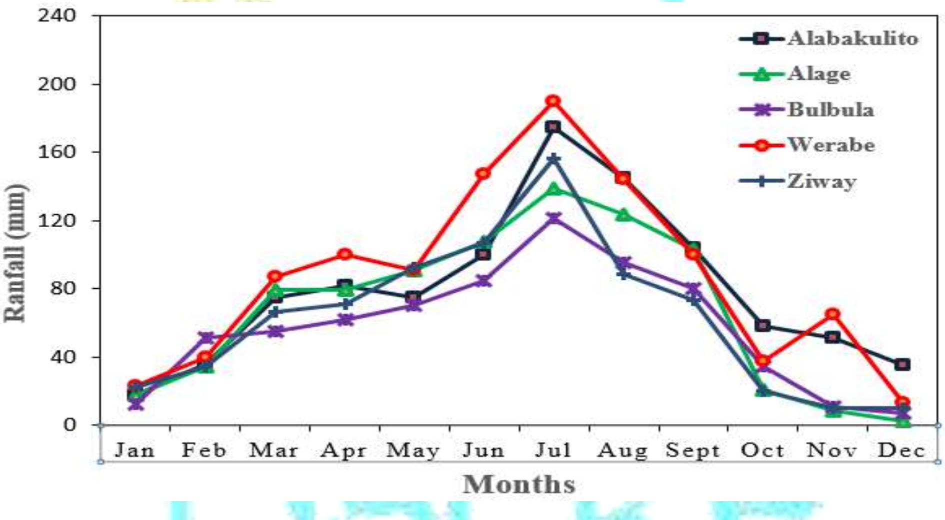


**Figure 2**. Long term mean monthly rainfall patterns of the selected stations within and around the Dijo river watershed

The year 2016 land use and land cover map of the Ethiopian rift valley basins (Table 3 and Figure 3B) indicates that land uses of the Dijo river watershed embraced cultivation land, woody land, built up areas, forest land, shrub land, grassland, and wetlands. Ensete and Chat is the main commercial crop grown in the Dijo river watershed along with home gardens and small holder coffee. The forest cover of the basin is more than 3.43%. The soil map of the watershed (Figure 3A) indicates that Eutric Cambisols is the main soil type found in the watershed and Eutric Vertisols is found in the flood areas of the river (Table 2 and Figure 3A). Chromic Luvisols and Luvic Phaeozems are the other soil types found in the watershed but to a smaller magnitude.

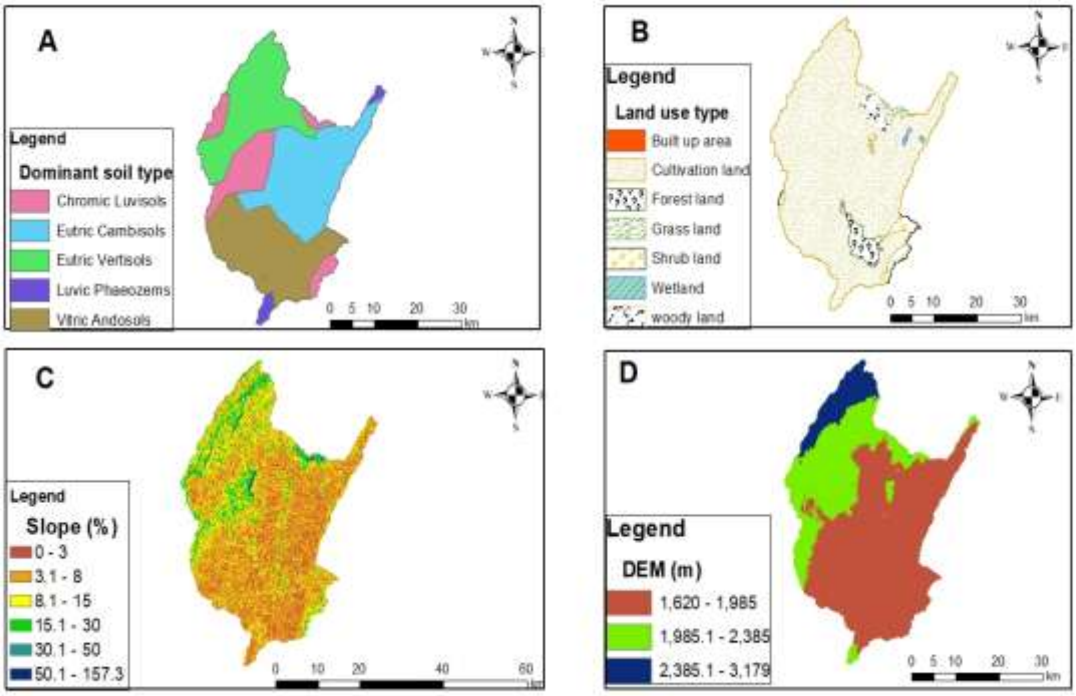


**Figure 3**. Dijo river watershed spatial data map A) major soil type, B) land use type, C) slope class, and D) DEM

## 1.2. Data Collection

### 1.2.1. Data types and sources

Both primary and secondary types of data were used for analysis and collected from various sources. The climatic data (i.e. daily rainfall) were collected from the National Meteorological Agency (NMA). This data was collected for five meteorological stations in and around Dijo watershed for the 34 years (January 1987 to December 2018) (Figure 2). Digital Elevation Model (DEM) with 30 m by 30 m cell size was obtained from high grid resolution raster data from the USGS databases of the SRTM (Shuttle Radar Topography Mission) website via (http://earthexplorer.usgs.gov/). Soil data were obtained from Digital Soil Map of the World (DSMW) website (http://fao.org/soils-portal/soil-survey/soil-maps/).

