University of Natural Resources and Life Sciences, Vienna

Doctoral program in Agriculture; cultural engineering and water management

Assignment of Environmental risk analysis and management Course

Title: Soil Erosion Risk Assessment

By: Wubhareg Belay Kassa (PhD Student)

Submitted to Prof. Dr. HANS PETER NACHTNEBE

May 8, 2023

1. Introduction

1.1. Objectives

1.1.1 **General objective**: to the main objective is to assess soil erosion risks

1.1.2 **Specific objectives**:

- To introduce the key factors that contribute to soil erosion and the method used to assess soil erosion risks
- To discuss the impacts and consequences of soil erosion(soil **No table of contents entries found.**health, water quality, economic loss)
- To introduce various strategies and appropriate measures to mitigate the risk of soil erosion

1.2. Background

1.2.1. Definitions and descriptions of soil erosion

1.2.1.1. Soil:

It is the upper most layer of the earth's crust, which is the mixture of organic maters, materials, soil water, gases, soil organisms that forms the Earth's surface. It is the very complex, dynamic it is a major natural life-supporting natural resource(FAO,2015). Soil is the most fundamental and basic natural resources that played great roles through providing various ecosystem services such as provisioning (food, water), regulating (nutrient cycling), cultural and supporting services to humans and environment (Schwilch et al., 2016),which in turn minimizes the environmental impacts of climate change and to maintain the world's biodiversity. However, due to various drivers soil is degraded.

1.2.1.2. Soil erosion:

Soil erosion is the process of removal or destruction of soil from its original location and transport and deposited to other locations by various natural caustic agents such as water, wind and gravity (FAO, 1986). Thus, the soil loss is measured as mass per unit area. Soil erosion is defined in different ways by various scholars for instance, Jones (2007) defined soil erosion as "the wearing away of the land surface by physical forces such as rainfall, runoff water, wind, ice, temperature change, gravity or other natural or anthropogenic agents that abrade, detach and remove soil or geological material from one point on the earth's surface to be deposited elsewhere.

Soil erosion is a natural phenomenon but it is significantly accelerated by human activities, 100 to 1000 times greater than natural(geological) soil erosion rate (0.25t/ha/year),it takes millions of year to occurs, and hence, it becomes a global serious societal, economic and environmental problem (Soeryantono, & Sulistioweni, 2013), mainly affecting natural resources and agricultural production (Pal et al., 2022).Soil erosion by water is a worldwide environmental problem which degrades soil productivity and water quality, causes sedimentation and increases the probability of flood.

1.2.1.2.1. Soil erosion by water

Water erosion is the most destructive erosion type worldwide, causing serious land degradation and environmental deterioration (Wei et al., 2009)

Water erosion is the most complex process and severe types of soil erosion. It occurs through the detachment and transport of soil particles (organic and inorganic) along the soil surface by raindrops and runoff water, ultimately deposit the eroded materials at lower landscape positions and in aquatic ecosystems (Blanco and Lal, 2008; Stefanos et al., 2021).Water soil erosion becomes a very serious global problem and the worst form of erosion that can leads to substantial loss of soil, loss of soil nutrients and sedimentation, land degradation, reduction in carbon storage, ,degradation of biodiversity, reduction of crop production etc(Suha et al.,2020; Eglinton et al., 2021),with serious environmental and socio-economic consequences.

1.2.2. Divers of Soil erosion

1.2.2.1. Human population growth

World's human population has been increasing at alarming rate that requires enormous amount of products that sustain the day-to-day life. According to UN (2017), the human population has increased from ca. 250 million in the year 1000, to 6.1 billion in the year 2000, and is projected to reach 9.8 billion by the year 2050.This leads to high demand of production from agriculture and industries and intuitive consumption of natural resources which put pressure on the availability and distribution of natural resources (Blanco and Lal, 2008).Because human being is directly and indirectly depend on soil capacity to sustain agricultural production and livestock, which contributes more than 95% of global food production (Borrelli et al.2015). As FAO, (2018) reported that at recent year, from ice free soils, croplands account for ca. 1600 million ha, and permanent meadow and pasture account for ca. 3300 million ha. Therefore, Human activity and related land use change are the primary cause of accelerated soil erosion through deforestation and changing vegetation cover. Such as intensive agricultural production, overgrazing, urbanization, timber, fiber and fuel production (Kopittke et al.2019; Borrelli et al.2013)

1.2.2.2. **Climate change:**

It has a significantly drives soil erosion by increasing precipitation concentration, volume and intensity, which has significantly impacted runoff. But extreme hydrographic phenomena are due anthropogenic activities (human intervention) that increase global warming (Borrelli et al.2020).

1.2.3. Types of water induced soil erosion

Water induced soil erosion is classified based on the nature and extent or form of soil removal. **The major once are** splash, sheet, rill, gully, stream bank, and tunnel erosion

1.2.3.1. Rain drop (Splash) erosion

Splash erosion is the first stage of soil erosion by water; the raindrops hit the bare soil, detach the soil particles and form craters (cavities, pore). As result it disperses and splashes the soil, and transporting detached the soil particles to a short distance (Nives et al., 2021).Therefore, the detached soil is easily washed away and eroded by flow water and other form of water soil erosion. According to Ghahramani et al. (2012)**,** if the soil particles are not detached, they will not be transported by the sheet flow, and, consequently, sheet flow will not have potential enough to dislodge more soil particles from the bare surface. However, the intensity of splash erosion depends mostly on the resistance of the soil to erosion and the kinetic energy of the raindrops.

1.2.3.2. **Sheet erosion**

It occurs when the thin layer of the soil removed by rain water and shallow surface flow. This type of erosion is called sheet because the soil particles are carried evenly and uniformly flow by rainwater over the entire surface of the soil that does not infiltrate into the ground. As the result the top fertile soil (nutrients and organic matter) is removed/lost gradual because the process is unnoticed but over time it leads large soil losses and reduces soil fertility(Blanco & Lal, 2008). It is common in agricultural area and the area which have little or no vegetation cover due to over grazing, deforestation and tillage.

