Estimation of Soil Erosion in Doddahalla Watershed, Chitradurga, Karnataka, Using Revised Universal Soil Loss Equation (RUSLE) and GIS

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Abstract: - To Estimate the soil erosion in Doddahalla watershed an integrated approach has been adopted using Revised Universal Soil Loss Equation (RUSLE) model and geographic information system (GIS) techniques. The rate of erosion calculation requires a much amount of information and data from various sources. The overlay of Land use and Land Cover, Soil Map, rainfall-runoff erosivity factor, soil erodibility factor, Crop Management Factor, slope length factor, Topographic factor and Conservation practice factor (P) results that the high amount of soil loss (615 tonn h-1 y-1) is significantly low and occupies 92% of the entire study area. It is concluded that 92% area of soil erosion rate is tolerable and has a low risk of erosion. Use of the erosion severity information coupled with basin wide individual RUSLE parameters can help to design the appropriate land use management practices and improved management based on the observations to minimize soil erosion in the basin. The study demonstrates that the use of remote sensing data and GIS has a huge advantage in predicting soil erosion rate for the sustainability and management planning of Doddahalla Watershed in Karnataka region.

Key Words: — ***RUSLE, GIS, Rainfall-Runoff Erosivity, Topographic Factor, Crop Management Factor.***

I. INTRODUCTION

Nowadays one of the major problems on global scale is the rapidly increasing demand to the food. This demand is of course totally parallel to the population growth. Even more land is used for agricultural purposes day by day. Cultivation without using specific control techniques, unplanned land use, such as establishing industrial facilities or constructing summer houses on the agriculture land, uncontrolled urban development and also destroying forests are fundamental factors of soil erosion (Biard and Baret, 1997).

Soils are the basis of support for most life, and a source of nutrients for marine life and fresh water. "Soil is basically broken-down rock materials and consists of decomposed rock debris and decayed organic matter (humus) which have been produced by weathering ".The process of destruction of soil and the removal of the destroyed soil material constitute soil erosion. Soil erosion is one form of soil degradation along with soil compaction, low organic matter, loss of soil structure, poor internal drainage, and salinization and soil acidity problems. Soil erosion is a naturally occurring process on all land and it becomes a problem when human activity causes it to occur much faster than under natural conditions.

Evaluating soil erosion risks is a difficult undertaking task due to several concurrent processes, which affects individually other multifaceted interactions and continues at amounts that vary in both time and space. Since the 1960s and on, soil decision-makers and scientists have examined models for calculating soil loss from erosion by water from rainwater, a hill slope, or a minor catchment. With the presence of GIS competencies, the efforts have been directed to be based on spatially distributed models simulating erosion dynamics and surface runoff of more complex and larger catchments.

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Several models have been developed and used for either research or operational purposes. Some of the most known soil erosion models are USLE (Universal Soil Loss Equation, 1965), EPIC (Erosion/Productivity Impact Calculator, 1984), EUROSEM (European Soil Erosion Model, 1993), RUSLE (Revised Universal Soil Loss Equation, 1997), Rill Grow (a model for rill initiation and development, 1998), SEMMED (Soil Erosion Model for Mediterranean Regions, 1999), EGEM (Ephemeral Gully Erosion Model, 1999), PESERA (Pan-European Soil Erosion Risk Assessment, 2003), and so forth.

Soil erosion models can be distinguished as mechanistic (or process based) when they simulate the physical erosion processes by specific formulas or empirical when they calculate erosion based on regression of soil loss based on the physical properties of land and climate features. They also can be characterized as dynamic when the time is a contained parameter. Long-term models are based on accumulated temporal data while event-based models describe single events. The soil erosion estimation models are focused on the identification and quantification of the erosion processes and the controlling factors, resulting in the sequential erosion models development beginning with the universal erosion equation (USLE) realized by Wischmeier and Smith [11], followed by a modified equation (MUSLE) for the quantification of the alluvium resulting from erosion following each rainfall realized by Williams, and eventually computerized and more complex equation (RUSLE) developed by Renard et al.