### 1.2.2. Meteorological data quality controls

Testing quality of meteorological data is an essential duty for reliable prediction of the model output. Basic data quality checks (i.e. the location of the station, homogeneity, consistency, persistence, filling missing data). were performed for selected stations. Different class (class I to class IV) meteorological station were located within and around the watershed (Table 1 and Figure 1b). The consistency of precipitation records at individual station were checked against the mean of the neighboring stations using a double mass analysis.
Table 1

Geographic information's for selected meteorological station

| ID | Stations Name | Lat ($^0$) | Long ($^0$) | precipitation | (%) of missing data | class |
|---|---|---|---|---|---|---|
| 1 | Alaba kulito | 7.31 | 38.09 | | 2.7 | III |
| 2 | Alage | 7.37 | 38.19 | | 8.2 | III |
| 3 | Bulbula | 7.72 | 38.65 | | 5.5 | IV |
| 4 | Werabe | 7.85 | 38.19 | | 3.7 | I |
| 5 | Ziway | 7.93 | 38.7 | | 2.69 | I |

1.3. Methodology

Soil loss prediction for the study area was carried out using the RUSLE model. Five parameters influencing the soil loss prediction amount were used which comprises parameter of rainfall erosivity factor (R), soil erodibility factor (K), slope length and steepness factor (LS), crop management factor (C) and support practice factor (P). Each of the elements derived separately in raster data format and the loss calculated using the map algebra functions by GIS software. Figure 4, illustrates the conceptual framework for the RUSLE model calculation and expressed by an equation 1.

$$A = R * K * LS * C * P \quad (1)$$

Where, A is soil loss (ton $ha^{-1}$ $yr^{-1}$), R is rainfall erosivity factor (mm $ha^{-1}$ $yr^{-1}$), K is soil erodibility factor (ton $ha^{-1}$ $yr^{-1}$), LS is dimensionless slope length and steepness factor, C is dimensionless crop management factor, and P is dimensionless support conservation practice factor.

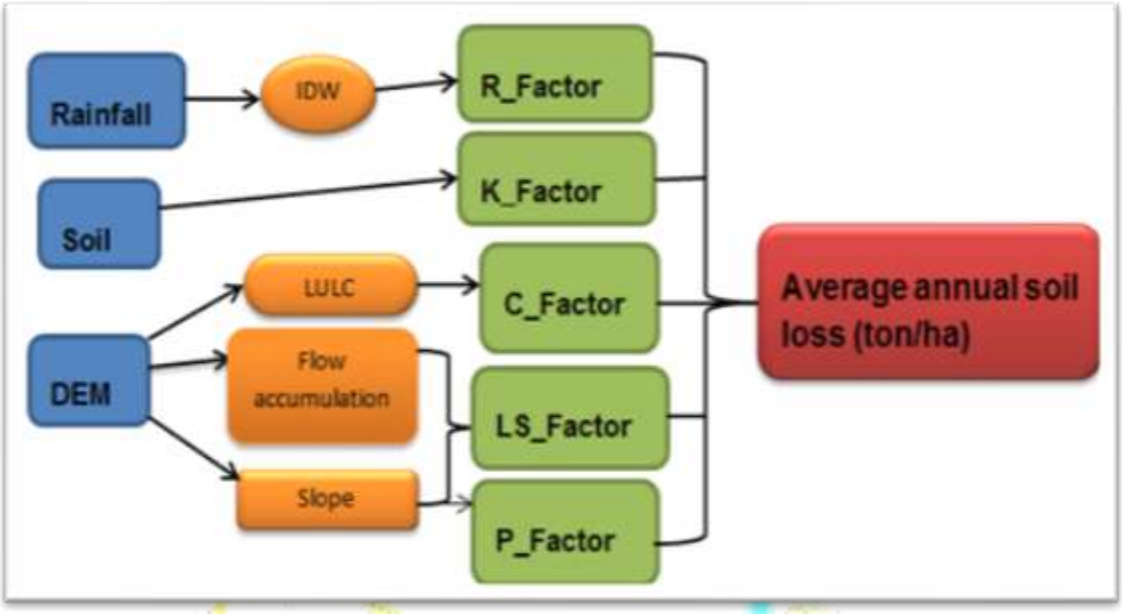


**Figure 4.** The overall chronological step used employed to compute soil loss by RUSLE model

1.3.1. RUSLE parameters computation

1.3.1.1. Rainfall erosivity factor (R)

The R factor characterizes the input that drives the sheet and rill loss process, and differences in R values represent differences in erosivity of the climate.it is essential for soil loss threat assessment under future land use and climate change (Stocking et al., 2001). During this study, the rainfall map produced by the National Meteorological Agency (NMA) used to generate a rainfall loss factor by Inverse Distance Weighted (IDW) methods using spatial analysis tools by map algebra and raster calculator. This map shows mean annual precipitation over the watershed, inline to Cooper (2011) R factor was determined in Arc GIS tools as equation 2.

$$R = 0.1523 * P^{1.36} \quad (2)$$

Where, R is rainfall erosivity factor (mm $ha^{-1}$ $yr^{-1}$), and P is mean annual rainfall in (mm).

1.3.1.2. Soil erodibility factor (K)

The K factor measures the susceptible soil types and their particles to detachment and transport by rainfall and runoff (Pawan. Th, 2020). Soil texture is the principal factor affecting K factor, but soil structure, organic matter and permeability also contribute. Soil types for the study watershed were extracted from Ethiopian soil map for the year 2017 to develop associated with soil hydrography, color and texture. For each soil type K value were converted to raster grid in ArcGIS conversion tools using $USEL\_K_1$ at as conversion value. Therefore, the soil erodibility factor (K) in our study watershed was described in Table 2 below.

