IJBPAS, January, Special Issue, 2022, 11(1): 352-367

ISSN: 2277–4998

International Journal of Biology, Pharmacy and Allied Sciences (IJBPAS)

'A Bridge Between Laboratory and Reader'

www.ijbpas.com

SPATIAL ASSESSMENT OF SOIL EROSION USING GIS-BASED UNIVERSAL SOIL LOSS EQUATION MODEL FOR ZUARI RIVER BASIN, GOA, INDIA

ARATI PANSHEKAR[1*] SAVITA KULKARNI[2] AND KRISHNA BADIGER[3]

1: Department of Geography, Government College of Arts, Science and Commerce, Sanquelim, Goa, India

2: Department of Geography, PDEA's Anna Saheb Magar College, Hadapsar-Pune, Maharashtra, India

3: Department of Geography, Government College of Arts, Science and Commerce, Sanquelim, Goa, India

[*]**Corresponding Author: Arati Panshekar: E Mail: panshekar.arti@gmail.com**

Received 10th June 2021; Revised 11th July 2021; Accepted 20th Aug. 2021; Available online 15th Jan. 2022

https://doi.org/10.31032/IJBPAS/2022/11.1.1041

ABSTRACT

Soil erosion is considered as one of the serious worldwide environmental problems due to its economic implications. Assessment of soil erosion in the watershed is cumbersome due to its uneven pattern and quantifying the soil loss is imperative for conservation, planning, and management of natural resources. There are several models to estimate the soil loss. They are employed based on costs, areal extent, data availability, time, and required accuracy. In the present study, the USLE model is used to estimate the total soil loss in the Zuari River basin with the help of geospatial tools as the region is subjected to soil erosion. Thematic layers of R-factor, K-factor, LS factor, C factor, and P factors are generated and multiplied in a raster calculator to estimate the total soil loss in the basin. The soil loss in the region varies from 0.63 to 23.05 t/ha-1/yr-1.The region is categorized as low, moderate, severe, and extreme soil erosion areas based on the amount of soil loss. Zuari watershed is also divided into ten sub-watersheds to estimate the soil loss in each sub-basins for better assessment of soil erosion. Results illustrate that the soil erosion in SW6 and SW7 is higher. These basins are in the eastern part of the study area that forms the Western Ghats with rugged and dissected, highly elevated topography, whereas the region close to the mouth of the river with low altitude constitute SW1 and SW10 experience lesser amount of soil erosion. These results will assist decision-makers to frame the appropriate policies to conserve soil resources.

Keywords: Zuari River Watershed, USLE Model, Remote sensing and GIS, Soil erosion

INTRODUCTION:

Soil is one of the vital natural resources where plant and animal life exist and it takes thousands of years to form. In recent years soil erosion has become a major environmental concern due to anthropogenic factors such as mining, agriculture, inappropriate land use pattern, urbanization, constructional activities, etc. that disturbs the topography, reduce the groundwater level and produce economically unproductive land (Lim *et al*., 2005, Bhat *et al*., 2017). Soil erosion refers to the mechanical process of detachment and transport of earth's materials by the influence of water or wind. Although soil loss was always existed due to natural factors but during the last few decades the rate of exploitation and destruction of natural resources has been increased owing to an increase in population which resulted in an accelerated rate of soil erosion (Tingting *et al*., 2008). It is relatively higher in agricultural areas and reduces agricultural productivity (Brown, 1984). The United Nations Environmental Program stated that 20 million ha of agricultural land is degrading every year in the world (United Nation Environmental Program, 1991). Soil erosion is regarded as a natural hazard and a major problem in mountainous regions (Sharma, 2010). The average annual rate of soil loss in the world is 12 to 15 t/ha/year and 11 million km^2 of the area is influenced by erosion due to surface runoff (Bou-imajjane & Belfoul, 2020). The average annual soil loss in India is 15.6 t/ha-1/yr-1 (Majhi *et al*., 2021). In India, 5334 million tons of soil is removed annually due to several anthropogenic activities (Narayan & Babu, 1983). In recent studies of global soil erosion modeling, India ranked third in the soil loss category after the USA and China (Majhi *et al*, 2021). Spatial and quantitative assessment of intensity and extent of soil erosion is essential to understand the severity of the problem and design strategies for effective management and conservation of natural resources (Bhat, 2017). It is not possible to completely stop soil erosion but it can be mitigated to some extent with the help of GIS technology (Jazouli *et al*., 2017). It is difficult to estimate accurate soil loss due to its intensity, fluctuating rates, and related complex processes. The estimation of soil loss by using geospatial technologies is helpful for sustainable resource development as it provides better accuracy. There are several methods to assess soil erosion, like empirical model, static and dynamic model, Deterministic model, event-based model, single-point model, Areal Non-point Source Watershed Environment Response Simulation (ANSWERS), Water Erosion Prediction Project (WEPP), Limburg Soil Erosion Model (LISEM), European Soil Erosion Model (EUROSEM), Soil and Water Assessment Tool (SWAT), Simulator for Water Resources in Rural Basins (SWRRB), Agricultural Non-point Source pollution model (AGNPS), etc. Among these entire models, the USLE model is the most extensively used at the national, state, and local level as it considers all the environmental and anthropogenic factors. This model is more preferred since it estimates the total soil loss from sheet and rill erosion, its widespread scientific literature, high degree of flexibility, and comparable results (Kinnell, 2000 & Alewell *et al*., 2019). However, inaccessibility of data remained a serious challenge for estimating soil loss from the USLE model. This model was first developed in the United States to analyze the soil loss from the agricultural fields considering soil type, topography, rainfall, and cropping pattern (Wischmeier & Smith, 1978). The USLE model is employed to assess the soil loss in the present study area.

