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 candidate)

Submitted to Prof. Dr. HANS PETER NACHTNEBEL

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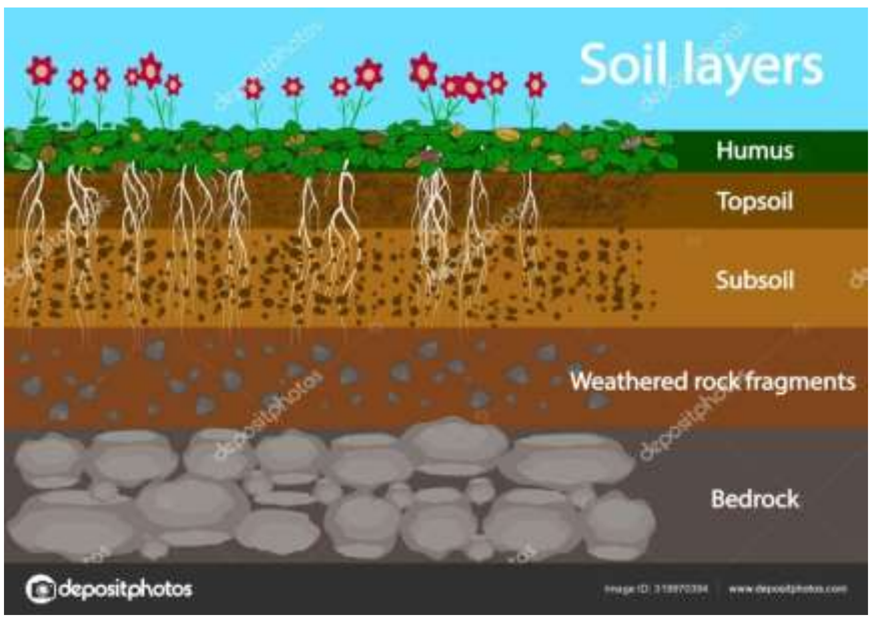
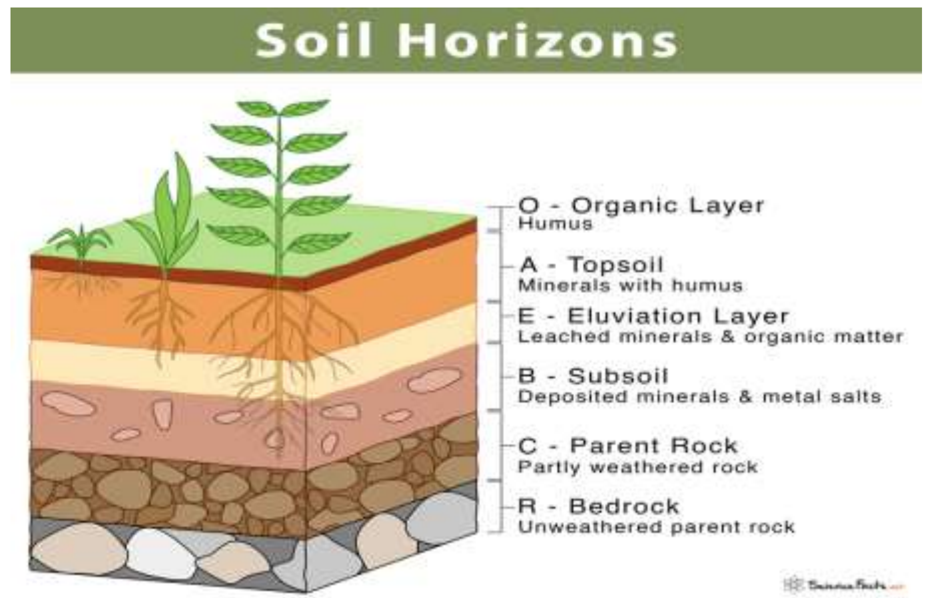
1.Introduction

- **Soil:** 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
- provid various ecosystem services: provisioning (food, water), regulating (nutrient cycling), cultural and supporting services to humans and environment (Schwilch et al., 2016)





➢ However, Soil erosion is a global problem

Intro…

1.1.Objectives

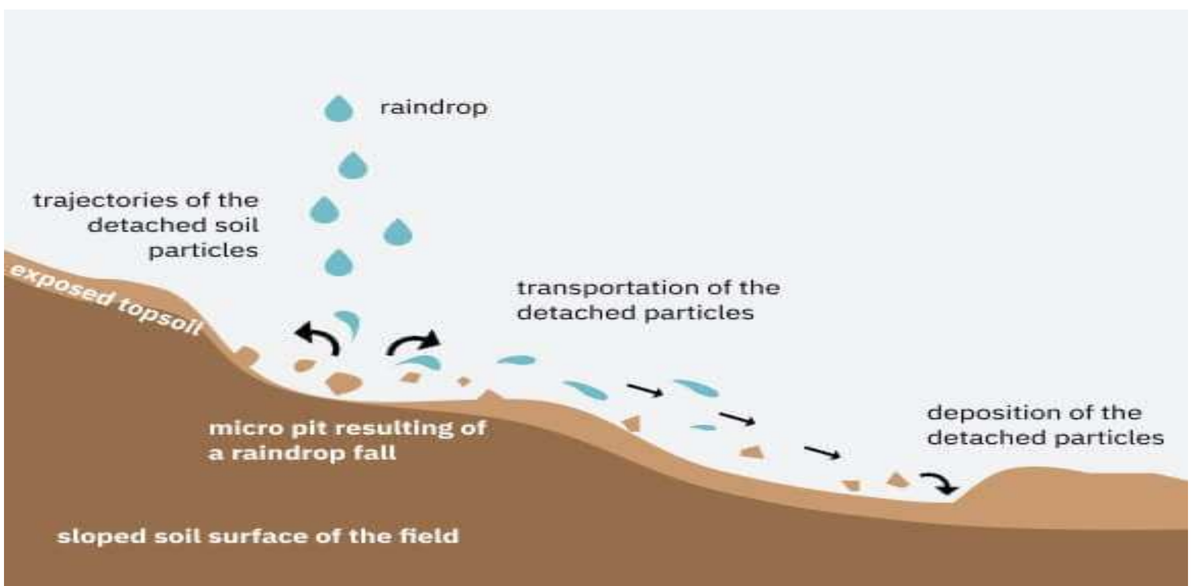
- To introduce the key factors that contribute to soil erosion and the method used to assess soil erosion risks
- To discuss the impacts and consequences of soil erosion(soil health, water quality, economic loss)
- To introduce various strategies and appropriate measures to mitigate the risk of soil erosion