Table 2

Soil erodibility factor (K) values for some soil in Dijo river watershed

| Soil type | HYDGRP | Texture | Soil color | Area (ha) | Percentage | K factor |
|---|---|---|---|---|---|---|
| Chromic Luvisols | B | Loam | Brown | 20609.77 | 14.45 | 0.133 |
| Eutric Cambisols | D | Clay | Brown | 42768.58 | 30 | 0.134 |
| Eutric Vertisols | D | Clay | Black | 35397.7 | 24.83 | 0.135 |
| Luvic Phaeozems | C | Clay loam | Brown | 2518.21 | 1.77 | 0.136 |
| Vitric Andosols | B | Sandy Loam | Black | 41286.8 | 28.96 | 0.158 |

Source: Recommended by Hurni (1983)

1.3.1.3. Slope length and steepness factor map (LS)

LS factor is the utmost vulnerable parameter of RUSLE in the soil loss estimation (Renard et al., 1997). The LS factor describes the collective effects of slope length (L) and slope gradient (S), which sturdily controls the transportation of soil particles. The LS factor is a ratio of soil loss under given circumstances to that location with the "standard" steepness slope of 9% and slope length of 22.13 m, with all other conditions remains the same (Williams, 1975; Alexakis et al., 2019). As slope length and slope gradient increased LS factor increased. Slope gradient highly signify the speed and erosive power of runoff (Wischmeier and Smith 1978; Renard et al., 1997). High grid resolution DEM of 30 m were used to compute flow accumulation and slope in degree, using spatial analysis tool and map algebra tools were used in ArcGIS for raster calculator as shown in equation 4 in line to (Bilal et al., 2020).

LS=POWER(flowacc*[cellresolution]/22.1,0.4)*POWER(Sin(sloperasterdeg*0.01745)/0.09, 1.4)*1.4 (4)

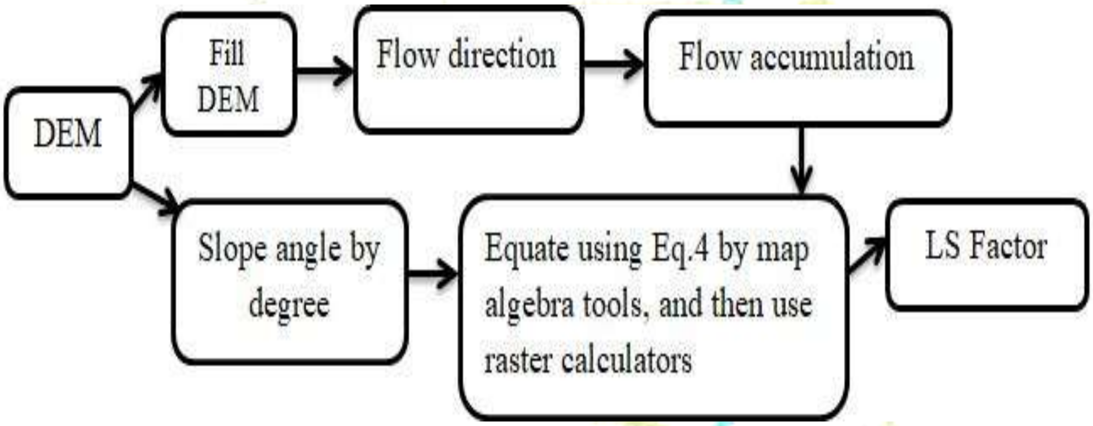


**Figure 5.** Procedures followed in producing LS factors in ArcGIS tools

1.3.1.4. Cover management factor (C)

The LULC map of the watershed was obtained from the land use map produced by the Ministry of Water Irrigation and Energy (MoWIE) department hydrology in 2016, and this study assumed that the LULC was not significantly changed during the past four years. The raster map conversion tools was used to convert vector polygon of LULC through raster to polygon tool and the attributes with the same land use type dissolve into a single class using ArcGIS 10.4.1 software, the study used seven types of land use (Figure 3B). C factor values were obtained in line to Table 3 as suggested by Hurni (1985) in Ethiopia for different land uses and matched with the land use map.

Table 3

Adopted cover management factor values of RUSLE for different Land use type in the study area

| Cover type | C_factor | Cover type | C_factor |
|---|---|---|---|
| Bad land hard | 0.05 | Sorghum_ maize | 0.1 |
| Bad land soft | 0.4 | Cereals, pulses | 0.15 |
| Dense grass | 0.01 | Teff | 0.25 |
| Degraded grass | 0.05 | Fallow hard | 0.05 |
| Dense forest | 0.001 | Fallow ploughed | 0.6 |
| other forest | 0.01 | Continuous fallow | 1 |

Source: C factor suggested by Hurni (1985)

1.3.1.5. Support practice factor (P)

P factor indicates the rate of soil loss according to the various cultivated lands on the earth. There are contour farming, strip cropping and terrace as a method and as an important factor that can control the loss. As Table 4 below indicated that the value of support practice factor assigns by considering the cultivation methods and slope in line to (Shin, 1999). P values ranges from 0 to 1, whereby the value 0 represents a very good manmade loss resistance facility and the value 1 no manmade loss resistance facility (Shin, 1999). Due to the constraints of field-based measurements concerning conservation practices put in place within the Land study area, we determined the values of the P factor based on an alternative method recommended by Wischmeier and Smith (1978). For this purpose, determining the slope map from the DEM was used to drive the spatial distribution maps of the P factor.