II. The Study Area And Materials

2.1 Study Area

Doddahalla watershed (Ibrahim-Bathis et al,2016) a rural watershed lies in Karnataka State of India and has a total watershed area of about 1082 sq kms. The Doddahalla River originates at an altitude of about 780 m and joins with the Tungabhadra River at an altitude of about 510 m. The terrain is characterized by an undulating topography with occurrences of hills, linear ridges and plain lands. The dominant soil groups existing in the watershed are black soil, red soil and red loamy soil. In general, the top soil depths appear to be shallow and at places of higher altitudes pediments and rock out crops are covered with very thin soil.

The watershed falls under semiarid climatic zone with an average annual rainfall of about 500 mm. The agriculture is mainly rainfed and at places irrigated by tanks. Besides, other vegetation include eucalyptus plantations and open scrub under degraded conditions within forest boundaries and the native vegetation.

The Doddahalla watershed is part of Krishna basin in southern India. The watershed covering an area of 1082 sq km lying in between Chitradurga, Hiriyur and Challakere taluk of Chitradurga district in Karnataka. Chronically, the study area is drought-prone with a mean annual rainfall of 688 mm. Agriculture and several of the other economic activities largely depend on rainfall. Geographically the area extends between 76°21'14.95"E to 76°50'34.82"E longitude and 14°4'9.42"N 14°25'24.19" N latitude. Undulating plains with a gentle slope cover the major part. Clay, clay loam, sandy clay and silt clay are major soils, and different food crops are the major agricultural practice.

Seventy-eight percent of the total area belongs to agricultural land that includes agricultural plantation and various other cash crops. Sixty percent of the net crop land belongs to Kharif season that entirely depends on rainfall. Double crops practices only along the tanks and stream where there is an abandoned source of water.

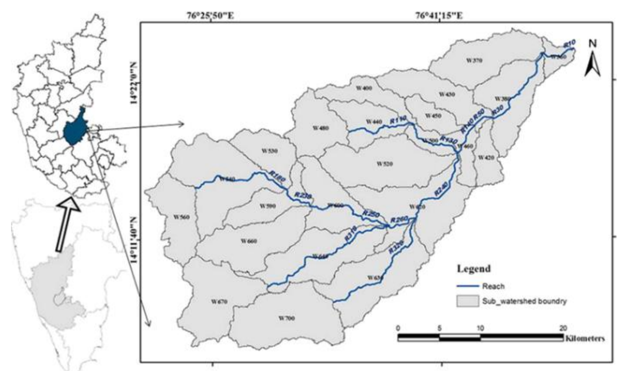

Fig.1. Location Map of Doddahall watershed, Chitradurga district

2.2 Materials

The total catchment area of Doddahalla watershed falling in Karnataka (1028 Sqkm) was delineated taking into consideration the contour map and drainage map. The Landsat 8, cartosat DEM and IRS LISS III images are used in Erdas Imagine 9.2 and ARC GIS 10.5 were used for generation of various thematic layers namely contour map, drainage map, landuse/land cover map and other data sets of the study area. The dominant model applied worldwide to soil loss prediction is USLE/RUSLE, because of its convenience in application and compatibility with GIS.

Therefore, soil erosion within each pixel was estimated with the RUSLE. Rainfall data is used for generated rainfall index.

III. METHODOLOGY

The estimation of soil erosion, the rainfall data of 10 years (2005-2014) were procured from the Indian Meteorological Department (I.M.D) from which the rainfall runoff erosivity factor (R-factor) was estimated. The Cartosat-I DEM with 30m spatial resolution was used to prepare the slope map and the flow accumulation map of the study area, which were then used for preparing the LS factor map in ArcGIS. The errors in the DEM represented as sinks were rectified using the fill tool in the GIS software.