1.2.3.3. Rill Erosion

Rill erosion occurs when the rainfall or irrigation water concentrates in the depressions or low points which can form small channels or rills on the soil surface. Thus, the soil is eroded more rapidly in this small channels (depth<30cm and >30 cm width) where runoff water concentrates, compared to sheet or inter-rill erosion. This is because the detachment of soil particles is caused by the energy of flowing water, rather than by raindrops as in sheet erosion (FAO, 1965). Rill erosion is commonly referred to as the stage between sheet erosion and gully erosion, and recognized as the second most common type of soil erosion (Blanco & Lal, 2008).

1.2.3.4. Gully

Gully erosion is the formation of U-shape channels with steep walls by the flow of concentrated surface runoff water after heavy rain which is deeper than 0.3m.Cattle paths, earth tracks, dead furrows, tillage furrows, or other small depressions down a slope favor concentration of water. Gully erosion is a sever and a geo-environmental problem because when it continues, the entire soil profile can be removed in confined segments and cause significant damage to soil, crops, roads, buildings and infrastructure, increasing the connectivity in the landscape, and transporting large quantities of sediment into the drainage systems(Alice et al.,2021).

Hillsides and areas with steep slope are more vulnerable to gully erosion, where soil exposed due to cleaned vegetations cover, through deforestation, over-grazing or other means. To prevent this type of erosion requires a combination of soil conservation practices such as terracing, contouring, and planting vegetation to protect the soil from water erosion.

1.2.3.5. Tunnel Erosion

It occurs when the runoff/surface water flow through the soil, cracks or holes of burrowing animal, and creates channels or cavities in subsoil layer called tunnels. This soil erosion is common in arid and semiarid lands. Eventually, the channels expand and cause collapsing of the overlying soil which leads the formation of potholes and gullies. It directly causes the loss of soil components and reduction of farm lands through formation and expansion of ditch heads and ditch walls, and induces the division and fragmentation of the ground. Which then leads serious risks such as human safety, damaging railways, roads, bridges, buildings, water diversion canals, and water storage and drainage facilities (Li et al.,2019).Tunnel erosion can be prevented through physical(diverting concentrated runoff),mechanical(disturbing the tunnel systems) and re-vegetation(trees, grasses, shrubs) techniques, and by implementing soil conservation practice(Contour furrows, deep ripping, chisel ploughing, and contour ripping).

1.2.3.6. Stream bank erosion

It is the collapse and cutting of banks along streams, creeks and rivers due to the flow of powerful runoff from uplands fields. As the result, the water removes the soil, carry sediments and other materials from stream banks. It is a complex natural geomorphic process which can occur in all channels through changes in water flow regime and sediment supply due to climate change and natural catchment disturbances. However, land cover and land use changes (urbanization and agricultural activities) increase stream bank erosion by accelerating the rate and magnitude of soil loss, sediment transport and pollutants to water bodies. Globally, stream bank erosion is considered as the major cause of non-point source pollution in freshwater ecosystem, and 80 % of total sediment loading in world's streams is directly related to stream-bank erosion (Fox et al. 2007).Various prevention measures can be taken to reduce the risk of stream bank erosion such as planting vegetations, constricting rating walls and engineering structures(tiles, gabions, dams, levees), mulching stream borders with rocks and woody materials and diverting runoff etc.

1.2.4.Factors influencing soil erosion

Soil erosion is a complex phenomenon which can be influenced by various both natural and socio-economic factors (human activities). The main factors are that influence the extent and rate of the soil erosion are climate, soil properties, topography, vegetation cover and land use (Marondedze and Schütt, 2020)

1.2.4.1. Climate

The magnitude and rate of soil erosion are influenced by climatic factors such as precipitation, humidity, temperature, evapotranspiration, solar radiation, and wind velocity (Blanco & Lal, 2008).

Precipitation**:** is one of the leading factors of soil erosion by water when raindrops partly detach the soil particles by the power of raindrops and runoff. Therefore, climate change can change precipitation volume and intensity which in turn increase the energy available in rainfall to detach and carrying soil as well as sediments (Maeda et al.2010).

Rainfall erosivity refers to the potential ability of rain drops and rainfall water flows to causes soil erosion through detaching and transporting soil particles. The rainfall erosivity is the function of its intensity, duration, and the raindrops' mass (amount), diameter and velocity (Morgan, 2005). Soil erosion rate changes with climate change due to the change of rain fall erosive power.

1.2.4.2. Soil properties

The soil susceptibility or erodibility by surface water/rainfall is depend on its texture(relative proportion of clay, silt and sand), particle composition, organic matter content, soil aggregate, moisture, and permeability and depth. Depending on the grain size of the soil particles their detachment and transport resistance is different. Fine particles can resist detachment due to large cohesive characteristics but easily transported, for example Silts and sands are the least detachment resistant particles. On the other hand large particles are resistant to transport due to high energy requirement (Morgan, 2005). Silts and sands are the least detachment resistant particles. Soil with organic materials is less erodible because organic matters stabilizes soil structure and coagulate soil colloids (Blanco & Lal, 2008).

1.2.4.3. Topography

It is the most influential factor of soil erosion(). It is the shape, slop and level of the land that determine the soil erosion. Topography is the measurement of the variations in elevation, slope length and steepness, and landscape position. Where the slope length and steepness of an area increases, the velocity and volume of runoff flow increase subsequently result in a higher rate of erosion (Morgan 2005).