Table 4

Conservation support practice (P) values of RUSLE for different slope class in the study area

| Land Use Type | Slope | Terracing | Strip cropping | Contouring (P_Factor) |
|---|---|---|---|---|
| Agricultural land use | <5 | 0.1 | 0.27 | 0.55 |
| | 5-11 | 0.12 | 0.3 | 0.6 |
| | 11-18 | 0.16 | 0.4 | 0.8 |
| | 18-27 | 0.18 | 0.45 | 0.9 |
| Non-agricultural land use | >27 | 0.2 | 0.5 | 1 |

Source: P factor suggested by Wischmeier and Smith (1978)

# III. Results and Discussion

1.4. RUSLE factor maps

The soil loss threat map was produced by using all the five RUSLE raster layers, which are, rainfall-runoff erosivity factor (R), soil erodibility factor (K), slope length and steepness factor (LS), cover and management factor (C), and support and conservation practices factor (P). These factors were estimated on a 30 m by 30 m high resolution grid cell of DEM was used for RUSLE parameters analysis purpose.

1.4.1. Rainfall-runoff erosivity factor map (R)

To compute the rainfall-runoff erosivity value for the study area and we used thirty year mean annual precipitation of the since 1985 to 2018. The prolonged R factor value for the study watershed varies ranged from 1819.95 and 2055.59 mm $ha^{-1}$ $yr^{-1}$ and the mean R factor recorded is 1937.77 mm $ha^{-1}$ $yr^{-1}$. The peak erosivity value was recorded in the southern and northern part of the watershed and R factor map was developed by using IDW with a power of 2 as shown in (Figure 6B). This shows that specifically topography can be categorized as the area of high rainfall compared with downstream site. Impact of certain variation in the results determines computed soil loss. Therefore, the rate of soil loss on the highland part of the watershed contributes the highest amount of sediment yield to Lake Shalla. However erosivity values of the study watershed is less than the global average, that is, 2000 MJ mm $ha^{-1}yr^{-1}$ Borrelli et al. (2013), the amount of soil loss contributed by this R factor is substantial. Some scholars, such as Meusburger et al. (2012); Ganasri and Ramesh (2016) found that soil erosion rate is more sensitive to rainfall runoff erosive

1.4.2. Soil erodibility factor map (K)

Soil erodibility factor map (K) value was calculated based on recommendation provided by Hurni (1983) for Ethiopian. Different physical and chemical soil properties were used to determine K factor value for each class of the soil. General the watershed contains five classes of soil and their recommended erodibility values were determined with respect to the recommend soil color and texture. Eutric Cambisols were the dominant soil type which covers 30% of the study area and the soil is categorized very slow infiltration rate with high runoff potential(Table 2 and Figure 3A). The spatial distribution of the soil type also indicates that Eutric Vertisols were located in highland of the watershed which resulted in high erodibility (Figure 3A).

The erodibility map was determined based on the value specified for each class which ranged from 0.13 to 0.16 with a mean of 0.14 (Table 2 and Figure 6A). The map indicated that Eutric Cambisols and Eutric Vertisols were considered highly vulnerable to erosion, with erodibility values of 0.13 and 0.14 respectively (Table 2). The lowest K value was allocated to Chromic Luvisols which is characterized well-drained soils of moderately fine to moderately coarse texture; both with a value of 0.13 located at the river mouth (Table 2). These values were found to be with the range reported by Yesuph and Dagnew (2016) in Gedalas watershed of the Blue Nile Basin, Northeastern Ethiopia.

1.4.3. Slope length and steepness factor map (LS)

The slope of the watershed ranged from 0 to 57 degree (0 to 157 %). The steepest slopes located in the southern and northern parts area and are highly susceptible to soil loss than the gentle slope. LS factor was estimated by using flow accumulation and slope in degree as inputs and it ranged from 0 to 5038.69 which correspond to the topography factor of the watershed and the mean LS factor value was 1628.19 (Figure 6C). The higher values of LS factor describe steep slopes which were found on the highland areas of the watershed with extreme erosion threats. These values were found to be with the range reported by Pawan.Th (2020) in Dolakha District of Nepal.

1.4.4. Land cover management factor (C) and support conservation practices factor (P)

LULC of the study area was used to compute C factor map and values were assigned for each cover management inline to Hurni (1985) as described in Table 3 above. The major land use type of the watershed is show in (Figure 3B). By using LULC map of watershed the values of C factor for the study area ranged from 0 to 0.2, where there is from no soil erosion to moderate erosion class (Figure 6F). This finding agrees with the finding of Foster et al. (2002); Tamene et al. (2006), the scholar's stated the value of C ranges between 0 (represent ideal case) where there is no soil erosion and 1 corresponds to the greater amount of soil erosion. Inline to Table 3 the lowest value which is 0.001 was assigned for dense forest whereas, the highest value assigned for continuous fallow with the value of 1, which indicated that the highest value of C factor accelerate soil loss. This finding inline with finding of Kidane et al. (2019) and Yesuph and Dagnew (2019) which indicated that the presence of vegetation greatly reduced soil loss Gudar watershed of Abay basin and Geldas watershed of Nile basin in Ethiopia. Further, dense vegetative cover characterizes the low soil erosion potentials because of its ability to resist high-intensity rains expected as a result of climate change (Singh et al., 2016).

Support practice (P) factor value for this study was computed based on Wischmeier and Smith (1978) inline to Table 4 above. Assigning p factor were considered different soil and water conservation practices applied in the steep slope area. However during on site demonstration in study area, soil and water conservation practices were constructed along the side of steep slope have poor design. Although the P values were estimated by considering the type of land use type and slope class based on the suggested values (Table 4). Based on the land use type and slope class P factor map value were created and used to compute the total soil loss. Higher p factor values were obtained for the higher slope class areas (Table 4 and Figure 6E). Land use type is considered as one of the most influencing factor for soil erosion (Kidane et al., 2019). P factor value for study watershed was ranged from 0.55 to 1 (Figure 6E), which indicate the lowest p factor value shows less potential to soil erosion. These values were found to be with the range reported by Yesuph and Dagnew (2019) in Gedalas watershed of the Blue Nile Basin, Northeastern Ethiopia and Kidane et al. (2019) in Guder sub watershed located in West Shewa Zone of Oromia Regional State, Ethiopia.

