**Integrated Journal for Research in Arts and Humanities**
ISSN (Online): 2583-1712
Volume-3 Issue-1 || January 2023 || PP. 150-163 https://doi.org/10.55544/ijrah.3.1.26

# Integrated Sediment Yield Assessment for Hirehalla Watershed in Koppal District, Karnataka, India Using Remote Sensing and GIS Techniques

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**www.ijrah.com || Vol. 3 No. 1 (2023): January Issue**

| **Date of Submission:** 05-01-2023 | **Date of Acceptance:** 21-01-2023 | **Date of Publication:** 31-01-2023 |
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**ABSTRACT**

**One measure of geomorphic activity is sediment yield, which is defined as the amount of sediment per unit area removed from a watershed by flowing water during a specified period of time. Changes in sediment yield can signal changes in many elements of the ecosystem, including rates of weathering and erosion, climate and human activity. In present research scenario application of Remote Sensing (RS) and Geographic Information System (GIS) has useful advantages for soil erosion rate assessment with proper management planning, particularly for the remote area (Sharma et al., 2001)[1]. In this study we have recorded all the necessary parameters for 26 mini watersheds of third-order streams to measure soil erosion rate in terms of sediment yield. This research work has been carried out with application of combine model of Universal Soil Loss Estimation (USLE) (Musgrave, 1947)[2] and Catchment Wise Erosion Estimation (CWEE) (Garde et al., 1985)[3] integrated with RS-GIS techniques. A sedimentation yield distribution map has been prepared. There we have considered three classes to depict erosion rate zones like High (190.56-257.8kg/ha/y), Medium (123.3-190.56kg/ha/y), Low 56.1- 123.3kg/ha/y). There highest erosion rate is at 4D3A8D2, E2, G1, I1, K1and K2 sample basins accounting 30.2%. It indicates that the high risk of soil erosion found in the Hirehalla basin. Maximum portion (69.2%) of the Hirehalla watershed falls under the medium and low rate of soil erosion zone.**

***Keywords***- Sediment yield, Remote Sensing (RS), Geographic Information System (GIS), Mini watershed.

## I. INTRODUCTION

Soil erosion is a complex dynamic process by which productive soil surface is detached, transported, and accumulated at a distant place. It produces exposed subsurface where the soil has been detached anddeposited in low-lying areas of the landscape or in water bodies downstream in a process known as sedimentation. Soil erosion and sedimentation are concurring environmental processes with varied negative and positive impacts. The negative impacts include the removal of nutrient rich topsoil in upland areas and subsequent reduction of agricultural productivity in those areas and at the same time if deposited in Lake or River bed than enhance the nutrients enrichment and reduce the storage volumes(SWALIM,2009)[4].

A number of significant studies have been carried out by different scientists and researchers of the country and also in abroad to measure the rate of soil erosion and to estimate total amount of soil loss using different models with various aspects of rill and gull erosion. Wischmeier and Smith (1972, 1978)[5,6] had applied the Universal Soil Loss Equation to measure soil erosion in the Alps Mountain belt. Douglas (1976)[7], Kirkby (1976)[8], Morgan (1976)[9], Cooke and Doornkamp (1978)[10], Gerrard (1981)[11], Hudson (1981)[12], Parsons (2005)[13], Stone and Hilborn (2000)[14], Blanco and Lal (2008)[15] have focused on soil erosion, erosion factors and erosion risk incorporating different types of model. At regional level,Jha and Kapat (2003, 2009, and 2011)[16,17,18], Ghosh and Bhattacharya (2012)[19], Ghosh and Guchhait(2012)[20] predicted the erosion rate of lateritic soils of the Birbhum District using USLE model. Some of the researchers estimated soil loss from catchment areas for measuring basin wise sediment production rate and related fluvio-geomorphological studies (Jain and Kothyari, 2000; Jain et al., 2001; Suresh et al.,

 

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2004)[21][22][23]. In present research scenario, application of RS-GIS has useful advantages for soil erosion rate assessment with proper management planning, particularly for the remote area (Sharma et al., 2001)[1]. This research work has been carried out with application of combine model of USLE (Musgrave, 1947)[2] and CWEE (Garde et al., 1985)[3] integrated with RS-GIS techniques.

