ESTIMATIONOFRUSLEPARAMETERSOFTHEOZATRI VERBASINUSINGREMOTESENSINGAND GIS

.

ABSTRACT

In India, soil erosion is a major problem that lowers water availability and agricultural land production. Detachment, transportation and deposition of soil particles from one place to another under the influence of wind, water or gravity forces is known as soil erosion. Therefore, Revised Universal Soil Loss Equation (RUSLE) with Remote Sensing and GIS study was found easy for estimation of soil loss in river basins. The selected watershed for this study was Ozat river basin is situated in Gujarat, having the catchment area 3410 km^2. The rainfall erosivity factor (R) was estimated using monthly and annual rainfall data.Sand, silt, clay and organic matter of soil were used to determine the soil erodibilityfactor(K).Thehighestandlowestestimatedrainfallerosivityfactorwerefound144.45MJ.mm.ha^{-1}.h^{-1}.$y^{-1}$to 147.37MJ.mm.ha^{-1}.h^{-1}.y^{-1}respectively.Thesoilerodibilitywasfoundintherangeof0.139tonnes-ha-hr/ha-MJ-mm to 0.172tonnes-ha-hr/ha-MJ-mm.Soil withhigher Kvaluesare more vulnerable tosoil erosion. However, lower Kvaluesare more resistant to soil erosion. Combining the utilization of the Remote Sensing and GIS provides faster and real-time information for studies related to natural resources management and the study of various parameters needed forsoil loss. Thus, different soil loss estimation model and tools may be applied extremely effectively and efficiently forthe planning of natural resources in watershed and the study of different factors in bigger or smaller basins.

Keywords:RainfallErosivity,SoilErodibility,RemoteSensingand GIS, OzatRiverBasin

1. INTRODUCTION

"Soil is the upper most weathered and disintegrated layer of the earth's crust which is composed ofminerals and the organic substances with the capability of sustaining plant life. The top layer of soil is continuously exposed to the actions of atmospheric activities. Wind and water are the two main active forces which are responsible for the dislodgingof the top soil layer and transportation of them from one place to another which can be referred as soil erosion. There are various negative impacts of soil loss on agriculture. Soil degradation limits the soils' ability to retain water and nutrients. This leads to the deposition of silt in lower areas of the watershed, which ultimately reduces the production capacity of upland areas and also reduces the nutrients level of topsoil of soil erodible area. Soil erosion is a global concern as itinvolves depleting nutrient-rich surface soil, greater flow through permeable subsurface and reduced water availability forthe plants.Overall it affects the sustainable development goal and ecosystem services"(Negese*et. al.*, 2021). "Soil erosionis also the most severe problem in the country, with changing economic implications and food security" (Sidi *et. al*., 2021)."Soil erosion is an obstacle in the path of sustainable development and needs attention for better management throughproper planning" (Kumar *et. al.*, 2021).

"Soil erosion is a major threat to biodiversity, as it affects crucial aspects of human, animal, and plant lives"(Koninger et. al., 2022)."Though soil erosion is a naturally occurring process, this has been accelerated by human activities such as intensive agriculture, improper land management, deforestation, and cultivation on steep slopes. Removal of vegetation cover and shaping of surface topography induce or accelerate soil displacement and movement. Serious soil erosion is occurring in most of the world's major agricultural regions due to the expansion of agriculture without adequate soil conservation practices". (Pimentel et al.,1987) "Moreover, crop residues are removed for fodder, biofuel, and industrial uses leaving the soil surfaces bared from a protective cover enhancing the vulnerability to lands for erosion. The resultingrunoff ultimately transports sediments, organic material, nutrients, and pesticide residues off-site impacting both water and soil quality. When lands are left as fallow to recover, the erosion problem is worsened due to minimal vegetative cover" (Bashir *et al*., 2018). "Soil erosion is reported to increase with higher magnitude of rainfall and frequent occurrences of heavy precipitation" (Panagos*et al.,* 2012).