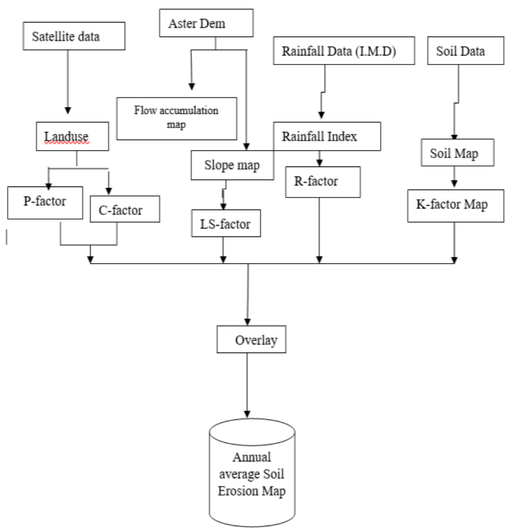

Fig.2. Flow chart of Methodology

3.1 Land Use Land Cover (LU/LC)

Spatiotemporal LU/LC changes are investigated from the integrated use of remote sensing and GIS in Doddahalla watershed The LU/LC was classified by onscreen digitizing using visual image interpretation techniques with regional knowledge of the real –time Google earth images. Standard LU/LC codification implemented up to level III, using multi-temporal images from Landsat satellite series, MODIS and IRS LISS III. Digital image processing methods like supervised classification and NDVI were performed for different season data (Nischitha et al,2014). The study shows that remote sensing and GIS are useful and efficient tools to study the dynamics of LU/LC change analysis carried out with accuracy assessment. The accuracy of the classified image is checked through field information along with the Google Earth visualization and pre-existing maps. Most of the area is classified under cropland consisting of Kharif, Rabi and double crops.

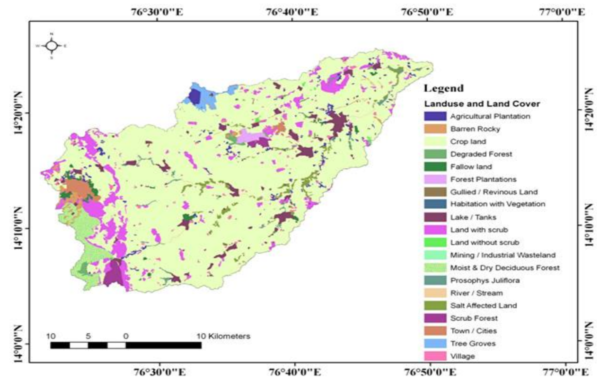

Fig.3. Land use and Land cover Map of Daddahalla watershed

Table.1. Land use and Land cover of Doddahalla Watershed Area

Land use and Land Cover	Area in sq km
Agricultural Plantation	17
Barren Rocky / Stony Waste / Sheet Rock Area	10
Crop land	820
Degraded Forest	4
Fallow land	9
Forest Plantations	5
Gullied / Revinous Land	1
Habitation with Vegetation	0
Lake / Tanks	37
Land with scrub	79
Land without scrub	1
Mining / Industrial Wasteland	0
Moist & Dry Deciduous Forest	32
Prosophys Juliflora	7
River / Stream	4
Salt Affected Land	16
Scrub Forest	10
Town / Cities	11
Tree Groves	10

3.2 Soil

A soil map of the study area is prepared and updated from the district soil map obtained from the Zilla Panchayat office at Chitradurga. The soils found in the area are sandy loam (31 %), sandy clay loam (23 %), and clay (20 %). Soils are further classified into four hydrological soil groups A, B, C and D (HSG) as per their infiltration rate .The major part of the area is covered by Sandy clay and clay loam.

Table.2. Soil Texture of Doddahalla Watershed area.

Soil Texture	**Area in sq km**
CLAY	259.349
CLAY LOAM	56.825
GRAVELLY LOAMY SAND	1.516
HABITATION MASK	20.682
LOAMY SAND	153.271
ROCK OUTCROPS	6.352
SANDY CLAY LOAM	224.315
SANDY LOAM	259.877
SILTY CLAY LOAM	59.819
WATER BODY MASK	39.985

Table.3. Classification of hydrological soil group based on the soil texture (USDA 1986; Kumar et al. 1997; Prakasa Rao et al. 2011)

HGS	**Infiltration rate**	**(mm/h)**	**Soil Texture**
A	High	>25	Sand,loamy sand, or sandy loam silt
B	Moderate	12.5-25	Loam or loam Sandy clay, loam clay
C	Low	2.5-12.5	Loam, silty clay loam, sandy clay.
D	Very low	<2.5	Silty clay or clay

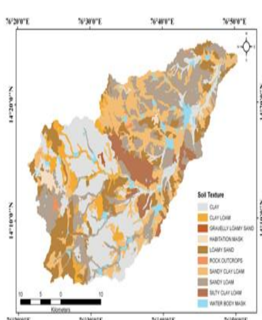
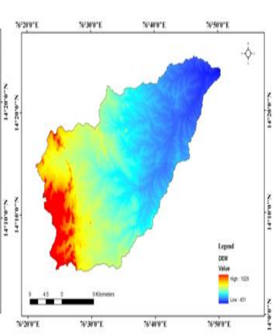

Fig.4. Soil Map of Doddahalla Watershed Fig.5. Dem Image of Doddahalla Watershed.

