Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 2, Number 8; April-June, 2015 pp. 649-653

http://www.krishisanskriti.org/jbaer.html

Comparison of Sediment Yield Estimation using RUSLE with Vegetation Cover Factor in a Mining Area using Geo-Informatics Approach

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Abstract—*Environmental degradation is one of the major threats faced due to mining activities. Accelerated soil erosion is resulted due to the human induced activities likes mining, construction and agricultural activities which disturb the land surface. Environmental impacts of mining include loss of biodiversity, contamination of soil, groundwater and surface water. The objective of this paper is to examine and to define the different environmental issues within the mining areas. Spatial approach will help the decision makers to estimate sediment yield and thereby identify the area vulnerable to soil erosion and to establish efficient erosion control plans. The paper deals with the study of sediment yield calculation in a watershed using RUSLE and comparison with vegetative cover factor in the mining watershed. Study on the change in hydrological regime of the area is carried out and also, amount of sediment load due to mine dumps are calculated. The relevance of this study is to monitor the mining area in terms of quantity of sediment yield generation using traditional Universal Soil Loss Equation (USLE) and the vegetation Factor method by using spatial approach of analysis. The paper compares that how much percentage of total sediment yield is contributed by mine dumps. The paper deals with the study of sediment yield calculation in watershed area, with and without vegetative cover and its comparison with existing empirical formulae. It has been observed through this comparative study the difference the quantity of sediment yield obtained by two methods mentioned above.*

Keywords: *RUSLE, Sediment Yield, Mining Dump, Arc Map*

1. INTRODUCTION

The industrial revolution which began in the 18th century was based on availability of coal to power steam engines. From those days itself environmental degradation was one of the major threats faced due to mining. Environmental impacts of mining include the loss of biodiversity, contamination of soil, ground water and surface water. Besides creating environmental pollution, the contamination resulting from leakage of chemicals also affects the health of local population.

It has been estimated that in India about 5334 m-tonnes of soil is being detached annually due to various reasons and about 113.3 m ha of land is subjected to soil erosion due to water. (Babu 1983) (Jain MK 2001)

2. STUDY AREA

The study is carried out in Chandrapur district of Maharashtra located 18° 8' and 20° 50' north latitude, 78° 8' and 80° 60' east longitude. Chandrapur district is rounded by Bhandra and Wardha in north, Godichiroli in east, yaratmal on west and Adilabad district of Telugana state in south. According to census 2011 Chandrapur had population of 2204307 with 193 people per sq.km. It has about 12 coal mine. Tadoba Sanctuary, which is famous for tiger reserve is in this region.

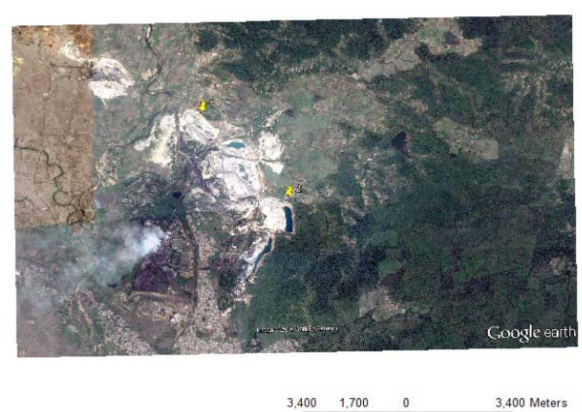


Fig. 1: Study Area: Erai Watershed

3. METHODOLOGY

RUSLE method is used to calculate soil erosion and method for calculating sediment delivery ratio is by power relation provided by vanoni,1975. (Vanoni 1975) For each plot soil erosion and sediment delivery ratio gives the sediment yield for that particular plot.

3.1 RUSLE

The Universal Soil Loss Equation (RUSLE) is one of the most significant developments in soil and water conservation in 20th century

RUSLE is expressed as,

SEi = R*K*LS*C*P

---1

where, SEi – Gross amount of soil erosion

R- Rainfall erosivity factor,

K- Soil erodibility factor,

LS- Slope steepness and length factor(dimensionless),

C- Cover management factor(dimensionless),

P- Supporting practice factor(dimensionless),

The layers for individual factor as described in RUSLE were prepared in Arc map. RUSLE factors are

3.1.1 R Factor

R is the rainfall runoff erosivity factor. it is the rainfall and runoff factor governed by geographic location. R factor for Erai sub watershed computed from rain gauge data. The daily rainfall data was collected from Indian Meteorological Department(IMD) and Maharashtra Agricultural Department of last 12 years.

