Soil Erosion Estimation of Watershed Using Quantum Geographic Information System (QGIS) and Universal Soil Loss Equation (USLE)

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Abstract: ***The economy of all the sectors is primarily based on the soil resource available in that region. Soil erosion within watersheds results in increase of level of sedimentation in the streams and reservoirs and thus reducing their storage capacity and life span as well. Universal Soil Loss Equation (USLE) and Geographic Information System (GIS) are the most popular and widely used field application models to compute soil erosion with considerable degree of accuracy. The average annual soil losses are computed by multiplying five USLE factors: R; the erosivity factor, K; the soil erodibility factor; LS, the topographic factor; C, the crop management factor and P; the conservat- -ion support practice. These USLE factors with associated attribute data, are digitally encoded in a QGIS database and spatial distribution maps of computed factors are prepared. In the present study, the average annual soil erosion of Khuldabad watershed is assessed using the USLE and QGIS. Study revealed that, soil erosion risk is low in 22% of the study area with soil loss of 6.11 t/yr, 12% of the area is under moderate erosion with soil loss of 11.06 t/yr. More than one-third (34%) of the area faces severe erosion with a loss of 19.34 t/yr and 18% of the study area is found to be under extreme erosion risk with soil loss of 35.37 t/yr.***

Keywords: Erosion, Watershed, Remote sensing, USLE, QGIS

1. Introduction

Soil erosion is a complex dynamic process in which productive soil surface is detached, transported and finally accumulated at a distant place resulting in exposure of subsurface soil directly to the atmospheric phenomenon [1]. In general, the Soil is said to be eroded when soil is removed through the action of wind and water at a greater rate than it is formed**.** The soil covering the surface of the earth has taken millions of years to form. The rate of formation of soil is only 1 cm every 100 to 400 years and it takes 3000 to 12000 years to build enough soil to form productive land [2]. It is a matter of great concern that out of the total geographical area of 329 Mha of India, about 167 Mha is affected by serious water and wind erosion problem and out of this 127 Mha is affected by soil erosion and 40 Mha is suffering from gully erosion, water logging and soil salinity in varying degrees [1]. It is also estimated that, the soil resource base is shrinking at an alarming rate of 0.25 M ha per annum due to rapid industrialization and urbanization [5]. Soil is an important nonrenewable resource and once destroyed it is gone forever. For maintaining and improving soil productivity, high priority should be given for conservation of soil resources by promoting optimum land use and watershed prioritization [9]. Planning, conservation and management of the watersheds are vital to restore the productivity of the soil and to prevent further loss of resources. A geographic information system (GIS) is used to develop and store the feature of watershed like topology, soil type, texture, existing land use land cover, water resources and drainage pattern as obtained from field measurement thus GIS has wide range of application and comes with GRASS interface and user support. The GIS modeling is a computer based and computationally efficient tool; it uses available inputs viz. vector or/and raster and allows users to study the present and long-term impacts [8].

2. Objective

The objective of present work is to estimate the soil erosion in the watershed and thus to analyze the various critical erosion zone in the study area by using QGIS and USLE model.

3. Methodology

3.1 Study Area

A study area watershed GV-42 is located in Khuldabad taluka. The study area falls in the eastern part of Aurangabad district as shown in fig 1. The watershed lies between $19^0$5’69’’N latitude and $75^0$25’49’’E longitude. The area covers under geological survey of India toposheet no. NE 43-3/ SERIES U503/ EDITION I-AMS. The scale of toposheet 1: 250,000 i.e. one inch measured on the map represents the 250, 000 inch on the ground surface. The toposheet of selected area is collected from the Survey of India topographic sheet. The watershed area is found to be 96060 hacters [8]. The average annual rainfall in the area varies from 500 mm to 850 mm [5]. The study area has varied land covers & uses namely water bodies, waste land, habitations, paddy fields, deciduous forest, plantations, marshy land etc. The soils in study area have mixed texture like clay, clay-loam, sandy clay loam, and gravelly loam, sandy loam etc. as per data obtained from the LU/LC and soil maps.