3.3 Data processing and RUSLE factors generation

The USLE/ RUSLE model has been widely used for both agricultural and forest watersheds to predict the average annual soil loss. It is a non-data-demanding and less expensive erosion model; therefore it can be fed by data usually available in institutional databases, such as low or medium spatial resolution satellite images and limited rainfall data etc. The methodology used in the present work was the implementation of USLE equation in a raster GIS environment for the calculation of specific factors and annual soil loss of the area under investigation. The climatic and terrain factors which are used in the equation were derived from rainfall data collected from Indian Meteorological Department (IMD), satellite image, soil texture map of soil survey organization. The cell size of all the data generated was kept in to 30 m x 30 m, in order to make uniform spatial analysis environment in the GIS.

The RUSLE method is expressed as:

$$A=RxKxLSxCxP$$

where A is the computed spatial average of soil loss over a period selected for R, usually on yearly basis ($tha^{-1}y^{-1}$); R is the rainfall-runoff erosivity factor ($MJ\ mm\ ha^{-1}\ h^{-1}\ y^{-1}$); K is the soil erodability factor ($t\ hah\ ha^{-1}\ MJ^{-1}\ mm^{-1}$); LS is the slope length-steepness factor (dimensionless); C is the cover management factor (dimensionless, ranging between 0 and 1.5); and P is the erosion control (conservation support) practices factor(dimensionless, ranging between 0 and 1).

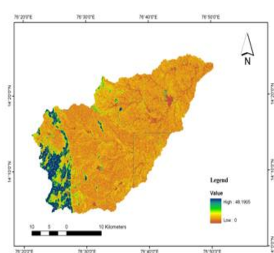
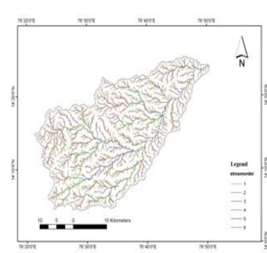

Fig.6. Slope Map of Doddahalla Watershed. Fig.7. Drainage Map of Doddahalla Watershed.

3.4 Rainfall Erosivity (R)

The rainfall factor, an index unit, is a measure of the erosive force of a specific rainfall. This is determined as a function of the volume, intensity and duration of rainfall and can be computed from a single storm, or a series of storms to include cumulative erosivity from any time period. Raindrop/splash erosion is the dominant type of erosion in barren soil surfaces. Rainfall data of 10 years (2005-20014) collected from Indian

Meteorological Department (IMD) were used for calculating *R*-factor using the following relationship developed by Wischmeier and Smith (1978) and modified by Arnoldus (1980):

$$R = \sum_{i=1}^{12} \quad 1.735 * 10^{\left(1.5 log\left(\frac{pi2}{p}\right) - 0.08188\right)} \qquad (1)$$

Where R is the rainfall erosivity factor (MJ mm ha^{-1} h^{-1} y^{-1}), *P*i is the monthly rainfall (mm), and P is the annual rainfall (mm). For the present analysis, *R*-factor for the watershed was computed from available rain gauge data, because the watershed has no record of daily rainfall intensity. The spatial interpolation techniques available in the ArcGIS software were used along with rainfall data of faraway rain gauge stations for assessing the spatial variability in the rainfall and rainfall erosivity in the study area.

Table.4. Annual rainfall data with average R-factor (MJ mm ha ^{1} h ^{1} y ^{1}).

Year	Rainfall Erosivity
2005	2132.706
2006	352.8496
2007	1165.17
2008	748.7362
2009	1338.946
2010	1664.764
2011	261.3482
2012	1503.419
2013	2386.124
2014	1378.433

While assessing the R-factor, it was found that, the variation of R-factor among the rain gauge stations were in the limit of ±3. In order to make the *R*-factor value most reliable, the spatial distribution of *R* was calculated from the available rainfall data by considering that the area experiences relatively uniform rainfall, both in intensity and duration across the study area and the average R value was used for further calculation.