The study area is the Zuari River watershed in Goa. The area is located between $15^0$00'0" & 15^0 30'0" north of equator and between $73^0$45'0" & 74^0 15'0" east of Greenwich (fig.1& fig.2). Its geographical area is about 989 km^2. The watershed is highly vulnerable to soil erosion due to the presence of more barren areas, fallow agricultural land, Kumeri cultivation: a traditional tribal agriculture, mining activities, construction activities, infrastructural developments, deforestation, etc. The topography of the region consists of diverse physical features such as the mountainous regions of the Western Ghats, plateaus, and coastal belt and river valleys with the alluvial plain. The length of the river is 69.91 km and its tributaries are Uguem, Panchamal, Guleli, Netorli, Cumbhari, Chirkanali, Kushavati, Gocoldem, Cavorem, and Santana. The region is situated in tropical Maritime and Monsoon type of climate, wherein the climate is uniform and moist throughout the year with minor variations. The average temperature in the study area is 28ºc with a variation of 4ºC to 6º C. The region receives heavy rainfall of about 350 cm annually from the southwest monsoon between June & September.

MATERIALS AND METHODS

To predict the soil loss in the study region Universal Soil Loss Equation Model is employed in the GIS environment. USLE model is a statistical technique that can be employed over a larger area due to its interpolation capabilities (Lufafa et.al, 2002) It is represented as follow:

A= R*K*LS*C*P (Wischmeier & Smith, 1978)

Wherein, A is the mean annual soil loss in metric tons per hectare per year (ton/ ha/year), R is rainfall erosivity factor measured in megajoule millimetres per hectare per hour per year (MJ mm /ha/hr/year), K is the Soil erodibility factor measured in metric ton hours per megajoules per millimetre (t. h/ MJ/mm), LS is the Slope length factor (dimensionless), C is the Cover and management factor (dimensionless), P is Support practice factor (dimensionless).

Rainfall Erosivity (R factor)

R factor indicates the impact of rainfall intensity, volume, and period on soil erosion (Kadam *et al*., 2018). The potentiality of soil erosion in the region is higher when the intensity and duration of a rainstorm are greater (Stone and Hilborn 2012). It is defined as the product of the kinetic energy of a storm and its maximum intensity during a 30 min interval (Chadli, 2016). It is the erosive force and detaching power of the raindrops that strike the land surface (Morgan, 1994). Isopleth map of rainfall is generated by using Inverse Distance Weighted (IDW) method (fig.3) in Arc GIS using the Spatial Analyst tool with the help of acquired data of rainfall from the Meteorological dept, Panjim. A prepared rainfall map is used as an input to estimate the R factor map in the following equation:

R= 79+ 0.363*P (Singh, 1981)

Wherein, R is the Rainfall erosivity factor and P is the average annual rainfall in mm. It is expressed in MJ mm /ha/hr/year.

Soil Erodibility (K factor)

K value is defined as the "mean annual soil loss per unit of rainfall erosivity for a standard condition of bare soil, recently tilled up-and-down slope with no conservation practice" (Morgan, 2005). It depicts the vulnerability of the region to soil erosion and the rate of surface runoff (Jazouli, *et al*, 2017). It is the measure of the vulnerability of soil particles to detachment and transport by runoff determined by texture, pH, and organic matter content (Chadli, 2016). It is the function of soil properties such as silt, sand, clay, pH, organic matter, infiltration rate, permeability, and water holding capacity (Kadam *et al*., 2018, Alewell *et al*., 2019). A Greater K value indicates a higher rate of soil erosion and vice versa (Adornado *et al*., 2009).

To calculate K factor following formulae is used proposed by David (1988)

K= [(0.043* pH) + (0.62/OM) + (0.0082* S) – (0.0062*C)]*Si

Wherein, pH= pH of the soil, OM= organic matter (%), S= sand content (%), C: clay ratio,

Clay ratio= % clay / (% sand+ % silt), Si: silt content, Si= % silt/100

Soil samples at 66 locations in the study area have been collected by using a random sampling method and their properties are identified in the laboratory of ICAR, Krishi Bhavan, Old Goa. Maps of sand, silt, clay, organic matter, and pH content in the soils of collected samples from the study area are prepared(fig.4) and used for statistical calculation of K factor (table no.1) in raster calculator of spatial analyst tool.

Slope Length and Steepness (LS factor)

LS factor depicts the impact of length and slope steepness of the topography on the amount and intensity of soil loss by sheet, rill, and inter rill erosion by water (Benavidez, *et al*, 2018). A higher length and steeper slope have more potentiality for soil erosion (Stone and Hilborn 2012). The steepness of the slope increases the flow velocity of the water that results in a higher rate of soil erosion (Byizigiro, 2020).

In the present study, the LS factor is calculated by using the formula given by Moore and Burch in 1986. It involves estimation of flow accumulation and percentage of slope. The formula is as follow:

LS = [(flow accumulation *30 /22.13)0.5 *(0.065+0.045* slope percent) + (0.0065*slope percent)]

Flow accumulation is derived from DEM (SRTM) data by processing it in SAGA GIS with the help of the Spatial Analyst tool. To create a raster of accumulated flow into each cell, the flow direction is used from DEM data. The slope raster is estimated from DEM data in Arc GIS. Considering all constant values as per the equation given by Moore and Burch along with flow accumulation and slope, the LS factor is calculated in Arc GIS with the help of a raster calculator (table no.2 & fig.5).