## II. DESCRIPTION OF THE STUDY AREA

The study area is one of the sub basins of Tungabhadra river basin. It is situated in the south western part of Koppal district covering parts of Gangavathi, Kustagi, Yelburga and Koppal talukas in Karnataka of India. It lies between longitudes $76^0$ 9' 11''and $76^0$ 46' 5''E and latitudes $15^0$ 29'38'' and $15^0$49'5'' N and extent of area covered is 724.37 Sq.kms and comprises of twenty six mini watersheds draining into Tungabhadra river in Koppal district of Karnataka. Study area is having maximum elevation of 610 m and a minimum of 380 m above mean sea level. The district is well connected by highways and other main roads. The average depth of annual rainfall in the study area is 584.6mm (Averaged over 40 years).The area experiences a temperature of $17^0$ C in winter and a temperature as high as $42^0$ C in summer. Heavy winds are blown during June to October period at a speed of about 30 Km/hr(IWMP report,2010).The location map of the study area is shown in Fig.1

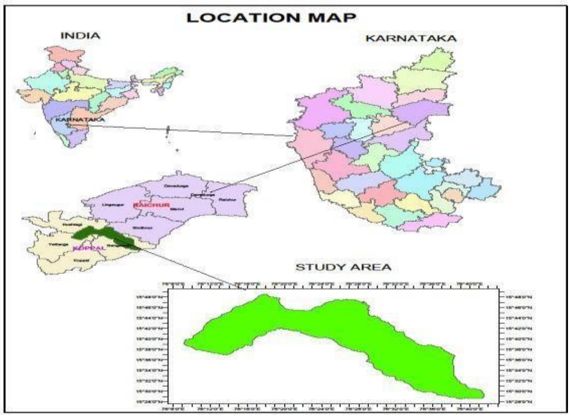


**Figure.1: Location Map of Study Area**

## III. METHODOLOGY

### *3.1 Data Collection*

Survey of India (SOI) top maps, Indian Remote Sensing satellite data (CARTOSAT and LISS IV) and collateral data were used for the present study. The various topographic maps that were used for the analysis of the study area that covers Hirehalla catchment are Survey of India Topographical map **57A** on 1: 250000 scale and **56A/2,A/5,A/6,A/9,A/10,A/11** on 1:50000 scale.

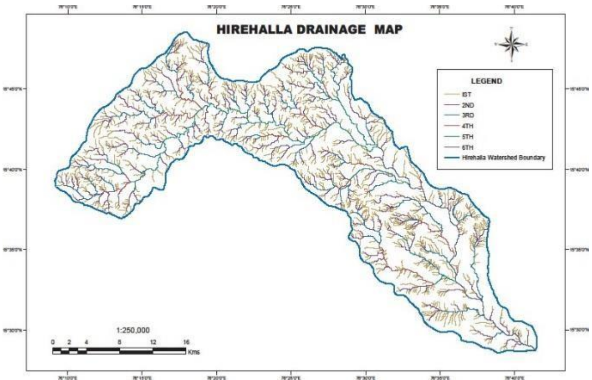


**Figure 2: Drainage pattern of the Study Area**

The digitization of drainage pattern(Fig.3) was carried out in GIS environment. The stream ordering was carried out using the Strahler (1964)[24] law. The fundamental parameters namely; stream length, area, perimeter, number of streams and basin length were derived from the drainage layer. The morphometric parameters for the delineated watershed area were calculated based on the formula suggested by Horton (1945)[25], Strahler (1964)[24], Hardly (1961)[26}, Schumn (1956)[27], Nookaratanm et. al. (2005)[28] and Miller (1953)[29].

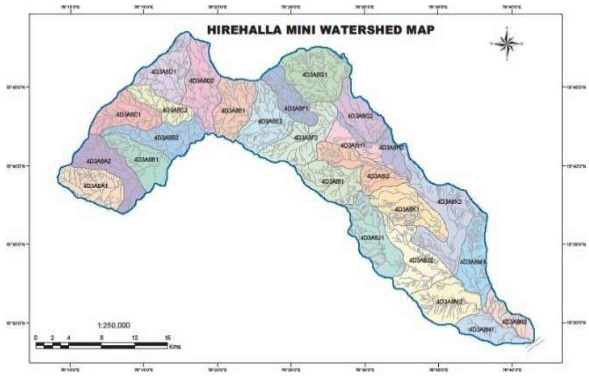


**Figure 3: Miniwatershed delineation of the study area**

### *3.2 Vegetative Cover Factor*

Vegetative cover factor is determined from the land use/land cover map(Fig.5). It is one of the parameters used for the computation of sediment yield. Vegetative cover factor is inversely proportional to the sediment yield.

