Estimation of Soil Erosion using USLE and GIS

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Abstract : ***Soil erosion is mainly a most essential environment issue which must be taken in to consideration so that natural or artificial disturbance in the environment will be prohibit.Soil erosion is dangerous for the areas and lands where the economy is primarily based on the agriculture. It removes the very uppermost layer of fertile soil by the actions of winds or rainfalls and soil particles travels from one place to another. In this study area we have calculated the annual soil loss by using the universal soil loss equation (USLE) and to calculate the various factors needed in the universal soil loss equation we have used the Geographic Information System (GIS) with help of GIS we analyze the potential areas by using the spatial information. The research is conducted in the Aurangabad, Maharashtra and nearly 950 square kilometer. The results revealed that nearly 81.68 % of total area has the soil erosion rate 2.02923 tons/ha/year to 10.5523 tons/ha/year. Less than 2% of total area has erosion rate that is very severe. From this study it suggests that the GIS based Soil Erosion model is economical and easy to build by using software like ARCGIS.***

Keywords : Soil Erosion, USLE, GIS, Watershed, Aurangabad

1.Introduction

This soil loss is very serious issue which affects the irrigation. As the population increases the food requirement also increases and the top layer of soil which is most suitable for crops is being reduced due to soil erosion. So, the preventive measures should be taken for the irrigation purposes. The most of fertility of soil is due to top layer of soil and as erosion increases the top layer gets removed subsequently the fertility rate of soil also decreases and results into poor crop yield. It affects the rural efficiency. Then it also causes off-site problems which includes the sedimentation problems and this sediment gets mixed in the water bodies and cause eutrophication. The life span of reservoir are decreases faster than planned because of increase in soil erosion that catchment area. Every year 1 millimeter of top soil lost with loss of 5,334 million tons in India, and the rate of misfortune is 16.4 tons per hectare consistently. So that is why the disintegration of regions are necessary for estimating exact soil erosion for preservation and prioritization of soil disintegration for that study area. Therefore, present work is very essential in analyzing impact of soil loss of the region and what preventive measures should be taking in limiting the soil erosion.

There are various causes of soil erosion on earth surface. Water is one of main agent of soil loss. Heavy rainfall, floods, rivers and sea water carry away the soil and sand particles. The other agents are as such wind, snow and due to human activities, such as agriculture and deforestation. Soil loss occurs when erosion rate is higher than the formation rate of soil. The soil is continuous process occurs either slowly or at an alarming rate. The result of action continuous ecological degradation, loss of topsoil, soil collapse etc. are responsible for soil erosion. Due to erosion when soil particles are transports and get deposit into water beds it is also the ultimate loss of highly efficient and rich nutrients of soil. The heavy rainfall causes surface runoff which is transports soil particles which are not protected by vegetation or land cover. Due to this the sediment concentration increases in river bed or in reservoirs and which indirectly responsible for efficiency of reservoir, its lifespan and capacity to store the water. The water quality and yielding of agricultural crops also gets reduce due to siltation. Therefore, to prevent soil loss, estimation of annual soil erosion is carried out. Conservative measures are taken into consideration hence, calculation of soil erosion is most suitable approach taken towards it and from this the preventive measures are taken in high prone areas.

2.Objective of Study

The main objective of the study is to estimate annual soil loss for watershed in Aurangabad region of Maharashtra state using the Universal Soil Loss Equation and GIS. To analyze critical soil erosion prone areas and to identify critical factor responsible for soil erosion. Also suggest conservation measures to overcome this issue.

3.1 Study Area

Aurangabad watershed is selected for present study as, the soil in this area is found to be a Black Cotton soil or 'Regur' formed by weathering of Deccan Trap Basalt. It has poor water retention capacity and hence vulnerable to soil erosion. The study area is located in Aurangabad district of Maharashtra, India. The watershed lies between 19.8762° N latitude and 75.3433° E longitude. The study area map is created in google earth pro. The total study area is 950 Square kilometer.

Fig 1 : Digital Elevation Model of Study Area

3.2 Data Collection

The rainfall data which are required for the calculation of rainfall erosivity factor ‘R’ was collected from IMD Pune. Soil map for the study area was downloaded from DSMW, to create study area in ARC GIS. BHUVAN data used to know land use land cover information about study area. Slope length and slope steepness was calculated from the ARC GIS and DEM. The DEM file was downloaded from USGS earth explorer. To calculate soil erodibility factor the data collected from DSMW. Where to obtain C and P factor was calculated from GIS.

