International Journal of Environmental Protection and Policy
2022; 10(5): 130-139
http://www.sciencepublishinggroup.com/j/ijepp
doi: 10.11648/j.ijepp.20221005.13
ISSN: 2330-7528 (Print); ISSN: 2330-7536 (Online)

Assessment of Spatial Soil Erosion Using RUSLE Model Integration with GIS and RS Tools a Case Study of Gojeb Catchment, Omo-Gibe Basin, Ethiopia

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To cite this article:

Eyasu Tafese Mekuria. Assessment of Spatial Soil Erosion Using RUSLE Model Integration with GIS and RS Tools a Case Study of Gojeb Catchment, Omo-Gibe Basin, Ethiopia. *International Journal of Environmental Protection and Policy*. Vol. 10, No. 5, 2022, pp. 130-139. doi: 10.11648/j.ijepp.20221005.13

Received: August 17, 2022; **Accepted**: October 25, 2022; **Published**: October 31, 2022

Abstract: Soil erosion is a natural process in which earth materials are entrained and transported across a given surface mainly by wind and water. Gojeb catchment is one of the catchments found in the Omo-Gibe Basin, Ethiopia with soil erosion problems. It covers 6932.345 km^2. The current study was undertaken with the application of RUSLE and Geographic information system (GIS) to estimate the soil erosion of Gojeb catchment and identifications of the most affected area based on severity level. To determine the parameters of RUSLE, rainfall, soil map, Landuse Landcover, Digital elevation model data's of Gojeb catchment was collected from different sources. The rainfall Erosivity (R), soil erodibility (K), topographic (LS), land cover (C), land management (P) were combined in Arc GIS environment using RUSLE. Annual soil loss of the catchment was determined by combining all the important parameters of RUSLE. The estimated annual soil loss value in the watershed varies from 0 to 85 ton/ha/yr, with an average value of 38 ton/ha/yr. The spatial soil erosion severity of the watershed was grouped into six classes low severity class covers 31.425%, moderate severity class covers 12.5%, high severity class covers 16.75%, very high severity class covers 7.63% sever severity class covers 11.4% and very sever severity class cover 20.3% of the area depending on soil loss hazards. In Gojeb catchment concerning stakeholders, for the different districts, which have exposed to very high to extreme sever loss classes given immediate priorities to proper conservation and mitigating measures.

Keywords: Arc GIS, Gojeb catchment, RUSLE, Omo-Gibe Basin, Ethiopia

1. Introduction

Soil erosion is a natural process in which earth materials are entrained and transported across a given surface. It is regarded as the major and most widespread kind of soil degradation and as such, affects significantly the sustainable agricultural land use. Soil can be eroded mainly by wind and water. High winds can blow away loose soils from flat or hilly terrain, while erosion due to the energy of water occurs when water falls toward the earth and flows over the surface [1]. Soil erosion is a major problem around the world because of its effects on soil productivity, nutrient loss, siltation in water bodies, and degradation of water quality [2]. In developing countries like Ethiopia, soil erosion by water and the resulting land degradation are an alarming problem that led to a significant economic crisis and negative environmental threat [3].

A geographic information system, remote sensing, and modeling tools are increasingly used in environmental studies for land use land cover planning and water management. Empirical models such as the Universal Soil Loss Equation (USLE), RUSLE, Chemical Runoff and Erosion from Agricultural Management systems (CREAMS), Agricultural Nonpoint Source Model (AGNPS) and Modified Universal Soil Loss Equation (MUSLE) are increasingly being used to predict erosion rates at spatio-temporal scales [4]. The USLE model was originally proposed in 1965 to estimate rill and sheet erosion from cultivated lands in the US However, the model is continuously being revised and used in different countries and ecosystems.

RUSLE is a simple and robust model, and has significant advantages in watershed scale erosion and sediment transport modeling [5]. RUSLE offers several improvements in the USLE factors to represent diverse land and crop management, and slope forms [6]. Briefly, R-values are minimized under flat slopes experiencing high rainfall intensity. The K factor has been greatly improved to account for seasonal variability (e.g. freezing and thawing, soil moisture, and soil consolidation), and to include repercussions of rock fragments on soil permeability and runoff. RUSLE also includes functions for slope steepness and for soil vulnerability to rill erosions relative to inter-rill, and generates a rather linear relation for slope steepness compared with the USLE model. It utilizes a sub-factor method consisting of historical land use, canopy, ground cover, and within-soil effects to improve estimates of weighted average soil loss. Additionally, P factor values are improved for contouring, terracing, strip-cropping, and rangeland conservation and management [6, 7].

Basically, RUSLE predicts the long-term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system, and management practices (soil erosion factors). For the past 15 years, more comprehensive research on soil erosion by water has been conducted. By including additional data and incorporating recent research results, the USLE methodology is improved and a revised version of this model (RUSLE) further enhanced its capability to predict water erosion by integrating new information made available through research of the past 40 years [8, 9].

The Gojeb river catchment as a whole receives a good amount of rainfall throughout the year, which flows through the Western side of Omo Gibe Basin and contribute high amount of flow to Gibe III Hydropower project. Apart from the hill topography, faulty cultivation practices and deforestation within the basin result in huge loss of productive soil and water as runoff [10]. There is a need for developing integrated watershed management plan based on hydrological simulation studies using suitable modeling approach in this catchment. Considering hydrological behavior of the basin and applicability of the existing models for the solutions of aforesaid problems, the current study was undertaken with the application of RUSLE and Geographic information system (GIS) to estimate the soil erosion of an intermediate watershed of Gojeb River. Therefore, this study is based on RUSLE to predict soil erosion of Gojeb watershed.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted at the Gojeb River Catchment, a part of the Omo-Gibe basin in Ethiopia. The Omo-Gibe basin is the third-largest perennial river in Ethiopia next to the Baro Akobo and Blue Nile rivers it lies between 5° 31′ to 10° 54′ N and 33° 0′ to 36° 17′ E and covers about 79,000 km^2 of land area in South and Southwest Ethiopia [11].