1.2 Background

1.2.1.Defination and Description of soil erosion

1.2.1.1.Soil erosion is the process of detachment, transport and deposition of soil particles on land surface by the action of water, wind and gravity agents (FAO, 1986)

- the loss is measured as mass per unit area
- It is a natural phenomenon but is significantly accelerated by human activities, causing serious societal, economic, and environmental problems



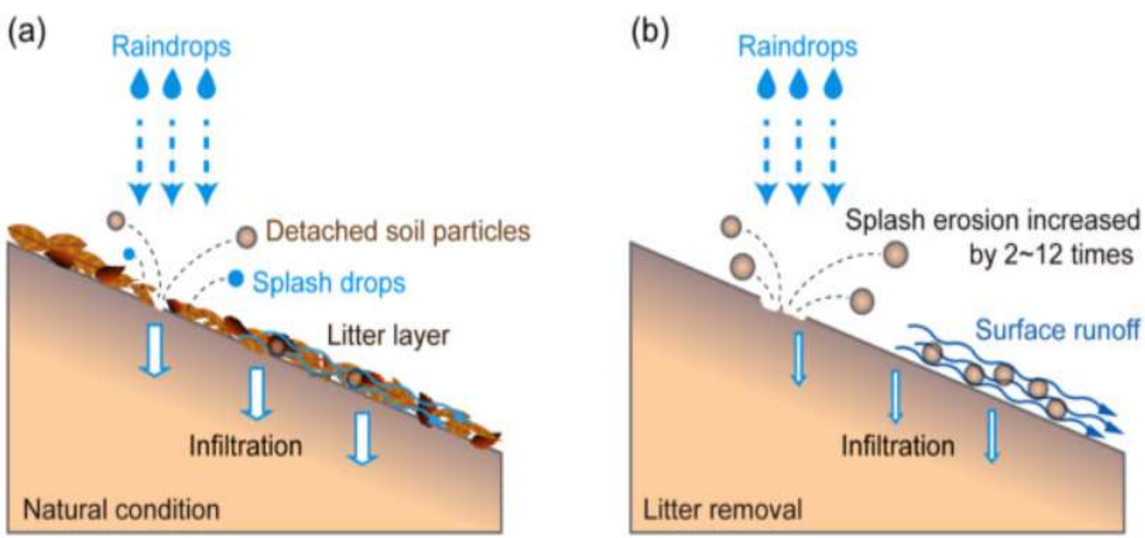
1.2.1.1.Soil erosion by water

- Is the most destructive erosion type worldwide
- occurs through the detachment and transport of soil particles along the soil surface by raindrops and runoff water

1.2.1.1.1. Types of water induced soil erosion

- Water induce soil erosion is classified based on the nature and extent or form of soil removal

A. Rain drop (Splash) erosion



→raindrops hits the exposed or bar soil
→first stage of soil erosion
→ready to washed away by sheet
→to prevent→ vegetation cover

B. Sheet erosion

- removal of soil particles in thin layers from sloping land by the impact of raindrop and shallow surface flowing water or runoff
- soil particles are carried evenly and uniformly flow
- Lose of finest soil with nutrients and organic mater
- Common in agricultural area

C. Rill Erosion

- Flow in the small channels that can become deeper and wider
- The water flow rapidly due concentrated water flow
- Particle detachment is due to the energy of flowing water, not by the rain drops like sheet erosion

D. Gully

- U-shape channels with steep walls by the flow of concentrated surface runoff water after heavy rain
- Form larger channels that cannot be easily restore
- **0.3m** width & **0.3m** depth (Blanco & Lal, 2008)
- Hillsides and areas with steep slope are more vulnerable