Table1: Value of R factor for the period of 12 years

R factor	
2002	291.23
2003	683.84
2004	156.55
2005	456.44
2006	561.29
2007	411.6
2008	1004.15
2009	95.55
2010	369.13
2011	370.78
2012	111.525
2013	133.6
R Factor= 383	

3.1.2 K Factor

K is the soil erodibility factor. Soil erodibility factor 'K' represents both susceptibility of soil to erosion and rate of runoff as measured under standard unit plot.

$$K_f = 1.292 *[2.10*10^{-6}* fp^{1.14} *(12- P_{om})] + .325 (S_{st-2})+ .025(f_{perm}-3) \quad 2$$

In which $f_{perm=}p_{silt}(100-p_{clay})$,

f_p is the particle size parameter(unit less),

p_{om} is the present organic matter(unit less),

s_{st} is the soil structure index(unit less),

f_{perm} is the profile permeability class factor(unit less),

p_{clay} is the percent clay(unit less),

p_{silt} is the percent silt(unit less)

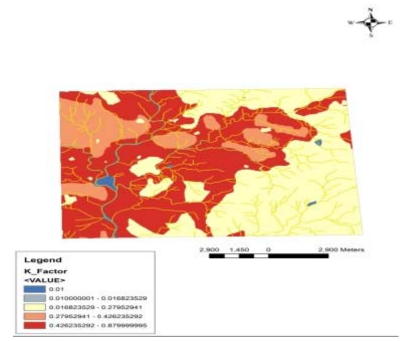
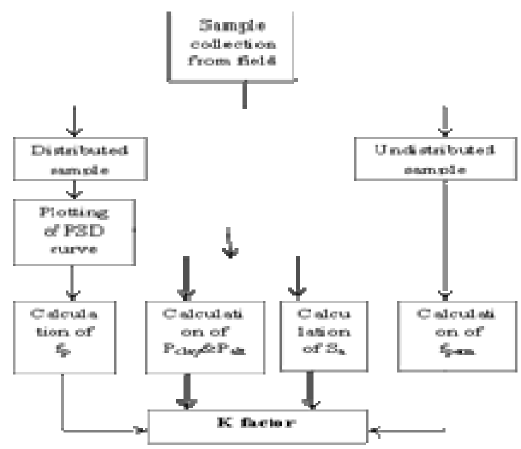


Fig. 2: K Factor



Flow chart 1: Flow chart showing steps involved in K factor calculations

Table 2: K factor for various soil types

#	Soil texture type	K Factor
1	Habitation mask	.02
2	Mining	.88
3	Gravelly sandy loam	.427
4	Sandy clay loam	.27
5	Clay loam	.28
6	Water body mask	.01
7	Sandy loam	.27
8	Gravelly sandy clay loam	.14
9	Clayey	.17

3.1.3 C Factor

The effect of vegetative cover on erosion of soil is taken in C factor. The value C=1 means absolutely no cover effect and soil loss comparable to that from bare land. The value C=0 means heavy cover effect and no soil loss

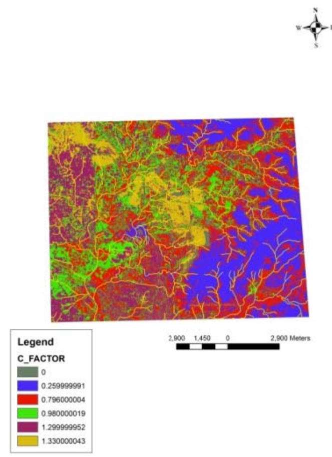
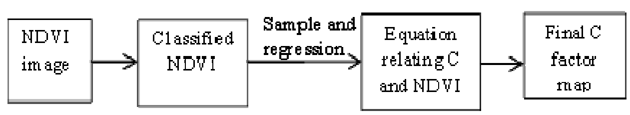