The Gojeb catchment is one of the major watersheds in the Omo-Gibe basin and is situated in the southern part of the country as shown in the below figure which covers an area of 6932.345 km^2. Gojeb catchment is located between 07°00′N and 08°00′N latitude and between 35°40′E and 37°20′E longitude.

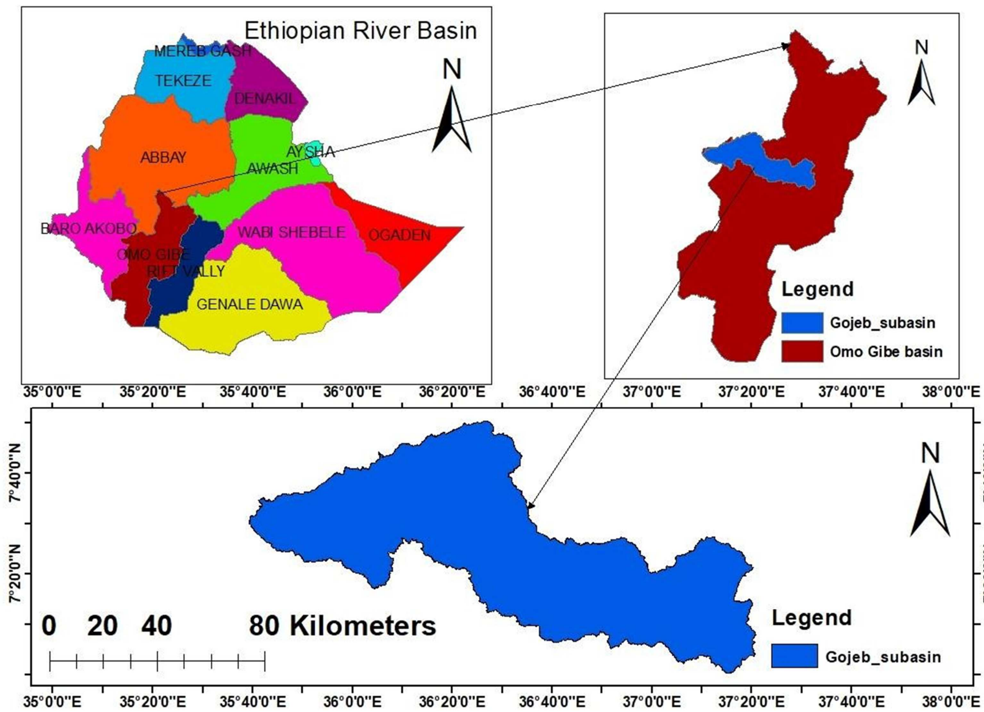

Figure 1. *Location of Gojeb catchment.*

2.2. Climate and Topography

The climate of the Gojeb Watershed varies from a hot arid climate in the southern part of the floodplain to a tropical humid one in the highlands that include the extreme north and north-western part of the Basin. The Intermediate between these extremes and for the greatest part of the basin the climate is tropical sub-humid. Rainfall in the river sub-basin varies from over 1900 mm per annum in the north-central areas to less than 300mm per annum in the south. Furthermore, the rainfall regime is unimodal for the northern and central parts of the basin and bimodal for the south. The mean annual temperature in the Gojeb watershed varies from 16°C in the highlands of the north to over 29°C in the lowlands of the south [12].

The topography of the Gojeb river sub-basin as a whole is characterized by its physical variation. The northern two- thirds of the basin have mountainous to hilly terrain. The northern and central half of the basin lies at an altitude greater than 697 m.a.s.l with a maximum elevation of 3851 m.a.s.l (located between Gilgel Gibe and Gojeb tributaries), and the plains of the lower part of the Gojeb watershed lies between 697 m.a.s.l [12].

2.3. Data Collections and Sources

2.3.1. Rainfall Pattern of Gojeb Catchment

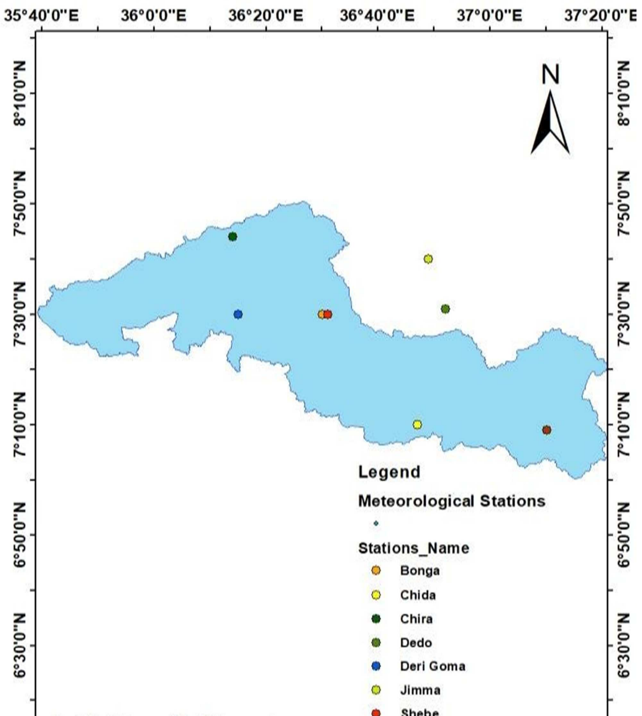

Figure 2. Meteorological stations around Gojeb catchment.

Eight Meteorological stations data were collected for the estimation of rainfall. Eight meteorological stations, stations located within as well as around the catchment, 25 years daily rainfall data were collected from national meteorological agency. Meteorological stations include Bonga, Tercha, Shebe, Jimma, Deri Goma, Dedo, Chira and Chida. The watershed annual rainfall of the study area ranges from 1444.44 mm to 1824.38 mm. The average annual Rainfall of the area is 1618.63 mm. The rainfall is uni-modal type with one long rainy season. The rainfall data was used to calculate rainfall erosivity (R) factors.

Table 1. Rainfall stations location and average annual rainfall.