"Soil erosion has a negative influence on the sustainability and productivity of agricultural areas, as well asbiodiversity" (Lin *et. al.*, 2022). "A decrease in soil fertility is also a consequence of soil erosion, which has caused waterquality problems and a threat to sustainable agriculture" (Stefanidis*et. al.*, 2022)."Gujarat is located in Western part of India covering total geographical area of 19.6 Mha, which is about 6% of the total geographical area of the country. Analysis of soil erosion data revealed that soil erosion rates vary enormouslyacross the state, ranging from less than 5 $tha^{-1}yr^{-1}$in 0.01% area to very severe (>40 $tha^{-1}yr^{-1}$) in 10.64% area. Percentage of area under slight (<10 $tha^{-1}yr^{-1}$), moderate (10-20 $tha^{-1}yr^{-1}$) and severe (20-40 $tha^{-1}yr^{-1}$) soil erosion classes are 16.07,61.23 and 10.99, respectively. Analysis of the data also revealed that nearly 82.96% area across the state has erosion rates of more than 10 $tha^{-1}yr^{-1}$, which indicates that soil erosion is a serious problem in major parts of the state. The severity of soil erosion is due to aggressive climatic conditions coupled with steep topography and erodible soils" (Kumar*et al.*, 2021).

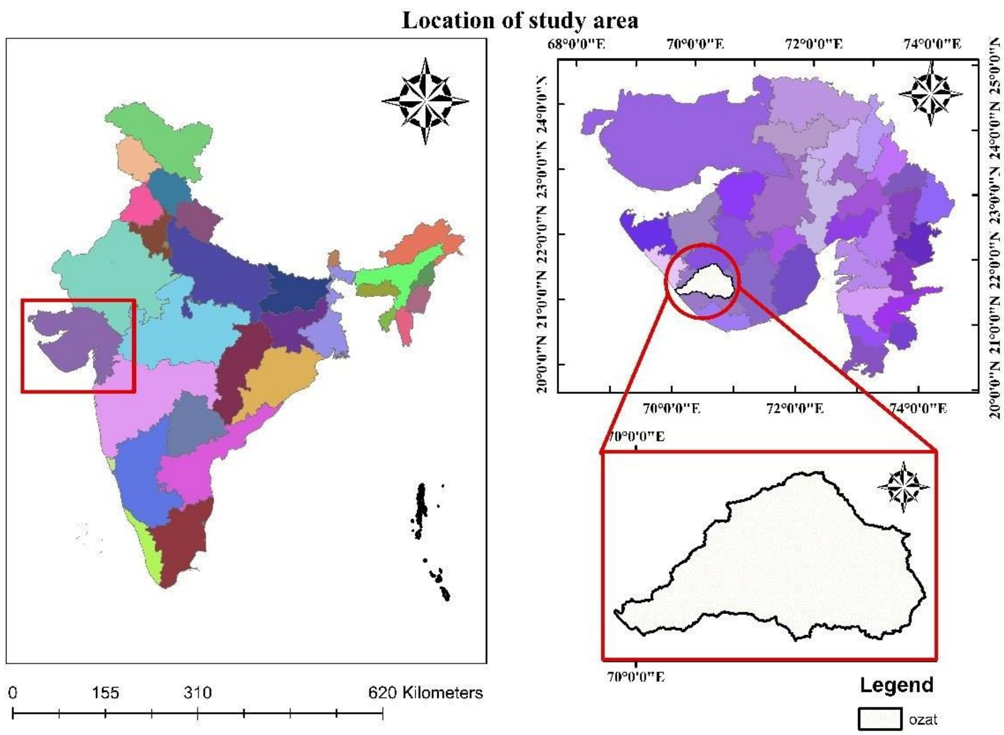
In recent years, advancements in Remote Sensing and Geographic Information System (GIS) technologies have provided valuable tools for assessing and monitoring soil erosion on a larger scale. Remote sensing involves the acquisition of data about the Earth's surface from air borne or satellite sensors, while GIS integrates and analyses spatial information to derive meaningful insights.

Keepingthisinviewpresentstudyhasbeenplannedwithfollowingobjectivei.e., To estimate the rainfall erosivity and soil erodibility factor of Ozat river basin.

2. MATERIALANDMETHODS

2.1 Location

Ozat river originates from Visavadar and meets in Arabian sea. It is situated between latitude of 21° N to 22° N and longitude of 70° E to 71° E. The perimeter of a basin is 390.11 Km having catchment area 3410 sq.km. DhrafadandOzatdams are located on this river having 169 sq.km. and 1138 sq.km. catchment area respectively. AbajalandPopatdi are right bank tributaries, and UbenandUtavali are left bank tributaries of this river. Agriculture is the main occupation in the area. Groundwater is the main source of irrigation on study area.