1.2.4.4. Vegetation Cover

The presences or absence, and distribution of vegetation on land surface significantly influence runoff and soil erosion. Next to topography, vegetation cover is the most important factors to control soil erosion, since they have the capability of reducing soil erosion through fixing soil in their root and reducing energy of raindrops with their canopy. As result, vegetation affect the runoff and soil erosion by changing the rainfall erosivity, protecting the soil surface from rain drop splash, and run-on scouring, enhancing the infiltration to reduce runoff volume and velocity as well as reducing the soil erodibility. Therefore, the effectiveness of vegetative cover to protect soil erosion depends on plant species, density, age, and root patterns (Blanco & Lal, 2008).

1.2.4.5. Land Management Practices

It is the conservation and management practices such as contour farming, contour strip cropping, terracing, conservation tillage, aforestation and grass waterway that are used in an area of land to control/reduce soil erosion. Thus, these practices can improve the soil texture, increase vegetation cover, organic content, and reduce the volume and speed of runoff .

1.2.5. Impacts and consequence of Soil erosion

Soil erosion by water has significant on-site and off-site negative impacts which lead socio-economic and ecological consequences. These are loss of top fertile soils, reduction of agricultural production increase runoff, increase flooding, climate change, increase aquatic pollution and economic impact.

Table.1. On-site and off-site impacts of soil erosion

On-site impacts	**Off-site impacts**
❖ Soil quality reduction ✓ Soil loss ✓ Loss of nutrients ✓ Loss of organic matter ✓ Damage plant and crops ▪ Reduce crops yield ▪ Production loss ▪ Sales drop	❖ Water and aquatic ecosystem quality reduction (rivers and lakes) • Sedimentation ✓ Reduce the storage capacity of water bodies e.g. silting-up of dams ✓ Affect hydropower plant ✓ affects drinking water quality ✓ affect aquatic habitat ➔ damage fish habitat ➔ human health problem • Nutrient flux(P&N) ▪ Water pollution due to transport of fertilizers and pesticides ✓ Eutrophication ▪ Algal bloom ▪ Anoxic condition ▪ Biodiversity loss ➔ Reduce fishery production ➔ Reduce recreational value ➔ Drops economical value ➔ Affect human health ❖ Increase runoff and flooding • Due to reduced infiltration of soil ✓ Soil compaction ✓ Accelerate bank erosion, obstruct stream and drainage channels ➔ Damage infrastructures eg. roads, buildings etc ❖ Climate change • Release the stored carbon in the soil ✓ Increase green house emission

Source : Humberto and Rattan(2008)

Table 2.Tends of soil erosion increased globally

Table III. Present mean value of potential soil erosion in each region (unit: ton ha^{-1} $year^{-1}$)

Region	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	2090s
Whole world	8·7	8·9	8·9	9·3	9·3	9·7	9·9	10·1	10·2	11·6
Continents										
Africa	3·8	3·7	3·8	3·9	3·8	4·2	4·5	4·5	4·4	6·0
Asia	10·4	10·8	10·8	11·2	11·3	11·8	12·0	12·0	12·2	14·4
Australia	2·4	2·4	2·5	2·4	2·7	2·7	2·8	3·1	3·0	4·1
Europe	10·7	11·4	11·2	11·6	10·7	11·5	11·6	11·6	11·1	8·9
North America	6·8	6·8	6·9	7·5	7·9	8·3	8·8	8·9	9·3	10·0
South America	6·1	6·3	6·4	6·8	7·0	7·0	7·2	8·2	8·5	10·3

Table. 3 Global Soil erosion impacts

		UD dollar	Reference
Average soil erosion by water	2000 t/km2 /y		Chuenchumet al.,2020
Mean rate of soil erosion	12 and 15 t ha−1 yr −1		
Land degraded(W+W)	84%		Chuenchumet al.,2020
Soil loss	75 tones /year	400 billon/year	FAO,2017
Sediment transported world's rivers into the ocean	15–30billion tons/year		Thomas et al. 2018

Table.4 Global Assessment of Human-induced Soil Degradation(GLASOD) estimates of human-induced soil degradation (million haa)

Kind of degradation	World	Asia	West Asia	Africa	Latin America and Caribbean	North America	Australia and Pacific	Europe
Water erosion	1094	440	84	227	169	60	83	115
Wind erosion	548	222	145	187	47	35	16	42
Nutrient depletion	135	15	6	45	72	–	+	3
Salinity	76	53	47	15	4	–	1	4
Contamination	22	2	+	+	+	–	–	19
Physical	79	12	4	18	13	1	2	36
Other	10	3	1	2	1	–	1	2
Sum	1964	747	287	494	306	96	103	218

Source: Bai et al. (2008).

2. Methodology for assessing soil erosion risks

2.1. Methodology and application

Appropriate soil erosion assessment method, tool and model are needed to analyze the load, exposure and quantify the different risks, and to take proper measurements in order to conserving natural resources, prevention and control soil erosion.

Various water induced soil erosion assessment tools and models are developed such as physical, conceptual and Empirical models. According to Karydas et al. (2014), around 82 water-erosion models are classified on different spatial/temporal scales with various levels of complexity. Empirical models are the most accepted, applied and widely used models around the world.

The most common and widely used models are Universal Soil Loss Equation (USLE), Revised Universal Soil Loss Equation (RUSLE), Modified USLE (MUSLE) ; RUSLE2, Water Erosion

Prediction Project (WEPP), Morgan–Morgan–Finney (MMF), Soil Loss Estimation Model for Southern Africa (SLEMSA), used data inputs generated through GIS

Among these, Revised Universal Soil Loss Equation (RUSLE) is the most widely applied and convenient tool in combination with satellite remote sensing (SRS) and Geographic Information Systems (GIS) for soil erosion risk assessments, which are very crucial to assess the soil erosion vulnerable areas quantitatively. To assess the temporal and spatial distribution of erosion

Therefore, to use RUSLE, various input data can be collected from different sources through different tools including field survey.