NO	Stations	Latitude	Longitude	AV.RF
1	Bonga	7.54	36.54	1824.38
2	Jimma	7.66	36.81	1585.95
3	Shebe	7.53	36.51	1444.44
4	Deri goma	7.52	36.25	1641.53
5	Chira	7.73	36.23	1802.70
6	Tercha	7.14	37.16	1533.88
7	Chida	7.16	36.78	1498.55
8	Dedo	7.51	36.86	1622.65

2.3.2. Landuse Landcover of the Study Area

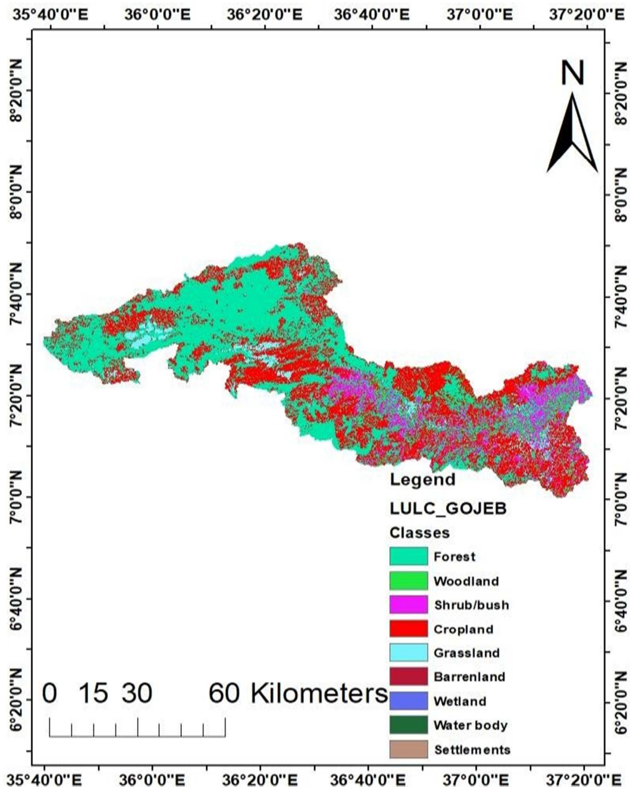

Figure 3. Landuse landcover map of Gojeb catchment.

Table 2. Landuse landcover map classification of Gojeb catchment.

Landuse landcover	Area in Km^2	% of total
Forest land	1559.08	22.49%
wood lands	1272.77	18.36%
shrub/bush	191.33	2.76%
crop land	3396.15	48.99%
Grass land	269.66	3.89%
Barren land	45.75	0.66%
wet land	67.931	0.98%
water body	36.741	0.53%
settlements	92.89	1.34%

The study watershed LULC was classified into nine classes, namely Forest land, wood lands, shrub/bush, crop land, Grass land, Barren land, wet land, water body and settlements. Cropland is the dominant land use type in the study area, which covers 3396.15 (48.99%). LULC map were downloaded from Ethiopia Sentinel2 website.

2.3.3. Topography

Digital Elevation Model (DEM) is the digital representation of the land surface elevation with respect to any reference datum. DEM is frequently used to refer to any digital representation of a topographic surface. DEM is the simplest form of digital representation of topography. DEMs are used to determine terrain attributes such as elevation at any point, slope and aspect. Terrain features like drainage basins and channel networks can also be identified from the DEM. The topography of the area is characterized by undulating, rugged, hilly topography with altitude ranging from 822 masl (meter above sea level) around central edge to 3320 masl in the Northern ridge.

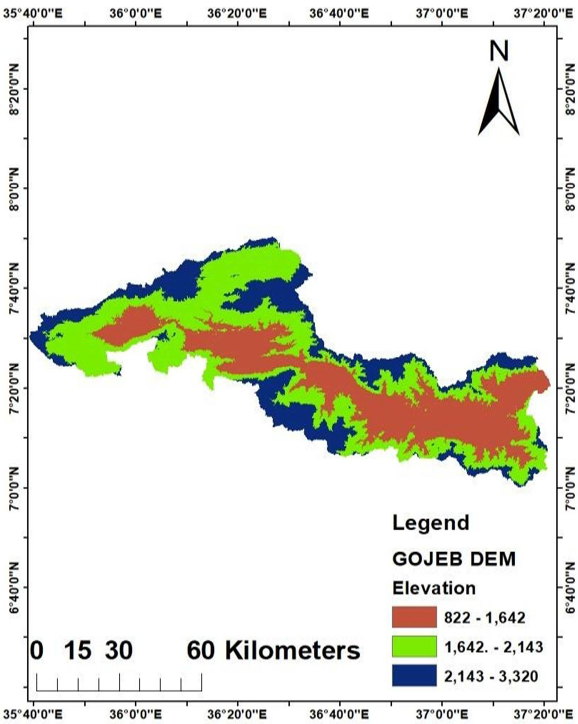

Figure 4. *Digital elevation model map of Gojeb catchment.*

2.3.4. Soil

Soil properties are one of the major factors affecting watershed response to the soil erosion of the catchment. The soil map of the study area was taken from the Food and Agriculture Organization (FAO) which is the digital soil map of the world in shape format found on the website http://www.fao.org/land-water/news-archive/news detail/en/c/1026564/. According to FAO soil classification Gojeb catchment has two main domain soil types those are Eutric Nitosols and Eutric Cambisols.

2.3.5. Slope Map

A slope map is a topographic map showing changes in elevation on a highly detailed level. The slope of the *Gojeb* catchment derives from a resolution of 12.5m*12.5m resolution DEM of the catchment. There is the possibility to **c**hoose simply a single slope class or multiple slope class. For this study, multiple slope class was selected and consider slope class one 0-10%, class two 10-20% class three 20-30% class four 30-40% class five >40% according to the Ethiopian highland studies result of slope classifications for most agricultural watersheds.