4. Methodology

Universal Soil Loss Equation (USLE) : For the soil loss from the selected study area Universal Soil Loss Equation (USLE) model has been used around the world. The formula/equation is given by the Wischmeier and Smith in 1978. E = R*K*LS*C*P Where, ‘E’ is Soil loss (ton/ha/year), ‘R’ is Rainfall erosivity factor (MJ mm/ha/hr/year), ‘K’ is Soil erodibility factor (ton/year), ‘LS’ is Slope length and slope steepness factor, ‘C’ is Cover management factor, and ‘P’ is Conservation practice factor.

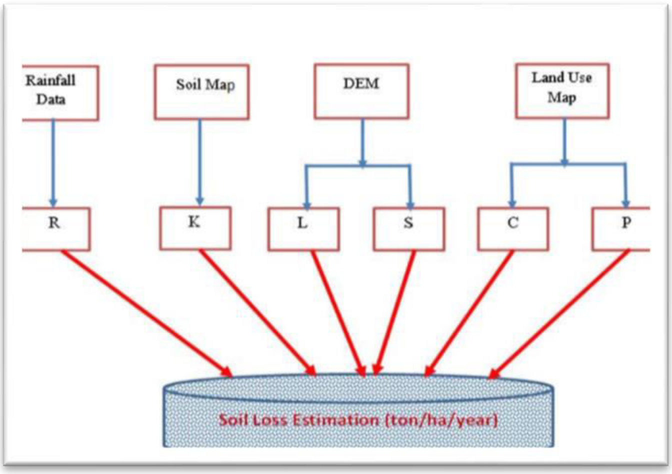

Fig 2 : Framework of soil loss equation

4.1.1 Model Description

For the estimation of universal soil loss equation the ARCGIS software has used and computed all the factors that has affected the soil erosion of the selected region. The study area shape file has extracted by using Google Earth Pro software. The USLE model for estimation of annual soil loss gives the value of annual average soil loss ‘E’ in ton/ha/year. This value is calculated in raster calculator by multiplication of five factors as R, K, LS, C & P. The methodology for estimation each factor is as stated below.

4.1.2 Rainfall erosivity factor (R)

R factor is measured rainfall’s kinetic energy by average index of multi-annual rainfall. In the soil loss the intensity of kinetic energy predicts the effect of rainfall on overall soil loss. The rainfall erosivity factor ‘R’ was given by Babu (2004), following is the formula.

R = 81.5 + 0.38 where, ‘R’ is Rainfall erosivity factor and ‘P’ is Annual rainfall.

4.1.3 Soil erodibility factor (K)

Soil erodibility factor is a measurement of the soil sensitivity factor of the soil particles that detachment and transport by rate of runoff. The ‘K’ factor is more sensitive for soil texture type and organic matter content because of their ability to govern the permeability, infiltration rate and structural stability of soil. Suresh, R., (2012). Depending on soil texture and organic content of soil erodibility ‘K’ factor computed using following formula given by the Williams (1995).

K = f_(csand)* f_(ci-si) * f_organic *f_hisand

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where, f_(csand): factor that lower the K indicator in soils with high coarse sand content and higher for soils with little sand f_(ci-si) : low erodibility factor for soil with high clay-to-silt ratios
f_organic : reduces K values in soils with high organic content
f_hisand : lowers K values for soils with extremely high sand content.

4.1.4 Slope length and slope steepness factor (LS)

To calculate the LS factor we are using an equation developed by Moore and Burch (1985). It calculates the L factor and S factor combine effect which elaborates as slope length and slope steepness of the study area.

The Moore and Burch equation we are using given as follows :

$$LS = (\text{Slope length}/22.13)^{0.4} * (0.01745 \sin\theta /0.0896)^{1.4} * 1.4$$

Where, Slope Length = Flow accumulation * Cell resolution (DEM) and θ = Slope in Degrees

4.1.5 Cover management factor (C)

The cover management factor C is associated with the land use land cover factor (LULC). Crop management factor shows the effects of cropping and management measures on soil erosion.