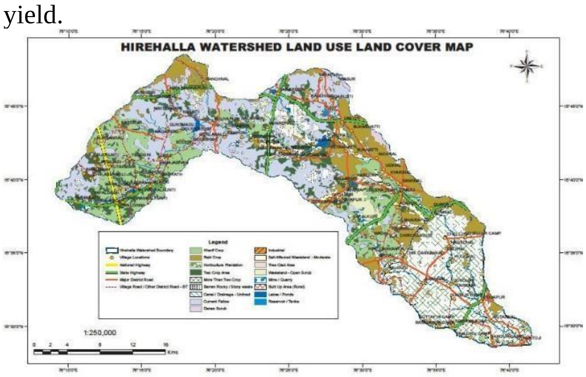


**Figure 4: Land Use and Land Cover Map of Hirehalla**

 

Watershed of Koppal District The vegetative cover factor is given by

$$Fc = 0.2F1+0.2F2+0.6F3+0.8F4+F5/F1+F2+F3+F4+F5 \quad 1$$

Where, F1 = Reserve & protected forest area in Sq. Km
F2 = Unclassified forest area in sq Km
F3 = Cultivated area in sq Km
F4 = Grass and pasture land in sq Km
F5 =Waste land in sq Km

### *3.3* ANNUAL RAINFALL

Monthly normal rainfall data at different weather stations in the watershed for a period of 50 years is collected. The normal annual rainfall from 1941 to 1990 of Hirehalla watershed is shown in the table and Average annual rainfall between 1941-1990 is 584.26 mm. Average annual rainfall between 2000-2010 is 554.2mm(Table.1).

**Table.1: Average annual rainfall**

| | **Actual Annual Rainfall from 2000 to 2010 (mms)** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Talukas** | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** |
| **Gangavathi** | 529.2 | 557.3 | 290.7 | 362.4 | 426.3 | 452.3 | 242.6 | 582.2 | 453.7 | 948.0 | 690.0 |
| **Koppal** | 651.0 | 614.8 | 402.4 | 309.9 | 462.4 | 649.5 | 348.8 | 824.2 | 573.3 | 917.0 | 871.0 |
| **Kushtagi** | 621.7 | 469.2 | 420.1 | 311.3 | 435.0 | 557.2 | 371.9 | 879.8 | 611.5 | 913.0 | 702.0 |
| **Yelburga** | 606.3 | 468.6 | 353.9 | 308.7 | 547.8 | 496.7 | 300.6 | 627.7 | 592.2 | 902.0 | 737.0 |
| **Total** | 602.1 | 527.5 | 366.8 | 323.1 | 467.9 | 538.9 | 316.0 | 724.4 | 557.7 | 921.0 | 751.0 |

**Source:** Indian Metrological Department

Average annual rainfall analysis over last 50 years (1941-1990) and recent fast 10 years (2000-2010) reveals that there is decreasing trend from 584.3mm to 554.2mm and mean temp is $24.2^0$C.

### *3.4 Computation of Runoff*

The Runoff formula developed by Garde et al., (1985)[3] is used in the present investigation. Runoff obtained by this formula is accurate and reliable for estimation of sediment yield using remote sensing techniques. The parameters involved in the computation of runoff are annual rainfall, mean temperature and vegetative cover factor

The Garde formula for runoff is

$$Rm = FC^{0.49} (Pm - 0.5Tm)^{1.59}/26.5 \quad 2$$

Where, FC =Vegetative cover factor: Pm=Annual Precipitation in cm Tm=Mean temperature $^O$ C:Rm = Mean annual runoff in m

Total annual runoff volume generated is given by

$$Qm = Rm \times A \quad 3$$

Where, Qm = Annual runoff in $Mm^3$: A = Area of the basin in $m^2$

### *3.5 Sediment Yield Model Used*

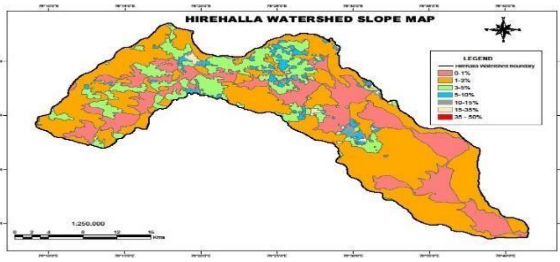


**Figure. 5: Slope Map of Hirehalla Watershed of Koppal District**

Using CWEE method Garde et al., (1985)[3] already prepared an iso erosion factor curves map for the whole India. But, as per Garde et al., (1985)[3] these values have less than ±30 percent error for 90 percent of data. As the importance of erosion factor (Fc) for estimation of soil erosion rate is noteworthy therefore it is very much essential to take accurate erosion factor value. To eradicate this error, Universal Soil Loss Estimation (USLE) model has been superimposed on the CWEE. The model of USLE has worldwide acceptance for the estimation of soil loss. Major parameters of soil erosion are directly or indirectly connected with soil characteristics which is applied in this model.