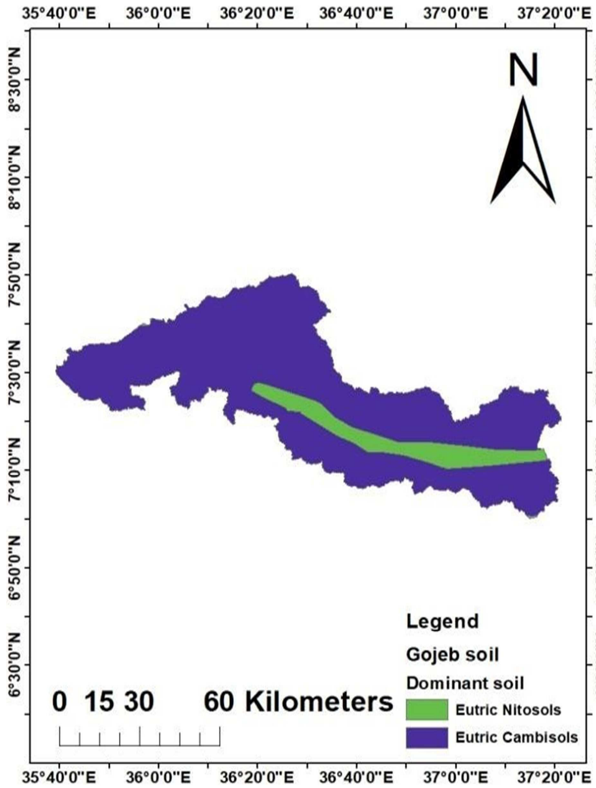

Figure 5. *Soil map of Gojeb catchment.*

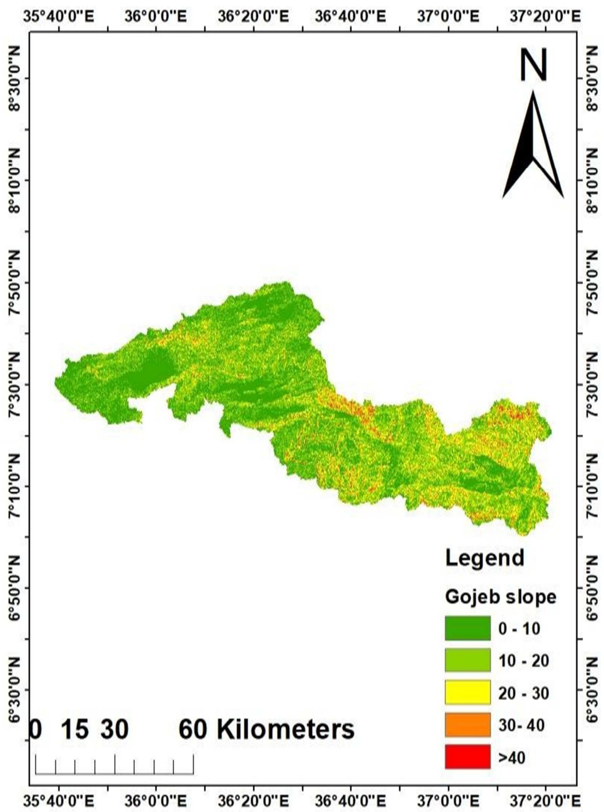

Figure 6. *Slope map of Gojeb catchment.*

2.4. RUSLE Equations

RUSLE is a flexible tool that has been adapted to landscape and watershed scales combined with Geographic Information Systems (GIS) in soil erosion assessments. There are several erosion prediction approaches widely used comprised of empirical, conceptual, and physical based models. Universal Soil Loss Equation (USLE), Modified Universal Soil Loss Equation (MUSLE), and Revised Universal Soil Loss Equation (RUSLE) are the most popular empirical models used globally for erosion prediction and control. RUSLE developed by the U.S. Department of Agriculture is used as a decision support system in soil conservation and land use planning. The other advantage of a selection of RUSLE is that the parameters of this model can be easily integrated with GIS for better analysis. The RUSLE was used as the model and it was interfering with the ArcGIS 10.8.

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

A = Average annual soil loss (metric t·ha−1·yr−1).

K = Soil erodibility index to water erosion (metric t/ha/MJ/mm).

LS = Topographic factor depending on the slope and its length (L in meter and S in%). C = Land cover.

P = Conservation and development factor.

2.4.1. Rainfall and Runoff Erosivity Factor (R)

Rainfall erosivity is defined as the aggressiveness of the rain to cause erosion. The R factor is considered to be the most highly correlated index to soil loss at many sites throughout the world. The erosive power of rainfall can be estimated by calculating the erosivity factor for a particular location. It depends on the amount and the intensity of rainfall [13].. The mean of the annual sums for the period under consideration gives the rainfall erosivity factor (*R* factor). Different researchers have developed equations from which the *R* factor has been derived and applied in different regions.

For Ethiopian the following formula was used to compute R factor (Regional formula).

$$R = 0.55 * MAR$$

Where MAR is mean annual rainfall.

2.4.2. Soil Erodibility Factor (K)

Erodibility defines the soil's resistance to detachment and transport. Soil resistance to erosion depends on topography, land slope, and soil disturbance. It is an estimate of the soil's ability to withstand erosion depending on the physical properties of each soil. The erodibility of the soil varies depending on the soil texture and aggregate stability, shear strength, infiltration capacity, and soil chemical content [14]. Soil erodibility is the inherent aspect of soil properties effecting the vulnerability of a soil to erode, as influenced by the biophysical and chemical characteristics of the soil [15].

Procedures to calculate K-factor.

It can be calculated by the equations

$$K\ factor = f_{sand} * f_{clay} * f_{org} * f_{silt} * 0.1317$$

$$f_{sand} = (0.2 + 0.3\exp[-0.256 m_{sand} (1 - \frac{msilt}{100})]) \quad f_{clay} = (\frac{msilt}{mclay + msilt})^{\wedge}0.3$$

$$f_{org} = (1 - \frac{0.0256 * orgC}{orgC + \exp[3.72 - 2.95 * orgC]})$$

$$f_{silt} = (1 - \frac{0.7(1 - \frac{msand}{100})}{(1 - \frac{msand}{100}) + \exp[-5.51 + 2.96(1 - \frac{msand}{100})]})$$

Where

fc -sand is the function of coarse sand content. fcl− is the function of the clay. forg- is the function of the organic carbon content.

fsand -is the function for high sand content.

ms is the sand content (%),

msilt is the silt content (%),

mc is the clay content (%),

Org C is the organic carbon content.