4.1.6 Conservation practice factor (P)

To minimize the effect of erosion, different conservation practices are studied and adopted through land management and shaping. The value of P factor depends on the type of conservation practices. The P factor estimated for Maharashtra is primary preservation practices, i.e.,(field bunding, contour bunding and terracing) were processed by (singh et.al 1990).

5. Results and Discussion

A. Results of Rainfall erosivity factor (R)

Table 1 : Rainfall Erosivity factor values

Year	Rainfall 'P'	Erosivity 'R'
1990	823.3	394.354
1991	860.7	408.566
1992	728.5	358.33
1993	681.7	340.546
1994	719.5	354.91
1995	532.3	283.774
1996	756.4	368.932
1997	742.1	363.498
1998	856.2	406.856
1999	694	345.22
2000	671	336.48
2001	651.7	329.146
2002	624.8	318.924
2003	641.6	325.308
2004	729.6	358.748
2005	662	333.06
2006	887.9	418.902
2007	564.58	296.0404
2008	725.78	357.2964
2009	604.94	311.3772
2010	730.2	358.976
2011	660.45	332.471
2012	386.83	228.4954
2013	727.2	357.836
2014	421	241.48
2015	483.09	265.0742
2016	719	354.72
2017	556.5	292.97
2018	415.8	239.504
2019	681.5	340.47
2020	770.234	374.18892

The R factor map has shown the results that values are varies from 298.54 to 363.641 and the average value is 331.6987. The R factor map is prepared in ArcGIS using 'Kriging' interpolation tool from 'Geostatistical Analyst tools'.

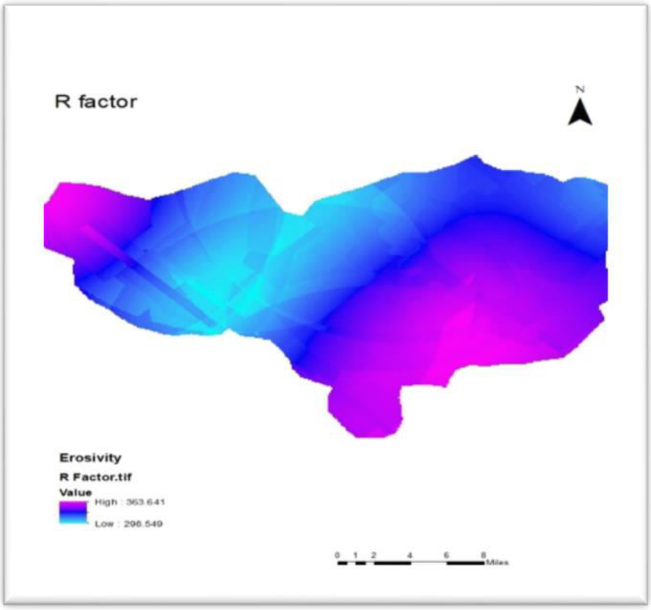

Fig 3 : R factor Map

B. Results of Soil Erodibility factor (K)

The world soil map is downloaded from the DSMW FAO and from it the study area is extracted. The soil types found in the study area are FAO soil Vc43-3ab and Bv12-3b. From this soil map the value of 'K' factor is estimated.

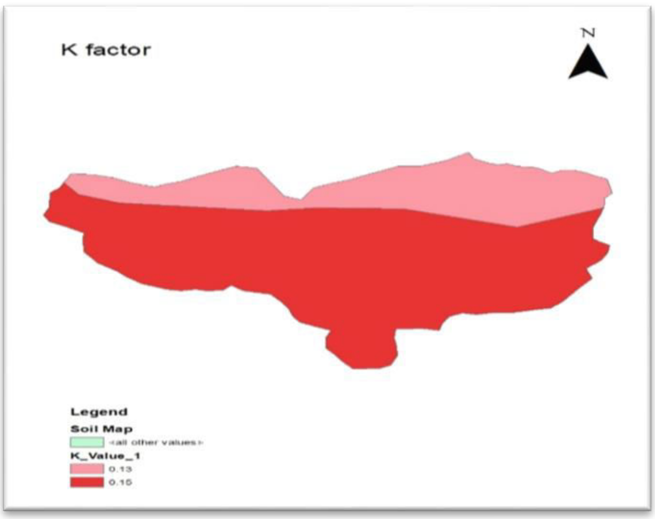

Fig 4 : K factor map

C. Results Slope length and slope steepness factor (LS)

The LS factor is estimated from DEM. From it flow accumulation and slope map formed in ArcGIS using equation LS= (Flow accumulation $*$ Cell resolution (DEM) / 22.13)$^{0.4}*(0.01745 \sin\theta /0.0896)^{1.4}*1.4$ in raster calculator.