Cover and Management Practices (C factor)

C factor portrays the impact of cropping and management practices on the rate of soil erosion and its values are determined by the type, growth, and cover of the vegetation (Jazouli, *et al*, 2017). It measures the effectiveness of crop or vegetation cover management to prevent soil loss, wherein fallow land has more capabilities to erode the soil (Chadli, 2016). It represents the influence of agricultural activities on soil erosion (Majhi *et al*, 2021). To estimate the C factor, the following formula is used. It is developed by Van der Knijff *et al*. (2000). The value of the C factor varies from 0 to 1 wherein 0 represents well-protected ground with less potentiality for soil loss and 1 denotes barren areas which are more susceptible to soil erosion (Kadam *et al*., 2018).

C = exp [α (NDVI/ β-NDVI)]

Wherein, α= 2, β =1, NDVI= (band 5- Band 4)/ (Band 5+ Band 4)

NDVI is derived from the LANDSAT 8 satellite image.

Support Practices (P factor)

P factor is the ratio of soil loss in a region with specific conservative practices that modifies the water flow pattern (Benavidez, 2018). It represents the effect of contour ploughing and tillage practices on soil erosion and its values range from 0 to 1, wherein value close to 0 depicts better conservation practices and 1 indicates poor conservation practices (Jazouli, *et al*., 2017). The widely used P factor influencing tillage practices are contour farming, Cross slope strip cropping, Strip cropping contour, Cross slope, and up and downslope (Stone and Hilborn 2012). In the study area, The P factor is estimated by considering the values for different conservative methods used by Gitas *et al*., 2009 (table no. 3).

RESULTS AND DISCUSSION

The spatial pattern of annual soil loss is estimated for the Zuari River watershed by integrating factors such as rainfall erosivity, soil erodibility, slope length and steepness, cover management and conservative practices in Arc GIS using spatial analyst tool which will serve as an effective tool to frame strategies for resource planning and management.

The results of R, K, LS, C, and P factors are discussed below:

Rainfall Erosivity (R factor)

Research studies claim that the major factor contributing to soil erosion is rainfall. The rainfall distribution in the region is uneven (fig.3) that has led to producing a variation in the R factor. The R factor in the study region varies from 282 to 375 MJ mm /ha/hr/year with a mean value of 335.91 MJ mm /ha/hr/year and standard deviation of 17.36 MJ mm /ha/hr/year. The R-value in the present study area gradually decreases towards the west in response to a decrease in the amount of rainfall. The R factor is higher in the eastern part of the region forming the Western Ghats where the rainfall is relatively higher representing upstream areas of the Zuari River. The result shows that the study region specifically the eastern part of the watershed is subjected to a considerable rainfall erosivity.

Soil Erodibility (K factor)

K factor value in the basin ranges from 0.13 to 0.31 t. h/ MJ/mm and its distribution is irregular (table no.1 & fig.4). A higher K value (0.31 t. h/ MJ/mm) is found in areas that are more susceptible to soil erosion and vice versa. 32.37% of the study region has a K value from 0.13 to 0.20 t. h/ MJ/mm which is lesser and indicates a lower risk of erosion, whereas, 67.63% of watershed has K value more than 0.20 t. h/ MJ/mm represents the higher vulnerability of the region to soil erosion.

Slope Length and Steepness (LS factor)

LS factor is the major constituent of the soil erodibility factor, along with the nature of rock; which also affects the erodibility. Hard rocks are more resistant to erosion and soft rocks are more fragile to erode (Roose, 1993). LS Factor values in the study region vary from 0.39 to 25.42 (table no.2). These results are grouped under 4 categories, wherein 96 % of the study region including the western flat alluvial plain has an LS factor less than 3.09 which is lesser prone to soil erosion (fig.5). The higher LS value from 0.39 to 25.42 is observed over 3.5% of the watershed in the eastern part of the region which is highly elevated and has an abrupt change in slope and is more susceptible to soil loss.

Cover and Management Practices (C factor)

Land use with a high value of C factor contributes more to soil erosion which includes barren land, however, land covered with vegetation is lesser susceptible to erosion. The seasonal barren land in the region spreads all over the study region which has increased the value of the C factor resulting in making the region more prone to soil loss. C factor in the region varies from 0 to 0.93 and it is lesser in the eastern part of the region (fig.6) due to vegetation cover where soil is less susceptible for erosion.

Support Practices (P factor)

In the study region, no significant land conservation practices are employed, however, based on farming methods P factor has been calculated for the watershed. P factor values in the region vary from 0.27 to 05(table no. 3& fig.7). The estimated high P factor value is in the eastern part of the region depicts more susceptibility of the region for soil erosion, whereas areas in the western part with lesser P factor value have a lesser risk of soil loss.

Assessment of soil erosion

Five layers of R, K, LS, C, P factors are overlaid and reproduced by using spatial analyst tools in Arc GIS and a soil loss map has been prepared for the entire basin along with its sub-watersheds. The average annual soil loss in the Zuari river basin is 0.43 ton/ ha/year. The highest value is estimated to be 23.05 ton/ ha/year observed in the eastern part of the region with higher elevation and steeper slope (table no.4 &5 &fig.8). Lower soil loss values are found in the plain coastal areas where the region is almost a peneplain. By using natural breaks, the values of soil loss are categorized as low (>0.63), moderate (-0.63 to 2.17, severe (2.17 to 5.17), and extreme (5.17 to 23.05). Sub basins namely SW6 and SW7 located on the extreme eastern parts of the study region with relatively steep slopes belong to the very high category of soil loss. There are two sub-watersheds namely SW1 and SW10 which are in the lower reaches of the study region score very low in terms of soil loss as per the USLE model. The basin number SW1 is open, shallow, and more of flood plain with hardly any vertical relief, and marginalized by relatively low elevation with broad open valley score very low value of soil loss as per the USLE model.

