Sediment Yield Assessment Using SAGA GIS and USLE model: A Case Study of Watershed – 63 of Narmada River, Gujarat, India.

Snehakumari S. Parmar[#1]

[#1] *Water Resources Engineering and Management Institute (WREMI) Samiala -391410,*
Faculty of Technology and Engineering,
The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat, India.

***Abstract* — *Sediments play vital role to sustain the life of aquatic environment. Due to sedimentation, many nutrients, contaminated substances are transported, which ultimately reduces land productivity. Remote Sensing (RS) and Geographic Information System (GIS) used integrally to find sediment yield and morphological parameters responsible for causing soil erosion. SAGA-GIS (System for Automated Geo-Scientific Analysis-Geographic Information System) software version 6.3.2 utilized for editing spatial data, preparing thematic maps, statistical data analysis, etc. To know the spatial prediction of soil loss and risk potential of erosion, ULSE model (Universal Soil Loss Equation) was used. Watershed: 63 selected for research work which is located in middle sub-basin of Narmada river. It is sited in Narmada district of Gujarat and Nan durbar district of Maharashtra. The Shuttle Radar Topographic Mission (SRTM) data employed for preparation of Digital Elevation Model (DEM) and to prepare slope maps. The results showed that study area comes under severe soil erosion class i.e. 47.79 Ton/ha/year and high sediment yield achieved as 19.14 tons/year. This is due to existence of moderate to steep slope, moderate land use practices, moderate drainage texture. This study will prove to be helpful in watershed management strategies and to conserve the natural resources according to priorities.*

Keywords — *Remote Sensing, GIS, USLE, Soil Erosion, Sediment Yield, Thematic Maps.*

I. INTRODUCTION

Erosion can define as the removal of soil particle with the help of rainfall, action of wind and surface runoff. Then after the deposition process of the eroded particles occurred is called sedimentation. Some other parameters responsible for erosion are construction activities which can accelerate erosion process, revealing large areas of soil to rain and running water becomes main reason for soil erosion [1]. Nowadays, in major area of land, cultivated process is carried out but it remains unproductive and renders economically because of such reason soil erosion becomes unstoppable [2]. Major parameter responsible for soil erosion risk are population explosion, deforestation, unsustainable agricultural cultivation, and overgrazing [3]. Basically, this process involves detachment, transportation and subsequently deposition of particles. With the help of raindrop impact and shearing force of flowing water the sediment gets detached from the surface of soil. Then detached sediments make downslope movement primarily by flowing water and transportation of particles occurs [4]. Raindrop splash also make small movement of downslope transport. In case of streams, when runoff get started over the surface areas, then with respect to the quantity and size of material transported will get increases with the velocity of the runoff, it depends upon slope and transport capacity. When the amount of sediment load will pass through the outlet point of a catchment area then it is known as sediment yield [5]. The information about occurrence of sediment yield in catchment area are achieved by analysing the point of view of the rate of soil erosion occurring within that catchment [6]. Watershed management and planning program involves proper utilization natural resources like land, water, forest and soil.

Many predictive models have been developed by researchers to estimate soil loss and to recognise the areas affected by erosion process and where conservation measures should be taken to reduce the impact of soil loss for assessment of soil erosion [5]. These models having different categories and three main categories are as empirical model, conceptual model and physical models [7]. Without being affected by development of such range of physical model and conceptual models, the Universal Soil Loss Equation (USLE) by Musgrave in 1947, the Modified Universal Soil Loss Equation (MUSLE) by

William in 1975 , and the Revised Universal Soil Loss Equation (RUSLE) by Renard et al. in 1991 are repeatedly becomes helpful in the estimation work , prediction and controlling surface erosion, to find out sediment yield for given catchment areas and these methods has been tested in many agricultural watersheds worldwide [4]. The most widely used model for estimating soil loss is known as Universal Soil Loss Equation (USLE) which is used in its original and modified forms [8]. Various parameters used in USLE model deals with rainfall distribution, soil characteristics, topographic parameters, vegetative cover and conservation support practice for controlling soil erosion.

Use of GIS is nowadays common in natural resources field like hydrologic, water driven demonstrating, mapping, watershed administration and so on. GIS techniques and Remote Sensing (RS) tool provide spatial input data to USLE model. This model becomes helpful to predict the sediment yield from the watershed areas [1,6]. A GIS tool can effectively manage spatial data and spatial characteristics of land use, vegetative cover, soil, topography and precipitation of the regarding watershed [9,10,20]. In the present study, the value of both magnitude and spatial distribution of soil erosion in the catchment is determined [11]. Generally, both of these quantities are having large variability because of the spatial variation of rainfall data and catchment heterogeneity which represents the state that diverse in catchment area [12,13,14]. Due to such variability it is advisable to use more intensive data and also to use process-based distributed models for the estimation of catchment erosion and sediment yield by discretising the catchment area into sub-catchment areas [15,16,17]. This study represents that Universal Soil Loss Equation used with GIS and RS techniques proves to be very powerful tool for quantifying the soil erosion and also useful for generating sustainable soil erosion management strategies and to understand hydrological behaviour of basin [18,21].

Nowadays soil erosion and deposition are worldwide problem. Following some of controllable measures of erosion and deposition of silt in Reservoirs and in water courses are mention below to reduce the soil erosion up to certain extent [6,19,20].

(1) Upstream sediment traps should be constructed and by developing effective methods for purpose of sediment routing and removal of trapped sediment from existing reservoirs.
(2) Contour farming and planting practices should be adopted along slope of a hill and following the natural contours of the land. Wind break should be planned for controlling Wind erosion. A windbreak may be constructed in form of row of trees, bushes etc.
(3) Deforestation of land should be prevented and adopting best practice for Afforestation.
(4) Controlled practice should have adopted for mining and balancing the ecological system.
(5) Frequently use the silt sluices for unloading the accumulated silt from the reservoirs.
(6) Construction of bunds along the erosion affected area and this practice also become helpful in desilting the deposited material.
(7) Minimize the amount of disturbed soil and healthy land cover should maintain.
(8) Reduce the velocity of the runoff traveling across the site which causing direct soil losses.
(9) Remove the sediment from onsite runoff before it leaves the site.
(10) Develop and implement a thorough monitoring and maintenance program.
(11) Surface stabilization measures should be given as primary attention.
(12) Some of commonly adopted surface stabilization and erosion control measures: Surface Roughening, Re-vegetation Seeding, Hydro seeding, Mulching, Matting, geotextile, Rock Riprap, Buffer Zones etc.

II. Objective of the Present Study

In the present study, an open source tool SAGA (System for Automated Geo-Scientific Analysis) GIS software with version 6.3.2 used to fulfil following objectives by preparing thematic maps and verifying the spatial extent of the area.

- To carry out integrated analysis of spatial data with remote sensing and GIS techniques by using Universal Soil Loss Equation (USLE) approach along with the assessment and estimating annual soil loss, sediment delivery ratio, sediment yield and also analysing morphometry parameters.
- To detect the soil erosion prone area from the analysis and also from the soil erosion map of the study area.