E. Stream bank erosion

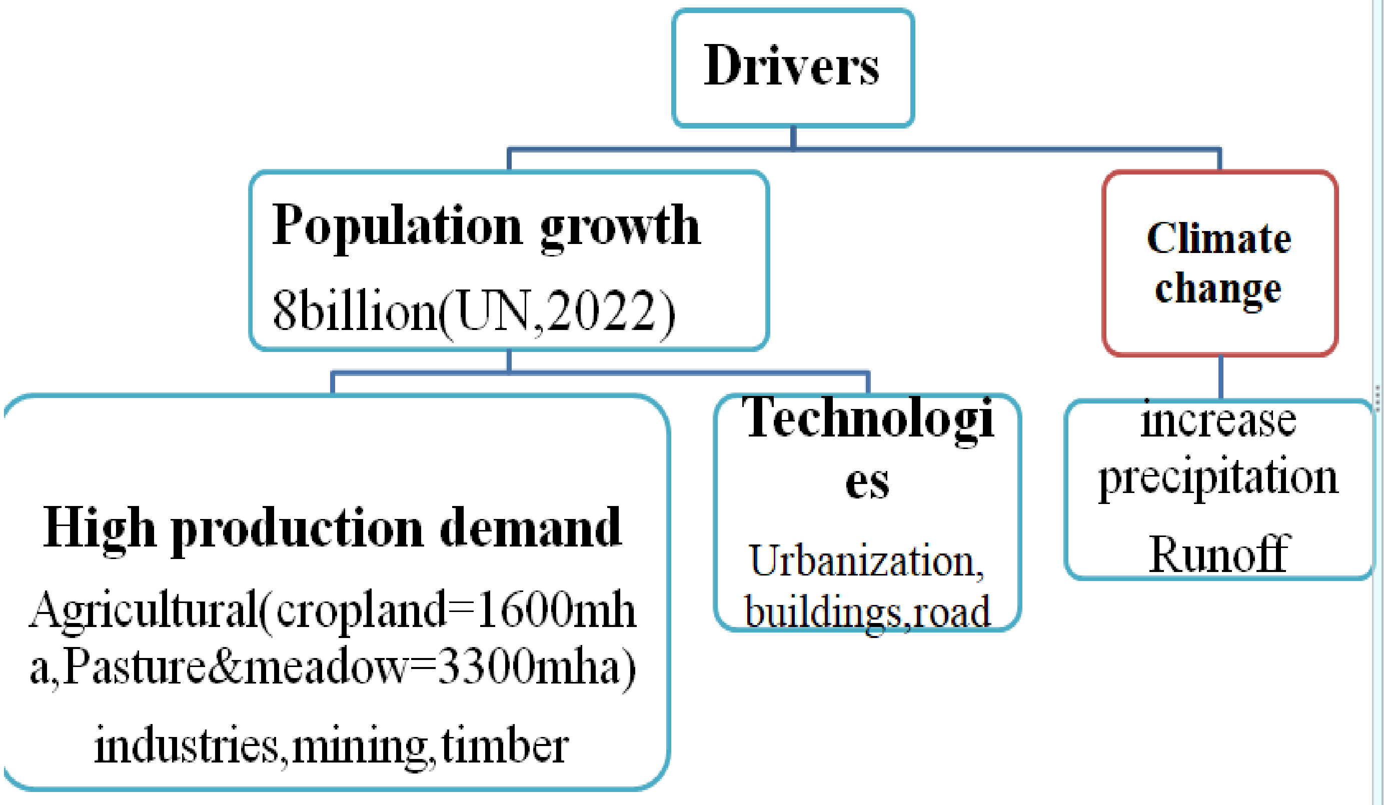
- the collapse and cutting of banks along streams, creeks and rivers
- due to the flow of powerful runoff from uplands fields

- 80 % of total sediment loading in world's streams is directly related to stream-bank erosion (Fox et al. 2007).

1.2.1.1.2.Dirivers of soil erosion

❖ **Human population growth and climate**

- World’s human population has been increasing

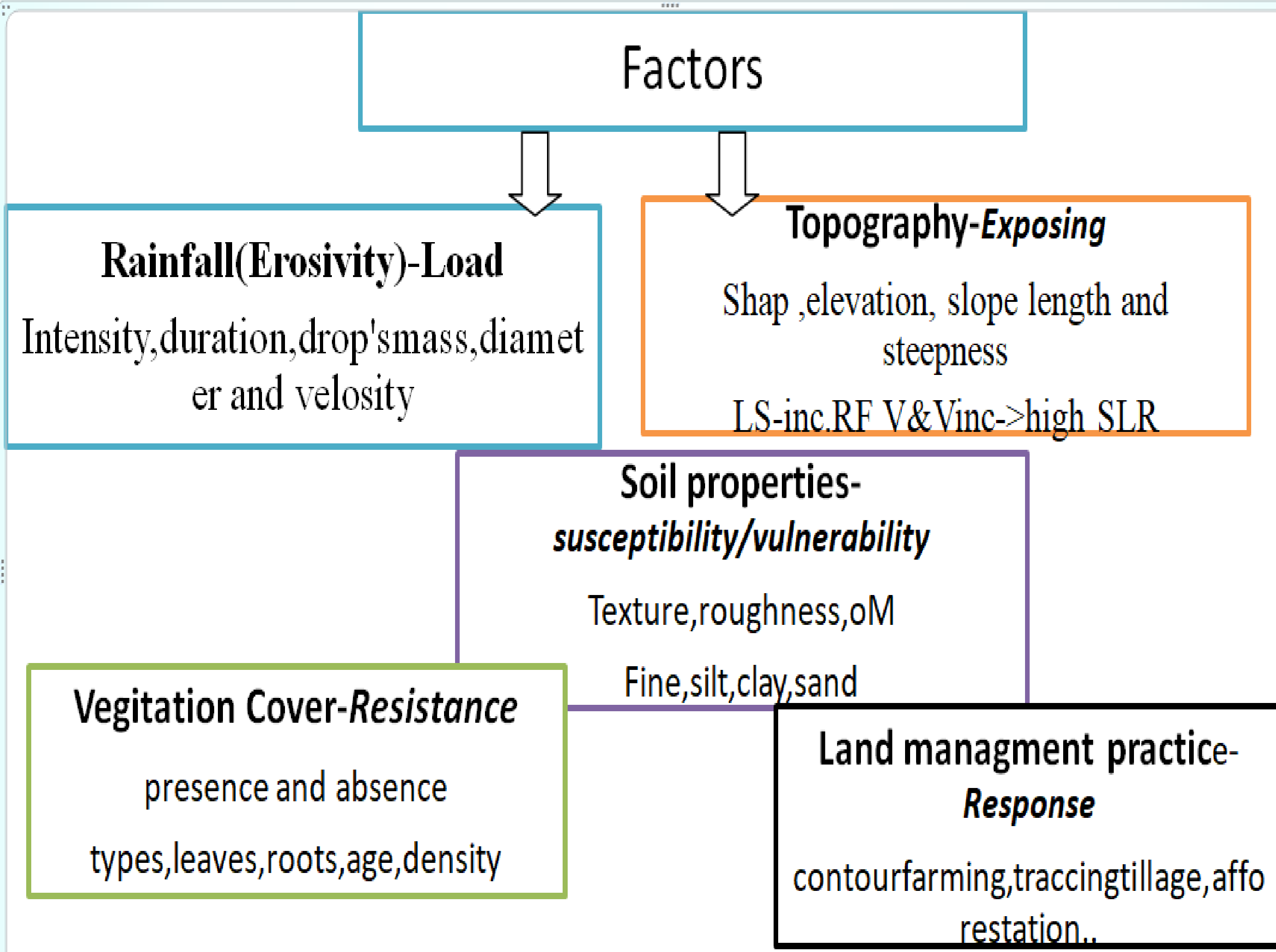


FAO,2015

- But extreme hydrographic phenomena →due anthropogenic activities → increase global warming (Borrelli et al.2020).