Fig. 3: C Factor



Flow chart 2: C factor calculation

C Factor = 1.14255548474972-(3.14977864202)*NDVI 3

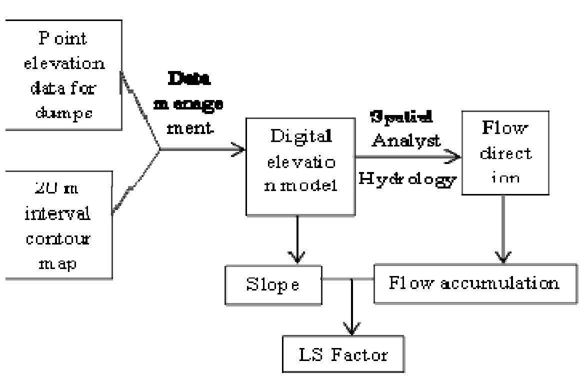
Table 3: NDVI and C Factor values for various classes

Land Class	Average NDVI value	C factor
Water Bodies	-.229	0
Dense Vegetation	.28	.259
Moderate Vegetation	.11	.796
Very Sparse Vegetation	.0506	.980
Sparse Vegetation	-.05	1.299
Barren Land	-.06	1.330

3.1.4 LS factor

The relationship between topography and soil erosion is established in LS factor. It is mainly the topographical factor.

LS factor =Pow (C flow acc)*resolution (22.1,0.6)+ Pow[sin(slope)*.01745]/(.04,1.3) -4



Flowchart 3. LS Factor calculation

3.1.5 P Factor

P factor is the ratio of soil loss with conservation practices like contouring, strip- cropping or terracing to that with straight row farming up and down the slope. For the dumps it is assumed that no special practices (terracing, contouring etc.) and the P factor simply left 1.A value of 0.7 is given for the non-dumps area to incorporate all other practices.

3.1.6 Soil Erosion (tonnes/ha/yr)

The sediment erosion map of watershed area is obtained by OVERLAY in ArcGIS with the help of mathematical functions. All the layers are converted to layer of 24m X 24m. Then overlaying using the PRODUCT function in FUZZY OVERLAYING in spatial Analysis tool box .The sediment erosion grid varies from 0 tonnes/ ha/yr to 623381.875 tonnes/ ha/yr

3.1.7 Sediment Delivery Ratio

Vanoni, 1975 provided a power relation of drainage area to sediment delivery ratio in his text *Sedimentation engineering equation (5)* (Vanoni 1975)

SDR= 0.42 A^-0.3

A= Drainage area in kms.

By using this equation sediment delivery ratio is calculated as 0.089.

3.1.8 Sediment Yield Calculation

The SDR value and gross erosion map of area as created are overlaid to generate the final sediment yield map of watershed. The value range from 0 tonnes/ ha/ yr to maximum 55481 tonnes/ ha /yr

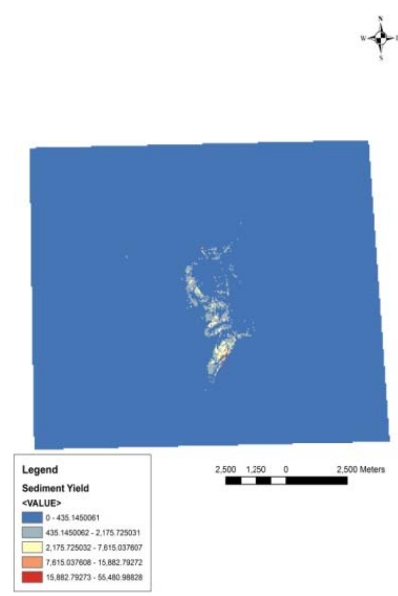


Fig. 4: Sediment Yield

4. CALCULATION OF SEDIMENT YIELD BY USING VEGETATIVE FACTOR

Sediment yield is calculated as per Garde's equation

Sediment yield, $Vs = 1.182 * 10^{6} * A^{1.03} * P^{1.129} * S^{0.08} * Q^{0.29} * D_d^{0.40} * Fc^{2.52}$ ---5

. From the land use land cover map created by using ArcGIS

MFc=(0.2F1+0.4F2+0.6F3+0.8F4+0.9F5+F6+1.2F7+0.8F8) /(F1+F2+F3+F4+F5+F6+F7+F8) --6

Where, F1 -Area under reserved and protected forest,F2 -Area of unclassified forest,F3-Cultivated area in sq.km,F4 - Grass and pasture land, F5 –Mining area, F6-Mining dump with vegetation, F7-Mining dump without vegetation, F8-Built up area.