Map..1StudyareamapofOzatriverbasin

2.2 Datacollected

a. Rainfalldata(monthlyandannual)

PERSIANN-CDR (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks-Climate Data Record) developed by the Canter for Hydrometeorology and Remote Sensing (CHRS) at the University ofCalifornia, Irvine (UCI) provides daily rainfall estimates at 0.25°for the latitude band 60N-60S. PERSIANN-CDR is aimed ataddressing the need for a consistent, long-term, high-resolution and global precipitation dataset for studying the changes andtrends in daily precipitation, especially extreme precipitation events, due to climate change and natural variability. For thepresent study the monthly and annual rainfall data for the duration 2003 to 2022 were downloaded.

b. Soildata

The FAO Digital Soil Map of the World shows 4931 mapping units consisting of soil associations, which are mixturesofdifferentsoiltypeswhichdefinesatotalof106soilunitsonthebasisofpresenceofdiagnosticpropertiesand4non-soil units. For the soil units estimates are provided of physical (% sand, % silt, % clay, bulk density) and chemical properties (pH,organic carbon, CEC, base saturation, C/N ratio, CaCO3-content) in the topsoil and subsoil. DSMW has been superseded bytheHarmonized World Soils Database(HWSD), which contains moredetailed information on soildistributions for anumber ofcountries, obtained since the publication of all volumes of the Soil Map of the World. For the present study the soil data wasdownloaded which are available in the ESRI shapefile format.

2.3 Software

ArcGIS is a geographic information system (GIS) used to create, manage, analyze, and map all types of data. ArcGIS connects maps, apps, data, and people in ways that help empower organizations to make data-driven decisions more efficiently. ArcGIS accomplishes this by making it easy for everyone in an organization to discover, use, make, and share maps from any device, anywhere, at any time.

2.4 Rainfallerosivityfactor(R)

Soil erosion is closely related to rainfall through the combined effect of detachment by raindrops striking the soil surface and by the runoff. According to USLE method, soil loss from the cultivated field is directly proportional to a rain storm parameter, if other factors remain constant.

Because installing rain gauge stations is expensive, they are rarely found all throughout India. Nonetheless, it is crucial to investigate the fluctuation in rainfall since it is the primary driver of soil erosion and it varies both in time and space. In order to overcome the fact that rainfall varies with time and space, the R factor was estimated in this study using the following formula. The Equation, below developed by Wischmeier and Smith (1978) and modified by Arnoldus (1980) will be used in the computation:

$$R=\sum_{i=1}^{12} 1.735\times 10\times\{1.5\times\log\{\frac{Pi^2}{P}\}-0.08188\}$$

Where,
Ristherainfallerosivityfactor(MJ.mm.ha $^{-1}$.h^{-1}.y^{-1}),$P_i$is the monthly rainfall (mm), and
Pistheannualrainfall(mm)

2.5 Soilerodibilityfactor(K)

International pipette method:" Pipette method is a standard method for particle size analysis of soils because of itsaccuracy, but it is time consuming and cannot be employed where large numbers of samples have to be analyzed. Particlesizeanalysis is done by usingsieves toseparateoutcoarsesandfromthefiner particles.Thesiltandclay contents arethendetermined by measuring the rate of settling of these two separates from the suspension in water. The time required by theparticles of a given size to settle can be calculated using Stokes law.Some of the soil properties that affect soil erodibilityinclude soil texture, drainage condition, soil depth, structural integrity and organic content" (Prasannakumar*et. al*., 2012).Among the different methods for computing the K-factor, the soil nomograph method, which uses the relative ratios of soiltexture, permeability, soil structure and organic matter content (Wischmeier*et. al*., 1978) is the most commonly usedmethod.

The susceptibility of soil particles to be separated from soil aggregates by any erosive agent is measured by soil erodibility (K), which is determined by the physicochemical properties of the soil. Given that soil qualities are inherent, the soil erodibility factor quantifies the susceptibility to soil erosion. The K factor value is a number between 0 and 1, where a value closer to 0 denotes the least sensitivity to soil erosion and a value closer to 1 denotes the highest susceptibility.

AnequationforestimatingK$_{RUSLE}$valuesgivenbyWiliams(1995):

$$K_{RUSLE}=K_w=F_{csand}\times f_{cl\text{-}si}\times f_{orge}\times f_{hisand}$$

Where,
f_{csand}isafactor,thatlowerstheKindicatorinsoilswithhighcoarse-sandcontentandhigherforsoilswithlittlesand; $f_{cl\text{-}si}$gives low soil erodibility factors for soils with high clay-to-silt ratios;
f_{orgc}reducesKvaluesinsoilswithhighorganiccarboncontentwhile,
f_{hisand}lowers K values for soils with extremely high sand content:

$$f_{csand}=\{0.2+0.3\times\exp[-0.256\times m_s\times(1-\frac{m_{slit}}{100})]\}$$

$$f_{cl\text{-}si}=(\frac{m_{slit}}{m_{c+}m_{slit}})^{0.3}$$

$$f_{orgc}=(1-\frac{0.25\times orgC}{orgC+[3.27-2.95\times orgC]})$$

$$f_{hisand}=\left(1-\frac{0.7\times\left(1-\frac{m_s}{100}\right)}{\left(1-\frac{m_s}{100}\right)+\exp\left[-5.51+22.9\times\left(1-\frac{m_s}{100}\right)\right]}\right)$$