The Rainfall erosivity factor *(R)* for the years 2005-2014 was found to be in the range of 261.34-2386.12 MJ mm ha^{-1} h^{-1} y^{-1}. The average R-factor was observed to be 1293.25 MJ mm ha^{-1} h^{-1} y^{-1}. The highest value (2386.12 MJ mm ha^{-1} h^{-1} y^{-1}) of R-factor was observed in 2013 and the lowest value (261.34MJ mm ha^{-1} h^{-1} y^{-1}) was in 2011.

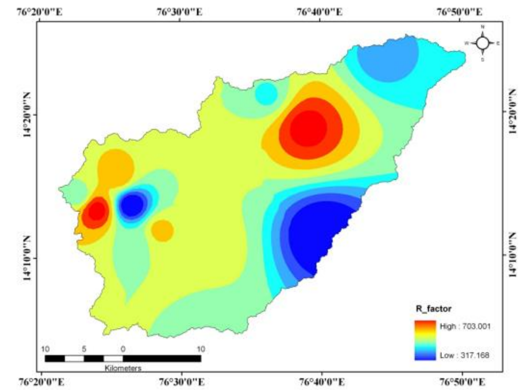

Fig.8. Rainfall Erosivity Map of Daddahalla Watershed.

3.5. Soil erodability factor (K)

The K-factor was calculated using the following relationship (Foster et al. 1991):

K = 2.8 x 10^{-7} x $M^{1:14}$ x (12 - a) + 4.3 x 10^{-3} x (b - 2) + 3.3 x (c - 3) (3)

Where, K =soil erodibility factor, t ha h ha^{-1} MJ^{-1} mm^{-1}, M=particle size parameter (per cent silt+per cent very fine sand) x (100 - per cent clay), a=organic matter content (per cent), b=soil structure code and c =soil permeability class. Percentage of sand, silt and clay was determined based on the soil types present in different sub watersheds using USDA triangle of soil. The different types of soils present in this area. The watershed has negligible content of very fine sand. Therefore, the content of silt and clay was only considered for calculating M. The organic matter content was calculated using SPAW software. The K-factor values were used to calculate weighted K-factor, which was used finally for the estimation of soil loss for different sub watersheds. The soil structure code for the entire watershed was considered to be medium or coarse granular for which the value was 3. The soil permeability class was considered moderate whose value was 3. Soil erodibility factor was found to be in the range of -3.36 to 9.99. The magnitude and the spatial distribution of soil erodibility (K) are presented in Fig 8.

Different soil types are naturally resistant and susceptible to more erosion than other soils and are function of grain size, drainage potential, structural integrity, organic content and cohesiveness. Erodability of soil is its resistance to both detachment and transport. Because of thick forested nature of the watershed, detailed field surveys of soils in the area were not possible. So a generalized soil texture map collected from the soil survey organization, used for the preparation of K factor map and the soil types are grouped into six major textural classes viz., sandy clay loam, sandy loam, clay loam, clay, loamy sand and silty clay loam. The corresponding K values for the soil types were identified from the soil erodability nomograph (USDA 1978) by considering the particle size, organic matter content and permeability class. The estimated K values for the different textural groups and soil erodobility are shown in table 5 and table 6.

Table.5.watershed showed different texture, Permeability code, saturated hydraulic conductivity, and Hydraulic Soil group

Texture	Permeability code	Saturated hydraulic conductivity(in/hr)	Hydraulic Soil group
Silty clay, clay	6	<0.04	D
Silty clay loam, sandy clay	5	0.04-0.08	C-D
Sandy clay loam, clay loam	4	0.08-0.2	C
Loam, silt loam	3	0.2-0.8	B
Loamy sand, sandy loam	2	0.8-2.4	A
Sand	1	>2.4	A+

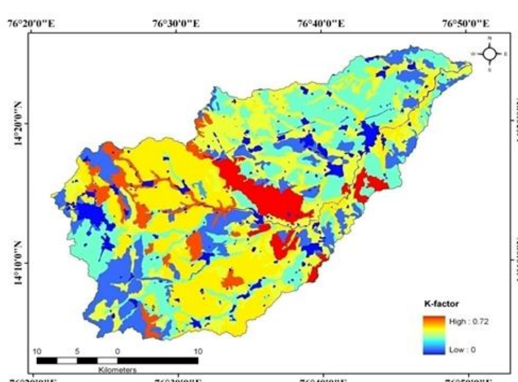

Fig.9. Soil Erodibility Map of Doddahalla watershed.