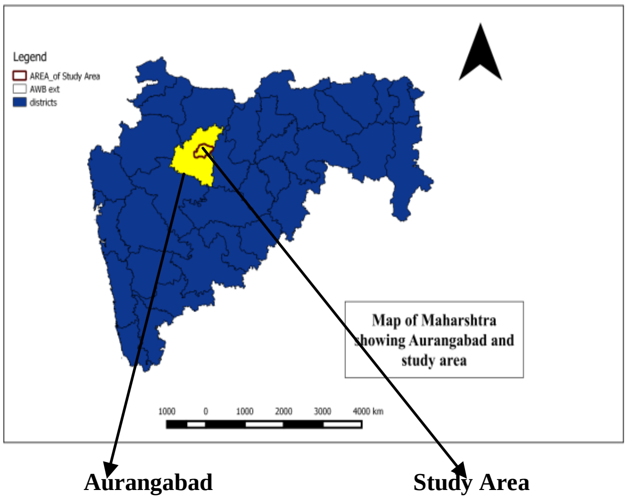

Figure 1: Map of Study area

3.2 Materials and Data

The rainfall data from rain-gage stations encompassing and within the study area for twenty years have been used for analysis purpose. Map of Maharashtra state is Geo-referenced and the digital elevation model (DEM) for the State is procured from BHUVAN-2D. Aurangabad District DEM is extracted through the QGIS as shown in fig 2.

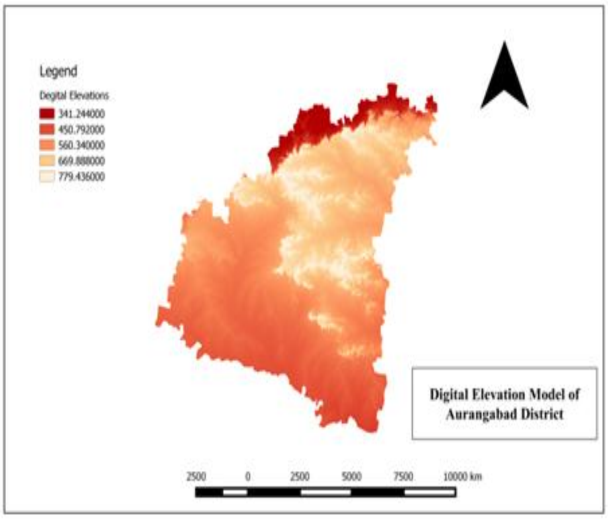

Figure 2: Digital Elevation Map

Using GRASS interface and taking inputs from the QGIS, macro-watersheds and streams in the district is developed in raster format as shown in fig 3.The study area is converted into vectorised format for the calculation of geometrical parameter such as area. The soil classification data along-with the properties like grain size distribution, organic content and permeability of soil samples of each class are prepared based on the information obtained from Soil map. Various types of crops such as jowar, bajri, wheat, and maize is cultivated and rotation farming is adopted in the study area. Major conservation practices implemented in study area are contour bunding, field bunding, mixed terracing etc [5]. All the required data are procured from IMD-Pune, NBSS & LUP -Nagpur and other authentic sources and finally the soil erosion map for the watershed is developed in the QGIS 2.2.2 environment.