Where,

m_s–thesandfractioncontent(0.05-2.00mmdiameter)[%]; m_{silt}–the silt fraction content (0.002-0.05mmdiameter)[%];

m_c–theclayfractioncontent(<0.002mmdiameter)[%]; org C – the organic carbon content [%]

3 RESULTSANDDISCUSSION

3.5 Rainfallerosivityfactor(R)

The rainfall erosivity factor (R) values for the study area were calculated by using the equation given by the Wischmeier and Smith (1978) and modified by the Arnoldus (1980). For the preparation of R factor map monthly and annual rainfall data were used for the year 2003 to 2022. These data were downloaded from the CHRS data portal(Center for Hydrometeorology and Remote Sensing at the University of California) in which Persian CDR (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Network- Climate Data Record) was used having the resolutionof0.25º×0.25º.Itwasgivenintiffformat.R-factormapwascalculatedbyusingtherastercalculatorinthe

ArcGIS 10.4 software. After finding the R factor for 20 years, the raster file was converted into the point format by using the 'rater to point' tool in conversion toolbox in ArcGIS. Interpolation was done for the study area. For the Interpolation IDW (Inverse Distance Weighted) was used. It interpolates a raster surface from points using an inverse distance weighted technique. The output value for a cell using the IDW is limited to the range of the values used to interpolate. Because IDW is a weighted distance average, the average cannot be greater than the highest or less than the lowest input.

ForthepresentstudyareaRfactorvaluesrangesfrom144.46MJ.mm.ha^{-1}.h^{-1}.y^{-1}to147.37MJ.mm.ha^{-1}.h^{-1}.y^{-1}.The R factor was calculated for the 20 years and average R factor map for the study area is shown in fig. 1. And the values of R factor for the period 2003 to 2022 are given in table.1. The low R values are distributed in some portions ofthe watershed, whereas the high R values are located in the area near the outlet of the watershed. Moderate R valueswere found in the middle portion of the watershed. The results of this work are compared with the studies conductedaround the world like Waseem *et. al.,* 2023 used the same equation and shown similar result for R factor. Also,Machiwal*et. al*., 2015 and Prasannakumar*et. al.,* 2012 have used same equation given by Wischmeier and smith andshown similar result for R factor.

Table:.1Rainfallerosivityvalueforyear2003to2022

Year	**RfactorValue(MJ.mm.ha^{-1}.h^{-1}.y^{-1})**
2003	136.49-156.13
2004	144.41-149.14
2005	158.03-168.30
2006	158.84-164.00
2007	179.90-182.28
2008	144.85-152.87
2009	104.65-122.18
2010	153.47-162.34
2011	161.58-167.62
2012	114.71-120.44
2013	154.90-165.42
2014	70.01-122.75
2015	113.25-130.28
2016	138.00-141.64
2017	157.75-160.49
2018	89.13-110.38
2019	170.19-174.75
2020	168.02-173.60
2021	133.81-146.51
2022	155.37-163.20

3.6 Soilerodibilityfactor(K)

Sand,silt,clayandorganicmattercontentdatawereusedtoevaluatetheOzatriverbasin'ssoilerodibilityfactor (K) map. For DSMW FAO data was used. DSMW FAO (Digital Soils Maps of the World) (Food and Agriculture Organization of the United Nations) provides the digital soil map of the world which is given in ESRI (Environmental Systems Research Institute) shapefile format. Study area was extracted from the world data and sand, silt, clay and organic matter content were tabulated as given in table 2 for the study area.

Fromthevalues in above table,sandfraction content (m_s),silt fraction content(m_{silt}),the clay fractioncontent (m_c) and organic carbon content were found out by using the equation proposed by the Williams (1995). The soil type found in the study area were Lithosols, CalcaricFluvisols and Chromic Vertisols. The values of m_s, m_{silt}, $m_c$and orgc for the soil type Chromic Vertisols, CalcaricFluvisols and Lithosols are given in table .3.