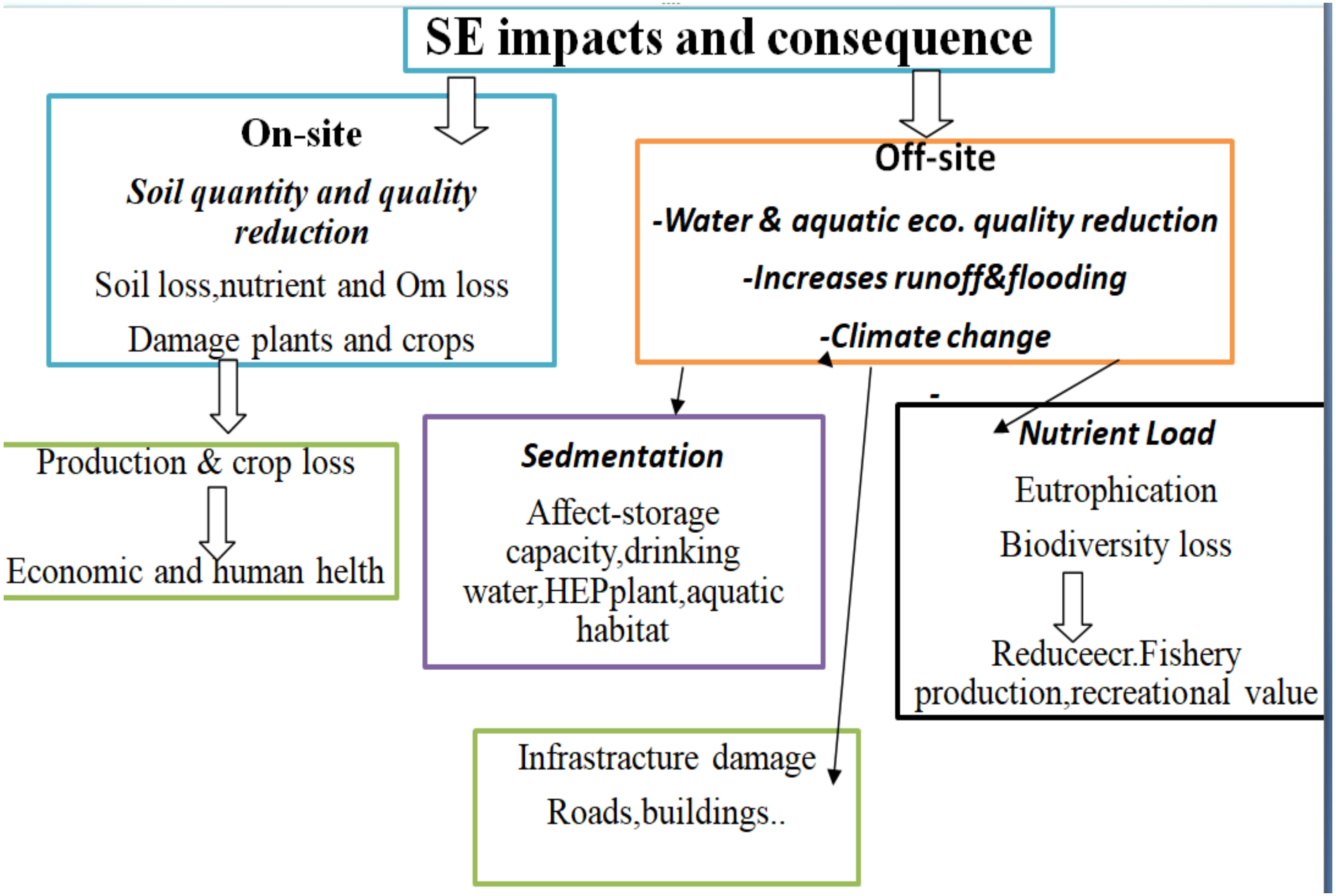
1.2.1.1.3.Factors influencing soil erosion

- Influenced by various both natural and socio-economic factors (human activities).



1.2.1.1.4.Impacts and consequence of Soil erosion

- SE has significant on-site and off-site negative impacts which lead socio-economic and ecological consequences(Humberto & Rattan 2008)