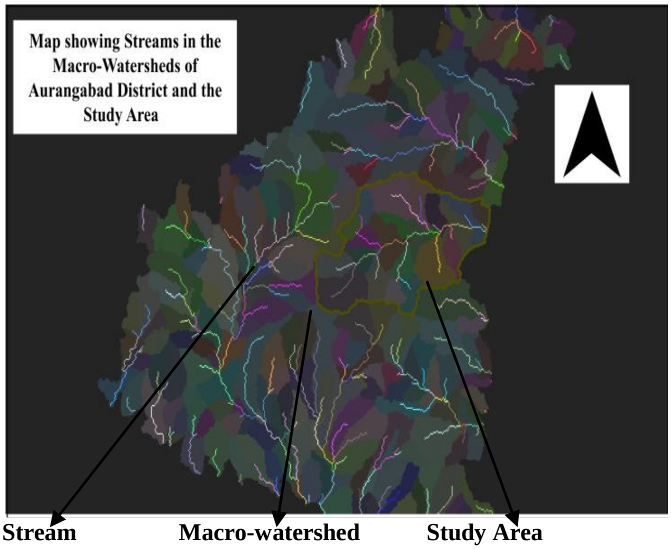

Figure 3: Map of Macro-watersheds and Streams

4. Model Description

The Universal Soil Loss Equation (USLE) is an empirical Model which was developed by Wischmeier and Smith (1978) is used to assess average annual soil loss from the study area [3]. This USLE equation is as given as, E=(R*K*L*S*C*P), where E is average annual soil loss (tones/yr), R is rainfall erosivity factor, K is the soil erodibility factor, L is the slope length factor, S is the slope steepness factor, C is the cover management factor and P is support practice factor which is dimensionless quantity.

4.1 Development of Model Database for USLE

Rainfall erosivity *'R'* (in metric units) is calculated by the formulae *R=1.73+0.363P*, where P= precipitation and 1.73 is metric conversion [1]. The average annual rainfall in Khuldabad watershed varies from 500 mm to 850 mm as stated earlier. Taking the sutaible value for precipitation as 670 mm, a *R-factor* map is prepared in QGIS 2.2.2. The area is classified into five categories of *R values* as shown in the fig 4. The *values* ranges between 0 to 599. However, the major part of the study area is dominated by *value* between 300 to 399.

Soil Erodibility *'K'* (t/yr) is derived by using the Equation *K= 1.313 [(2.1 *10-4 M1.14 *(12-a)) + (3.25*(b-2)) +(2.5*(c-3))] /100*, Where M= (% silt + very fine sand) *(100-% clay),a=% organic matter, b= soil structure code no., c=permeability class number [4]. Five soil classes are identified in study area. Studying the characteristics of the soil from the soil map, inputs are given to the above equation and the *K values* are derived. The *k values* so obtained are divided into four classes and then *K-factor* map is prepared in QGIS 2.2.2 as shown in fig 5. The value lies in the range of 0.10 to 0.40 depending upon the infiltration, soil structure, soil permeability, organic matter and soil mineralogy.