III. Significance of Study

The open-source software SAGA GIS 6.3.2 is used for analysis work. Very less research work is carried out using SAGA GIS software in geomorphologic studies. Due to this reason, it is aim that this research work would fill gap of knowledge up to certain extent and eventually encourages other researchers to use such soft wares. This study will prove to be helpful in watershed management strategies and to conserve the natural resources according to priorities. Moreover, one of the predominant duty for planners, engineers and decision makers is to estimate sediment yield to control the process of sedimentation in watershed.

IV. STUDY AREA

Narmada River is seventh largest river among all other Indian rivers on basis of drainage area. It is located in the central part of India. Drainage area of this river is 98,796 km^2 and total length is 1312 km. It has 150 sub-watersheds. The Narmada Middle sub-basin has 63 no. of watersheds with different ranges of size from 338.11 to 957.42 (Sq.km). For present study watershed number 63 of middle Narmada river basin is selected for analysis which is bounded by latitude 21° 49' 49.818" N and longitude 73° 44' 54.6756" E in Narmada district of Gujarat and latitude 21° 54' 24.0876" N and longitude 74° 1' 23.1204" E in Nan durbar district of Maharashtra. Area covered by watershed-63 is 690 km^2 and according to Survey Of India (SOI) watershed 63 is presented in topo-sheet number 46A and G. Watershed: 63 divided into two sub watersheds. Some of the major projects in the basin are Bargi dam, Barna, Indra Sagar, Kolar, Omakareshwar, Maheshwar, Bhagwant Sagar, Tawa and Sardar Sarovar dam. Among the 29 major dams constructed for Narmada river, the Sardar Sarovar dam is the largest having a proposed height of 163 meters and with a Sardar Sarovar reservoir located in Narmada district. Narmada main canal project, is the longest lined irrigation canal in the world. Near the Sardar Sarovar dam site, a Shoolpaneshwar Sanctuary situated in Gujarat covers an area of about 607 Sq.km that includes a major watershed feeding the Sardar Sarovar reservoir and, a tributary of Narmada in Gujarat known as Karjan reservoir located on the Karjan River. Narmada basin has well defined physiographic zones. Nan-durbar and part of Narmada districts covers under the lower hilly areas. Fig. 1 showing location plan of study area.

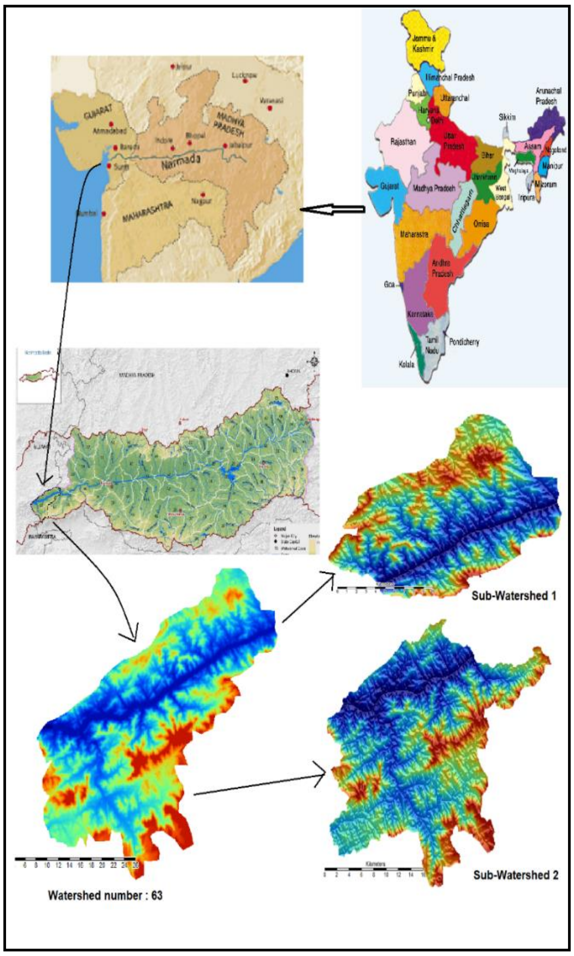

Fig. 1 Location map of study area

V. METHODOLOGY

For estimating soil erosion many erosion models have been developed. For example, Universal Soil Loss Equation (USLE), Revised Universal Soil Loss Equation (RUSLE), Soil Erosion Model for Mediterranean Regions (SEMMED), Modified Universal Soil Loss Equation (MUSLE), Soil and Water Assessment Tool (SWAT), Water Erosion Prediction Project (WEPP), Areal Non-Point Source Watershed Environment Response Simulation (ANSWERS), European Soil Erosion Model (EUROSEM) etc. were used in regional assessment. Each model having its unique characteristics and application in different field. The superior model applied all over the world to predict the soil loss is as USLE or RUSLE.

The DEM were mosaicked and watershed boundary was delineated from Shutter Radar Topography Mission (SRTM) DEM (Digital Elevation Models) or ASTER DEM data of the Narmada watershed no: 63 collected from website of BHUVAN and USGS with 30 m resolution. Co-ordinate transformation of that DEM data or bands or any grid by using Co-ordinate transformation tool in SAGA GIS. For India selecting Kalianpur 1975/India zone IIa as Projected co-ordinate system in authority code. Then Coordinate transformed data have utilised for succeeding analysis of drainage network by flow accumulation tool in SAGA GIS. As a result, the digitized drainage lines achieved and overlaid them on DEM of watershed 63. Digital elevation model, slope and aspect were generated from the vectorised contour by using spatial analyst extension in SAGA GIS. The drainage network of the basin and the stream ordering and morphometric parameters were calculated using standard methods as adopted by Horton Schumn and Strahler. Different Bands of Landsat -8 with spatial resolution 30 meters downloaded for finding Normalise Difference Vegetation Index (NDVI) in land use/land cover analysis from the link http://www.earthexplorer.usgs.gov. using SAGA GIS. With help of Google earth pro standard visual image interpretation method was carry out to recognize the elements such as texture of soil, size, shape, pattern, soil conservation practice and field knowledge was followed. Land use / land cover categories such as agriculture land, dense forest, open forest, open scrub, settlement, stone quarry, exposed rock, waste land and water body, etc. were delineated on the basis of image interpretation or unsupervised classification techniques of satellite image and the accuracy of the classified image is ground checked and verified in from SAGA GIS. Apart from that digitization, editing in topology of building also achieved from SAGA GIS. Basin, sub basin , watershed code, number of stream, topo-sheet number, sharing states and area achieved from the link http://cgwb.gov.in/watershed/cdnarmada.html.

According to Yoder & Lown (1995), RUSLE model having specific improvements over the USLE model. The improvements are as follow:

(1) RUSLE model may incorporates more data as compare to USLE model. RUSLE model includes the data of different crops and cropping systems ranging from forest to rangeland known as open land while evaluating erosion. RUSLE model proves efficient tool by adopting minor changes in crop management practices.

(2) RUSLE model may corrects the errors in the USLE analysis. RUSLE model contains different formulas to fills the gaps in the original data. When data is not sufficiently available for estimating erosion for example, many soil conservation planning situations are not known to user at that time the RUSLE model provides process-based calculations to fill those gaps in data. Adapting these theoretical algorithms into the RUSLE empirical structure which gives the flexibility to solve more complicated problem in systems, which allows user to do modelling with greater variety of systems and other alternatives.