- ✓ **Rainfall**: a time series(Spatio-temporal) mean annual rain fall () can be collected from rain gauge stations of National Meteorological agency, Satellites imagery(RS) *Rainfall Erosivity (**R-factor**)* can be derived from this data
- ✓ **Field survey**: Soil sample can be collected for the analysis of soil texture, organic matter content, infiltration capacity
- ✓ **Remote sensing**: the satellite imageries can gather land use and or land cover, topography (slope length and steepness) data. The ERDAS Imagines (the satellite images/photographs) are processed and analyzed by GISArc software and categorize the land cover in to forest, cropland, bare land and urban area etc.
  →The Shuttle Radar Topography Mission (SRTM) 30m resolution DEM can be used (United States Geological Survey) can be used to describe the boundary and classify the topography→drive ***LS-factor***
- ✓ GIS: GIS used Digital elevation model (DEM) to drive hydrological data, flow direction, slope and slope length , the remote sensing data(spatial data) and field survey data are combined /integrated with GIS, and analyzed and creates map for LULC, topography, soil types and used by RUSLE.

Therefore, to use and apply RUSLE model to assess the risk of soil eroion,five major factors should be considered and used as input: : Rainfall erosivity (R) factor, Soil erodibility (K) factor, Slope length and Steepness (LS) factor, cover management (C) factor, and conservation practice (P) factor determined in an ArcGIS environment

Thus, according to Renard et al.(1997)the Mean annual rates of soil loss due to sheet and rill erosion can be estimated using RUSLE:

$$A=R*K*LS*C*P$$

where A is average annual soil loss (t ha^{-1} y^{-1}); R is the rainfall-runoff erosivity factor((MJ mm ha^{-1} h^{-1} yr^{-1}); K is a soil erodibility factor(t ha h ha^{-1} MJ^{-1} mm^{-1}); LS is a slope length-steepness factor; C is a cover management factor, and P is a support practice factor. LS, C,and P factors are dimensionless

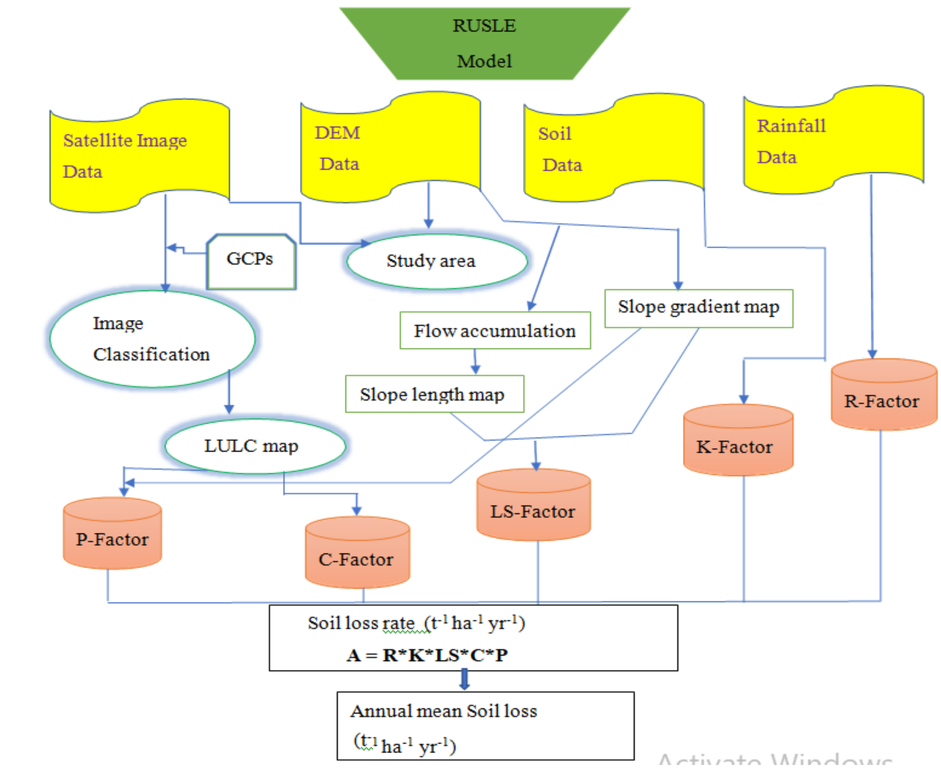


Fig.1 Flow chart for RUSLE model (Source: Kassa,2022)

2.1.1. Rainfall Erosivity Factor(R-factor):

It refers to the potential ability of rain to cause erosion. R-factor is a multi-annual average index that measures rainfall's kinetic energy and intensity to describe the effect of rainfall on sheet and rill erosion. It is estimated using the EI30 measurement: R is the average annual sum of the event rainfall-runoff (erosivity) factor, when this factor is given by the product of the kinetic energy of the rainstorm E and the maximum 30 minutes rainfall intensity I30 (Renard et al., 1997).

In this case Load analysis: R-factor value can be calculated using this equation:

$$R = -8.12 + (0.562 * P)$$

2.1.2. **Soil erodibility (K-factor):**

Refers to the susceptibility of soil to erosion to rainfall and runoff erosivity. The K-factor is defined as the rate of soil loss per unit of R-factor on a unit plot and its value ranges from 0 to 1 (Renard et al.,1997)

In this case susceptibility analysis: K-factor value can be calculated:

$$K = 0.0034 + 0.0405 \cdot \exp[-0.5(\frac{\log D_g + 1.659}{0.7101})^2]$$

Where K : Soil erodibility factor (t ha h ha^{-1} MJ^{-1} mm^{-1}); Dg : Geometric mean weight diameter of the primary soil particles (mm)**;** Dg is a function of surface texture, and its value can be calculated using:

$$D_g = \exp(\sum f_i \cdot \ln(\frac{d_i + d_{i-1}}{2}))$$

For each particle size class (clay, silt, sand), dI is the maximum diameter (mm), dI-1 is the minimum diameter and fI is the corresponding mass fraction.