F1=0 km^2

F2= 52.66 km^2

F3 =49.419 km^2

F4=9.4 km^2

F5=13.81 km^2

F6=3.1 km^2

F7=7.81 km^2

F8=21.41 km^2

Total area of water catchment=162.28 km^2

Modified vegetative cover factor is calculated as 0.558

4.1 Drainage density (D_d)

It is the ratio of total length of streams of all orders within the basin to the total basin area.

Length of stream of all order is 282.52km

Total area of basin is 162.28 km^2

The drainage density (D_d) is calculated as 1.741/km.

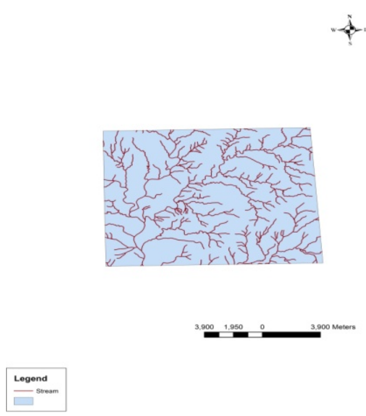


Fig. 5: Drainage density

4.2 Stream slope(S)

Stream slope, S=Total fall of main stream (T_f)/Length of main stream (L) 7

where, total fall (T_f) – Difference in elevation between the extreme end points in the main stream .

Total fall of main stream is 0.015km

Length of main stream is 4.10km

Stream slope is calculated as 0.00365

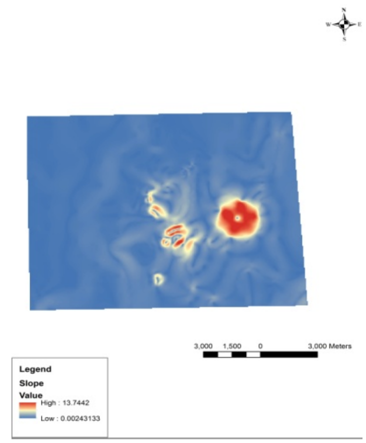


Fig. 6: Slope

4.3 Annual Runoff (Q)

Total quantity of rainfall available,

$Q_m = R_m * A$ 8

Where, A - Area of basin=162.28km^2,

R_m- Mean Annual Runoff in Cm

Q_m-Annual Runoff in Mm3

R_m =MFc*0.49(Pm - 0.5Tm) 0.59(Pm- 0.5* Tm)/ 26.5 9

Pm - mean annual precipitation obtained over a period of 12 years = 190.43Cms (Indian meteorological department IMD)

Mean annual temp, T_m=33.620℃,

Mean annual Runoff, R_m = 55.62 cm,

Q_m= 77.49 Mm3

4.4 Sediment yield

Substituting all the values for the parameters sediment yield is calculated as 237.56 m^3 /km^2/ year

5. COMPARISON OF SEDIMENT YIELD VALUES WITH EXISTING FORMULAE

The governing parameters are less in these empirical formulae. The effect of spatial variation such as the topography, soil, rainfall, vegetation of sediment yield is not reflected. The existence of the variation in the value is due to the lack of these erosion governing factors.

Table 4: Sediment Yield values

Sl No	Formula	Values m3 /km2/ year
1	JOGLEKAR (.00597)/(A^(.24))	1759.99
2	JOGLEKAR (3180*A^.72),A<2500ha	124113.18
3	Khosla(3.23*10^-3*A^.72)	126064

6. CONTRIBUTION OF MINING DUMP TO SEDIMENT YIELD

Using the zonal statistics table in the spatial analyst tool mean and summation are tabulated. The mining area covers about 1.51% of the total study area of watershed. The mean sediment yield of mining area is found to be 5129.3 tonnes/ ha/ year, the mining area contribute to around 51.5% of the total sediment yield. ArcGIS is strong tool through sediment yield rates of area can be classified into 5 field and major contributes area are identified.

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