Table 5
Annual soil erosion rates, extent and area coverage

| Soil loss rates (t ha−1 yr−1) | Severity classes | Area (ha) | Percent of total | Estimated annual loss (ton) | Percent of total | Priority class for conservation |
|---|---|---|---|---|---|---|
| 0–5 | Very Slight | 85560 | 60 | 949281.6 | 60 | 5th |
| 5.1–15 | Slight | 21390 | 15 | 237320.4 | 15 | 4th |
| 15.1–30 | Moderate | 14260 | 10 | 158213.6 | 10 | 3rd |
| 30.1–50 | Severe | 12834 | 9 | 142392.2 | 9 | 2nd |
| >50 | Very Severe | 8556 | 6 | 94928.16 | 6 | 1st |
| Total | | 142600 | 100 | 1582136 | 100 | |

## 1.5. Estimation of annual soil loss in Dijo river watershed

The estimated annual soil loss values of the watershed ranged from 0 in flat areas to healthy over 350 ton $ha^{-1}$ $yr^{-1}$. In the lower outlet degraded steep sloping areas, banks of river and at the specific hot spots of steep slopes of the watershed soil erosion rate exceed 947 ton $ha^{-1}$ $yr^{-1}$ (Figure 6D). The mean annual soil loss value for the watershed was around 48.4 ton $ha^{-1}$ $yr^{-1}$, whereas 89% ton $ha^{-1}$ $yr^{-1}$ was generating from the agriculture land, which encompasses the largest number of mean annual soil loss in the watershed. This result agrees with finding of FAO (1986); Hurni (1985); Reusing et al. (2000); Maeda et al. (2008); Ouyang et al. (2010) and Kayet et al. (2018) they point out that soil loss was significantly higher on crop land and low in forested areas. Further, this finding is also analogous with Hurni (1983) found around the loss of 4 mm topsoil depth per year.

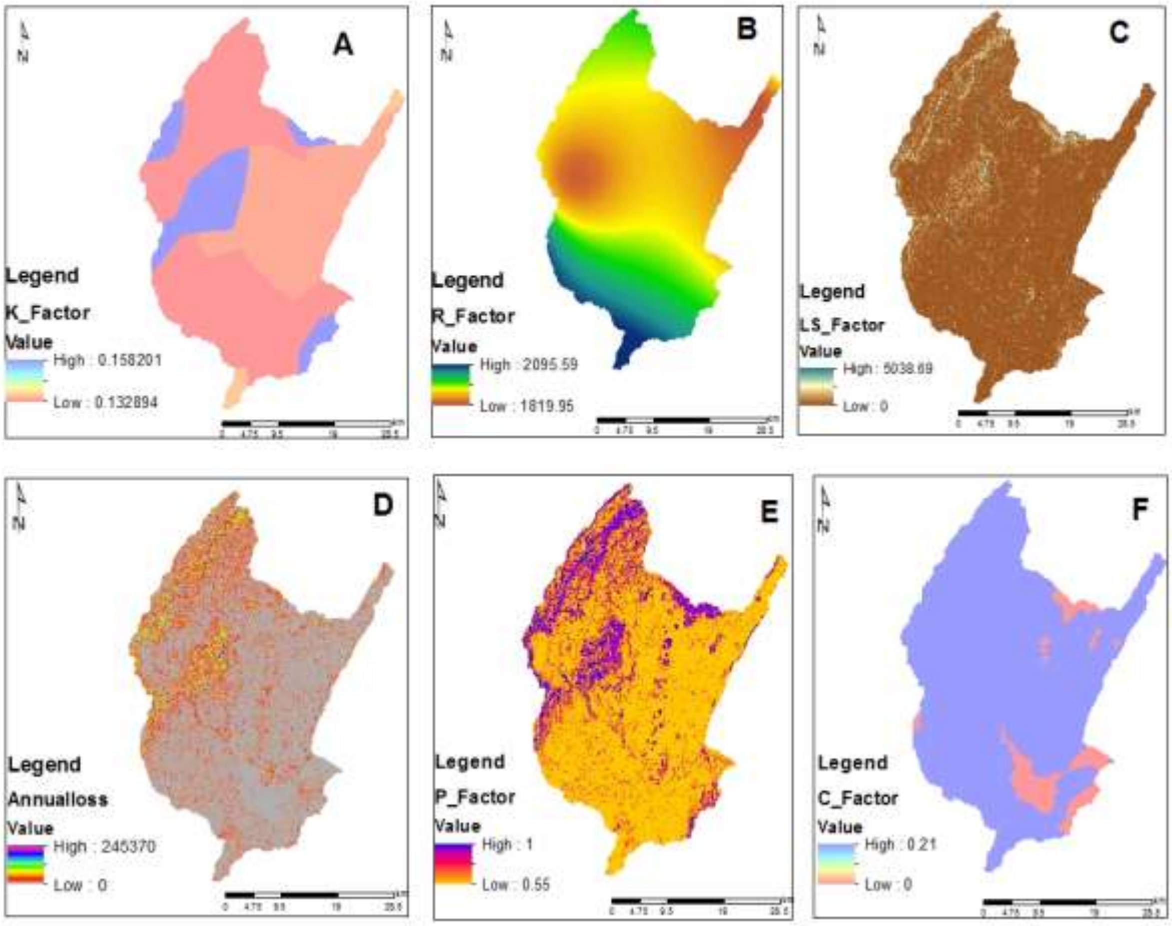


**Figure 6.** RUSLE parameters maps of study area (A) soil Erodibility factor map; (B) rainfall erosivity factor map; (C) topographic factor map; (D) annual soil loss map; (E) support Practice factor map; and (F) cover management factor map