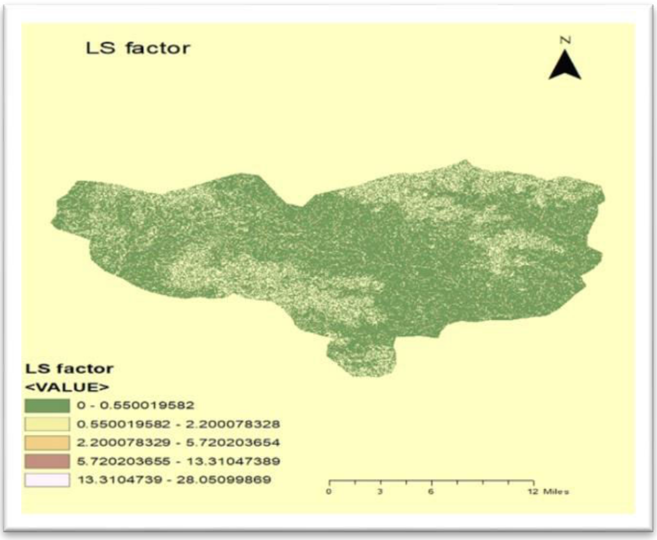

Fig 5 : LS factor map

D. Results of Crop management factor (C)

The LULC map is first prepared to know the land types in respected study area and from this 'C' factor map is estimated.