→Human health impact and Socio-Economic loss

For example

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

Imapacts	**Quantity**	**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

2. Methodology for assessing soil erosion risks

2.1.Methodology and application

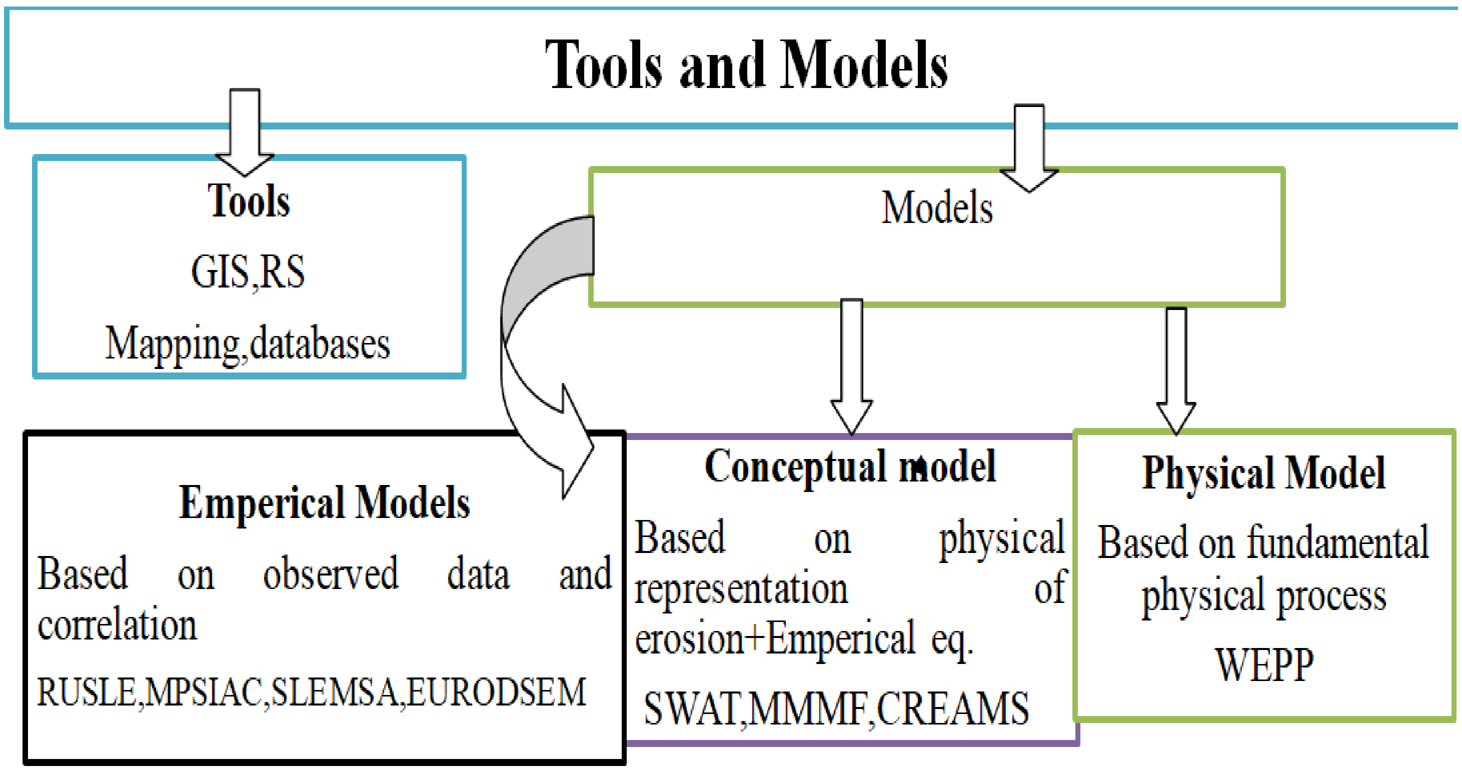


Fig. 3 Model &tools to assess soil erosion risks

Revised Universal Soil Loss Equation (RUSLE) is the most widely applied model → combined with GIS and RS for soil erosion risk assessments

2.1.1 Soil erosion loss analysis

- Revised Universal Soil Loss Equation(RUSLE)

- Mathematical model that predict soil erosion rate based on five factors
- estimate the long-term average annual soil loss per unit area (Renard et al. 1997)

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

Where by: A= computed spatial average soil loss temporal average soil loss per unit of area (ton/ha/year)

R= rainfall erosivity factor (J mm ha–1 h –1 year–1)

K= soil erodibility factor (T ha h ha–1 J–1 mm–1)