The entire mean annual soil loss rates of the Dijo river watershed are higher than as compared to soil formation rate for the abundant land units of Ethiopia, which ranges from 2 to 22 ton $h^{-1}$ $yr^{-1}$ (Hurni 1983). The result of estimated soil loss limits for soil loss rate acceptance recommended by Rose (1994) 10 ton $ha^{-1}$ $yr^{-1}$ for tropical region) and Hurni (1986) 2-18 ton $ha^{-1}$ $yr^{-1}$ for the different agro-ecological belts of Ethiopia and 10 ton $ha^{-1}$ $yr^{-1}$ to the northern highlands of Ethiopia, it is still higher despite conservation efforts through an integrated watershed management approach in place (Yesuph and Dagnew, 2019). Further, as per the suggestion of Morgan (2005), annual soil loss rate threshold for the sustainable crop lands use is 10 ton $ha^{-1}yr^{-1}$. Inline to Kouli et al. (2009), any soil loss rate which exceeds 10 ton $ha^{-1}$ $yr^{-1}$ is not reversed within a short periods. Depending on this threshold, the total area with the higher soil erosion risk than the soil loss tolerance was 29873.95 ha Table 5, covering 20.95% of the whole watershed area (Table 5). Yet, it should be noted that the tolerable level of soil loss was put the judgment based on location condition and specifically depending on soil type and depth, current land use status, soil formation rate, topography, rainfall intensity and its duration (Foster et al., 2002).

The computed soil loss values and its spatial distribution in the watershed is generally reasonable, compared to what can be seen in the field and weighed against comparable studies reported by 47.4 ton $ha^{-1}$ $yr^{-1}$ by Gelagay and Minale (2016) in the Koga watershed and 45 ton $ha^{-1}$ $yr^{-1}$ by Wolka et al. (2015) in rift valley parts of Ethiopian. Opposing to this result, other comparable investigation was undertaken in different parts of the highlands of the country reported a relatively higher average soil loss rates. For example, the estimated finding of this study was lower than the mean soil loss rate of 243 ton $ha^{-1}$ $yr^{-1}$ by Gete (2000) in northwestern highlands of Ethiopia; 93 ton $ha^{-1}$ $yr^{-1}$ by Bewket and Teferi (2009) in the Chemoga watershed; 84 ton $ha^{-1}$ $yr^{-1}$ by Yihenew (2013) in Northwestern Ethiopia, and from 0.2 to 321 ton $ha^{-1}$ $yr^{-1}$ by Amare (2007) in the eastern escarpment of Wollo. Furthermore, Haregeweyn et al. (2017); Molla and Sisheber (2017) reported that the current on observed soil loss due to sheet and rill erosion at national level show an annual soil loss of 29.9 ton $ha^{-1}$ $yr^{-1}$ from 25 observation sites in different parts of the country. Therefore soil loss is a serious agricultural problem, which presents a major problem to the reduction of soil fertility and land productivity in the watershed. This threat coupled with lack of and inappropriate soil and water conservation structures intensify the extent of the problem.

## IV. Conclusions

Land use land cover (LULC) alteration is a major cause of soil loss at watershed, regional and global scales (Kidane et al., 2019). Soil loss is a serious socio-economic and environmental problem in the Dijo river watershed. Even though it was commenced by human induced activities, such as, inappropriate cultivation on a steep slope and certain biophysical factors like topography, soil type, climate, vegetation also greatly influence on soil loss. This investigation is not only quantified mean annual soil loss value under current conditions but also mapped the spatial distribution of soil loss by using RUSLE model. The result showed that the mean annual soil loss for the study watershed was 48.4 t $ha^{-1}$ $yr^{-1}$, which is substantially exceeded the soil loss tolerances limits for Ethiopian highlands. Due to poor vegetation cover, inappropriate conservation practices, bare lands expansion, steep slopes and mountainous areas cultivation very slight soil loss level tends to dominate, extreme and very extreme soil loss is not rare for large parts of the watershed.

The watershed map of soil loss risk produced in this study provides reasonable computation of annual soil loss in the Dijo river watershed of the central rift valley basin of Ethiopia, which is suitable for applying more efficient, and effective soil conservation practice and SLM. The study indicated poor vegetation cover, poor land management practices, Steep topographic features, very fine texture soil and high rainfall runoff erosive rate; contribute to the highest soil erosion prone areas. Therefore, it is essential to prioritize erosion prone areas and reclaim by using integration of both biological and physically SWC structures to reduce soil degradation. This includes institutionalizing sustainable land management (SLM) measures to mitigate soil degradation and improve the livelihood of the local community in the watershed. Our results revealed the continuous loss of soil from cultivated land due to improper land management practices and an increasing level of soil loss over the study period which calls for collective efforts to be taken to reduce soil erosion and its associated problems. Lastly, the study indicated that linking RUSLE with ArcGIS and remote sensing data are vigorous approaches to better estimation of soil erosion values, delineate and identify erosion prone areas, and prioritize the areas for effective and efficient planning of SLM based on erosion severity levels in the watersheds.

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## Reference

[1]. Alexakis, D.D.; Tapoglou, E.; Vozinaki, A.K.; &Tsanis, I.K.(2019). Integrated Use of Satellite Remote Sensing, Artificial Neural Networks, Field Spectroscopy, and GIS in Estimating Crucial Soil Parameters in Terms of Soil Erosion. Remote Sens. 11, 1106.