2.1.3. Topographic (L S-Factor):

It refers to the effect of slop length and slop angle on soil erosion (sheet and rill), and it is the most detraining factor of soil erosion more than other factors (Oliveira et al.2013).LS-factor can be calculated as :

$$L = 1.4(\frac{A_s}{22.13})^{0.4}$$

$$S = (\frac{\sin\beta}{0.0896})^{1.3}$$

Where:

A_s : Specific contributing area (m^2/m)
β : Slope angle (degrees)

2.1.4. **Vegetative cover (vegetation cover management factor (C-factor):**

It is the second most crucial factor next to topology. It is expressed as the ratio of soil loss from land cropped under specified conditions to the corresponding loss from clean-tilled, continuous fallow Wischmeier and Smith, 1978). C-factor is calculated as

The value of C mainly depends on the vegetation's cover percentage and growth stage, and the C factor is determined through the normalized difference vegetation index (NDVI) estimated from satellite

$$C = \exp\left[-\alpha \cdot \frac{NDVI}{(\beta - NDVI)}\right]$$

Where: α(=2), β(=1) : Parameters that determine the shape of the NDVI-C curve,

2.1.5. **Support practice factor (p-factor):**

According to Renard et al., (1997), it can be defined as the ratio of soil loss under a specific soil conservation practice (e.g. contouring, terracing) compared to a field with upslope and down slope tillage. **P-factor is estimated as:** P = Pc × Ps × Pt

Where Pc is contouring factor for a given field slope, Ps is strip cropping factor, and Pt is terrace sedimentation factor.

- Thus, the calculated values of these five respective RUSLE factors are multiplied and give the mean annual rates of soil loss. And the mean annual rate of soil loss of a certain study area can be categorized by using common standards for example: FAO, USDA, NRCS and WSCE

Table.5.soil erosion risk classification with standards (FAO,1997,2015)

Soil loss rate(t ha^{-1} $year^{-1}$)	Soil erosion risk classification
>5	Very low
5-10	low
10-20	moderate
20-50	high
>50	Severe

3. Study Result and Discussion

Case Studies and study findings: Soil erosion risk assessment using RUSLE in different parts of Ethiopia.

3.1. A study conducted by Fanta et al.(2021) on the assessment of soil erosion in the Ethiopian river basins using RUSLE.

- The result showed that due to water induced soil erosion, majority of the river basin are at high risk of soil erosion based on the result of five RUSLE factors
- The mean annual soil loss rate for the river basins varied from 1.09(**very low**) to 99.11t/ha/year (**sever**) with average 20.17 t/ha/year. It is beyond the maximum tolerable limit of soil loss at national scale, 18 ton /ha/y (Hurni 1985).

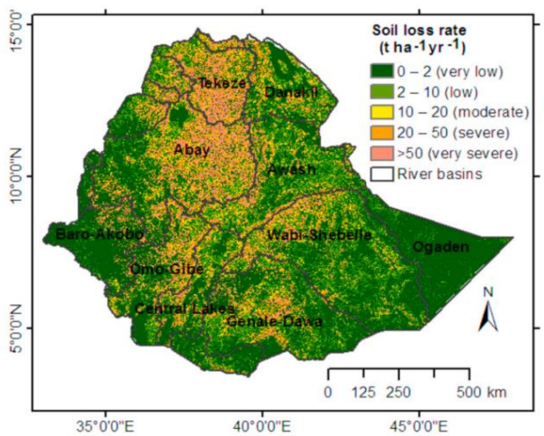


Fig. 4 Spatial distribution of rates of soil loss by water erosion and corresponding soil loss severity classes estimated for Ethiopia (Source: Fenta et al., 2021).

Table.6

Mean rates of soil loss by water erosion, annual gross soil loss, corresponding fraction of total soil loss, and percent area with mean soil loss rates above 10 t $ha^{-1}yr^{-1}$ for major land cover types in Ethiopia.

Land cover	Area (10^6 ha)	% of total area	Mean soil loss rate (t $ha^{-1}yr^{-1}$)	Annual gross soil loss (10^6 t)	% of total soil loss	% area with soil loss rate >10 t $ha^{-1}yr^{-1}$
Cropland	26.0	23.0	36.5	948.6	50.6	52.7
Shrubland	33.1	29.2	10.0	332.8	17.7	17.5
Herbaceous veg.	17.4	15.4	19.9	345.7	18.4	33.8
Bare/sparse veg.	8.1	7.1	8.8	70.7	3.8	17.5
Woodland	21.2	18.8	7.4	157.9	8.6	11.0
Forest	6.4	5.6	2.1	13.5	0.9	2.5
Urban	0.2	0.1	–	–	–	–
Waterbodies	0.9	0.8	–	–	–	–
Total/overall mean	113.2	100.0	16.5	1870.0	100.0	25.8