L= slope length factor

S= slope steepness factor

C= cover management factor

P= support practice factor

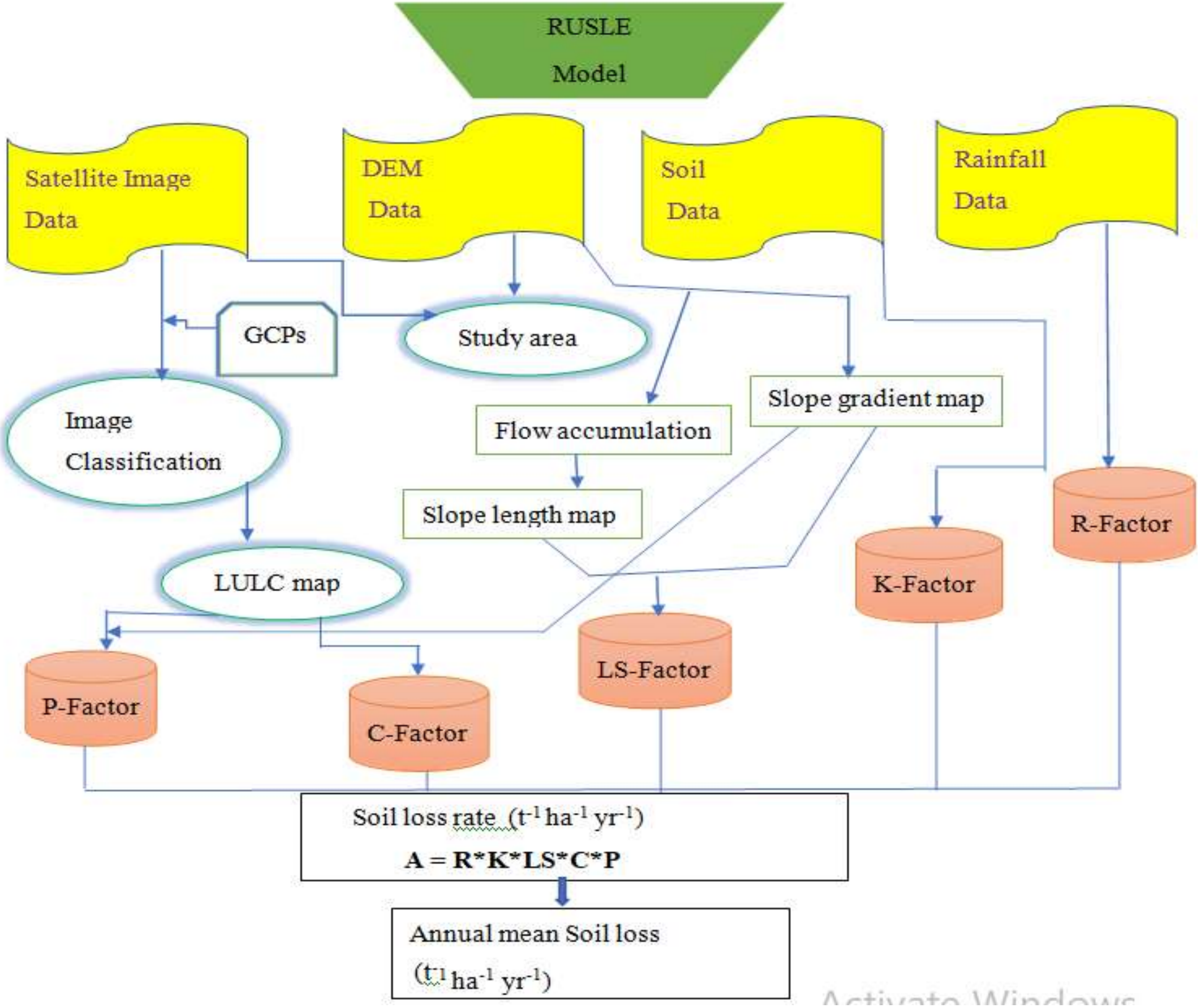


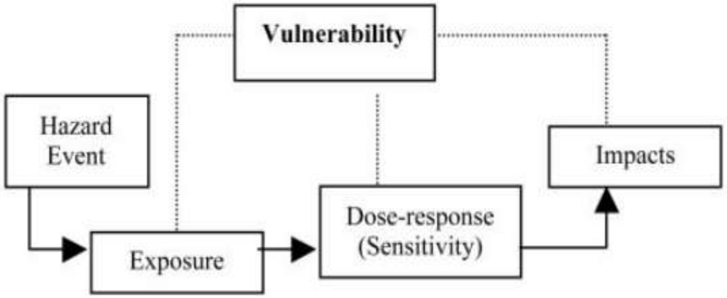
Fig.4 Flow chart for RUSLE model (Source: Kassa,2022)

Table.6.Summary of the five-factors and their formula and sources

Factors	Formula	Descriptions	Reference
R-factor	R =-8.12 + (0.562 *P)	P is the mean annual rainfall (mm year− 1).	
K-factor	K=0.036*exp(0.0053*S)*(1-exp(-0.35*MO))*(1-exp(-0.6*T) Or soil erodibility nomograph $K = [(2.1 \times 10^{-4} M^{1.14}(12 - OM) + 3.25(s-2) + 2.5(p-3)) / 100] * 0.1317$ $M = [(Sil + vFSa) \times (100 - Cla)]$ $K = 27{:}\ 66 * m^{1.14} * 10^{-8} * (12 - a) + (0.0043 * b - 2) + (0.0033 * (c - 3))$ Or	S-soil texture, range 0 to1 T-soil structure and permeability, range 1 to 8 MO-organic matter range 0 to 1 M-soil texture P-permeability	Wischmeier and Smith 1978 Modified by Wischmeier and Smith 1978
LS-factor	LS =(FlowAccumulation * Cellsize/22.13) $^{0.4}$ * (Sinslope/0.896) $^{1.3}$ $LS = (\lambda^{0.3}/22.1) \times (S/9)^{1.3}$	0 and 1, where 0 represents less susceptibility to erosion and 1 for higher susceptibility -λ is flow length, and S is slope in percent.	Wischmeier and Smith 1978 Pijlet al. (2020); Renard et al.(1997)
C-factor	$C = \exp\left[-\alpha \cdot \frac{NDVI}{(\beta - NDVI)}\right]$	Where: α(=2), β(=1) : Parameters that determine the shape of the NDVI-C curve, 0 to 1, where 0 indicates no susceptibility, and 1 indicates high exposure to soil erosions	
P-factor	P = Pc × Ps × Pt	- range 0 to1, with 0 representing areas with strong protective measures whereas 1 represents the areas with no support practice	Renard et al.(1997)

❖**Therefore**, Risk analysis: using frame works and statistical analysis

- ✓**Risk =Load*Exposure*Vulnerability*Impact**
- ✓**DPSIR framework →**to link load to impacts
- ✓**RH framework→** based of the hazards and the
- ✓vulnerability of the system



Turnerll et al.2003

Fig. 1. RH framework (common to risk application). Chain sequence begins with hazard; concept of vulnerability commonly implicit as noted by dotted lines.

Table.7 soil erosion risk classification with standards

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

(FAO,1997,2015)

3. Study Result and Discussion

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

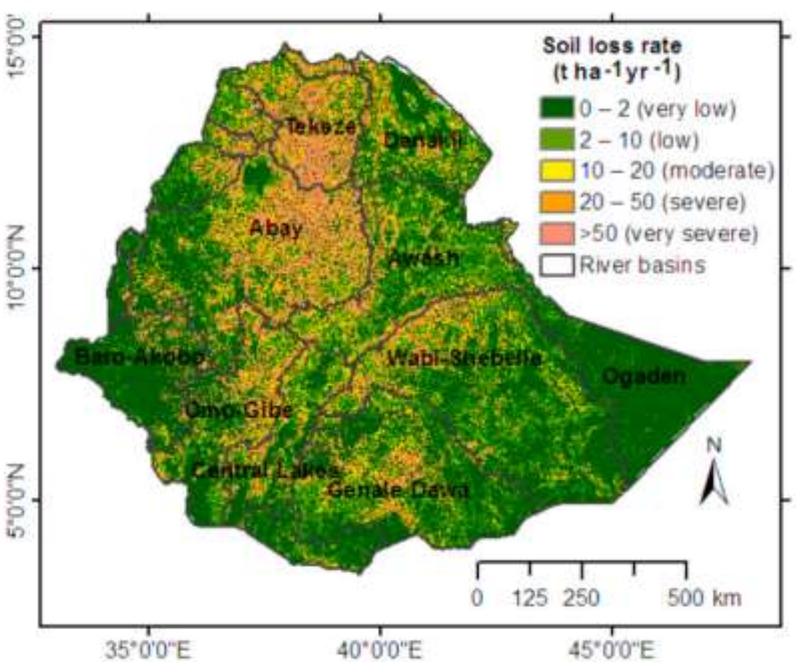


Fig. 5Spatial distribution of rates of soil loss by water erosion and corresponding soil loss severity classes estimated for Ethiopia (Source: Fenta et al., 2021).