Table.6. Watershed consisted different soils and soil erodibility are shown below.

Types of soil	Soil Erodibility (tonn ha^{-1})
Sandy clay loam	0.45
Sandy loam	0.29
Loamy sand	0.09
Clay	0.49
Clay loam	0.67
Silty clay loam	0.72

Source: Ministry of Agriculture, food and rural affairs

3.6. Topographic factor (LS)

Slope length factor (L) the L-factor was calculated based on the relationship developed by McCool et al. (1987). The equation follows as:

$$L = (\ell/22.13)^m \quad (4)$$

where L=slope length factor; ℓ=field slope length (m); m=dimensionless exponent that depends on slope steepness, being 0.5 for slopes exceeding 5%, 0.4 for 4% slopes and 0.3 for slopes less than 3%. The percent slope was determined from DEM, while a grid size of 30 m was used as field slope length (l). Similar assumption of field slope length.

Slope steepness factor(S) the S-factor was calculated based on the relationship given by McCool et.al. (1987) for slope longer than 4m as:

$$S=10.8 \sin \sin \theta + 0.03 \text{ for slopes} < 9\% \quad (5a)$$

$$S=16.8 \sin \sin \theta - 0.50 \text{ for slopes} \geq 9\% \quad (5b)$$

Where S=Slope steepness factor and θ = slope angle in degree. The slope steepness factor is dimensionless. LS factor was derived with the help of ARC GIS. The spatial distribution of these factors so derived is shown in given fig. below. Topographic factor was found to be in the range of 0.1 to 53.1.

$$L= \left(\frac{219309}{22.13}\right)^m$$

Where ℓ =219309 which is main Stream length of watershed obtained by ARC GIS and m= watershed covers almost 3% of slope is 0.3 by average of Slope is 0.35

L= 25.0395

Slope steepness factor, S =10.8 sin θ + 0.03 for slope < 9 %

$$S = 0.5901$$

Where θ = average degree of watershed slope.

$$LS = 25.039 \times 0.590$$

$$LS=14.773$$

(Or)

LS=Power ("flowaccumulation"*[cellresolution]/22.1,0.4)*Power(Sin("slope of degree"*0.01745))/0.09, 1.4)*1.4

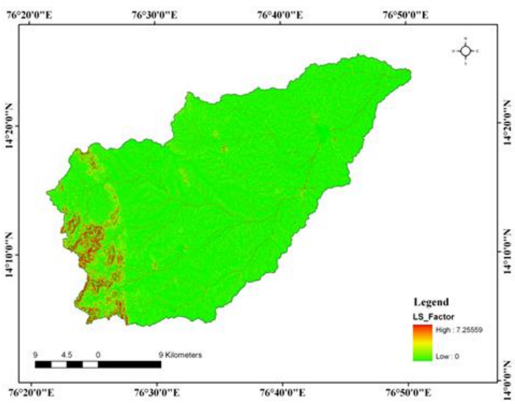

Fig.10. Topographic factor Map of Doddahalla Watershed.

3.7 Crop Management Factor (C)

Conservation factor (P) depend on land use/cover information of the study area. Crop management factor is the expected ratio of soil loss from a cropped land under specific condition to soil loss from clean tilled fallow on identical soil and slope under the same rainfall conditions. The type of the land cover, the manner in which ,it is managed and the changes that have taken place over time form the basic premise for evaluating sediment yield from a watershed allocation of C and P factors for different land use classes.

The C factor values were the representative values for allocating the USLE land cover and management factors corresponding to each crop/vegetation condition. The study area has been classified into eight land use classes namely; (1) water body, (2) wasteland, (3) settlement, (4) dense forest, (5) degraded forest, (6) open forest, (7) agriculture (upland crops), and (8) agriculture (paddy). Finally, crop management factor was assigned for different land use patterns using Table 7. The magnitude and the spatial distribution of crop management factor are given in Fig. below. Crop management factor was found to be in the range of 0.004 to 1.00

Table.7. Crop management factor for different land use/land cover classes.