Table 1: Area and the percentage of area under different erodibility class

Erodibility Class	Area (km^2)	Area (%)
0.13-0.18	72.23	7.29
0.18-0.20	248.28	25.08
0.20-0.22	326.98	33.07
0.22-0.25	255.33	25.80
0.25-0.31	86.75	8.76
Source: Estimated by researcher		

Table 2: Area and the percentage of area under different LS class

LS Class	Area (km^2)	Area (%)
0-0.39	739.27	74.70
0.39-1.49	147.81	14.93
1.49-3.09	68.63	6.93
3.09-5.48	28.52	2.88
5.48-25.42	5.34	0.56
Source: Estimated by researcher		

Table 3: P factor values

Up and down slope	1
Cross slope	0.75
Contour farming	0.50
Cross slope strip cropping	0.37
Strip cropping contour	0.25
Source: Gitas *et al.*, 2009	

Table 4: Soil loss, area and percentage of area under each soil loss category				
Sr. No.	Soil loss ($t/ha^{-1}/yr^{-1}$)	Erosion	Area (km^2)	Area (%)
1	<0.63	Low	723.12	78.20
2	0.63 – 2.17	Moderate	148.16	16.02
3	2.17 – 5.17	Severe	44.76	4.83
4	5.17 – 23.05	Extreme	8.76	0.95
Source: Estimated by researcher				

Table 5: Sub basin wise area under soil loss category of the study area									
Sr. No.	Soil Loss (unit)	<0.63		0.63 – 2.17		2.17 – 5.17		5.17 – 23.05	
	Soil loss category	Low		Moderate		Severe		Extreme	
	Sub basin	Km^2	%	Km^2	%	Km^2	%	Km^2	%
1	SW1	59.96	71.74	13.04	15.60	7.12	8.51	3.45	4.15
2	SW2	27.52	72.02	4.64	12.14	3.88	10.15	2.17	5.69
3	SW3	44.6	71.88	9.98	16.08	6.02	9.70	1.44	2.34
4	SW4	38.36	68.63	9.47	16.94	6.23	11.14	1.83	3.29
5	SW5	87.16	75.45	19.25	16.66	5.81	5.02	3.29	2.87
6	SW6	75.72	80.69	13.16	13.85	3.96	4.22	0.99	1.24
7	SW7	34.36	76.16	7.24	16.04	2.72	6.02	0.79	1.78
8	SW8	77.84	72.99	18.2	17.06	8.08	7.57	2.52	2.38
9	SW9	174.93	74.53	41.18	17.54	15.02	6.39	3.56	1.54
10	SW10	58.45	72.99	14.40	17.98	5.73	7.15	1.49	1.88
Source: Estimated by researcher									