[2]. Aksoy, H., & Kavvas, M.L. (2005). A review of hillslope and watershed scale erosion and sediment transport models. Catena, v.64, p.247-271, 2005. DOI: 10.1016/j.catena.2005.08.008.

[3]. Amare, B. (2007), Landscape transformation and opportunities for sustainable land management along the eastern escarpment of Wollo (EEW), Ethiopia, PhD dissertation. University of Bern, Bern.

[4]. Amsalu, A., Stroosnijder, L., & Graaf, de. J. (2007). Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highlands of Ethiopia. J Environ Manag 83(4):448–459.

[5]. Amsalu T., & Mengaw, A. (2014). GIS based soil loss estimation using RUSLE model: the case of Jabi Tehinan Woreda, ANRS, Ethiopia. Natural Resources, vol. 5, no. 11, pp. 616–626.

[6]. 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. https ://doi.org/10.1002/ldr.944.

[7]. Bilal, A., Ahsen, M.; Shahzaib; Zaheer, A. K.; Mahmoud, S.; Fahad, A.; Muhammad, H. B.; Rana, F. T.; & Danish, F. (2020). Effects of Landscape Changes on Soil Erosion in the Built Environment: Application of Geospatial-Based RUSLE Technique. Sustainability 2020, 12, 5898; doi:10.3390/su12155898.

[8]. Borrelli, P., Robinson, D.A., Fleischer, L.R., Lugato, E., Ballabio, C., Alewell, C., Meusburger, K., Modugno, S., Schütt, B., Ferro, V., Bagarello, V., Van Oost, K., Montanarella, L.,& Panagos, P. (2013). An assessment of the global impact of 21st century land use change on soil erosion. Nat. Commun. 8.

[9]. Carvalho, D.F. de., Durigon,V. L., Homem Antunes, M. A., Almeida, W.Sa de., & Oliveira, P. T. S. de. (2014). Predicting soil erosion using Rusle and NDVI time series from TM Landsat 5. Pesq. agropec. bras., Brasília, v.49, n.3, p.215-224, mar. 2014 DOI: 10.1590/S0100-204X2014000300008.

[10]. Foster, G., Yoder, D., Weesies, G., McCool, D., McGregor, K., & Binger, K. (2002). User's Guide—Revised Universal Soil Loss Equation Version 2 (RUSLE 2. USDA–Agricultural Research Service Washington. DC Google Scholar.

[11]. FAO. (1986). Ethiopian highlands reclamation study, Ethiopia. Final Report. FAO, Rome.

[12]. Ganasri, B.P., & Ramesh, H. (2016). Assessment of soil erosion by RUSLE model using remote sensing and GIS - a case study of Nethravathi Basin. Geosci. Front. 7, 953–961.

[13]. Gelagay, H.S., & Minale, A.S. (2016). Soil loss estimation using GIS and remote sensing techniques: a case of Koga watershed, Northwestern Ethiopia. Int Soil Water Conserv Res 4:126–136.

[14]. Gete, Z. (2000). Landscape dynamics and soil erosion process modeling in the North-Western Ethiopian highlands. African Studies Series A16. Geographica Bernensia, Berne.

[15]. Haregeweyn, N., Tsunekawa, A., Poesen, J., Tsubo. M., Meshesha, DT., Fenta, A. A., Nyssen, & Adgo, J. E. (2017). Comprehensive assessment of soil erosion risk for better land use planning in river basins: case study of the Upper Blue Nile River. Sci Total Environ 574:95–108.

[16]. Hootsmans,R.M., Bouwman, A.F., Leemans,R., & Kreileman, G.J.J. (2001). Modelling land degradation in IMAGE 2, National Institute of Public Health and the Environment, Bilthoven, theNetherlands.

[17]. Hurni, H. (1983). Soil formation rates in Ethiopia. Ethiopian highlands reclamation study. Soil Conservation Research Project, FAO, UTF/ETH/037/ETH Working Paper 2.

[18]. Hurni, H. (1985). Erosion–productivity–conservation systems in Ethiopia. In: Proceedings 4th international conference on soil conservation, Maracay, Venezuela, pp 654–674.

[19]. Hurni, H. (1986). Guidelines for development agents on soil conservation in Ethiopia soil conservation research project. Community Forests and Soil Conservation Development Department, Ministry of Agriculture, Addis Ababa.

[20]. Hurni, H. (1993). Land degradation, famine, and land resource scenarios in Ethiopia. In: Pimentel D (ed) World soil erosion and conservation. Cambridge University Press, Cambridge, pp 27–62.

[21]. Kayet, N., Pathak, K., Chakrabarty, A., & Sahoo, S. (2018). Evaluation of soil loss estimation using the RUSLE model and SCS-CN method in hill slope mining areas. Int. Soil Water Conserv. Res. 6, 31–42.

[22]. Kidane, M., Tolessa, T., Bezie, A., Kessete, N., & Endrias, M. (2019). Evaluating the impacts of climate and land use/land cover (LU/LC) dynamics on the hydrological responses of M. Kidane et al. Heliyon 5 (2019) e02981 12 the upper Blue nile in the central highlands of Ethiopia. Spatial Inf. Res. 27 (2), 151–167.

[23]. Kinnell, P.I.A. (2010). Event soil loss, runoff and the Universal Soil Loss Equation family of models: a review. Journal of Hydrology, v.385, p.384-397, 2010. DOI: 10.1016/j. j hydrol.2010.01.024.

[24]. Kouli, M., Soupios, P., & Vallianatos, F. (2009). Soil erosion prediction using the Revised Universal Soil Loss Equation (RUSLE) in a GIS framework, Chania, Northwestern Crete, Greece. Environ Geol 57:483–497.