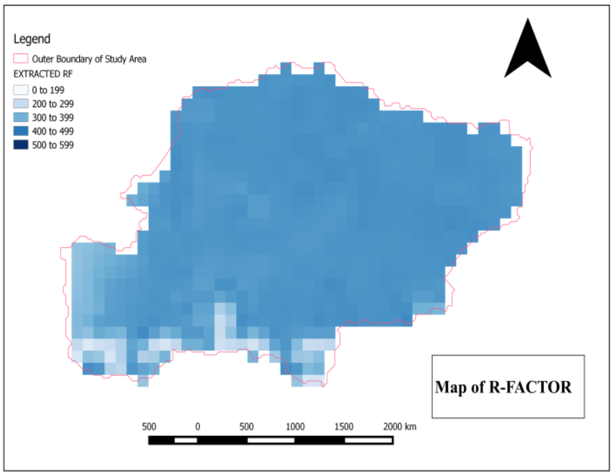

Figure 4: Map of R-FACTOR

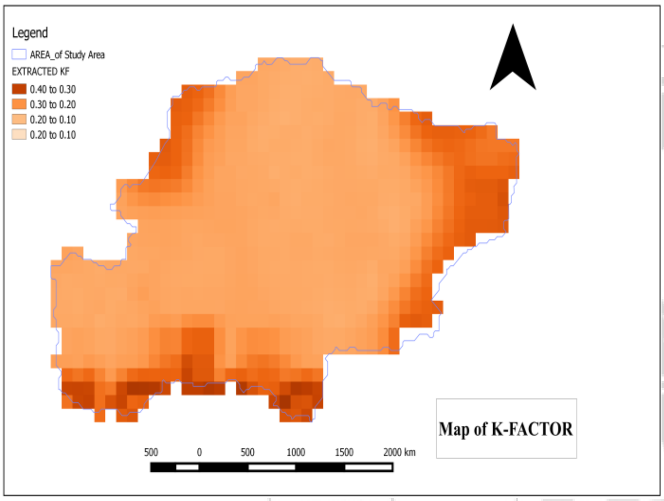

Figure 5: Map of K-FACTOR

For obtaining the Slope length '*L*' and Slope steepness factor '*S*' contours with 20 m interval is worked out as shown in fig 6. *L-factor* and *S-factor* is derived by using the equation $L = (\lambda / 22.13)^m$ and $S = (0.0065s^2 + 0.045s+.065)*h$, here λ = slope length, s=% slope, m=exponent function [4]. The pixel size kept as 23.5 m which acts as slope length λ. For the study area the value of exponent m is adopted as 0.3[9]. Uniform value of 1.02 is thus works out for length factor *L* and for contour of 20 m interval, slope *s* in *%* is derived. Hence, the combined *LS-factor* is found to be in the range of 15% to 0.10% as shown in fig7.

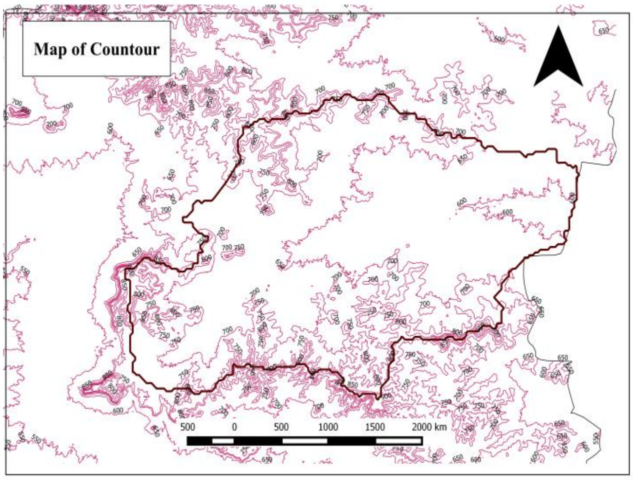

Figure 6: Map of 20m interval Contour

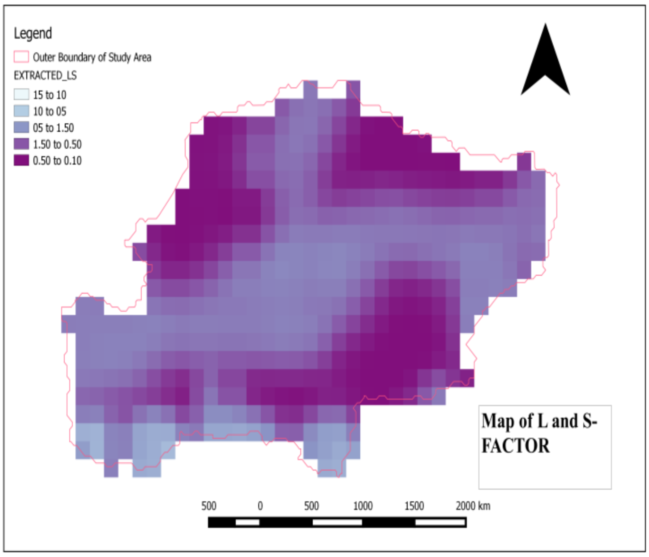

Figure 7: Map of LS-FACTOR

Cover management factor '*C*' is associated with land use and land cover (LU/LC). LU/LC for the Aurangabad is obtained from BHUVAN-2D. Suitable values of *C* are adapted from data developed by earlier researchers and thus by carefully matching with the present geographical conditions of the study area the *C-values* are mapped into four divisions viz. fallow land, bushy forest, degraded land and farm land in the range value of 0.01 to 0.40 through QGIS 2.2.2 as shown in the fig.8.