A. USLE Model Description and Limitations:

By inspecting the USLE model, variables in this equation has been divided into two different parts. First part is environmental variables and another one is management variables. The environmental variables comprise of the R, K, L, and S factors. These variables remain comparatively constant over the period of time. The management variables involve the C and P factors and they vary over the period of time. The USLE model can predict erosion potential on a cell-by-cell basis, which is effective when trying to identify the spatial pattern of soil loss present within a large region of watershed basin. USLE was created initially for agricultural regions. Soil-erosion potential is detected in non-agricultural regions is not very much consistent. USLE model requires six input data layers to be multiplied together, the errors are uncontrollable then contributing to an even larger error in the derived soil loss values. Fig. 2 show the methodology to find soil erosion and which data are basically required to find average annual soil loss (A).

The USLE model calculates potential average annual soil loss (A) by using basic equation as following.

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

Where,

A is average annual soil loss in tons per hectare per year,

R is the rainfall and runoff erosivity factor in MJ mm per hectare per hour per year,

K is the soil erodbility factor in Tons * hour per MJ-1 mm,

LS is slope length and slope steepness factor which is dimensionless,

C is the crop and cover management factor which is dimensionless and

P is the soil conservation practices or land use factor which is also dimensionless.

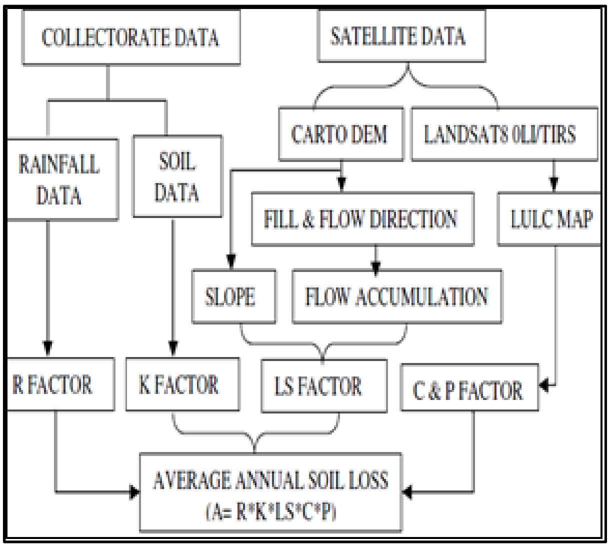

Fig. 2 Methodology of the flowchart

B. Model Input Processing and Factor Generation

a) Rainfall and Runoff Erosivity (R - Factor) Estimation: Soil erosion occurred due to rainfall-runoff process which includes detachment of soil particles due to impact of rainfall. The R factor is the product of the long term average annual event of rainfall kinetic energy and the maximum rainfall intensity in 30 minutes in mm per hour. Such values derived from the data of rainfall intensity. Rainfall erosivity is estimation of rainfall data with long-time intervals that have been attempted by several workers for different regions of the world. Renard et al. (1997) recommended that R-factor value defines the effect of raindrop impact and rate and amount of runoff due to that rainfall. The value of R-factor derived by Wischmeier and Smith (1965) appears to meet these kind of requirement in better way when plotted against other parameters. Wischmeier and Smith represents the following equation to find out the value of R-factor.

$$R = \frac{1}{n}\sum_{j=1}^{n}\left(\sum_{k=1}^{m}(E)(I30)_k\right)$$

Where,
R= Rainfall erosivity factor
n= number of year to achieve average R value
j= counter for each year to achieve average R value
k= counter for number of storm in a year
m=number of storm in n year
E= total storm kinetic energy
I30=maximum 30minute rainfall intensity

The value of erosion potential for individual storm is denoted by EI. Hence, R factor values is sum of all individual EI values during each rainfall event. R-factor value calculated by monthly or seasonal or annual rainfall data from different rain gauge stations. Using the data for storms from several rain gauge stations located in different zones, linear relationships were established between average annual rainfall and computed EI30 values for different zones of India and iso-erodent maps were drawn for annual and seasonal EI30 values. Due to lack of rainfall intensity data number of storm is constrain to find R factor. In USLE model, soil loss occurred from cultivated land is proportionate to average annual rain storm (if other factors prevail constant). The following relationship has given first priority to estimate R factor value. This following equation (Eq.1) derived to find out the value of R-factor (Chaudhary and Nayak, 2003).

$$\mathbf{Ra = 79 + 0.363 * Xa} \qquad (1)$$

Where,
Xa = average annual rainfall in mm,
Ra =Annual R factor,

A 10-year average annual data (2004-2013) has been used to calculate the average annual R- factor values over the study area. Since the rainfall data available for the study area is not homogenous, average annual rainfall data is considered. Daily rainfall data for the 10 years collected from Indian Meteorological Department and form Global Weather Data.

b) Soil Erodibility Factor (K - Factor) Estimation: Soil Erodibility factor shows susceptibility of soil against detachment and transportation of soil particle. Generally, K factor values are varying from 0 to 1. Where 0 shows minimum susceptibility and 1 shows maximum susceptibility while erosion occurred. The value of K factor achieved from following table 1. Table show different soil textures and their susceptibility to water erosion and accordingly ranges of K factor. Direct measurement of K factor value required natural runoff plotting at various location with respect to time and number of attempts made from data of soil property and standard profile description.

TABLE I INDICATION OF GENERAL SUSCEPTIBILITY AND K-FACTOR VALUE OF SOIL TEXTURE

Surface Soil Texture	Relative Susceptibility to Water Erosion	K ranges1
Very fine sand	Very highly susceptible	>0.05
Loamy very fine sand	Highly susceptible	0.04 - 0.05
Silt loam		
Very fine sandy loan		
Silty clay loam		
Clay loam	Moderately susceptible	0.03 - 0.04
Loam		
Silty clay		
Clay		
Silty clay loam		
Heavy clay	Slightly susceptible	0.007 - 0.003
Sandy Loam		
Loamy fine sand		
Fine sand		
Coarse sandy loam		
Loamy sand	Very slightly susceptible	<0.007
Sand		
1 K values may vary, depending on particle sixe distribution, organic matter, structure and permeability of individual soils		

c) Slope Length (L) and Steepness (S) Factor (LS - Factor) Estimation: The LS factor convey the effect of local topography which leads to soil erosion and contribution of combining effects of slope length (L) and slope steepness (S). The longer the slope length then larger amount of cumulative runoff occurs. Slope of the land is steep then higher the velocities of the runoff contributes to soil erosion. The theoretical relationship based on unit stream power theory. It is based on the work of Moore et al. for calculation of the S and L-factors as given below by equation (Eq. 2).

$$LS = 1.07 \left(\frac{\lambda}{22.13}\right)^{0.28} \left(\frac{\alpha}{10°}\right)^{1.45} \qquad (2)$$

where,
λ: slope length in meter,
α: slope angle in degrees.

d) Crop Management Factor (C - Factor) Estimation: Crop management factor value depends on vegetation type, stage of development or growth and land cover percentage. It is considered as major factor for soil erosion control. C-factor values vary between 0 to 1 based on types of land covers availability. Normalized Difference Vegetation Index (NDVI) values have direct correlation with crop management factor. The linear or non-linear regression equations are formed using correlation analysis between NDVI values obtained from remotely sensed image and corresponding C-factor values obtained. The study predicts that there exists a linear correlation between NDVI values and C factor values and for guidance consider bare soil and forest NDVI values as reference values. Though C factor values range from 0 for well-protected soil / forest land cover and 1 for bare soil in regression analysis.