2.4.3. Slope Length and Slope Steepness (LS) Factor

The slope length (*L*) and slope steepness (*S*) define the landscape's topography, which mostly influence the extent of soil erosion. L and S are the two most important parameters with regard to soil erosion modeling and most importantly when calculating the transporting power of surface runoff [16].. Slope steepness has been considered as one of the most model parameters in RUSLE analysis due to the fact that the steeper the slope of a field, the more it is pushed down hill, the faster the water runs and the greater will be the amount of soil loss from erosion by water. Soil erosion by water also increases as the slope length increases due to the greater accumulation of runoff [17].

The LS value was calculated by the following formula.

LS=power (Flow accumulations*38.2185/22.1,0.6*(sine slope(0.1745))/0.09,1.3)) [18]

2.4.4. Crop Management Factor (C)

The cover management factor (C) was used to indicate the effect of cropping and management practices on erosion rates in agricultural lands. The role of vegetation canopy and ground covers on reducing soil erosion in forested regions varies with season and crop production system. The seasonal variation of C-factor depends on many factors such as rainfall, agricultural practice, type of crops and others [19].

The crop management factor is indicative of the influence of vegetation cover and specified management practices on soil erosion. The *C* factor is derived based on prior land uses, canopy shading factor, percent soil cover by crop remains, soil surface roughness, and above all soil moisture [20].

The factor C is defined as also a ratio of soil loss on land cultivated under specific conditions to corresponding soil loss on fallow land. The cover factor (C) is an index which reflects, on the basis of the land use, the effect of cropping practices on the soil erosion rate [3].

***Table 3.** Crop management factor values.*

Land use land cover type c-factor	(Wischmeier, 1978) value
Forest	0.01
Shrub land	0.01
Grazing land	0.01
Cultivated land	0.15
Bare land	0.05
Urban built up area	0.05
Wet land	0.01
Water body	0.00

2.4.5. Support Practice Factor (p)

The P factor refers effectiveness of support practices that will diminish the amount and rate of soil erosion. A support practice is most successful when it causes eroded sediments to be deposited on the upslope, very close to their source than close to the end of the slope. However, the effectiveness of P factor is influenced by a range of activities functional on the farm such as cross slope cultivation, contour farming, strip cropping and terracing [21].

The P-factor mainly represents how surface conditions affect flow paths and flow hydraulics. P factors have been developed to reflect conservation practices on rangeland. The practices require estimates of surface roughness and runoff reduction. Of all the USLE factors, values for the P factor are the least reliable. The P-factor mainly represents how surface conditions affect flow paths and flow hydraulics [6].

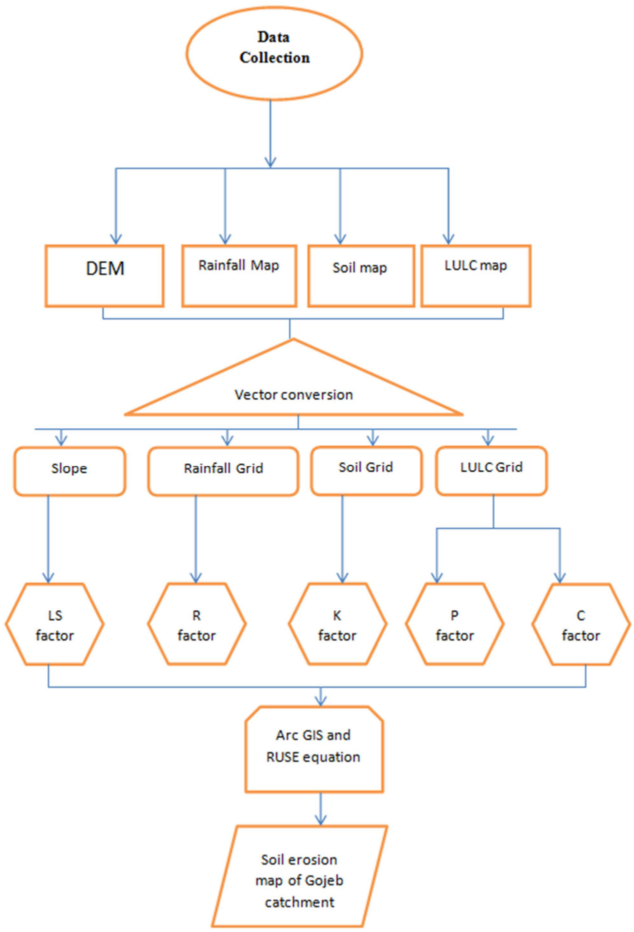

***Figure 7.** General methodology.*

***Table 4.** Support practice factor values.*

Slope%	Contouring	Strip cropping	Terracing
0-7	0.55	0.27	0.1
6-11.3	0.6	0.3	0.12
11.3-17.6	0.8	0.4	0.16
17.6-26.8	0.9	0.45	0.18
26.8>	1	0.5	0.2

3. Result and Discussion

3.1. Rain Fall Erosivity Factor (R)

The rain fall-runoff erosivity factor obtained by calculating the prescribed procedures were ranges 743.52 to 881.65 MJ mm/ha/y. A graphical relationship between the estimated rain fall erosivity factor value and the maximum rain fall was established. The mean erosivity factor value computed from eight (8) rainfall gauging stations in Gojeb watershed was 812.585 MJ mm /ha/y. The highest R- factor value was identified in the Eastern, north west and middle parts of study areas whereas, the lowest R-value are occupied in the western part of the study area. High rain fall erosivity value can cause damages surface soil through hit the bare soil for long time. Generally, rainfall erosivity map of study area could show spatial overview of the erosive power of rainfall.