**A= R*K*LS*C*P**

Where, A= average annual soil loss (tonnes/ha./y)
R= rainfall erosivity factors: K= soil erodibility factor; L= slope length factor; S= slope steepness factor;
C= crop management factor, and P= soil conservation practice factor.

In the Grade's model, the parameters like runoff, rainfall, drainage density(Fig.3), and slope(Fig.6) are used, which are more or less similar to the USLE's R, L, S parameters. CWEE model did not mention the geological condition of an area but that is so important for the erosion factor calculation. Therefore, K factor of USLE model has been joined with Fc value of CWEE model. Grade et al., (1985)[3] used land use/ land cover data for the large catchment areas and prepared iso-erosion factor curve for all over the India. And hence in a micro level study it is not suitable. In this respect, C and P factors of USLE model are used and also joined with Fc value of CWEE model.

$$Vs = 1.182x10^{-6} x A^{1.026} x P^{1.289} x Q^{0.287} x S^{0.075} x Dd^{0.398} x Fc^{2.422} \quad [4]$$

Where,Vs== Annual sedlment yield (t/ha/yr): A= Watershed area ha
P =Annual Rainfall (cm): Q =Annual runoff ($Mm^3$)

S = Slope of the watershed in %: Dd = Drainage density

 

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(Km/Km$^2$) and Fc = Vegetative cover factor