The NDVI was then used to obtain new images of a rescaled C factor (Cr), as per the following equation which was given by Durigon et al. in 2014.The regression equation (Eq. 3) was found as:

$$\mathbf{Cr = [(-NDVI + 1/2)]} \qquad (3)$$

e) Soil Conservation Practices Factor (P - Factor) Estimation: The soil conservation practice P-factor value can have utilized to comprehension the conservation practices. Such practices directly decrease the amount of runoff. Wischmeier and Smith gave the P-factor value by combining the conservation practice at particular site and the value of slope, general land use land cover type. P-factor value given by group the land in to agricultural land (cultivated land) and other major land types of land use. Table 2 shows the cultivated land / agricultural land of the watershed was categorized into six slope class and respective P-values because many land management projects are highly dependent on slope of the area.

TABLE II P- FACTOR VALUE

Land Use Type	Slope (%)	P- Factor
Agricultural Land (Cultivated Land)	0 – 5	0.1
	5 – 10	0.12
	10 – 20	0.14
	20 – 30	0.19
	30 – 50	0.25
	50 – 100	0.33
Other Land	All	1

f) Method of Calculating Soil Erosion (A): To find soil erosion, the factors used in USLE model i.e. R – factor, K – factor, L – factor, S – factor, C – factor P – factor were multiplied using the empirical formula as shown below and soil erosion was mapped. Table 3 show Soil erosion class group occur by water in India. Suggested with reference of Rambabu and Narayan. The USLE model calculates potential average annual soil loss (A) as following equation (Eq. 4).

Annual soil loss A = R - factor * K - factor * LS - factor * C - factor * P -factor (4)

TABLE III DIFFERENT SOIL EROSION CLASS GROUPS

Sr. No.	Soil Erosion class group	Soil Erosion range
	-	(ton / ha / year)
1	Slight	0 – 5
2	Moderate	5 – 10
3	High	10 – 20
4	Very High	20 – 40
5	Severe	40 – 80
6	Very Severe	>80

g) Sediment Delivery Ratio (SDR) Estimation: A part of the soil eroded in an overland region deposits within the catchment before reaching its outlet. The ratio of sediment yield (SY) to total surface erosion (A) is termed the Sediment Delivery Ratio (SDR). It is found that SDR affected by physiography of catchment, sources of sediment, sediment transport system, texture of eroded material, land cover etc. Sediment delivery mainly concerns with sediment storage occurred at reservoirs. Sediment delivery procedure used to determine delivery to a specific location. SDR is expressed as a percent and represents the efficiency of the watershed in moving soil particles from areas of erosion to the point where sediment yield is measured. A catchment area, land slope and land cover are variables which are mainly used as parameters in empirical equations (Eq.5) for finding out the value of SDR.

$$SRD = 1.29 + 1.37 \ln Rc - 0.025 \ln A \quad (5)$$

Where,
A=Basin area (km^2),
Rc = Gully density (Total length of gully measured on topographic map of scale 1:100000 divided by area of watershed, km/km^2)

h) Sediment Yield Calculation (SY): The ratio of sediment delivered at a given catchment area in the stream system to the gross soil erosion is the sediment delivery ratio for that drainage area. Thus, the annual sediment yield of a watershed is given as following equation (Eq.6):

$$SY = (A)\,(SDR) \quad (6)$$

Where,
A = total gross soil erosion computed from USLE,
SDR = sediment delivery ratio.

i) Estimation of Soil Erosion and Sediment Yield Using GIS: Identify the sediment source areas from which sediments reaching the outlet of each catchment. Such areas producing large sediment amounts in the catchments have been identified. In SAGA GIS, MMF Model (Morgana-Morgana–Finney Model) is used to identify maximum erosion affecting area. First priority should be given to areas from where more sediment loss occurs, for the introducing controlling measures against erosion. If result shows that the soil erosion rate is not controlled, siltation is a big problem that is reducing the life of all the dams much faster than expected.

VI. RESULTS AND ANALYSIS

In this study, value of soil erosion estimated using Universal Soil Loss Equation (USLE) method by dividing the watershed in sub watershed level. Middle Narmada river basin have total 63 watersheds and watershed – 63 has two sub watersheds as given below in Fig. 3 Orange and red colour show Sub watershed -1 having area 205 km^2. Sub watershed – 1 having rain gauge station Khasra. Sky blue and blue colour indicating sub watershed- 2 having area of 516.17 km^2.Sub watershed – 2 having rain gauge between Sankali and Piplod.

In order to understand slope characteristics of the watershed, slope map was derived from DEM using Slope and aspect tools and Morphometric features tool in SAGA GIS. Slope divided in three classes: Flat / low slope (0˚ - 6.87˚), moderate slope (6.87˚ - 18.33˚), and steep slope (18.33˚ - 22.91˚) for Sub Watershed - 1. For sub watershed – 2. Slope get divided in three classes as low / flat slope (0˚ - 11.45˚), moderate slope (11.45˚ - 18.33˚) and steep slope (18.33˚ - 25.21˚) for sub watershed - 2. Fig.4 and Fig.5 show slope map of SW-1 and SW -2.