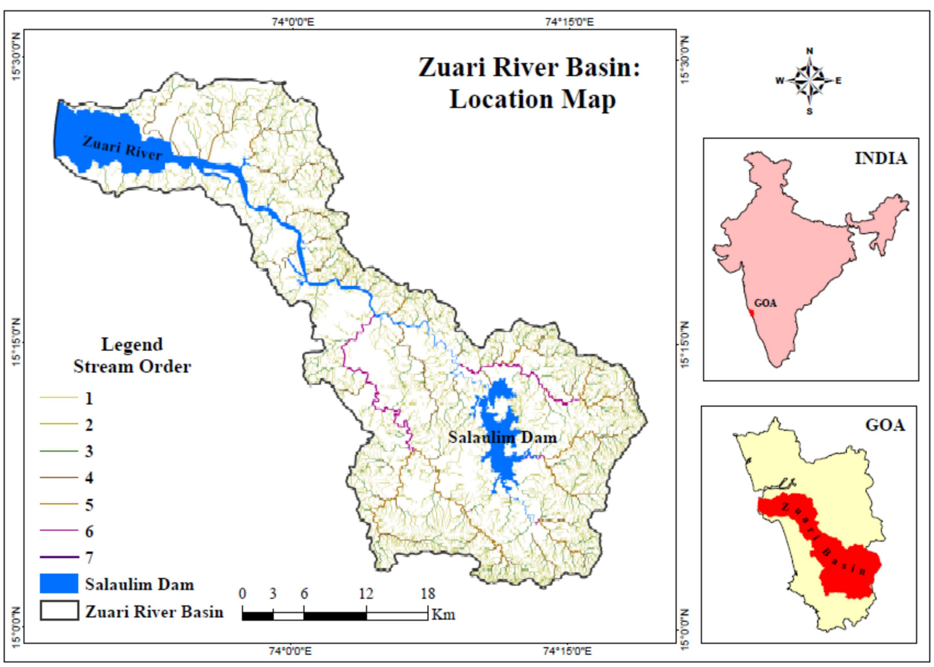

Figure 1

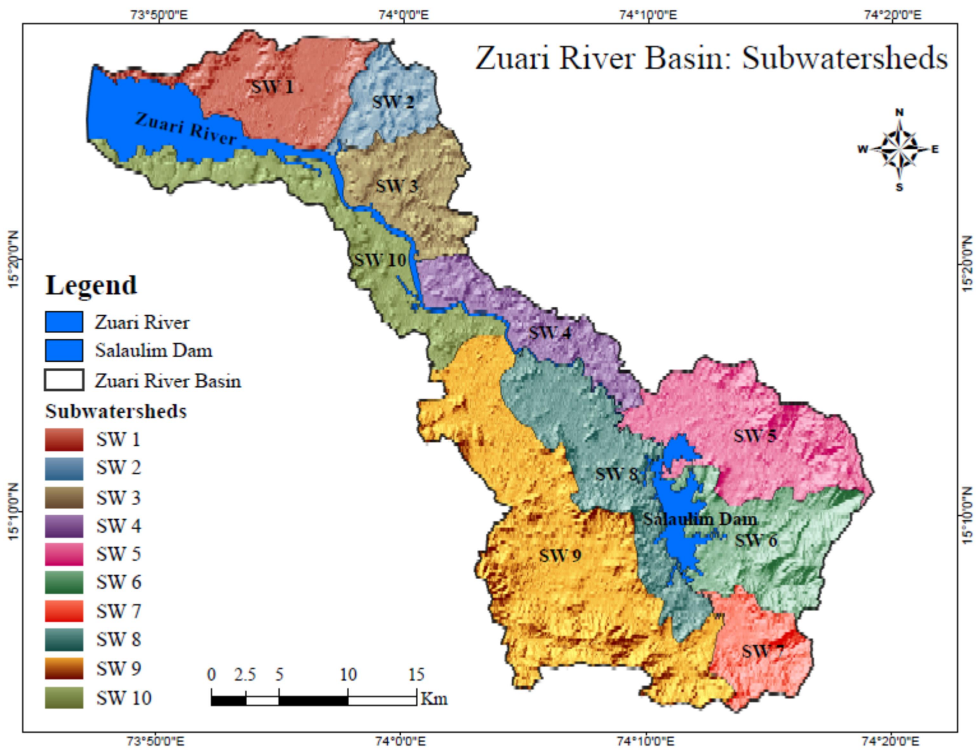

Figure 2

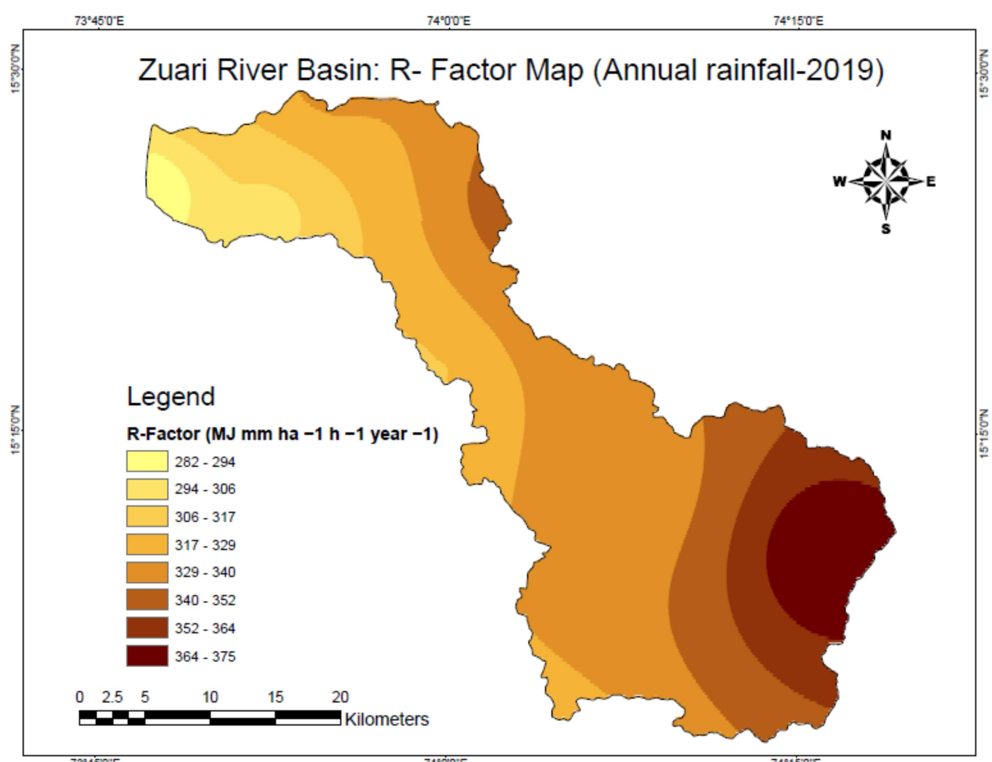

Figure 3

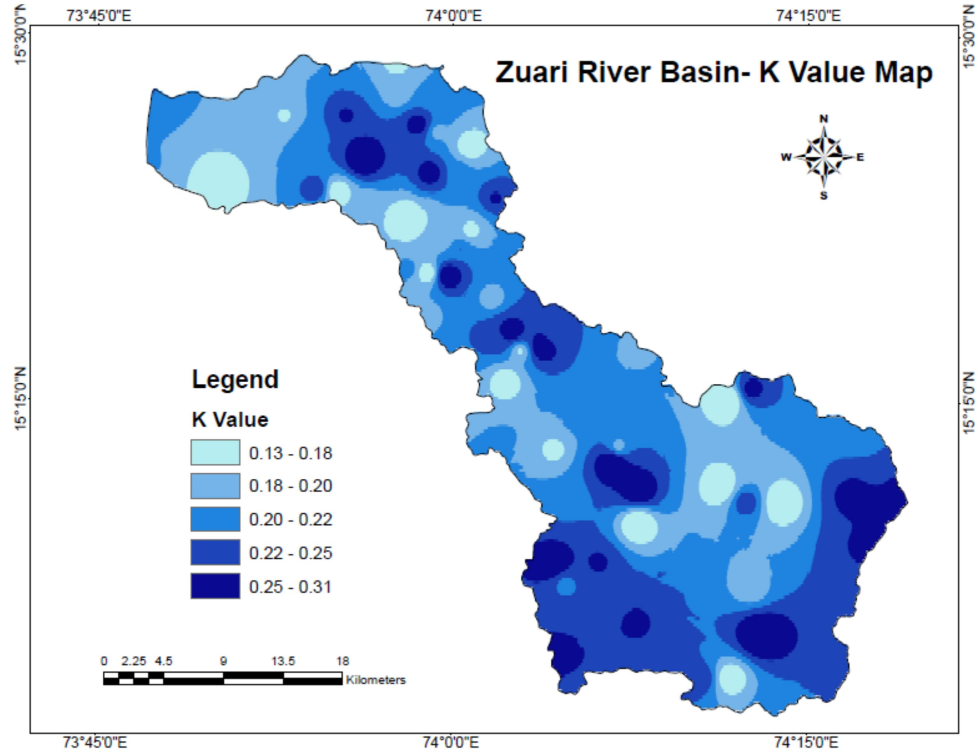

Figure 4

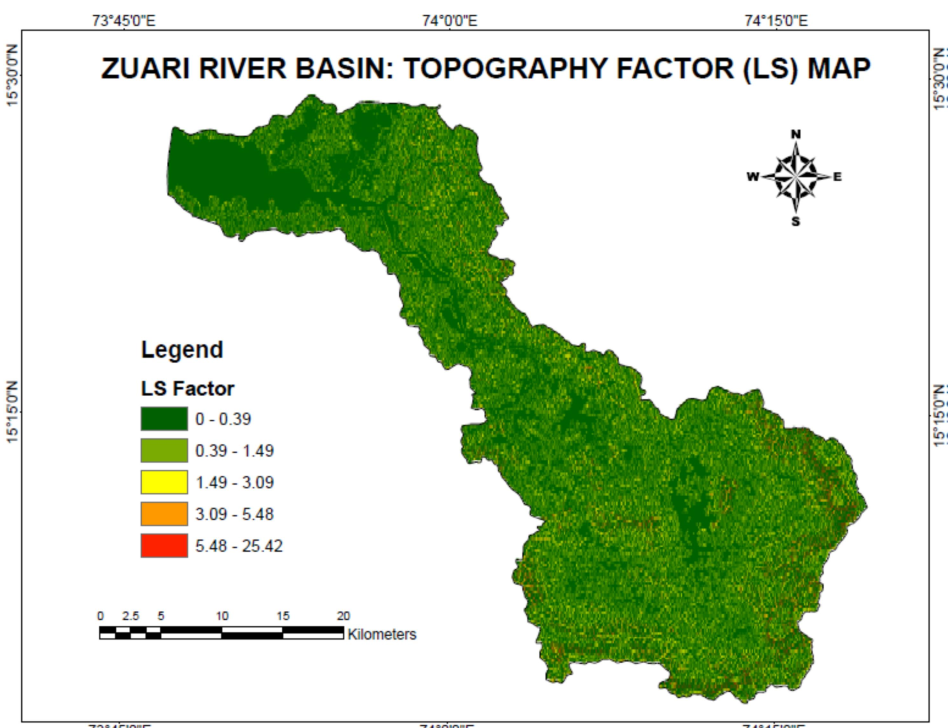

Figure 5

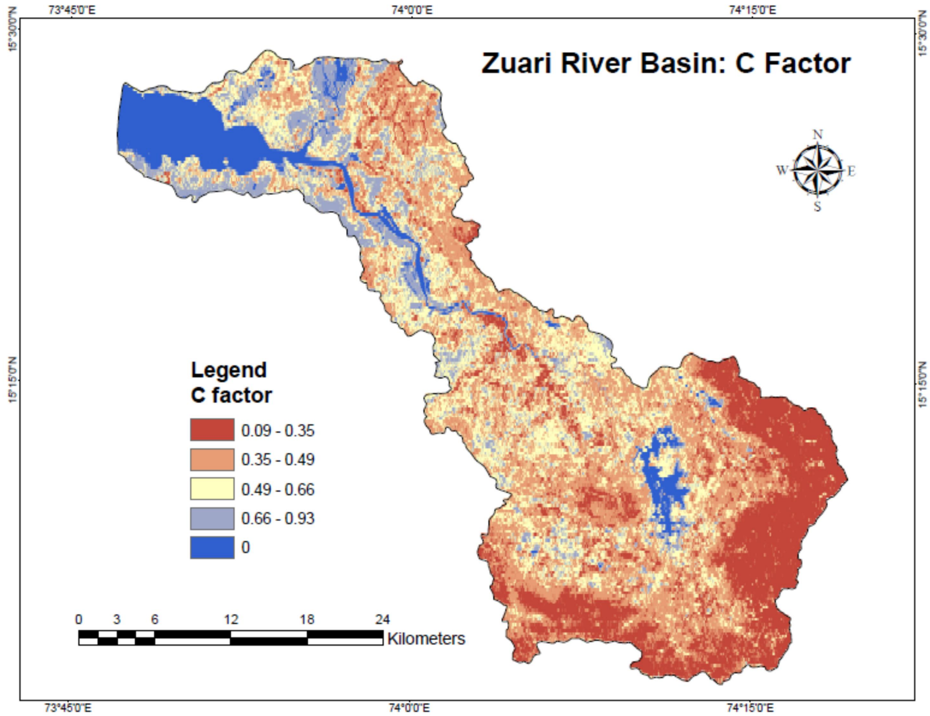

Figure 6

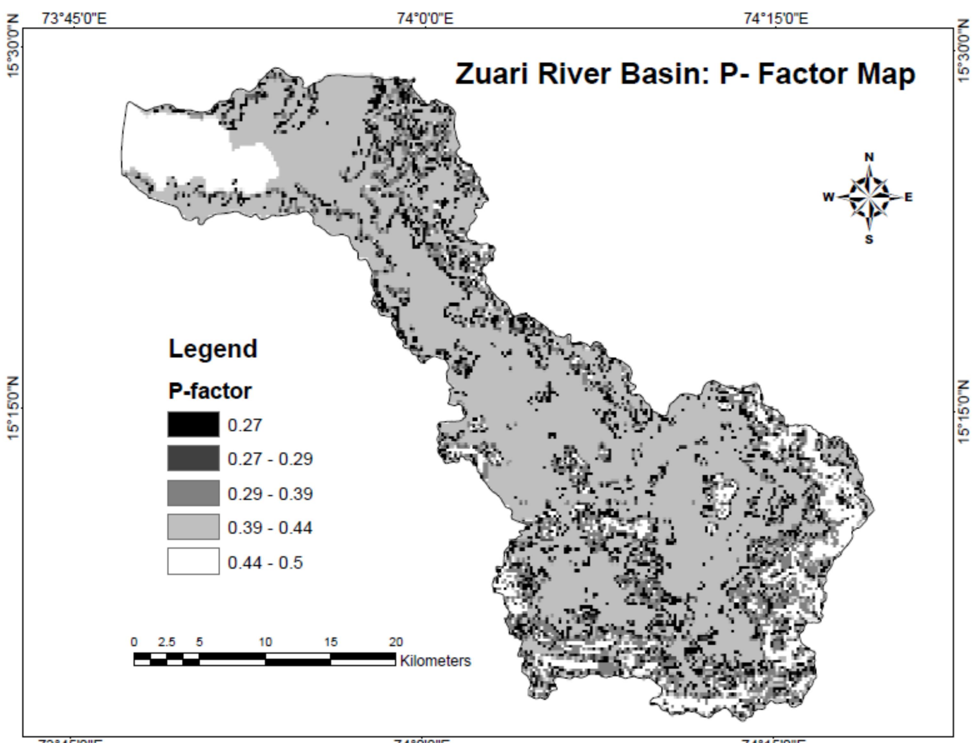

Figure 7

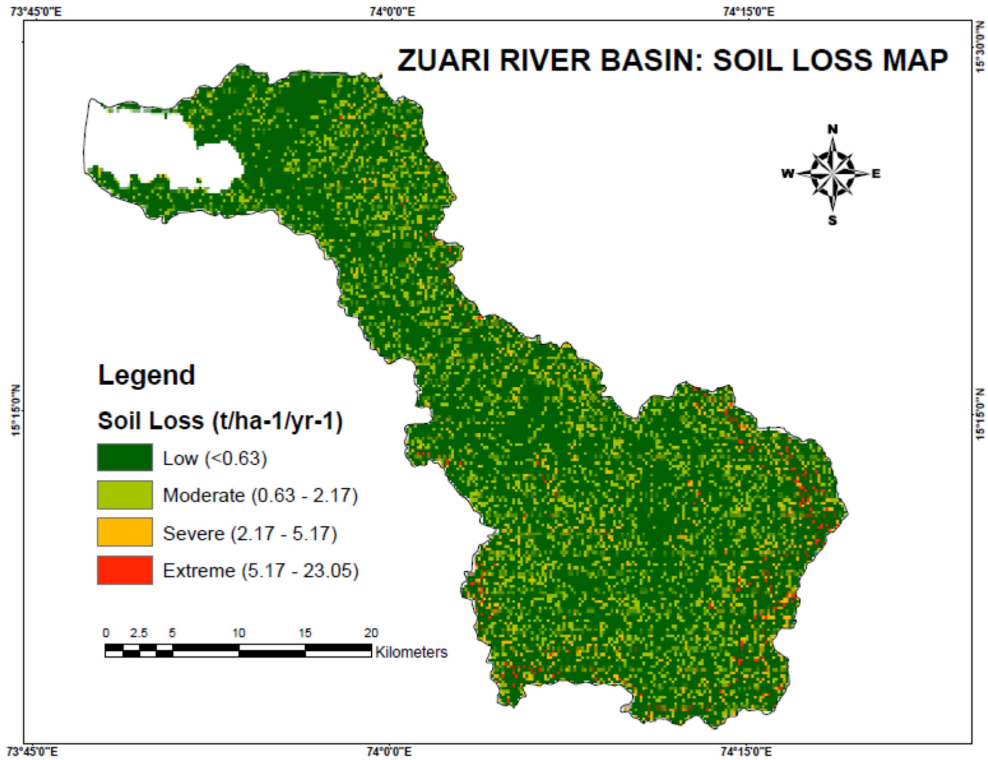

Figure 8

CONCLUSION

The Zuari River Basin is characterized by uneven rainfall, varied types of soils, varied topography and high relief in the east and slope variation, differential vegetation cover, and different land use/land cover patterns. Soil erosion is a major concern in the basin. The quantitative analysis of soil erosion by using the USLE model clearly shows that the annual average soil loss in the Zuari watershed is 0.43 ton/ ha/year. It is higher in the highly elevated