The K factor value was estimated by substituting all the above value in equation and the K factor value for the study area ranging between 0.139 tonnes-ha-hr/ha-MJ-mm. to 0.172 tonnes-ha-hr/ha-MJ-mm. K factor value for different soil type is given in table .4. The K factor values refelect a compound relationship between soil physical properties andtheir impact on increasing soil erosion (Benavidez*et. al.,* 2018 and Doulabian*et. al.,* 2021)

It was found that the clay content has low K factor values 0.0139 tonnes-ha-hr/ha-MJ-mm. and 0.140 tonnes-ha-hr/ha-MJ-mm, because the clayey soils are highly resistant to detachment of soil particles. The medium textured soilssuch as loam have K factor value 0.172 tonnes-ha-hr/ha-MJ-mm. The finding of this research is compared with studiesconducted by Waseem *et. al.,* 2023 in the case study of Jhelum River basin. They have used FAO data to find K valueswhichwere intherangeof 0.14to0.16 tonnes-ha-hr/ha-MJ-mm.Alsoshownthesimilar Kfactor valuesforthestudydoneby Ejaz *et. al.,* 2023 which was between 0.139to 0.151 tonnes-ha-hr/ha-MJ-mm. and Ghosh *et. al.*, 2022 found K value inthe range of 0.120 to 0154 tonnes-ha-hr/ha-MJ-mm. The similar K factor value was found in results given by Machiwal*et al.* (2015).

Table:.2Sand,silt,clayandorganicmattercontentinsoiltypesofstudyarea

Soilsample	m_s(sand) Topsoil%	m_{silt}(silt) Topsoil%	m_c(clay) Topsoil%	Orgc Organiccarbon%
Vc	22.8	24.5	52	0.69
Jc	39.6	38.9	20.8	0.70
I	57.9	16.3	24.9	0.90

Table:.3Sandfractioncontent(m_s),siltfractioncontent(m_{silt}),theclayfractioncontent(m_c)andorganiccarbon content of study area

Soil sample	F_{csand}	F_{cl-si}	F_{orgc}	F_{hisand}
Vc	0.20	0.71	0.97	0.99
Jc	0.20	0.88	0.98	0.98
I	0.20	0.76	0.93	0.97

Table:4Kfactorvaluesfordifferentsoiltypesofthestudyarea

Sr.No.	Soil	FAOsoilclass	Kfactorvalue tonnes-ha-hr/ha-MJ-mm.
1	**Vc**	**ChromicVertisols**	**0.140**
2	**Jc**	**CalcaricFluvisols**	**0.172**
3	**I**	**Lithosols**	**0.139**