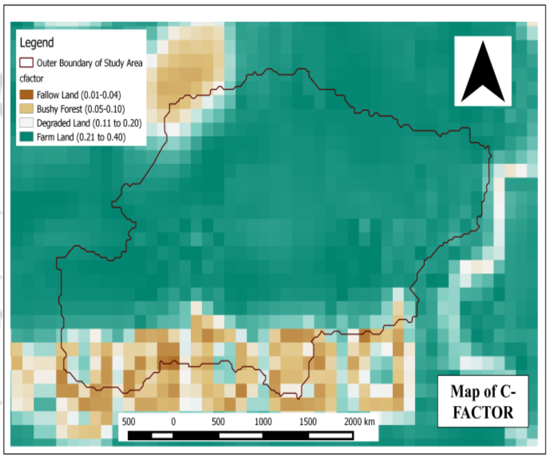

Figure 8: Map of C-FACTOR

Land conservation practice factor '*P*' is the most important parameter because it is the factor which checks the erosion at any location. Governmental agencies such as NBSS-LUP with the state authorities carried out soil and water conservation works under watershed treatment plan. Various land conservation practices such as field bunding, terracing can even be followed at the local level also. In the present study the compounded effect of such conservation works has been considered and the *P-values* are modified proportionately. It is observed that about 28% of watershed does not have any conservation practice which increases the risk of erosion in the area. Watershed is classified into four blocks and accordingly the values for the conservation practices in the range of 0.10 to 1.00 are given as shown in the fig 9.

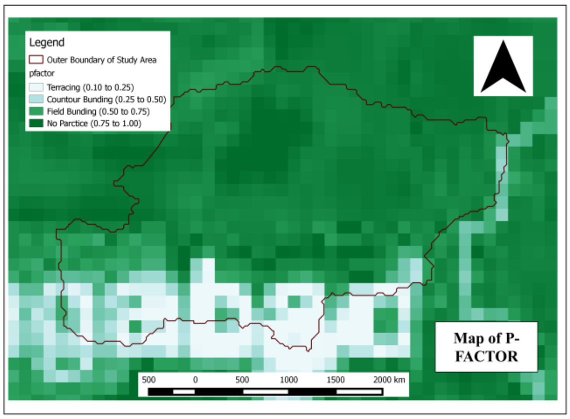

Figure 9: Map of P-FACTOR

5. Result and Discussion

The erosion rates as derived from the raster integration of USLE factors are shown in the Table1. The erosion rates range from 0(zero) to more than 45 t/yr. These rates are classified into various classes viz. slight erosion, moderate erosion, severe erosion and very severe erosion and extreme erosion. These classes show erosion of 1cm (slight erosion) to 100 cm soil depth (extreme erosion).

It can be observed that, soil erosion risk is low in 22% of the study area with soil loss of 6.11 t/yr, 12% of the area is under moderate erosion with soil loss of 11.06 t/yr. More than one-third (34%) of the area faces severe erosion with a loss of 19.34 t/yr. The very severe erosion class is spread over 14% of the area and it accounts for the soil loss of 28.12%.It is to be noted that 18% of the study area is found to be under extreme erosion risk with annual soil loss of 35.37 tones.