**Table.4 Soil Erosion Rate of Hirehalla sub watersheds**

| Sl. NO | Watershed Code | Area (A) ha | Annual Runoff (Q) M m$^3$ | Drainage Density( Dd) KM/KM² | Slope % | Fc (Garde, 1985) | K t/ha/ y | C | P | Mean Fc | Vsab t/ha/year | Vsab kg/ha/year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4D3A8A1 | 2774 | 3.29 | 2.61 | 0.69 | 0.61 | 0.13 | 0.38 | 0.43 | 0.39 | 0.14607 | 146.1 |
| 2 | 4D3A8A2 | 2983 | 3.53 | 0.77 | 0.66 | 0.61 | 0.14 | 0.37 | 0.43 | 0.39 | 0.09846 | 98.5 |
| 3 | 4D3A8B1 | 2696 | 3.22 | 1.50 | 0.70 | 0.62 | 0.15 | 0.37 | 0.45 | 0.40 | 0.12037 | 120.4 |
| 4 | 4D3A8B2 | 2857 | 3.36 | 1.90 | 0.68 | 0.60 | 0.14 | 0.37 | 0.41 | 0.38 | 0.12521 | 125.2 |
| 5 | 4D3A8C1 | 2564 | 3.04 | 1.64 | 0.72 | 0.61 | 0.15 | 0.36 | 0.43 | 0.39 | 0.10983 | 109.8 |
| 6 | 4D3A8C2 | 1647 | 1.95 | 2.19 | 0.78 | 0.61 | 0.14 | 0.36 | 0.45 | 0.39 | 0.06930 | 69.3 |
| 7 | 4D3A8D1 | 3096 | 3.67 | 2.08 | 1.08 | 0.61 | 0.13 | 0.37 | 0.43 | 0.39 | 0.15940 | 159.4 |
| 8 | 4D3A8D2 | 3266 | 3.96 | 2.09 | 1.47 | 0.64 | 0.14 | 0.35 | 0.50 | 0.41 | 0.19918 | 199.2 |
| 9 | 4D3A8E1 | 2872 | 3.43 | 2.37 | 0.91 | 0.62 | 0.13 | 0.35 | 0.49 | 0.40 | 0.16003 | 160.0 |
| 10 | 4D3A8E2 | 3191 | 4.02 | 2.34 | 1.07 | 0.69 | 0.12 | 0.34 | 0.55 | 0.43 | 0.22390 | 223.9 |
| 11 | 4D3A8F1 | 1941 | 2.63 | 2.15 | 1.41 | 0.80 | 0.10 | 0.18 | 0.66 | 0.44 | 0.12422 | 124.2 |
| 12 | 4D3A8F2 | 3313 | 4.05 | 1.94 | 0.83 | 0.65 | 0.13 | 0.37 | 0.50 | 0.41 | 0.18920 | 189.2 |
| 13 | 4D3A8G1 | 4126 | 4.97 | 2.46 | 1.66 | 0.63 | 0.12 | 0.35 | 0.46 | 0.39 | 0.25778 | 257.8 |
| 14 | 4D3A8G2 | 2279 | 2.76 | 1.65 | 1.29 | 0.64 | 0.13 | 0.35 | 0.45 | 0.39 | 0.09913 | 99.1 |
| 15 | 4D3A8H1 | 1360 | 1.63 | 1.95 | 1.04 | 0.62 | 0.17 | 0.37 | 0.45 | 0.40 | 0.05611 | 56.1 |
| 16 | 4D3A8H2 | 1406 | 1.74 | 1.89 | 1.70 | 0.67 | 0.16 | 0.36 | 0.53 | 0.43 | 0.0722 | 72.2 |
| 17 | 4D3A8I1 | 2836 | 3.55 | 2.41 | 1.14 | 0.68 | 0.13 | 0.35 | 0.52 | 0.42 | 0.18383 | 183.8 |
| 18 | 4D3A8I2 | 2669 | 3.38 | 2.09 | 1.42 | 0.70 | 0.14 | 0.33 | 0.56 | 0.43 | 0.17320 | 173.2 |
| 19 | 4D3A8J1 | 3674 | 4.49 | 1.98 | 0.98 | 0.65 | 0.14 | 0.38 | 0.51 | 0.42 | 0.23451 | 234.5 |
| 20 | 4D3A8J2 | 3398 | 4.03 | 2.17 | 1.23 | 0.61 | 0.16 | 0.38 | 0.37 | 0.38 | 0.17372 | 173.7 |
| 21 | 4D3A8K1 | 3212 | 3.99 | 2.45 | 1.49 | 0.67 | 0.15 | 0.35 | 0.52 | 0.42 | 0.22183 | 221.8 |
| 22 | 4D3A8K2 | 5061 | 6.00 | 2.07 | 0.82 | 0.61 | 0.17 | 0.38 | 0.36 | 0.38 | 0.27900 | 279.0 |
| 23 | 4D3A8M1 | 2750 | 3.26 | 1.61 | 0.46 | 0.61 | 0.17 | 0.38 | 0.44 | 0.40 | 0.12288 | 122.9 |
| 24 | 4D3A8M2 | 3156 | 3.71 | 2.04 | 0.43 | 0.60 | 0.17 | 0.38 | 0.42 | 0.39 | 0.15102 | 151.0 |
| 25 | 4D3A8N1 | 1868 | 2.23 | 1.24 | 0.58 | 0.62 | 0.17 | 0.38 | 0.45 | 0.41 | 0.07214 | 72.1 |
| 26 | 4D3A8N2 | 1442 | 1.74 | 1.99 | 0.33 | 0.63 | 0.17 | 0.38 | 0.47 | 0.41 | 0.05961 | 59.6 |
| | Total | 72437 | | | | | | | | | | |

**Table.5 Soil Erosion Risk of Hirehalla sub watersheds**

| Sl.No | Subwatershed | Risk of erosion | Percentage of Area |
|---|---|---|---|
| **1** | 4D3A8D2,E2,G1,J1,K1,K2 | High | 30.8 |
| **2** | 4D3A8A1,B2,D1,E1,F1,F2,I1,I2,J2,M2 | Medium | 40 |
| **3** | 4D3A8A2,B1,C1,C2,G1,H1,H2,M1,N1,N2 | Low | 29.2 |


**Figure.6 Map of Soil Erosion Risk distribution of Hirehalla sub watersheds**

## IV. RESULTS AND DISCUSSION

In this study we have recorded all the necessary parameters for 26 third-order streams to measure soil erosion rate in terms of sediment yield with the help of combine model of USLE (Musgrave, 1947)[2] and CWEE (Gardeet al., 1985)[3] integrated with RS-GIS techniques is presented in Table.4. A sedimentation yield distribution map has been prepared. There we have considered three classes to depict erosion rate zones like High (190.56- 257.8kg/ha/y), Medium (123.3-190.56kg/ha/y) and Low (56.1-123.3kg/ha/y). There highest erosion rate is at 4D3A8D2, E2, G1, I1, K1and K2 sample basins accounting 30.2%. It indicates that the high risk of soil erosion found in the Hirehalla basin. Maximum portion (69.8%) of the Hirehalla watershed falls under the medium and low rate of soil erosion zone, which indicates better opportunity for a proper land use planning and agricultural practices

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