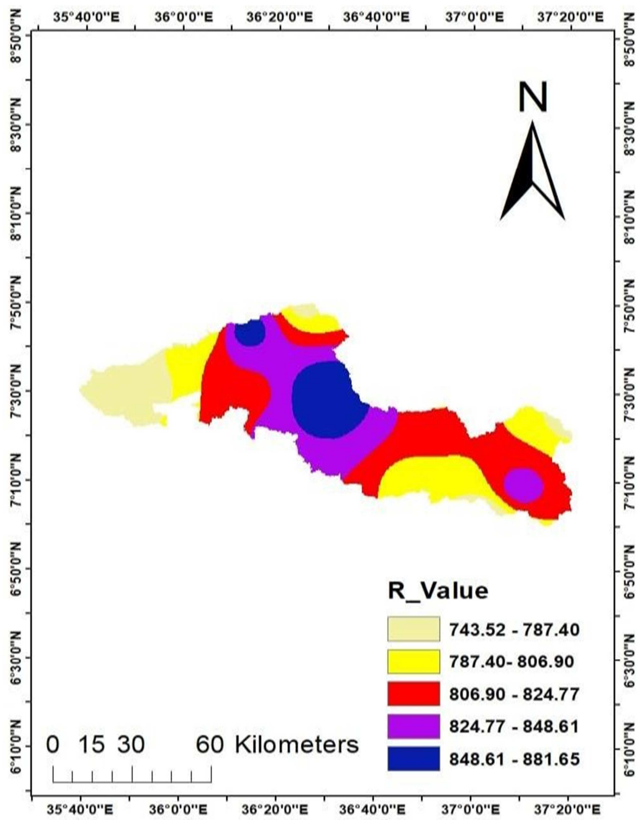

***Figure 8.** Rainfall erosivity factor values of Gojeb catchment.*

3.2. Soil Erosivity Factor (K)

Erosivity factor is very crucial from RUSLE input parameters to estimate soil erosion loss. In this study the RUSLE factor has considered the major soil type profiles of study area. Basically the major dominant soil types of the study area were Eutric Nitosols and Eutric cambisols but the major parts were covered by Eutric cambisols. They characterized as Clay soil textures, organic matter and aluminum or iron compounds. From the map of study area, the soil erodibility factor value typically ranges from 0.134 to 0.151. The result of soil erodibility map, indicates that Eutric cambisols are highly susceptibility or exposed to soil erosions with K-values of 0.151. While Eutric Nitosols have less susceptibility to erosion with k- value of 0.134. So k- value indicates strength conservation practices have been carry out in easily erodible areas.

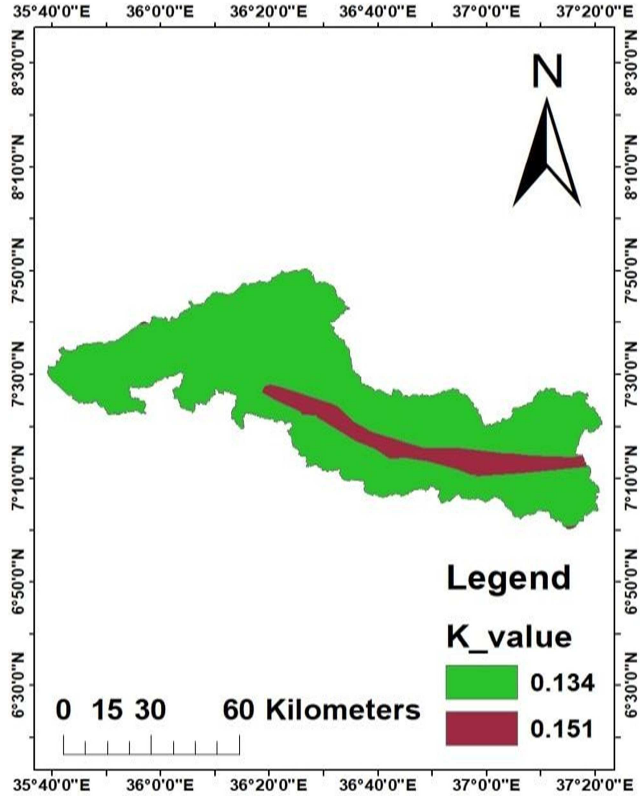

Figure 9. *Soil erosivity factor values of Gojeb catchment.*

3.3. Slope Length and Steepness Factor (LS)

LS factor was calculated by using flow accumulation and slope in degree as inputs. LS factor value ranged from 0 to 2829.8. When slope and flow accumulation increase, LS factor increases. Higher LS factor was observed in the Northern upstream area of the basin. Maps obtained from LS-factor outlined that the slope in Gojeb watershed have tendency of increasing with in elevation and along the banks of rivers. In fact, the steepest the slope lengths the highest erosion potential are occur. LS Factor values are stretching from 0 to 2829.8.

3.4. Cover Management Factor (C)

Forest 0.01, Shrub land 0.01, Grazing land 0.01, Cultivated land 0.15, Bare land 0.05, Urban built up area 0.05, Wet land, 0.01 Water body 0.00. Cultivated land, Bare land and built up land areas critically these areas are exposed to distinct rainfall runoff and which have high soil erosion loss. As a result, soil erosion is happened during the period of rainy season in the area of no ground cover. Densely and sparsely forest of the study area reflects good ground cover, to this they lowery exposed to soil erosion. Relatively lands of bush and bamboo were moderately cover the ground surface so, slightly sensitive to soil erosion. As seen figured 11 higher C- factor value, indicated in red with related to cover management practices that contribute highly to rainfall Erosivity power compare to green which have lower C-factor values. For instance, lands of the central and eastern region of the watershed (illustrated in red) have c-factor values of 0.05 to 0.15. The spatial distributions and magnitude of c-factor values ranges 0 to 0.15.