Land use/land cover	C-value
A Agriculture(paddy)	0.28
Degraded forest	0.008
Dense forest	0.004
Fellow agriculture	0.180
Jhum cultivation	0.33
Open forest	0.008
Settlement	1.0
Waterbody	0.280

Source: USDA-SCS (1972), Rao (1981)

Table.8. Based on USDS-SCS (1972), Rao (1981) our watershed land use/ land cover classes the C-factor are assigned as below.

Landuse/Land cover	C_factor
Agricultural Plantation	0.28
Crop land	0.28
Forest Plantations	0.28
Prosophys Juliflora	0.28
Tree Groves	0.28
Fallow land	1.00
Lake / Tanks	0.00
River / Stream	0.00
Degraded Forest	0.008
Moist & Dry Deciduous Forest	0.008
Scrub Forest	0.008
Land without scrub	0.18
Gullied / Revinous Land	0.7
Habitation with Vegetation	0.7
Land with scrub	0.7
Barren Rocky / Stony Waste / Sheet Rock Area	1.00
Mining / Industrial Wasteland	1.00
Salt Affected Land	1.00
Town / Cities	1.00
Village	1.00

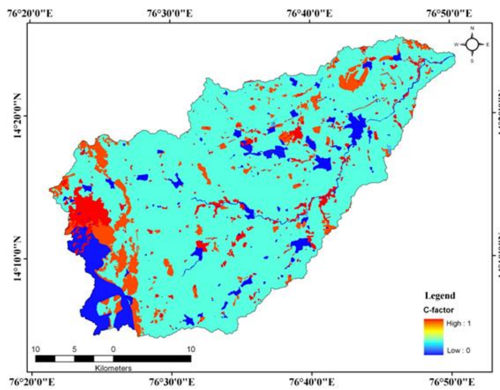

Fig.11.Crop Management Factor Map of Doddahalla Watershed

3.8. Conservation practice factor (P)

Conservation practice factor *(P)* is the ratio of soil loss with a specific support practice to the corresponding loss with up and down slope cultivation. In the study area, no major conservation practices are followed. The values for P-factor were assigned to be 0.28 for area under paddy cultivation and 1.0 for other area. The values are based on the values suggested by Rao (1981). The magnitude and the spatial distribution are given in Fig 8. The conservation factor was found to be 0.28 and 1.00.

Table.9. Erosion Control Practice factor (USDA-SCS (1972), Rao (1981)

Landuse Classes	**P-factor**
Settlement	1.0
Vacant land	1.0
Quarry / Brick kilns	1.0
Crop land	0.28
Fallow land	0.28
Plantations	0.28
Dense forest	1.0
Open forest	1.0
Degraded forest	1.0
Land with scrub	1.0
Land without scrub	1.0
Marshy	1.0
Water bodies	1.0

Table.10. Based on USDS-SCS (1972), Rao (1981) our watershed landuse/ land cover classes the P-factor are assigned as below.

Landuse/Land cover	**P_factor**
Agricultural Plantation	0.28
Crop land	0.28
Forest Plantations	0.28
Prosophys Juliflora	0.28
Tree Groves	0.28
Fallow land	0.28
Lake / Tanks	1.00
River / Stream	1.00
Degraded Forest	1.00
Moist & Dry Deciduous Forest	1.00
Scrub Forest	1.00
Land without scrub	1.00
Gullied / Revinous Land	1.00
Habitation with Vegetation	1.00
Land with scrub	1.00
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Mining / Industrial Wasteland	1.00
Salt Affected Land	1.00
Town / Cities	1.00
Village	1.00

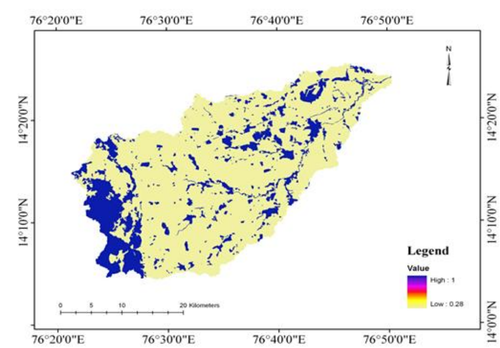

Fig.12.Conservation practice factor Map of Doddahalla Watershed.