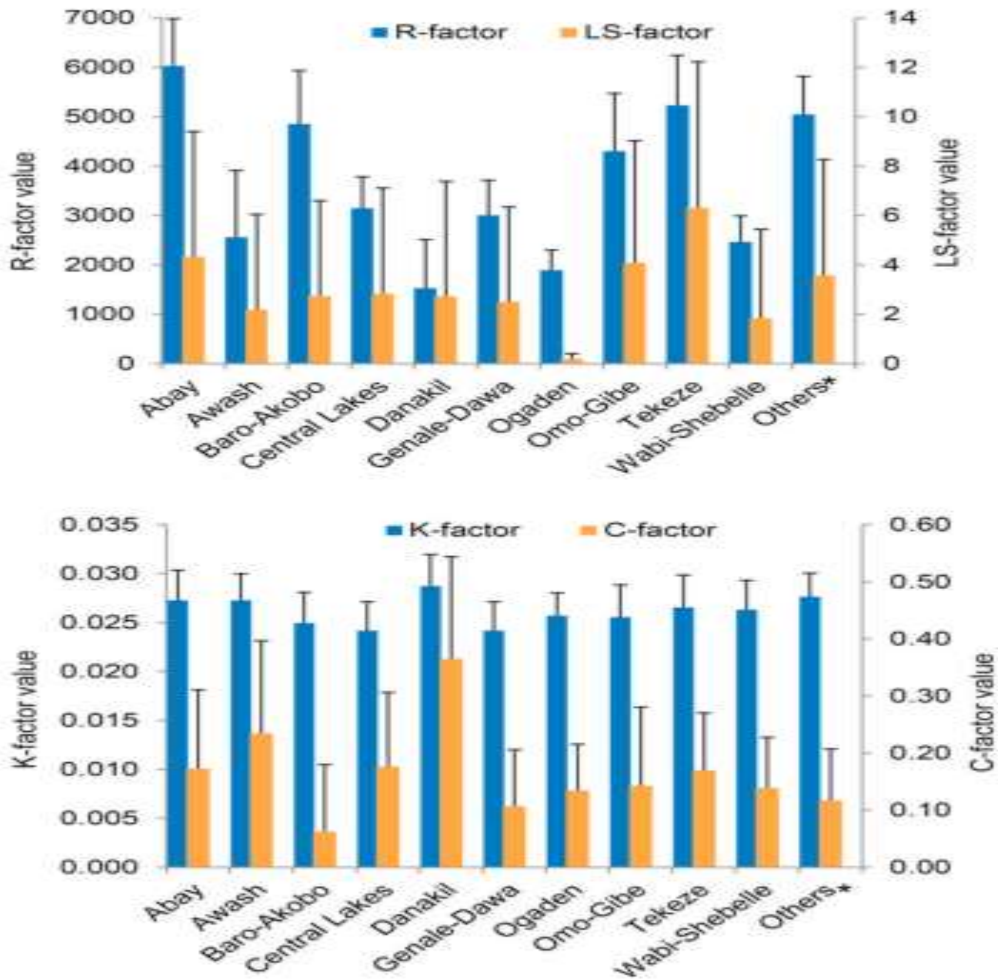


Fig.6 Mean values of RUSLE factors for major river basins of Ethiopia: rainfall erosive (R-factor; MJ mm ha− 1 h− 1 yr− 1), slope length and steepness (LS-factor; dimensionless), soil erodibility (K-factor; MJ mm ha− 1 h− 1 yr− 1), and land cover and management (C-factor; dimensionless).

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)

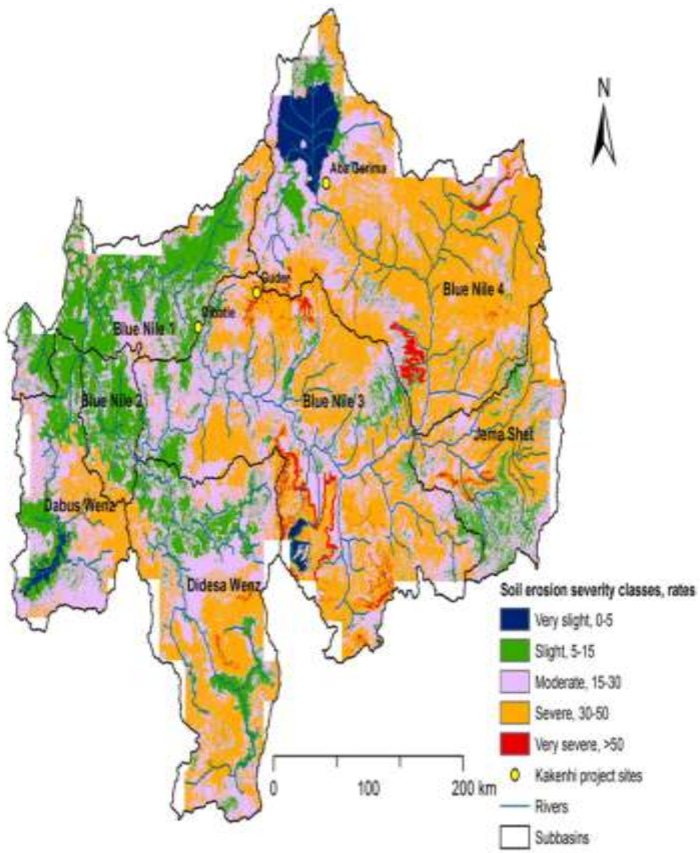


Fig. 7. Soil erosion severity levels and corresponding rates ($t\ ha^{-1}\ yr^{-1}$) for the UBNR basin. Seven subbasins are identified and may be prioritized for intervention based on their erosion risk from "very slight" to "very severe." Kakenhi project sites: Aba Gerima, Guder and Dibatie has been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