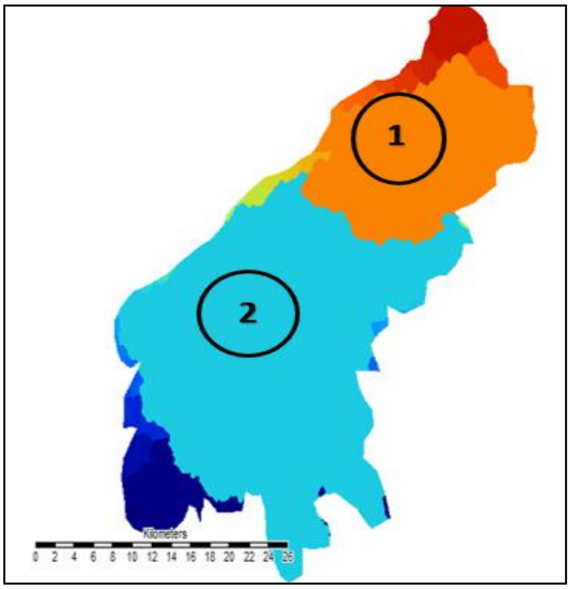

Fig. 3 Sub Watersheds of Study area

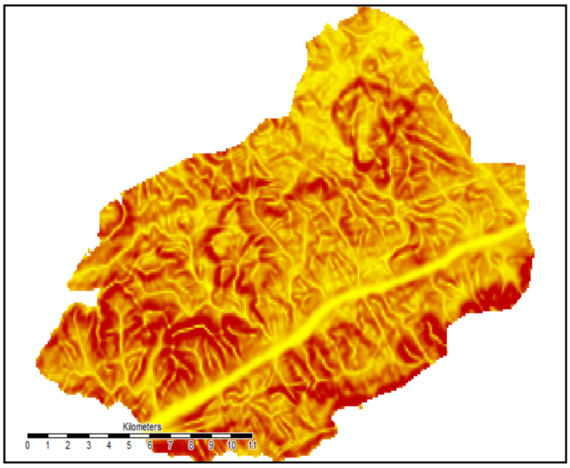

Fig. 4 Slope map of sub watershed - 1

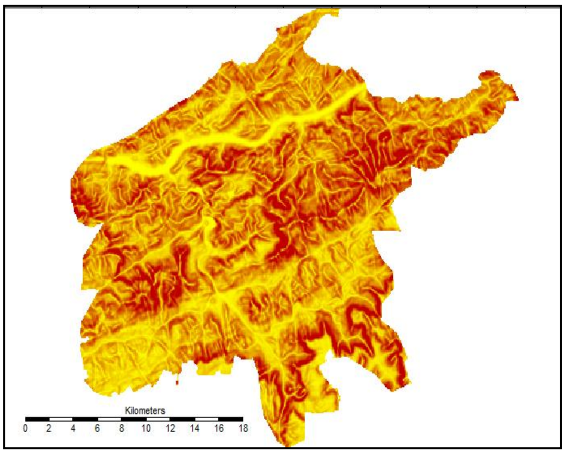

Fig. 5 Slope map of sub watershed – 2

A. Rainfall and Runoff Erosivity Factor (R-Factor)

Finding out the value of R-factor for SW-1 and SW-2 by equation (Eq.1). Fig. 6 and Fig.7 show effective rainfall pattern for SW-1 and SW- 2. Pattern of effective rainfall achieved from SAGA GIS by using MMF models. The red colour or higher R factor showing area indicates higher rainfall occurring area where chances of erosion are high and yellow and green colour or lower R factor show moderate rainfall and chances of erosion is medium.

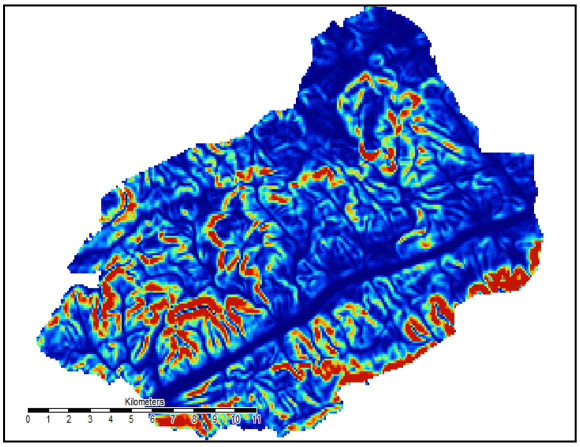

Fig. 6 Effective Rainfall in Sub Watershed -1

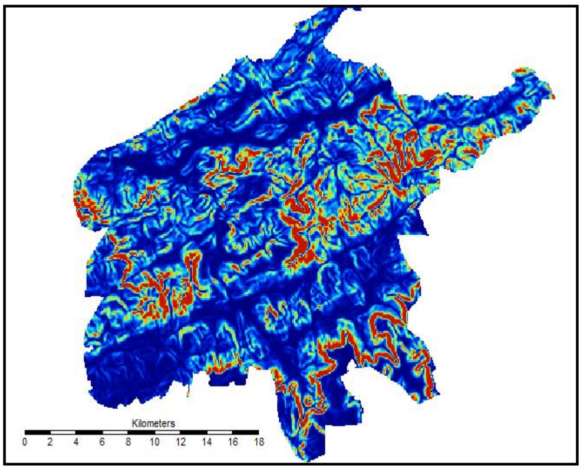

Fig. 7 Effective Rainfall in Sub Watershed -2

B. Soil Erodibility Factor (K-Factor)

The value of K-factor achieved from table 1. Finding out type of Soil texture available from SAGA GIS by using Soil Texture Classifications tool. It is found that sub basins having clay loam type of soil texture. K- Factor for Clay loam type of soil texture is varies from 0.03 to 0.04 t / ha / h / ha - 1/ MJ-1 mm - 1. Fig.8 and Fig.9 show soil texture group for SW-1 and SW-2.

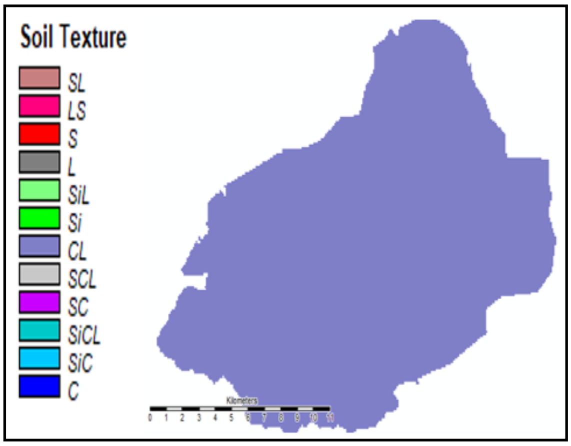

Fig. 8 Soil Texture group for Sub Watershed -1

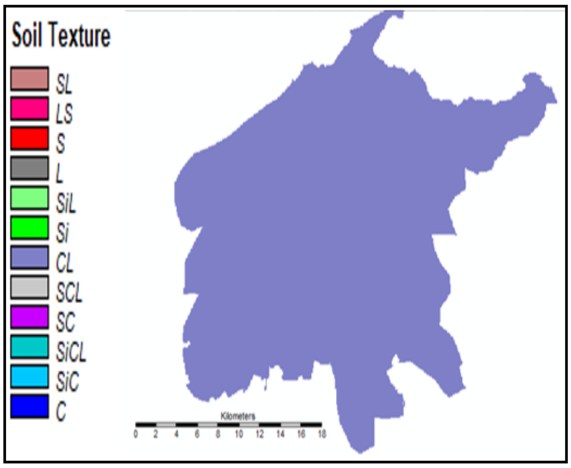

Fig. 9 Soil Texture group for Sub Watershed -2

C. Slope Length (L) Factor and Slope Steepness (S) Factor (LS-Factor)

The value of LS factor calculated from equation (Eq.2). The value of S and L factor increases then surface runoff increases. Arithmetic mean value of LS-factor achieved as 3.18 for SW-1 and 3.54 for SW-2 in SAGA GIS. Fig.10 and Fig.11 show LS factor map respectively for SW- 1 and SW-2.

Slope length (λ) is 947.56 meters and slope angle (α) is 22.9183 ˚ for SW-1.

$$LS = 1.07\left(\frac{\lambda}{22.13}\right)^{0.28} \quad \left(\frac{\alpha}{10°}\right)^{1.45}$$

$$LS = 1.07\left(\frac{947.56}{22.13}\right)^{0.28} \quad \left(\frac{22.9183}{10°}\right)^{1.45}$$

= 10.18.