The corrected DEM was utilized to deduce the flow direction to prepare the flow accumulation map. The LS factor map was then prepared using the slope and flow accumulation map in raster calculator in ArcGIS. The LISS III satellite image of the year 2014 was helpful in mapping the recently formed drainage channels. The different LU/LC categories due to its high spatial resolution, and therefore helped in mapping up to the second level of LU/LC. The LU/LC map was used for preparing the land cover and management factor (C-factor) map. The values of C-factor were assigned to the different landuse and land cover classes in the study area keeping reference of the earlier studies. The P-factor map was also prepared using the landuse land cover map of the watershed and the values of P-factor were assigned to the different features based on the soil conservation practices taken up in the study area referring to previous studies.

All the 5 parameter maps (having the same coordinate system) were converted to grid with 30m x 30m cell size (so as to maintain uniform cell size at par with spatial resolution of Cartosat-I DEM). The layers were then overlaid and multiplied pixel by pixel, using Equation (1), to estimate the soil erosion and the spatial distribution of different soil erosion zones in the Doddahalla watershed. Raster Calculator was used to build the expression: R * [K] * [C] * [P] * [LS] which, when applied to all cells in a raster coverage of the watershed, produced a map of average annual soil erosion.

IV. RESULTS AND DISCUSSIONS

RUSLE is a straightforward and empirically based model that has the ability to predict long term average annual rate of soil erosion on slopes using data on rainfall pattern, soil type, topography, crop system and management practices.

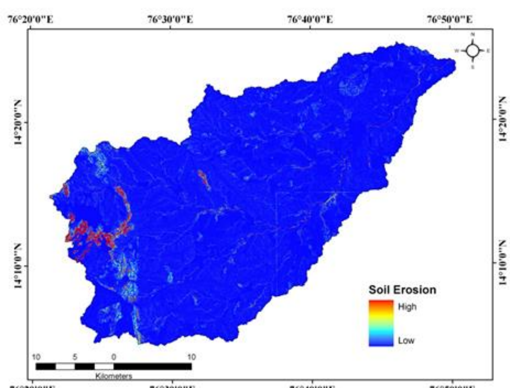

Fig.13.Annual Soil Erosion Map of Doddahalla Watershed

In the present dissertation, annual soil erosion rate map was generated for Doddahalla watershed, which represents most of the terrain characteristics by an undulating topography with occurrences of hills, linear ridges and plain lands.

Potential annual soil loss is estimated from the product of factors (R, K, LS, C and P) which represents geo-environmental scenario of the study area in spatial analyst extension of Arc GIS software. The results were also compared with the studies carried out in areas having rainfall characteristics (Adediji et al., 2010) and were found to be comparable with an annual average soil erosion rate of 615 tonn h^{-1} y^{-1}. The assessed average annual soil loss of Doddahalla watershed was grouped into different classes based on the minimum and maximum values. The results presented about 92% of the study area is classified as low potential erosion risk, while rest of the area is under moderate to high erosion risk. The spatial pattern of classified soil erosion risk zones indicates that the areas with high and severe erosion risk are located in southern terrain regions of the study area, while the areas with low erosion risk are in the north, eastern and central parts of the study area.

V. CONCLUSION

A quantitative assessment of average annual soil loss for Doddahalla watershed is made with GIS based well-known RUSLE equation considering rainfall, soil, land use and topographic datasets. In the watershed the land use pattern in areas prone to soil erosion indicates minimum rate of soil erosion, while areas with that areas with natural forest cover in terrain have high rate of soil erosion >615 tonn h^{-1} y^{-1}. Terrain alterations along with high LS-factor and rainfall prompt these areas to be more susceptible to soil erosion. The predicted amount of soil loss and its spatial distribution can provide a basis for comprehensive management and sustainable land use for the watershed. The areas with high and severe soil erosion warrant special priority for the implementation of control measures. While the present analytical model helps mapping of vulnerability zones, micro-scale data on rainfall intensity, soil texture and field measurements can augment the prediction capability and accuracy of remote sensing and GIS based analysis.

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