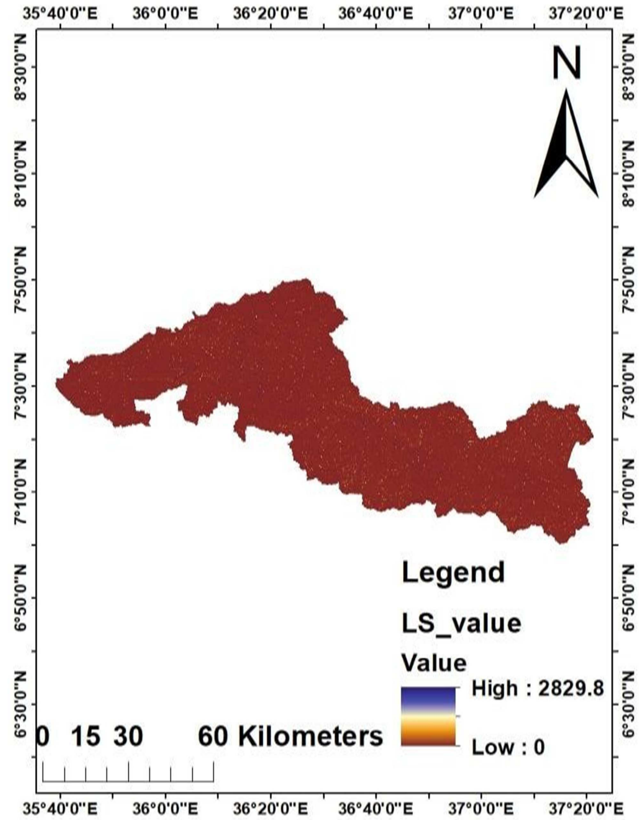

Figure 10. *Slope length and steepness factor values of Gojeb catchment.*

3.5. Conservation or Support Practice Factor (P)

The P-factor value results from the product of P sub factors that taken into account individual support practices, some of which are used in combination. P-values of the watershed were found in the ranges of 0 to 1. Slope% 0-7% p values of 0.27, 6-11.3% p values of 0.3, 11.3-17.6% p values of 0.4, 17.6-26.8% p values of 0.45, 26.8%> p values of 0.5. The P-factor value is little in the middle part and in the eastern, western and some of the northern parts of the study area have the biggest p-factor values as result of no human activities for conservation practice are followed. The most significant impacts related with soil detachments in Gojeb watershed; unsustainable agricultural and lands uses, poor water-soil management and sever wildfire expanding as a result of human need activities are increase.

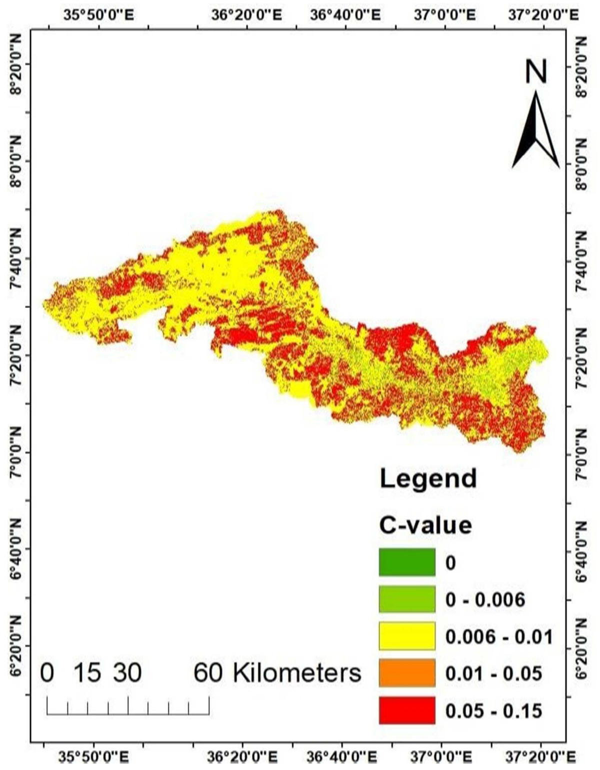

Figure 11. Cover management factor values of Gojeb catchment.

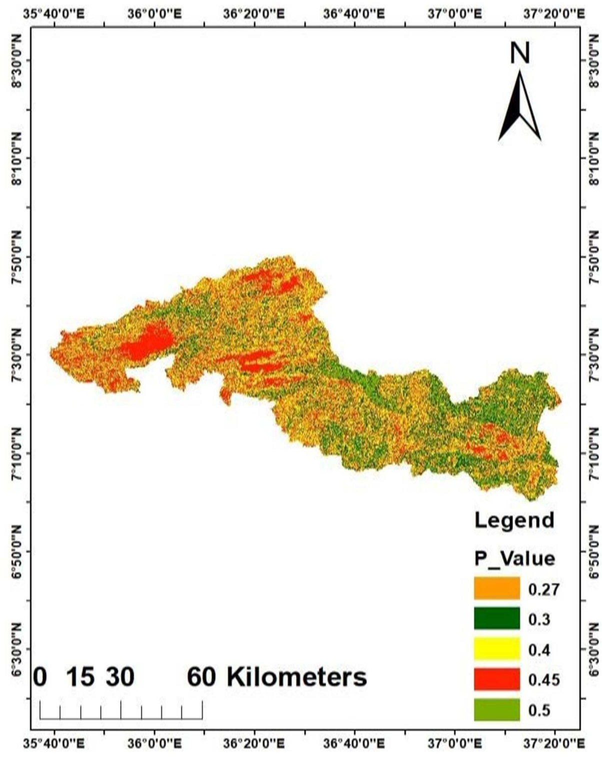

Figure 12. Conservation or support practice factor values of Gojeb catchment.

3.6. Estimation of Annual Gross Soil Loss Rate

The estimated annual soil loss value in the watershed varies from 0 to 85 ton/ha/yr, with an average value of 38 ton/ha/yr. The spatial soil erosion severity of the watershed was grouped into six classes, depending on soil loss hazards with slight modifications in group. Therefore, the result of soil loss rate obtained was spatially varied from low to very sever particularly in some areas of the study watershed. For this brief Annual average soil loss rate severity classes with their magnitude and spatial distribution of soil loss risk map of Gojeb watershed are illustrated below in figure 13.