Slope length (λ) is 1026.29 meters and Slope angle (α) is 25.2101 ˚ for SW-2.

$$LS = 1.07\left(\frac{\lambda}{22.13}\right)^{0.28} \quad \left(\frac{\alpha}{10°}\right)^{1.45}$$

$$LS = 1.07\left(\frac{1026.29}{22.13}\right)^{0.28} \quad \left(\frac{25.2101}{10°}\right)^{1.45}$$

= 11.95

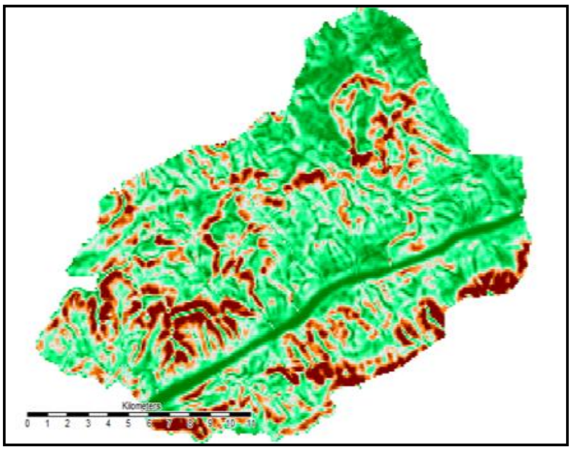

Fig. 10 LS factor map for SW – 1

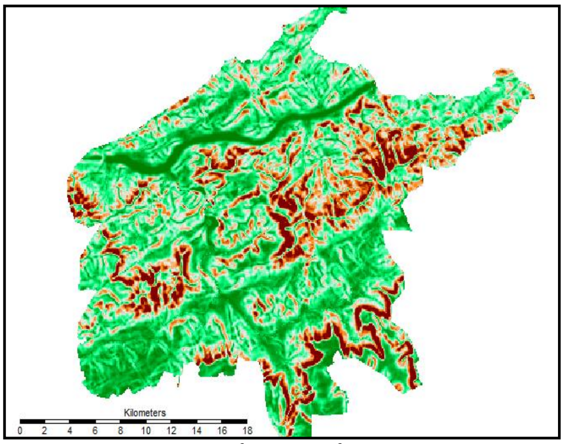

Fig. 11 LS factor map for SW– 2

D. Crop Management Factor (C-Factor)

The value of C factor achieved from equation (Eq.3). Arithmetic mean value of NDVI generated in SAGA GIS and put this value in equation (Eq.3). As value of C – factor increases soil erosion also increases. Because less value of NDVI presents less vegetative cover on soil surface. Fig.12 and Fig. 13 show NDVI map for SW-1 and SW-2 respectively.

For SW-1, Arithmetic Mean of NDVI = 0.29,

$$Cr = [(-NDVI + 1/2)]$$

$$Cr = [(-0.29 + 1/2)]$$

$$= 0.21$$

For SW-2, Arithmetic Mean of NDVI = 0.37,

$$Cr = [(-NDVI + 1/2)]$$

$$Cr = [(-0.37 + 1/2)]$$

$$= 0.13$$

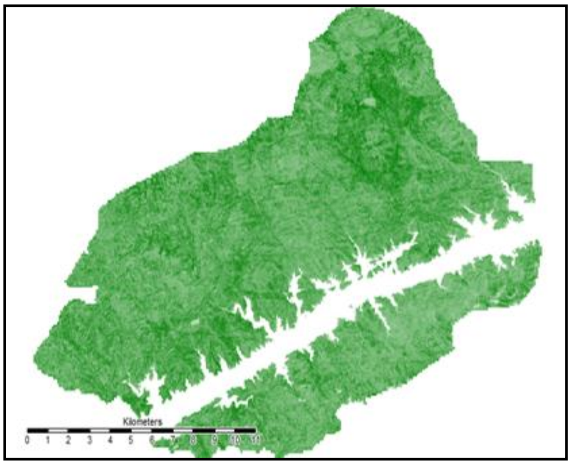

Fig. 12 NDVI map for sub watershed - 1

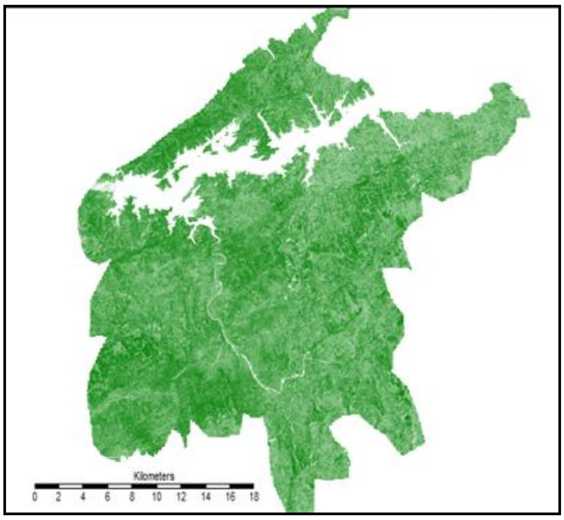

Fig. 13 NDVI map for sub watershed – 2

E. Conservation Practice Factor (P-Factor)

Taking value of P - factor from table 2. Unsupervised classification carried out to identify different land covers. In our study, combining general land use type i.e. agricultural land and also other land types area. Such as water body, grazing, shrub, forest, open forest or scrub present. As value of P – factor increases soil erosion increases. Fig. 14 and Fig. 15 shows different soil layers appear in SW-1 and SW-2 respectively. Maximum slope achieved for given SW-1 is 22.91 ˚ and SW-2 is 25.2101 ˚. Hence, considering mean value for agricultural land and other type of land is 0.19 and 1 respectively.

Mean value = (19 + 1)/2 = 0.66.

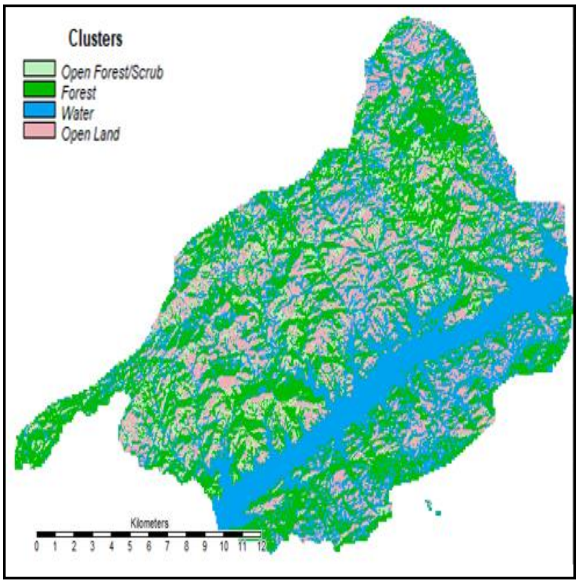

Fig. 14 Soil layers for sub watershed – 1

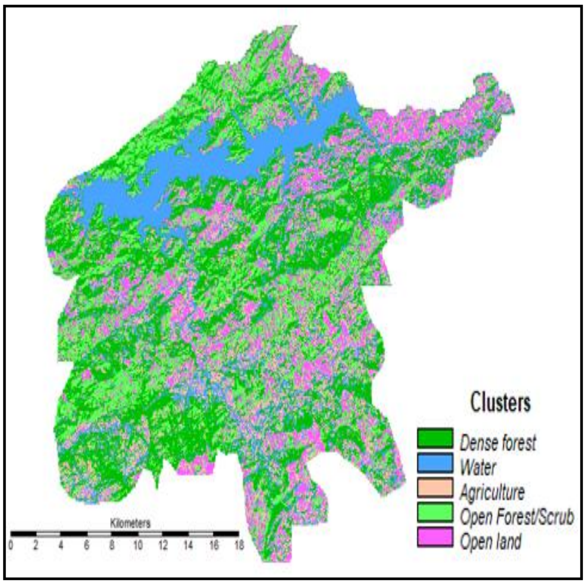

Fig. 15 Soil layers for sub watershed – 2

F. Calculation of Soil Loss (A)

Soil loss is achieved by multiplying all factors in equation (Eq.4) for SW-1 and SW-2. Table 4, 5 and 6 below show soil loss occurred in SW-1, SW-2 and watershed -63 respectively.