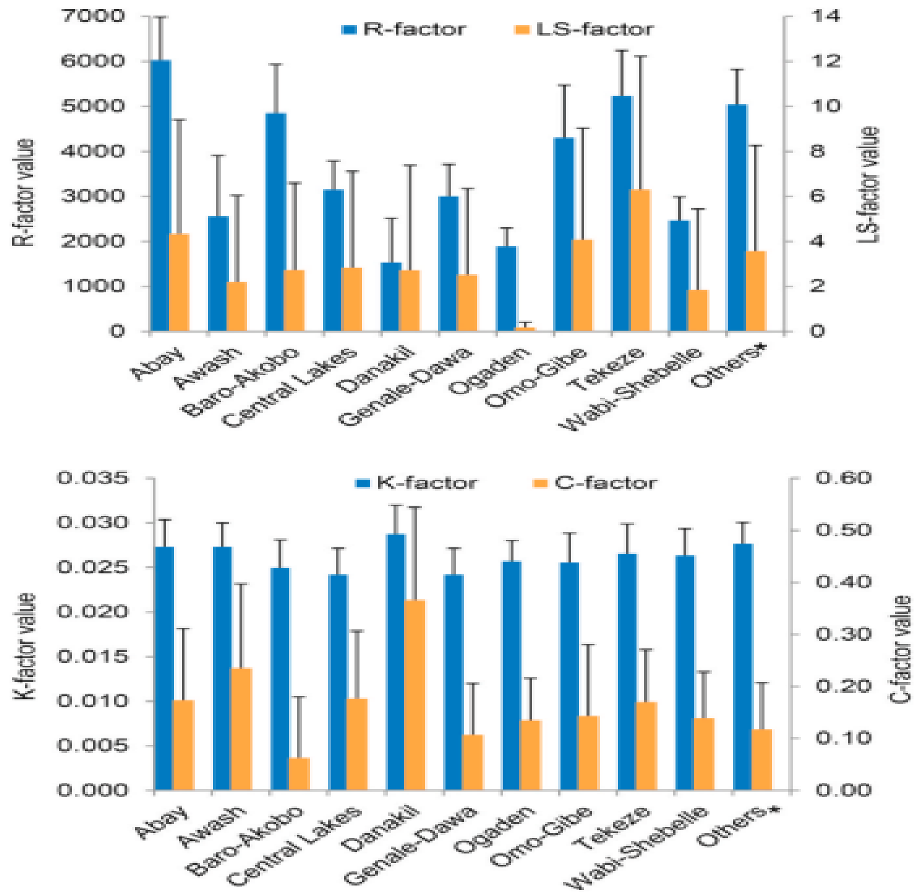


Fig.5 Mean values of RUSLE factors for major river basins of Ethiopia: rainfall erosive (R-factor; MJ mm ha− 1 h− 1 yr− 1), slope length and steepness (LS-factor; dimensionless), soil erodibility (K-factor; MJ mm ha− 1 h− 1 yr− 1), and land cover and management (C-factor; dimensionless).

Table.7.Summary for the low and high mean annual soil loss for major ERB

	Mean annual soil loss Rate(t/h/y)	**Slop**	**Vegetation cover**	
Tekeze	43.8 ton/ha/y	Very high	low	→spare vegetation cover →Steep slop
Baro-Akobo	9.5ton/ha/y	low	Very high	→gentler slop and more vegetation cover

➔ This shows that Topography (LS-factor) and Vegetation cover(C-factor) are the most determining factors for water inducing soil erosion and management plan to reduce soil erosion risks.

3.2. Case Study:

A study conducted on soil erosion risk in the Upper Blue Nile River basin of Ethiopia by Haregeweyn et al. (2017)

- ➔ **The main aim of this study is to provide better assessment and land use planning strategies (management) of erosion risk in river basins.**
- ➔ through integrated application of field observations, spatial analysis, and modeling
- ➔ Used RUSLE to estimate soil erosion rate, its impact and identify the main factors that contribute soil erosion.
- ➔ Consider the Five RUSLE factors (k-factor, R-factor, C-factor, LS-factor and P-factor)

- **The study results showed that this river basin had a high soil erosion risk. With:**
  - ➔ average soil loss rate of 27.5 t ha−1 yr−1(range 0-200) and a gross soil loss of ca. 473 Mt yr−1→It is beyond the maximum tolerable limit of soil loss at national scale, 18ton/ha/y (Hurni 1985),and high at least by African standards (Vanmaercke et al. 2014).
  - ➔ About 39% of the basin area is experiencing severe to very severe (>30 t ha−1 yr−1) soil erosion risk, linked to population density(high human activities).
  - ➔ The study found that the most influential factors are LS-factor and C-factor, K-factor and R-factor in the second place
  - ➔ **The dominant soil type in the area were Leptosols (21%), Alisols(21%), Nitosols (17%), Vertisols(11%) and Acrisols(11%)**
- Such losses threaten the sustainability of downstream reservoirs, including the GERD, irrigation and hydroelectric generation and affect the downstream countries(Sudan and Egypt)→ by inducing excessive sedimentation and Eutrophication,

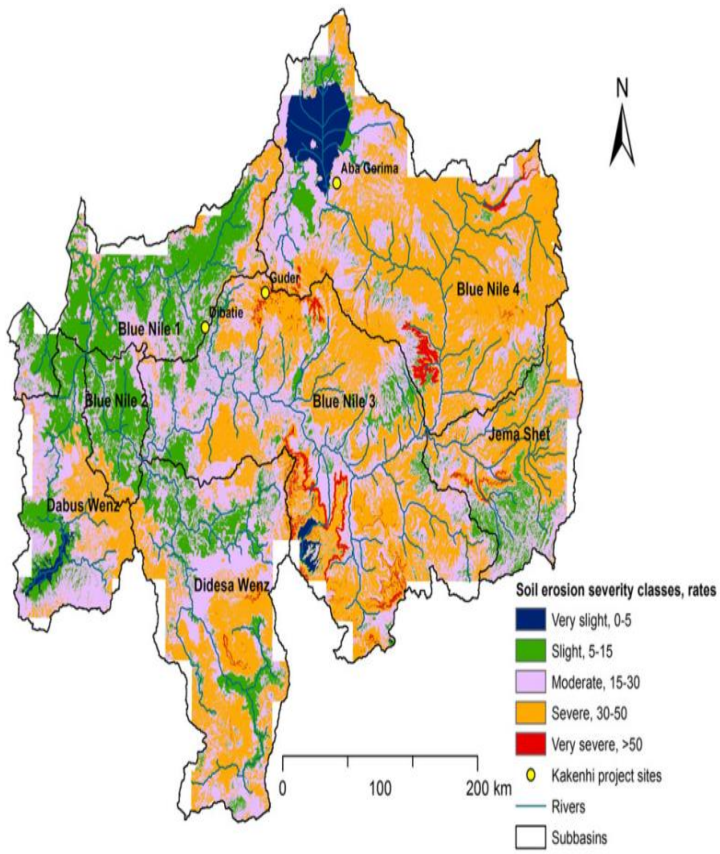


Fig. 7. Soil erosion severity levels and corresponding rates (t ha^{-1} yr^{-1}) for the UBNR basin. Seven subbasins are identified and may be prioritized for intervention based on their erosion risk from "very slight" to "very severe." Kakenhi project sites: Aba Gerima, Guder and Dibatie has been rated as moderate, high and low erosion risk areas based on expert opinion and this corresponds well with our modeling result.