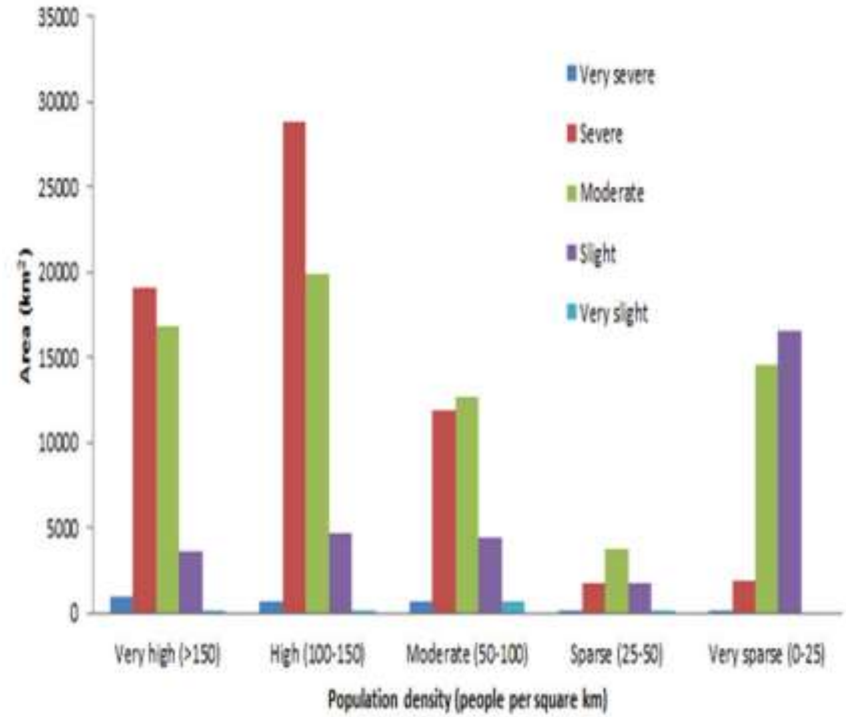
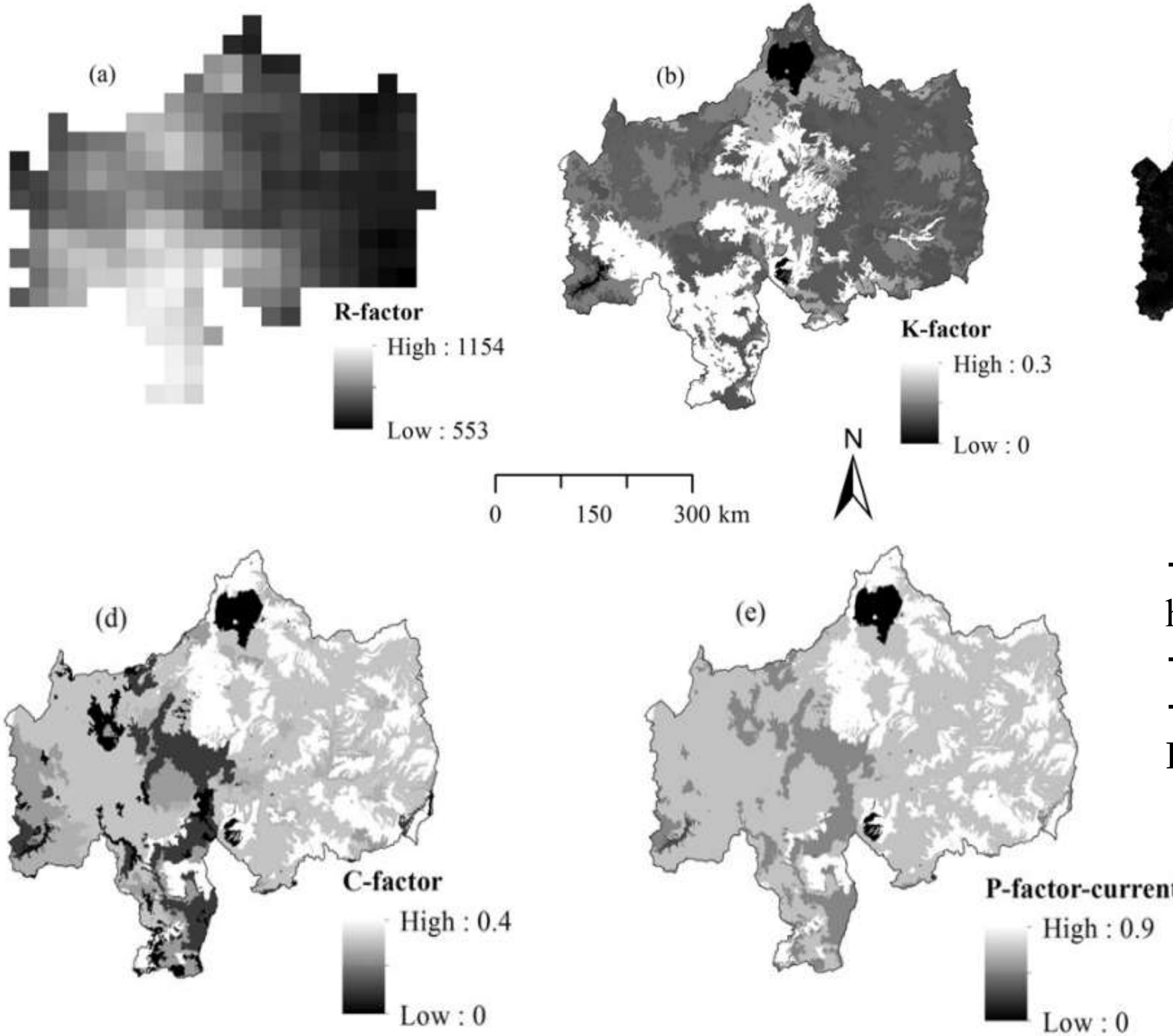


Fig. 8. Histogram showing the association between population density and land area in the UBNR basin, classified by soil erosion severity level.



→average soil loss rate of 27.5 t ha−1 yr−1
→About 39% of the basin area
→severe to v. severe risk .Due to PoP. density

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

4.Mitigate Soil Erosion risks





5. Conclusion

- Soil erosion is a significant environmental, economic, and social problem caused
- The main drivers are by human activities and climate change.
- The five key factors determine the soil erosion rate
- 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

6.References

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THANK YOU SO MUCH

FOR YOUR ATTENTION !!!