Table 4 and Table 5 shows mean value of soil loss in 10 years is 25.30 T / ha -1 / y – 1 for SW-1 and for SW-2 it is 22.48 T / ha -1 / y – 1 which comes under very high class group of soil erosion. Table 6 shows mean value of soil loss in 10 years is 47.79 T / ha -1 / y – 1 for entire watershed - 63 which comes under severe class group of soil erosion. Fig. 16 shows below represents the value of Soil Loss versus Year achieved for watershed – 63 in Column form. The value of soil erosion is higher and factors responsible for this are heavy rainfall, land cover, soil texture, steepness of soil and length of slope, soil conservation practices adopted at such watershed.

TABLE IV CALCULATION OF SOIL LOSS (A) FOR SUB WATERSHED -1

Sr No	Year	R – Factor	K – Factor	LS – Factor	C - Factor	P – Factor	Soil Loss (A)
-	-	MJ mm / ha – 1 / h – 1 / y – 1	t / ha / h / ha - 1 / MJ-1 mm -1	Dimensionless	Dimensionless	Dimensionless	T / ha -1 / y - 1
1	2004	495.68044	0.03	10.18	0.21	0.66	20.98138
2	2005	455.57983	0.03	10.18	0.21	0.66	19.28398
3	2006	519.80905	0.03	10.18	0.21	0.66	22.00271
4	2007	833.82946	0.03	10.18	0.21	0.66	35.2947
5	2008	481.99534	0.03	10.18	0.21	0.66	20.40211
6	2009	342.26212	0.03	10.18	0.21	0.66	14.48742
7	2010	514.9993	0.03	10.18	0.21	0.66	21.79912
8	2011	810.2635	0.03	10.18	0.21	0.66	34.29719
9	2012	779.47384	0.03	10.18	0.21	0.66	32.99391
10	2013	744.22654	0.03	10.18	0.21	0.66	31.50195
	Avg.	**597.8119**	**0.03**	**10.18**	**0.21**	**0.66**	**25.30445**

TABLE V CALCULATION OF SOIL LOSS (A) FOR SUB WATERSHED -2

Sr No	Year	R – Factor	K – Factor	LS – Factor	C - Factor	P – Factor	Soil Loss (A)
-	-	MJ mm / ha – 1 / h – 1 / y – 1	t / ha / h / ha - 1 / MJ-1 mm -1	Dimensionless	Dimensionless	Dimensionless	T / ha -1 / y - 1
1	2004	551.8402	0.03	11.95	0.13	0.66	16.97422
2	2005	520.045	0.03	11.95	0.13	0.66	15.99622
3	2006	540.5001	0.03	11.95	0.13	0.66	16.6254
4	2007	912.8691	0.03	11.95	0.13	0.66	28.07921
5	2008	510.1278	0.03	11.95	0.13	0.66	15.69118
6	2009	332.8241	0.03	11.95	0.13	0.66	10.23744
7	2010	551.3356	0.03	11.95	0.13	0.66	16.9587
8	2011	1119.616	0.03	11.95	0.13	0.66	34.4386
9	2012	1112.123	0.03	11.95	0.13	0.66	34.20814
10	2013	1159.843	0.03	11.95	0.13	0.66	35.67597
	Avg.	**731.1124**	**0.03**	**11.95**	**0.13**	**0.66**	**22.48851**

TABLE VI TOTAL SOIL EROSION IN WATERSHED – 63

Sr No	Year	Soil Loss in SW– 1	Soil Loss in SW- 2	Total Soil Loss in Watershed – 63
-	-	Ton / ha / year	Ton / ha / year	Ton / ha / year
1	2004	20.98138	16.97422	37.9556
2	2005	19.28398	15.99622	35.2802
3	2006	22.00271	16.6254	38.62811
4	2007	35.2947	28.07921	63.37391
5	2008	20.40211	15.69118	36.09329
6	2009	14.48742	10.23744	24.72486
7	2010	21.79912	16.9587	38.75781
8	2011	34.29719	34.4386	68.73579
9	2012	32.99391	34.20814	67.20205
10	2013	31.50195	35.67597	67.17792
	Avg.	**25.30445**	**22.48851**	**47.79295**

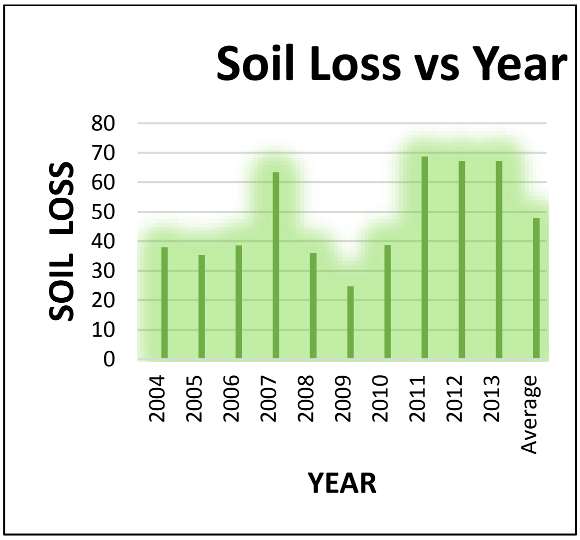

Fig. 16 Representation of Soil Loss versus Year for watershed - 63 in Column form

G. Sediment Delivery Ratio (SDR)

Sediment Delivery Ratio achieved from equation (Eq. 5). The SDR value represents the efficiency of the watershed in moving soil particles from areas of erosion to the dam site (a point where sediment yield is measured).

For SW-1, A= 205 km^2, Rc = 119.15 / 205 = 0.581

$$SRD = 1.29 + 1.37 \ln Rc - 0.025 \ln A$$

$$SRD = 1.29 + (1.37 \ln 0.581) - (0.025 \ln 205)$$

= 0.41

For SW-2, A= 516.17 km^2, Rc = 0.583

$$SRD = 1.29 + 1.37 \ln Rc - 0.025 \ln A$$

$$SRD = 1.29 + (1.37 \ln 0.583) - (0.025 \ln 516.17)$$

= 0.39

H. Calculation of Sediment Yield (SY)

Sediment yield is achieved from multiplying value of soil loss and sediment delivery ratio. (Eq.7) for SW-1 and SW-2. Table 7 shows sediment yield for entire watershed – 63.Fig. 17 shows below represents the value of Sediment Yield versus Year achieved for watershed – 63 in Column form. Average sediment yield occurred in 10 years for entire watershed – 63 as 19.14 tons / year. Fig.18 and Fig.19 shows soil loss occurred in SW-1 and SW-2 respectively from SAGA GIS. Fig. 20 represents soil erosion pattern for whole Narmada basin for comparison which is collected from India- WRIS website. This shows watershed – 63 comes under severe and very sever soil erosion condition.