Fig.6

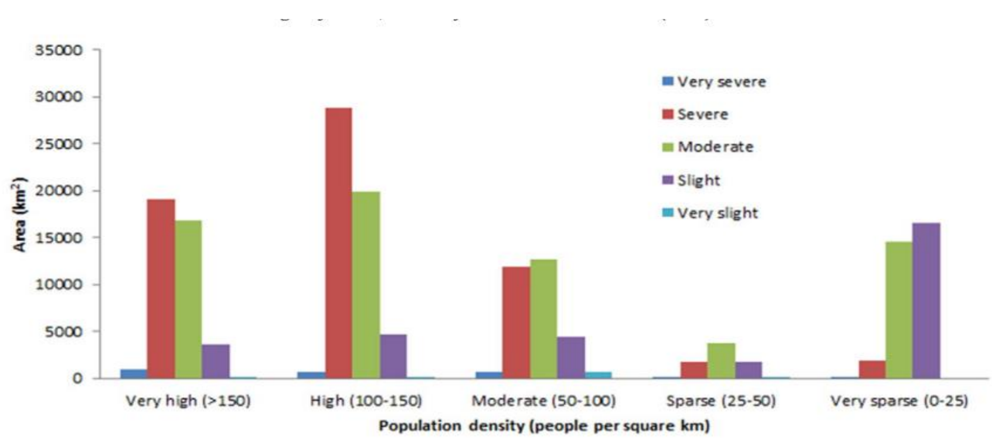


Fig. 8. Histogram showing the association between population density and land area in the UBNR basin, classified by soil erosion severity level.

Fig.7

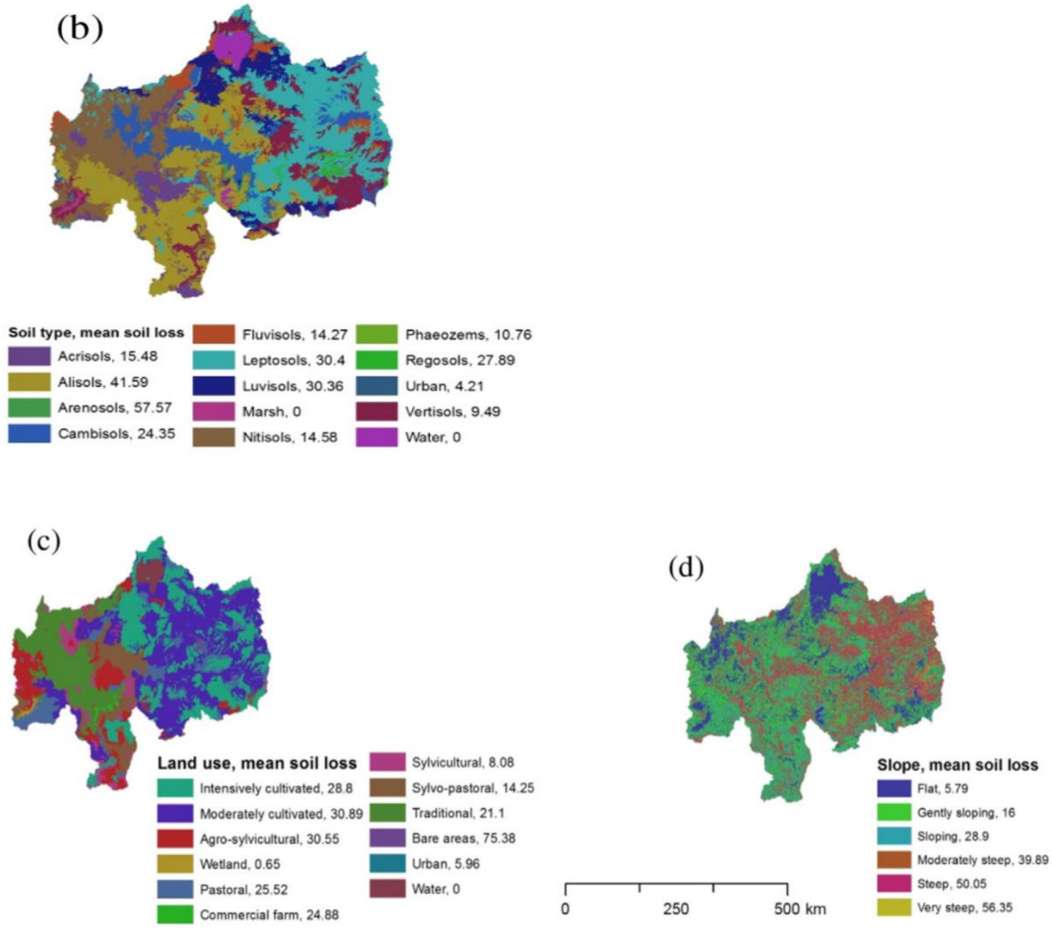
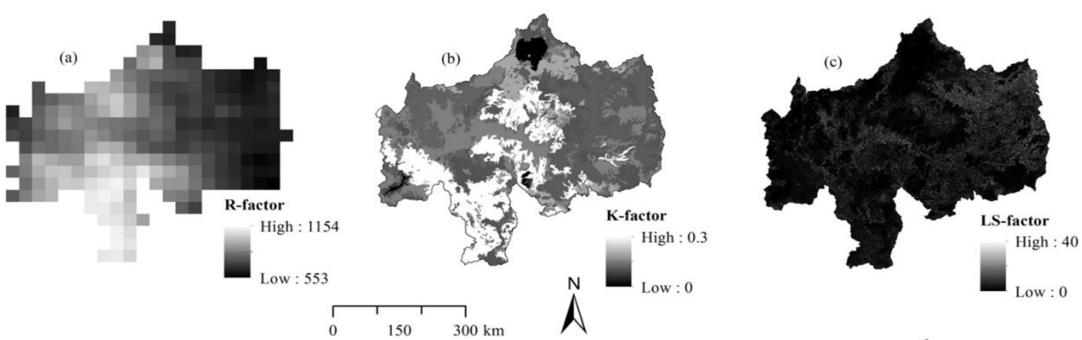