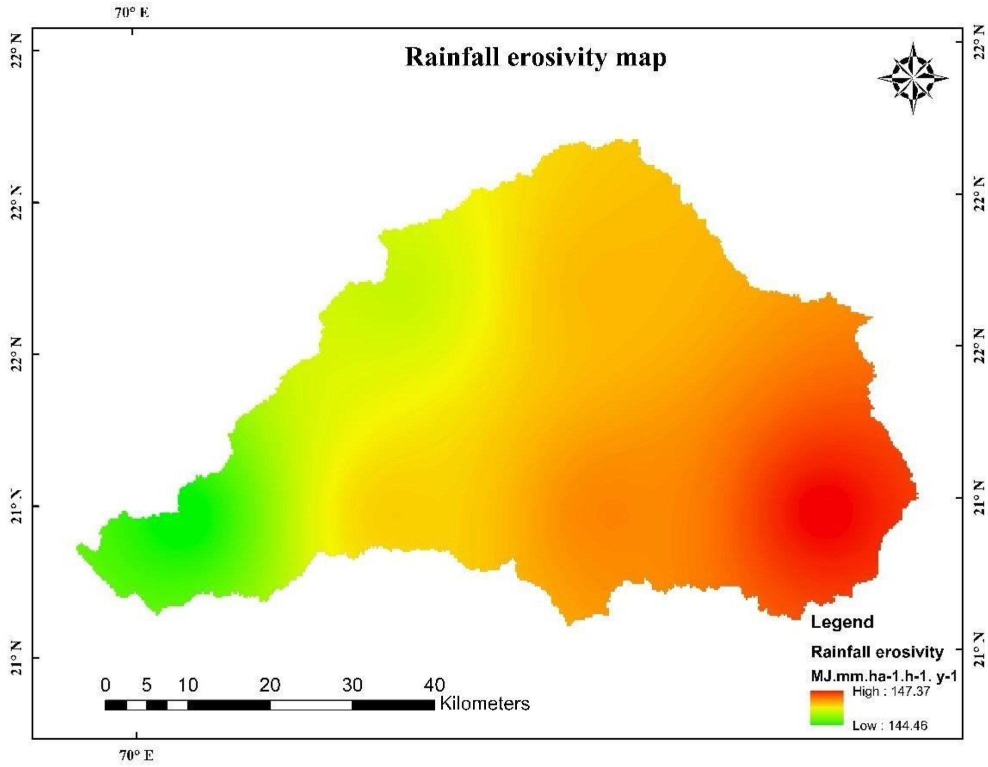


Fig..1RainfallerosivitymapofOzatriverbasin

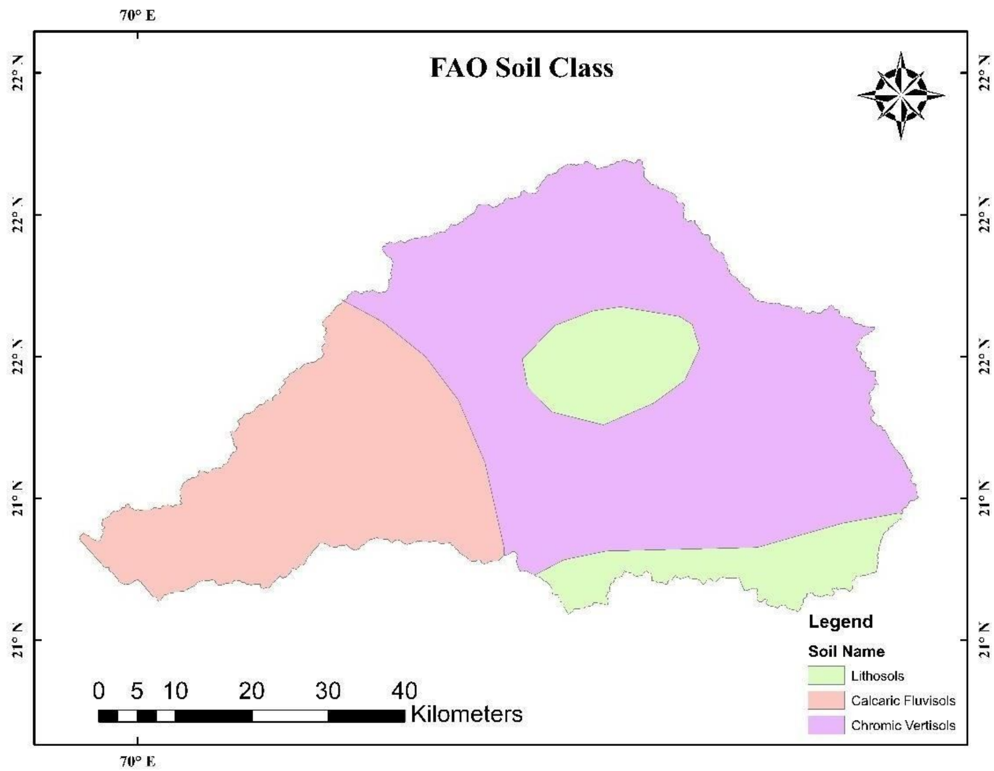


Fig.2FAOsoilclassmapofOzatriverbasin

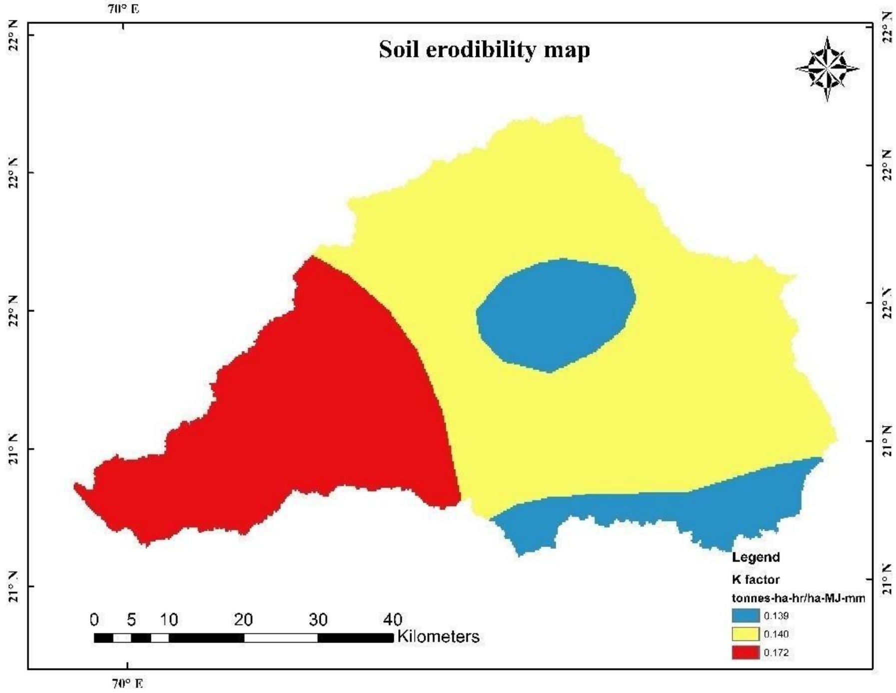


Fig..3SoilerodibilitymapofOzatriverbasin

Humanactivitiesincludingovergrazing,overcropping,anddeforestationalsocontributedtosoilerosion.Alloftheseactions will contribute to desertification, which is the growth of extremely salty, desert-like regions as a result of humanactivity speeding up soil erosion. The rate of soil erosion is expected to increase in the future. To combat this, moretechniques like windbreaks, tree planting, contour ploughing, and stubble planting will be required in order to conserve thesoil. Furthermore, constructing stone walls along to the contours of the soil will stop soil erosion downslope and enable rainwater to seep through the soil instead of running off the slope. Additionally, mulching aids in halting soil erosion. Since soil is essential to many basic ecological functions, its conservation is vital. Through the growth of microbial activity, the soil filters the water, supplying the nutrients required for agricultural crops. At the same time, forests work to control greenhouse gas emissions and the planet's temperature.

4 CONCLUSION

The rainfall erosivity factor for the Ozat river basin was ranging between 144.46 MJ.mm.ha^{-1}.h^{-1}. y^{-1}to 147.37 MJ.mm.ha^{-1}.h^{-1}.y^{-1}.ThesoilerodibilityfactorofOzatriverbasinwasrangingbetween0.139tonnes-ha-hr/ha-MJ-mmto 0.172 tonnes-ha-hr/ha-MJ-mm. It was found that the clay content has low K factor values 0.139 tonnes-ha-hr/ha-MJ-mm. and 0.140 tonnes-ha-hr/ha-MJ-mm, because the clayey soils was highly resistant to detachment of soil particles. The medium textured soils such as loam have K factor value 0.172 tonnes-ha-hr/ha-MJ-mm. Soil with higher K