areas of Western Ghats with steeper slopes forming part of the upper reaches of the river. In addition, high rainfall and irregular barren patches of land are responsible for high soil erosion in these areas. The result shows that 74.06% of the basin has a lower risk of erosion in the western part of the study area near the mouth and in the middle course of the river due to a flat alluvial plain with diminishing relief and slope, forming rolling lowlands. 16.48% of the watershed has a moderate risk of erosion, 7.15% severe erosion, and 2.36% of the total area has an extreme risk of soil erosion due to higher elevation and steeper slopes. In general, it can be concluded that nearly ($86km^2$)10 percent of the study area is at high risk of soil erosion and hence, it is high time to take necessary measures for conservation of further loss of soil. As mentioned above it is not easy to completely stop soil erosion but it can be reduced with suitable land-use practices and management.

REFERENCES

[1] Jazouli, A., Barakat A., Ghafiri A., Moutaki S., Ettaqy A.& Khellouk R. (2017) Soil erosion modeled with USLE, GIS,and remote sensing: a case study of Ikkour watershed in Middle Atlas (Morocco) *Geosci. Lett. 4:25*

[2] Adornado, A., Yoshida, M., & Apolinares, H. (2009) Erosion Vulnerability Assessment in Reina, Quezon Province, Philippines with Raster-based Tool Built within GIS Environment.Journal of Agricultural Research.,18(1), 24–31

[3] Majhi, A., Shaw, R., Mallick, K.& Patel, P. (2021) Towards improved USLE-based soil erosion modelling in India: A review of prevalent pitfalls and implementation of exemplar methods. Earth-Science Reviews 221, 103786

[4] Brown, R. (1984) Conserving soilsIn: Brown, L.R. (Ed.), State of the World. Norton, New York, pp. 53– 75.