Fig.8 Soil type(b),Land use(c), Slope(D),and their corresponding mean soil loss of UBNR



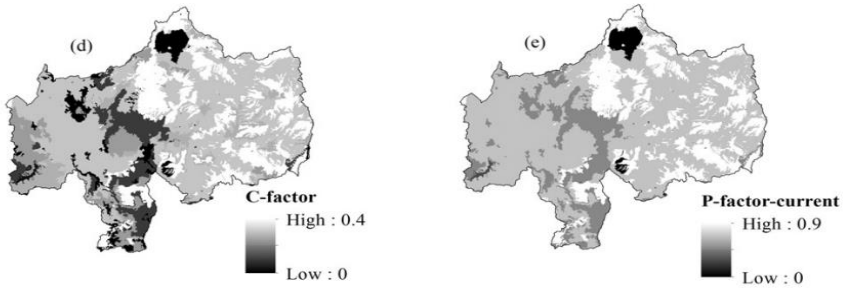


Fig.9 RUSLE's R-factor, K-factor, LS-factor, C-factor and P-factor values for UBNR

- Therefore, based on the study result the researchers recommended the appropriate soil conservation measures to reduce risks, mitigate soil erosion and protect soil health. For example: Tracing, vegetation management and soil improvement practice

4. Strategies and soil conservation practice to Mitigate Soil Erosion risks

- Conservation tillage – reduced tillage or no-till farming
- Crop rotation – alternating crops to maintain soil health and fertility
- Cover crops – planting crops to cover the soil surface during the off-season
- Terracing – constructing terraces on steep slopes to reduce runoff and soil erosion
- Riparian buffers – planting vegetation along streams to reduce stream bank erosion
- Grassed waterways – constructing channels to slow down and filter runoff

5. Conclusion and Summery

- Soil erosion is a significant environmental, economic, and social problem caused by human activities and climate change.
- The five key factors determine the soil erosion loss
- Assessing soil erosion risk and implementing appropriate measures can help mitigate the negative impacts of soil erosion
- By applying appropriate tools and Models(RUSLE,GIS,RS

5. Reference

Bai, Z. G., Dent, D. L., Olsson, L., & Schaepman, M. E. (2008). Proxy global assessment of land degradation. Soil Use and Management, 24, 223–234.

Benavidez R, Jackson B, Maxwell D and Norton K (2018). A review of the (Revised) Universal Soil Loss Equation ((R)USLE): with a view to increasing its global applicability and improving soil loss estimates Hydrol. Sci. J. 22 6059–86

Blanco-Canqui, H.; Lal, R. Principles of Soil Conservation and Management, 1st ed.; Springer: Haarlem, The Netherlands, 2008; p. 617.

Bhange HN, Deshmukh VV. A RS and GIS approaches for the estimation of runof and soil erosion in SA-13 watershed. In: Hydrologic modeling. Singapore: Springer; 2018. p. 307–30.

Borrelli, P., Robinson, D., Panagos, P., Lugato, E., Yang, J., Alewell, C., & Ballabio, C. (2020). Land use and climate change impacts on global soil erosion by water (2015–2070). Proceedings of the National Academy of Sciences, 117, 1–8. https://doi.org/10.1073/pnas.2001403117

Chuenchum, P.; Xu, M.; Tang, W. (2020). Estimation of Soil Erosion and Sediment Yield in the Lancang–Mekong River Using the Modified Revised Universal Soil Loss Equation and GIS Techniques. Water, 12, 135.

FAO. Climate Change and Food Security: Risks and Responses; Food & Agriculture Organization: Rome, Italy, 2015

Fenta, A. A., Tsunekawa, A., Haregeweyn, N., Tsubo, M., Yasuda, H., Kawai, T., et al. (2021). Agroecology-based soil erosion assessment for better conservation planning in Ethiopian river basins. Environmental Research, 195, 110786. https://doi.org/10.1016/j.envres.2021.110786

Ghahramani, A., Ishikawa, Y., Mudd, S.M. 2012. Field experiments constraining the probability distribution of particle travel distances during natural rainstorms on different slope gradients. Earth Surface Processes and Landforms 37, 473-485

Haregeweyn, N.; Tsunekawa, A.; Poesen, J.; Tsubo, M.; Meshesha, D.T.; Fenta, A.A.; Nyssen, J.; Adgo, 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. [CrossRef]

Marondedze MAK, Schütt B (2020) Assessment of soil erosion using the RUSLE model for the Epworth district of the Harare Metropolitan province, Zimbabwe. Sustainability 12(20):8531. https://doi.org/10.3390/su12208531

Morgan, R.P.C. (2005). Soil Erosion and Conservation (3rd ed.). Blackwell Publishing, 1-304.

Plan Bleu. Threats to soils in Mediterranean countries, Plan Bleu Papers, Document Review; 2003. http://www.planbleu.org/publications/cahie rs2_sols_us.pdf

Wilkinson, B.H.; McElroy, B.J. The impact of humans on continental erosion and sedimentation. Geol. Soc. Am. Bull. 2007, 119, 140–156. [CrossRef]

Zuazo VHD, Pleguezuelo CRR. Soil-erosion and runof prevention by plant covers: a review. In: Sustainable agriculture. Dordrecht: Springer; 2009. p. 785–811