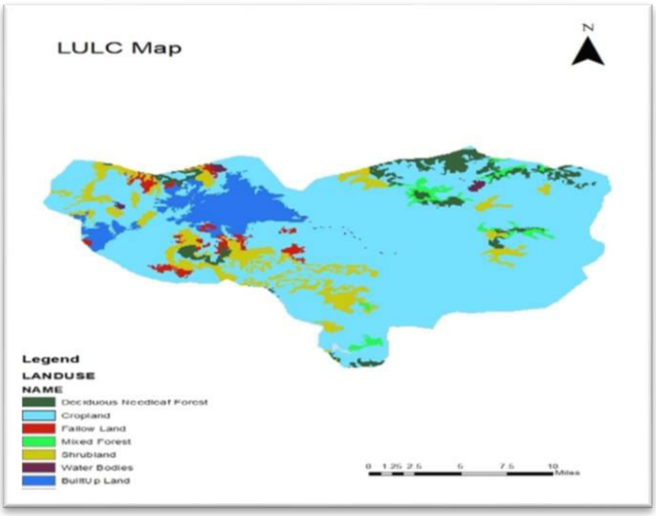

Fig 6 : LULC map

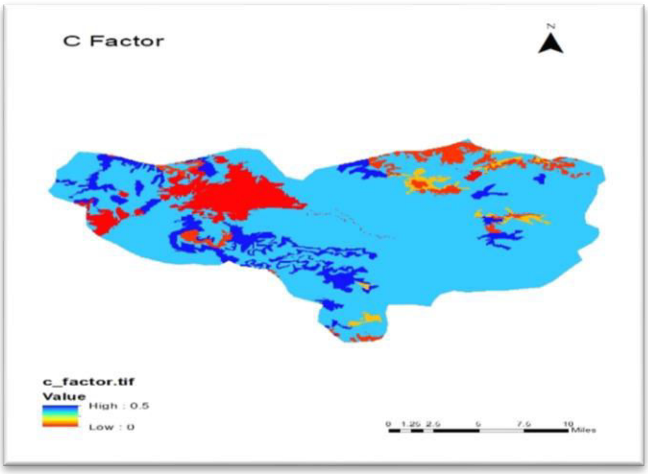

Fig 7: C factor map

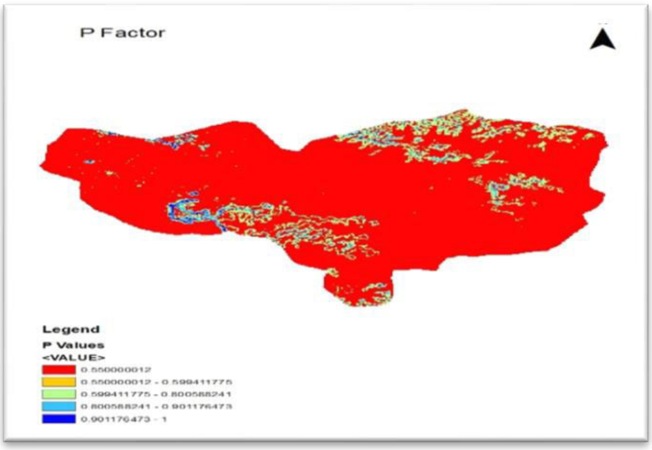

Fig 8 : P factor map

The result of 'P' factor is ranging from 0.55 to 1. From (Shin,1999) 0 value shows the good manmade soil erosion resistance practices and 1 value shows as poor manmade soil erosion resistance practices.

E. Results of Conservation Practice factor (P)

The computation of 'P' factor includes contou farming, strip cropping and terracing. The following table shows the values of support practice factor on basis of cultivation methods and slope (Shin,1999).

Table 2 : Conservation Practice Values

Slope%	Contouring	Stripcropping	Terracing
0-7	0.55	0.27	0.1
7-11.3	0.6	0.3	0.12
11.3-17.6	0.8	0.4	0.16
17.6-26.8	0.9	0.45	0.18
26.8>	1	0.5	0.2

F. Results of Soil Erosion

After getting all factors of soil loss equation the all maps are computed together in Arc.GIS and by multiplying all five factors using 'Raster Calculator' tool we get end product as Soil Erosion value in tons/ha/year.

The more than 65% of area has soil erosion 2.02927 ton/ha/year and more than 10% 0f total area has erosion value 10.5622 ton/ha/year and very low nearly less than 2% of area has erosion in vere severe condition that is 103.49 ton/ha/year.

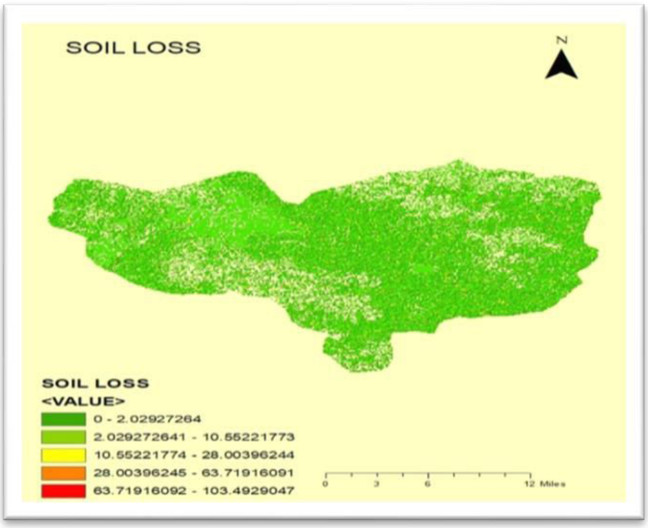

Fig 9 : Soil Erosion map

6. Conclusion

It is concluded that from the above study old and coventional techniques gives the erosion results but they are lengthy and time consuming while on other hand USLE method using softwares like GIS are easy to build the soil losses and in comparitively less time.

This study has been related with the execution of soil and water conservation practices measures in the study area as well as this value may change with change in the methodology of the study. In this study we have use all five factors of USLE formula and estimate the soil loss ‘K’ factor is estimated using Sharpley & Williams equation ‘R’ factor estimated using Ram babu equation, P factor computed based on the values given by Shin, if the methodology of the equations change the variation may occur in end results.

It is also seen that rainfall erosivity factor, conservation practices and slope of ground are main driving force in increasing soil erosion of the study area.

The soil erosion taking place in the region and its severe effects on the agriculture and crop productivity, there should be need of soil and water conservation activities. In region where the area is under severe erosion needs immediate attention and problem should be immediately solved. To avoid the loss of fertility of the land due to soil erosion, it is necessary to adopt soil conservation activities as fast as possible. The areas that are identified as moderate and minimum erosion areas also require attention and if that is ignore at this stage, then soon they may will become severe erosion areas and more practices has to perform to bring back its original condition.

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