values aremore vulnerable to soil erosion. However, lower K values are more resistant to soil erosion. The current study will support more sustainable river basin development as well as improved environmental hazard planning and management. A cost-effective and efficient method of estimating soil erosion model parameters is to merge the usage of GIS and remote sensing. Additionally, it might help create management scenarios, give policymakers answers for concerns to soil erosion, and prioritize basin areas for restoration.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.
3.

REFERENCES

Arnoldus, H.M.J.,de Boodt,M.and Gabriels, D.(1980).An Approximation oftherainfallfactor intheUniversalSoilLoss Equation; John Wiley and Sons Ltd.: Chichester, UK.

Bashir,S.,Javed,A.andBibi,I.(2018).Soilandwaterconservation.UniversityofAgriculture,Faisalabad,Pakistan.

FAO/Unesco.SoilMapoftheWorld1:5,000,000SouthAsia;FoodandAgricultureOrganization:Rome,Italy,1977;

Benavidez,R.,Jackson,B.,Maxwell,D.andNorton,K.(2018).Areviewofthe(Revised)universalsoillossequation((R)USLE):With aviewtoincreasingitsglobalapplicabilityandimprovingsoillossestimates.*Hydrol.Earth Syst.Sci*.,**22**:6059–6086.a

Doulabian, S., ShadmehriToosi, A., Humberto Calbimonte, G., GhasemiTousi, E. and Alaghmand, S. Projected climatechange impacts on soil erosion over Iran. (2021). *Journal of Hydrology*, **598**: 126432.

Ejaz,N.,Elhag,M.,Bahrawi,J.,Zhang,L.,Gabriel, H. F.,Rahman, K.U.(2023). Soilerosion modellingand accumulationusing RUSLE and Remote Sensing Techniques: Case Study Wadi Baysh, Kingdom of Saudi Arabia.*Sustainability,* **15**: 3218.

Ghosh, A., Rakshit, S., Tikle, S., Chatterjee, B. P., Alataway, A., Al-Othman, A. A., Dewidar, A. Z. and Mattar, M. A.(2022). Integration of GIS and remote sensing with RUSLE model for estimation of soil erosion. *Land*, **12**:116.