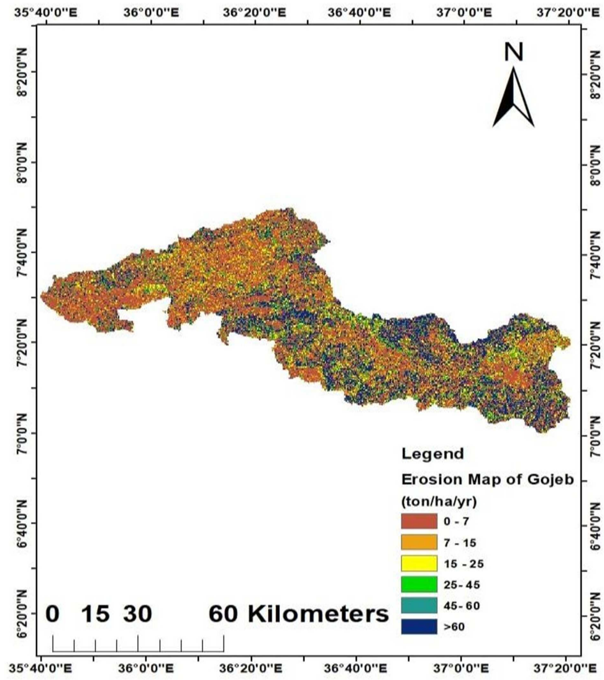

Figure 13. Annual gross soil loss map of Gojeb catchment.

3.7. Severity Map of the Gojeb Catchment

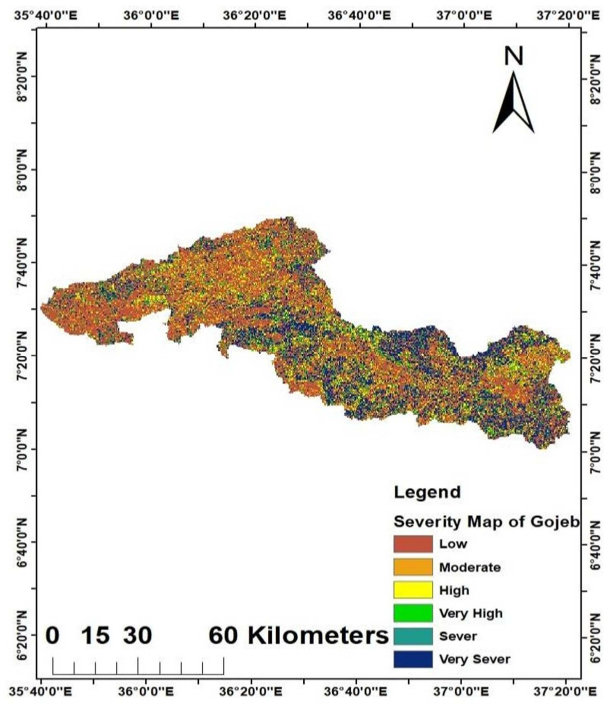

Figure 14. Severity map of the Gojeb catchment.

RUSLE was applied for the identification and prioritization of the Gojeb watersheds on the basis of average annual soil loss. The predicted amount of soil loss and its spatial distribution can provide a basis for comprehensive management and sustainable land use for the watershed. The areas with lowest and moderate severe soil erosion were in the western and northern part of Gojeb watershed, the highest and very highest severe soil erosion were almost in all parts of Gojeb watershed with minimum sever and the very severe soil erosion were almost in the middle and eastern part of Gojeb catchment and it needs special priority for the implementation of control measures. This method is helpful when the soil loss potentials of different sub-watersheds do not have considerable variations.

Table 5. *Severity level and area coverage of Gojeb catchment.*

Severity level	value	Area coverage percent%
Low	0-7	31.42
Moderate	7-15	12.5
High	15-25	16.75
Very high	25-45	7.63
Sever	45-60	11.4
Very sever	>60	20.3

4. Conclusion

Soil erosion by water is considered as the major cause degradation processes. Understanding the extent and its spatial distribution is essential to make sustainable land management more effective with limited resources especially in developing countries like Ethiopia. RUSLE is a flexible tool that has been adapted to landscape and watershed scales combined with Geographic Information Systems (GIS) in soil erosion assessments. Adoption of the RUSLE model requires large data sets such as rainfall, soil, topography, land use, land cover, and land management. The Gojeb catchment is one of the major watersheds in the Omo-Gibe basin and is situated in the southern part of the country which covers an area of 6932.345 km^2. Gojeb catchment is located between 07°00′N & 08°00′N latitude and between 35°40′E & 37°20′E longitude. The daily rainfall data was collected from Bonga, Chida, Shebe, Tercha, Chira, Dedo, Deri Goma by using this value the R-factor value was determined. LS from slope and flow accumulation, P from effectiveness of support practices, C from the effect of cropping and management practices, K from the soil's resistance to detachment and transport effects all the values was determined. The data such as Digital Elevation Model (DEM), Soil map, Land use and Land cover, Slope map were collected from different sources. Filling the missing rainfall data was performed by using both arithmetic mean method and normal ratio method. Data adequacy and reliability test for was done by outlier test and data consistency test was done by double mass curve.

The rainfall-runoff Erosivity factor obtained by calculating the prescribed procedures were ranges 743.52 to 881.65 MJ mm/ha/y. From the map of study area, the soil erodibility factor value typically ranges from 0.134 to 0.151. LS factor was calculated by using flow accumulation and slope in degree as inputs and LS factor value ranged from 0 to 2829.8. according to the types of landuse landcover the C factor values was determined, Forest 0.01, Shrub land 0.01, Grazing land 0.01, Cultivated land 0.15, Bare land 0.05, Urban built up area 0.05, Wet land, 0.01 Water body 0.00. P-values of the watershed were found in the ranges of 0 to 1. Slope% 0-7% p values of 0.27, 6-11.3% p values of 0.3, 11.3-17.6% p values of 0.4, 17.6-26.8% p values of 0.45, 26.8%> p values of 0.5. By combining all the important parameters, the soil erosion capacity of Gojeb catchment was computed. The estimated annual soil loss value in the watershed varies from 0 to 85 ton/ha/yr, with an average value of 38 ton/ha/yr. The spatial soil erosion severity of the watershed was grouped into six classes low, moderate, high, very high, sever and very sever depending on soil loss hazards. The areas with lowest and moderate severe soil erosion were in the western and northern part of Gojeb watershed, the highest and very highest severe soil erosion were almost in all parts of Gojeb watershed with minimum sever and the very severe soil erosion were almost in the middle and eastern part of Gojeb catchment and it needs special priority for the implementation of control measures.

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