Table 1:Details of soil erosion quantity for study area

Sr. no.	*Soil Erosivity Class*	*Area*		*Soil Erosion Quantity*		*Remarks*
		Ha	*%*	*tones/yr*	*%*	
1.	Slight Erosion	21133.2	22	2.80	6.11	Normal rates
2.	Moderate Erosion	12527.2	12	5.06	11.06	Normal rates
3.	Severe Erosion	31660.4	34	8.86	19.34	Needs to be normalized
4.	Very Severe	13448.4	14	12.88	28.12	At high risk
5.	Extreme Erosion	17290.8	18	16.20	35.37	At high risk
Total		96060.0	100	45.80	100	

Due to continuous occurrences of erosion the rich soil mass of this area has been washed and there is no significant soil cover available in the region of extreme erosion. In such circumstances, it is necessary to check the soil depth and thus normalize the result.GIS is a soft computing tool, taking the inputs of all the parameters of Universal Soil Loss Equation (USLE) into QGIS environment, various map-sets are obtained for each parameter for estimating average annual soil losse and finally Soil Erosion map showing various critical erosion zones is obtained as shown in fig.10, hence effective study on the soil erosion for the khuldabad watershed is performed.

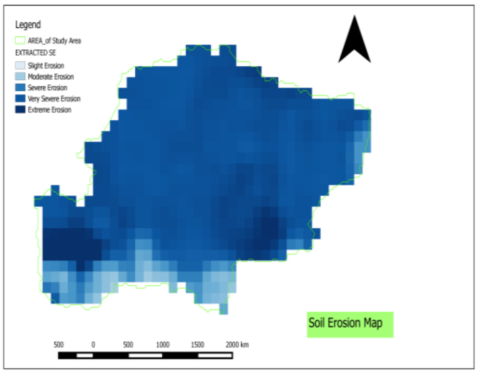

Figure 10: Soil Erosion Map for study area

6. Conclusion

Creation and attribution of database through conventional methods is time consuming, tedious and quite difficult to handle. The identification of priority area for erosion control strategies is made easier in GIS framework. Out of total area of 96060 hacters ,17290.8 hacters (18%) of the khuldabad watershed is under extreme erosion zone and accounts for annual loss more than 16 tones (35.37%) of useful valuable land resources.

References

[1] Sanjay K. Jain, Sudhir Kumar, Jose Varghese, “Estimation of Soil Erosion for a Himalayan Watershed Using GIS Technique”, Journal of Water Resources Management, Springer, 2001, pp 41-54.

[2] Agricultural Department of Republic of South Africa. [Online].Available: http://www.nda.agric.za/publications

[3] Dhruva V. V. Narayana and Ram Babu, “Estimation Of Soil Erosion In India”, Journal of Irrigation and Drainage Engineering, American Society of Civil engineers, 2001, pp 419-434.

[4] Khire.M.V, Nakil, M.B, Mundhe M.S, “Sedimentation Analysis Using USLE Model with Modified Parameters”, Indian Geotechnical Conference, IGS Mumbai Chapter & IIT Bombay, 2010.

[5] O. Challa, R.S. Kurotbe & K.S. Gajbbiye "Soil Erosion in Maharashtra" NBSS Publ. No. 82, NBSS & LUP, Nagpur (2001).

[6] S. Saravanan , S. Sathiyamurthi, D. Elayaraja, “Soil Erosion Mapping of Katteri Watershed using Universal Soil Loss Equation and GIS”, Journal of the Indian Society of Soil Science, Springer, 2010, pp 804-808.

[7] Nilgun B. Harmancioglu, Okan Fistikoglu, “Integration of GIS with USLE in Assessment of Soil Erosion”, Journal of Water Resources Management, Springer, 2002, pp 447-467.

[8] Nilgun B. Harmancioglu, Okan Fistikoglu, “Integration of GIS with USLE in Assessment of Soil Erosion”, Journal of Water Resources Management, Springer, 2002, pp 447-467.

[9] Ashish Pandey, V. M. Chowdary, B. C. Mal, “Identification of critical erosion prone areas in the small agricultural watershed using USLE, GIS and remote sensing”, Journal of Water Resources Management, Springer, 2008, pp 1783-1798.