Kirthigaa, C. and Sakthive,l R.(2022). Estimation of soil erosion risk using rusle and debris flow susceptibility mapping using bivariate spatial models, Palakkad district, Kerala. *International Research Journal of Modernization in Engineering Technology and Science*, **4** :8.

Köninger, J., Panagos, P., Jones, A., Briones, M. J. I. and Orgiazzi, A. (2022). In defence of soil biodiversity: Towards aninclusive protection in the European Union. *Biol. Conservation*, **268**: 109475.

Kumar,R., Bhardwaj, A. K., Rao, B. K., Vishwakarma, A. K., Kakade, V., Dinesh, D., Singh, G., Kumar, G., Pande, V. C., Bhatnagar,P.R.and Bagdi, G.L.(2021).Soilloss hinders therestorationpotential oftreeplantations on highly eroded ravine slopes. Journal of Soils and Sediments, 21, pp.1232-1242.

Kumar, S. and Hole, R. M. (2021). Geospatial modellingof soil erosion and risk assessment in IndianHimalayanregion—A study of Uttarakhand state. *Environ. Adv*., **4**: 100039.

Lin, D., Shi, P., Meadows, M., Yang, H., Wang, J., Zhang, G. and Hu, Z. (2022). Measuring compound soil erosion bywind and water in the eastern agro–pastoral Ecotone of northern China. *Sustainability,* **14**: 6272.

Machiwal, D., Katara, P. and Mittal, H. K. (2015). Estimation of soil erosion and identification of critical areas for soil conservation measures using RS and GIS-based Universal Soil Loss Equation. *Agricultural Research*, **4(2):** 183–195.

Negese, A., Fekadu, E. and Getnet, H. (2021). Potential Soil Loss Estimation and Erosion-Prone Area Prioritization Using RUSLE, GIS, and Remote Sensing in Chereti Watershed, Northeastern Ethiopia. *Air Soil Water Resources*.

Panagos, P., Karydas, C. G., Gitas, I. Z.and Montanarella, L.(2012). Monthly soil erosion monitoring based on remotely sensed biophysical parameters: a case study in Strymonas river basin. **5**:461–487.

Pimentel,D.,Allen,J.andBeers,A.(1987).Worldagricultureandsoilerosion.*Bioscience*,**37**:277–283.

Prasannakumar, V., R. Shiny, N. Geetha and H. Vijith. (2011). Spatial prediction of soil erosion risk by remote sensing,GIS and RUSLE approach: a case study of Siruvani river Watershed in Attapady valley, Kerala, India.*Environmental Earth Science*, **913(3)**: 965-972.

Prasannakumar, V., Vijith, H., Abinod, S. and Geetha, N. (2012). Estimation of soil erosion risk within a smallMountainous sub-watershed in Kerala, India, using Revised Universal Soil Loss Equation (RUSLE) and geo-information technology, *Geosci. Front*., **3** :209-215.

Rahaman Abdul, A., Aruchamy, B., Jegankumar, C. and Abdul Ajeez, D. (2015). Estimation of annual average soil loss,based on rusle model in kallar watershed, Bhavani basin, Tamil Nadu, Indias. Remote Sensing and SpatialInformation Sciences. Joint International Geoinformation Conference, Kuala Lumpur, Malaysia.

Sidi Almouctar, M. A., Wu, Y., Zhao, F. and Dossou, J. F. (2021). Soil Erosion Assessment Using the RUSLE Model andGeospatial Techniques (Remote Sensing and GIS) in South-Central Niger (Maradi Region). *Water*, **13**: 3511.

Stefanidis, S., Alexandridis, V. and Ghosal, K. (2022). Assessment of Water-Induced Soil Erosion as a Threat to Natura2000 Protected Areas in Crete Island, Greece. *Sustainability*, **14**: 2738.
Volume7,ISBN 92-3-101344-0.

Waseem, M., Iqbal, F., Humayun, M., Umais Latif, Javed, T. and Kebede Leta. (2023). Spatial assessment of soil erosionrisk using RUSLE embedded in GIS environment: a case study of Jhelum River watershed. *Applied science*,**13**:3775.

Williams, J. R. (1995). Chapter 25. The EPIC Model. In Computer Models of Watershed Hydrology; Singh, V.P., Ed.; Water Resources Publications: Littleton, CO, USA.

Wischmeier, W. H. and Smith D. D. (1965). Predicting rainfall-erosion losses from cropland east of Rocky Mountains: guide for selection of practices for soil.

Wischmeier, W. H. and Smith, D. D. (1978). Predicting Rainfall Erosion Losses: A Guide to Conservation Planning;Department of Agriculture, Science and Education Administration: Washington, DC, USA.