[5] Alewell, C., Borrelli, P., Meusburger K.& Panagos, P. (2019) Using the USLE: Chances, challenges and limitations of soil erosion modelling. International Soil and Water Conservation Research 7. 203-225

[6] Roose, V. Kabore, & Guenat, C. "Le za¨ı: fonctionnement, limites et am´elioration d'une pratique traditionnelle africaine de r´ehabilitation de la v´eg´etation et de la productivit´e des terres d´egrad´ees en r´egion soudano-sah´elienne (Burkina Faso). Cahiers ORSTOM," *S´erie P´edologie*, vol. 28, no. 2, pp. 159–173, 1993.

[7] Kadam, A., Karnewar, A. S., Umrikar, B. & Sankhua, R. N. (2018) Hydrological response-based watershed prioritization in semiarid, basaltic region of western India using frequency ratio, fuzzy logic and AHP method. *Environ. Dev. Sustain*., 1-25. DOI: https://doi.org/10.1007/s10668-018-0104-4

[8] Chadli, K.(2016) Estimation of soil loss using RUSLE model for Sebou watershed (Morocco) Model. Earth Syst. Environ. (2016) 2:51

[9] Kinnell, P.I.A. (2000) AGNPS–UM: applying the USLE–M within the agricultural nonpoint source pollution model. Environmental Modelling and Software 15, 331– 341.

[10] Lim K.J., Sagong, M., Engel B. A., Tang, Z., Choi, J. & Kim, K. (2005): GIS-based sediment assessment tool. Catena 64 (2005) 61–80

[11] Latifa, B.& Belfoul M.A.(2020) Soil Loss Assessment in Western High Atlas of Morocco: Beni Mohand Watershed Study Case Applied and Environmental Soil ScienceVolume

2020, Article ID 6384176, 15 pages https://doi.org/10.1155/2020/6384176

[12] Lufafa, A., Tenywa, M.M., Isabirye, M., Majaliwa, M.J.G. & Woomer, P.L. (2003): Prediction of soil erosion in a Lake Victoria Basin catchment using a GIS based Universal Soil Loss Model. Agricultural Systems, 76, 883–894.

[13] Tingting，L.V., Xiaoyu，S., Dandan，Z., Zhenshan，Z.& Jianming, G.(2008) Assessmentof Soil Erosion Risk in Northern Thailand. The International Archives of The Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B8. Beijing

[14] Morgan, R. P. C.: Soil Erosion and Conservation, National Soil Resources Institute, Cranfield University, https://doi.org/10.1002/9781118351475.ch22, 2005.

[15] Narayan, V. V. D. & Babu, R., 1983. Estimation of soil erosion in India. Journal of Irrigation and Drainage Engineering, 109 (4), 419-434. DOI: https://doi.org/10.1061/(ASCE)0733-9437(1983)109:4(419)

[16] Benavidez, R. Jackson, B., Maxwell, D.&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. Hydrology Earth System Sciences, 22, 6059–6086

[17] Sharda, V.N., Mandal, D., Ojasvi, P.R. (2013) Identification of soil erosion risk areas for conservation planning in different states of India. J. Environ. Biol. 34, 219–226.

[18] Stone, R.P. & Hilborn, D. (2012) Universal soil loss equation (USLE) factsheet. Ministry of Agriculture, Food and Rural Affairs, OntarioUN Plan of Action to Combat Desertification. UNEP, Nairobi, Kenya.

[19] United Nation Environmental Program (1991) Status of Desertification and Implementation of the

[20] Wischmeier, W.H. & Smith, D.D. (1978) Predicting rainfall erosion losses. A guide to conservation planning. The USDA Agricultural Handbook No. 537.

[21] Byizigiro, R. V., Rwanyiziri, G., Mugabowindekwe, M., Kagoyire, C.& Biryabarema, M. (2020)Estimation of Soil Erosion Using RUSLE Model and GIS: The Case of Satinskyi Catchment, Western Rwanda.Rwanda Journal of Engineering, Science, Technology and Environment, Volume 3, Special Issue, June 2020

[22] Sharma, A. (2010) Integrating terrain and vegetation indices for identifying potential soil erosion risk area. Geo-

Spatial Information Science. 13(3):201e209.

[23] Bhat, S.A., Hamid, I. Dar, M., Rasool, D., Pandit, B.A.& Khan, S. (2017) Soil erosion modelling using RUSLE & GIS on micro watershed of J&KJournal of Pharmacognosy and Phytochemistry 6(5): 838-842

[24] Morgan, R.P.C. (1994) Soil Erosion and Conservation. Silsoe College, Cranfield University.

[25] Sajja, G., Mustafa, M., Phasinam, K., Kaliyaperumal, K., Ventayen, R., & Kassanuk, T. (2021). Towards Application of Machine Learning in Classification and Prediction of Heart Disease. *2021 Second International Conference On Electronics And Sustainable Communication Systems (ICESC)*. https://doi.org/10.1109/icesc51422.2021.9532940

[26] Veluri, R., Patra, I., Naved, M., Prasad, V., Arcinas, M., Beram, S., & Raghuvanshi, A. (2021). Learning analytics using deep learning techniques for efficiently managing educational institutes. *Materials Today: Proceedings*. https://doi.org/10.1016/j.matpr.2021.11.416

[27] C.M. Thakar, S.S. Parkhe, A. Jain *et al*., 3d Printing: Basic principles and applications, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2021.06.272