[25]. Kurt Cooper. (2011). Evaluation of the Relationship between the RSULE R-Factor Mean Annual Precipitation. December 1.

[26]. Lu, H., Gallant, J., Prosser, I.P., Moran, C., Priestley, G., (2001). Prediction of sheet and rill erosion over the Australian continent, incorporating monthly soil loss distribution. In: CSIRO (Ed.), CSIRO Land and Water, Canberra, pp. 40.

[27]. Maeda, E.E., Formaggio, A.R., & Shimabukuro, Y.E. (2008). Impacts of land use and land cover changes on sediment yield in a Brazilian amazon drainage basin. GIScience Remote Sens. 45 (4), 443–453.

[28]. Meusburger, K., Steel, A., Panagos, P., Montanarella, L., & Alewell, C. (2012). Spatial and temporal variability of rainfall erosivity factor for Switzerland. Hydrol. Earth Syst. Sci. 16, 167–177.

[29]. Molla, T., & Sisheber, B. (2017). Estimating soil erosion risk and evaluating erosion control measures for soil conservation planning at Koga watershed in the highlands of Ethiopia. Solid Earth 8, 13–25.

[30]. Monsieurs, E., Dessie, M., & Adgo, E. (2015). Seasonal surface drainage of sloping farmland: a review of its hydrogeomorphic impacts. Land Degrad Dev 26(1):35–44.

[31]. Morgan, R.P.C. (2005). Soil erosion and conservation, 3rd edn. Blackwell Publishing, Oxford.

[32]. Oliveira, P.T.S., Wend land, E., & Nearing, M.A. (2012). Rainfall erosivity in Brazil: a review. Catena, v.100, p.139-147, 2013b. DOI: 10.1016/j.catena.2012.08.006.

[33]. Ouyang, W., Hao, F., Skidmore, A.K., & Toxopeus, A.G. (2010). Soil erosion and sediment yield and their relationships with vegetation cover in upper stream of the Yellow River. Sci. Total Environ. 409, 396–403.

[34]. Pawan, Th. (2020). Spatial Estimation of Soil Erosion Using RUSLE Modeling: A case study of Dolakha District, Nepal. Department of Geomatics Engineering, Kathmandu University, Dhulikhel, Nepal pawan.thapa@ku.edu.np.

[35]. Renard, K.G., Foster, G.R., Weesies, G.A., Mccool, D.K., & Yoder, D.C. (1997). Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss 224

[36]. Reusing, M., Schneider, T.,& Ammer, U. (2000). Modelling soil loss rates in the Ethiopian Highlands by integration of high resolution MOMS-02/D2-stereo-data in a GIS. Int. J. Remote Sens. 21 (9), 1885–1896.

[37]. Rose, C.W. (1994). Research on soil erosion processes and a basis for soil conservation practices. In: Soil erosion research methods. Columbus, pp 179–181.

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

[39]. Singh,R., Arya, D. S., Taxak, A. K., ojinovic,Z., & Vojinovic, Z. (2016.) Potential impact of climate change on rainfall intensityduration-frequency curves in roorkee, India. Water Resources Management, vol. 30, no. 13, pp. 4603–4616.

[40]. Sonneveld, B., & Keyzer, MA. (2003). Land under pressure: soil conservation concerns and opportunities for Ethiopia. Land Degrad Dev 14(1):5–23.

[41]. Stocking, M.A., Murnaghan,N. & Murnaghan,N. (2001) A Handbook for the Field Assessment of Land Degradation. Routledge, London, UK, 169 p.

[42]. Tamene, L., Park, S., Dikau, R.,& Vlek, P. (2006). Analysis of factors determining sediment yield variability in the highlands of northern Ethiopia. Geomorphology 76 (1-2), 76–91. Taye, M.T.,

[43]. Tebebu, T.Y., Abiy, A. Z., Zegeye, A.D., Dahlke ,H.E., Easton, Z.M., Tilahun, S.A., **…** Steenhuis, T.S. (2010). Surface and sub-surface fow efect on permanent gully formation and upland erosion near Lake Tana in the northern highlands of Ethiopia. Hydrol Earth Syst Sci 14:2207–2217.

[44]. Williams, J.R. (1975). Sediment routing for Agricultural Watersheds. Water Resour. Bull. 11, 965–974.

[45]. Willems, P., Block, P., 2015. Implications of climate change on hydrological extremes inthe Blue Nile basin: a review. J. Hydrol.: Reg. Stud. 4, 280–293.

[46]. Wischmeier, W. H., & Smith, D. D. (1965). Predicting Rainfall Erosion Losses from Crop Land East of the Rocky Mountains, United States Department of Agriculture, Washington DC, USA.

[47]. Wischmeier, W.H., & Smith, D.D. (1978). Predicting rainfall erosion losses: a guide to conservation planning. Washington: USDA, 58p. (USDA. Agriculture handbook, 537).

[48]. Yesuph, A.Y., & Dagnaw, A.B., 2019. Soil erosion mapping and severity analysis based on RUSLE model and local perception in the Beshillo Catchment of the Blue Nile Basin, Ethiopia. Environ. Syst. Res. 8, 17.

[49]. Yihenew, G., &Yihenew, B. (2013). Costs of nutrient losses in priceless soils eroded from the highlands of Northwestern Ethiopia. J Agric Sci 5(7):1916–9752.

[50]. Wolka, K., Tadesse, H., Garedew, E., & Yimer, F. (2015). Soil erosion risk assessment in the Chaleleka wetland watershed, Central Rift Valley of Ethiopia, Environmental Systems Research, pp 45.