TABLE 7 TOTAL SEDIMENT YIELD OF WATERSHED – 63

Sr No	Year	Sediment Yield in SW- 1	Sediment Yield in SW– 2	Total Sediment Yield in Watershed - 63
-	-	Tons / year	Tons / year	Tons / year
1	2004	8.602366	6.619945	15.22231
2	2005	7.906433	6.238526	14.14496
3	2006	9.02111	6.483907	15.50502
4	2007	14.47083	10.95089	25.42172
5	2008	8.364865	6.119558	14.48442
6	2009	5.939843	3.9926	9.932443
7	2010	8.937638	6.613892	15.55153
8	2011	14.06185	13.43105	27.4929
9	2012	13.5275	13.34117	26.86867
10	2013	12.9158	13.91363	26.82943
	Avg.	**10.37482**	**8.770518**	**19.14534**

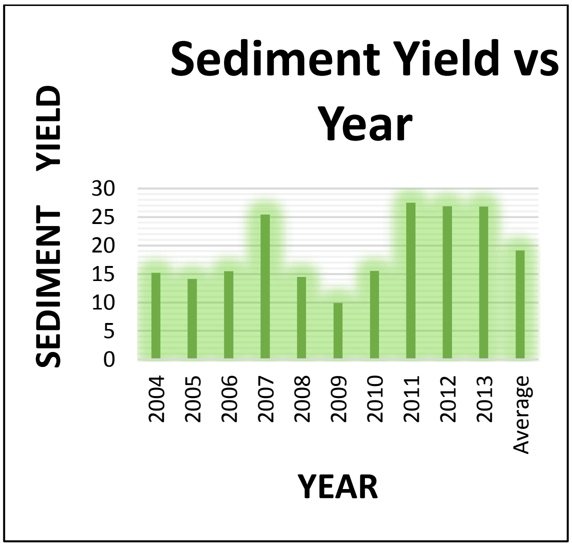

Fig. 17 Representation of Sediment Yield versus Year for watershed - 63 in Column form

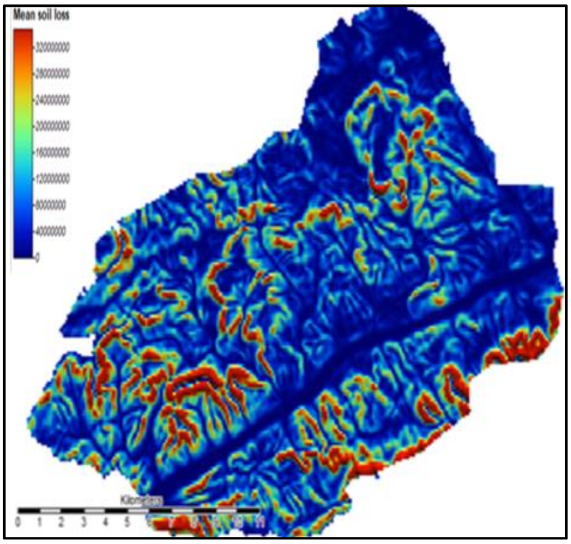

Fig. 18 Soil loss in sub watershed – 1

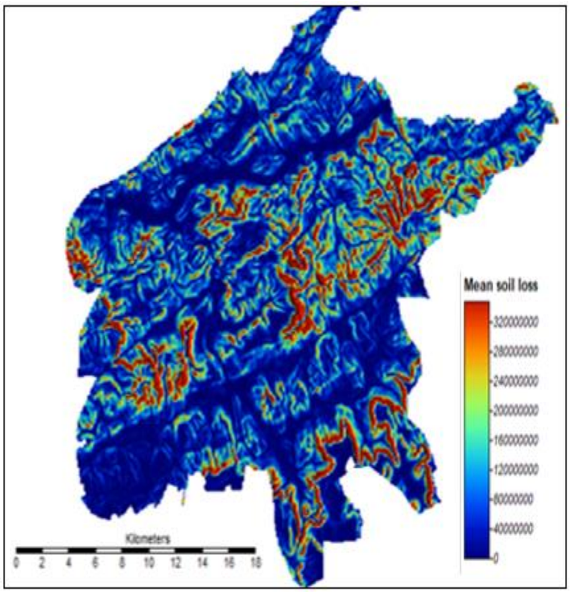

Fig. 19 Soil loss in Sub watershed – 2

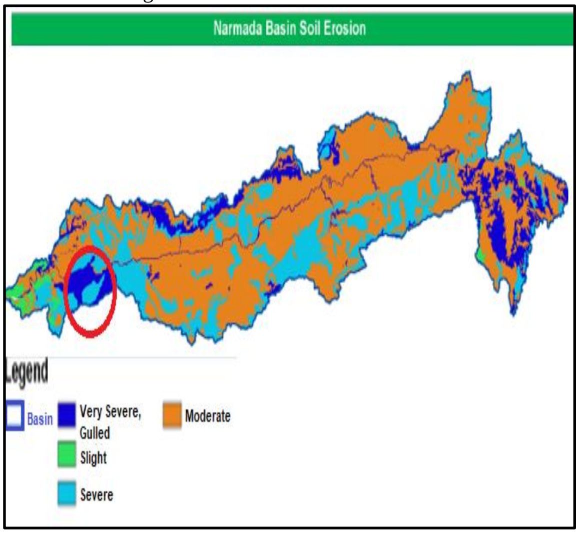

Fig. 20 Soil Erosion map of entire Narmada basin from INDIA-WRIS

VII. CONCLUSIONS

In last, while concluding all this points it is found that the spatial distribution pattern of soil erosion for watershed – 63 of Narmada River Middle Basin is achieved, the analysis of the relationship between Soil loss and Year indicated that mean soil loss from year 2003 to 2014 is 47.793 tons / ha / year, Which includes 25.3044 tons / ha /year from SW-1 and 22.4885 tons/ ha /year from SW-2, which is in the range of (40 – 80 tons / ha / year) which comes under severe erosion class group. The analysis of the relationship between Sediment Yield and Year indicated that mean sediment yield from year 2003 to 2014 is 19.1453 tons / year, which includes 10.3748 tons /year from SW-1 and 8.7705 tons / year from SW-2 by USLE approach. Hence, first priority for precautionary measures against erosion should be given to SW – 1. As well as such soil loss prone area identified from soil loss map. The morphometric parameters responsible for causing sediment yield such as homogeneity in texture of basin, gradient is initially flatter and then it becomes steeper as the stream order increases. Some areas of the basin are characterized by variation in lithology and topography and elongated basin. Highly permeable subsoil, vegetative cover, homogenous geologic materials, old topography of basin, land without floodplains or the field areas of crop is nearer to the reservoir or streams, watershed formation with flat slope surface. As a result of analysis these may be few reasons behind higher value of SDR. Due to this reasons watershed – 63 leads to severe soil erosion effect and will ultimately affect the life of dam. While estimating dead storage capacity, soil loss contributes to Sardar Sarovar reservoir from watershed-63 and other neighbouring watersheds should be considered.

ACKNOWLEDGMENTS

I feel glad to offer my sincerest gratitude and respect to god as well as my parents for their invaluable advice, and guidance from the foundational stage of this research and providing me extraordinary experiences throughout the work. I am immensely obliged to them for their elevating inspiration, encouraging guidance and kind supervision in the completion of my project.

FUNDING

This work was not funded by any agency.

DECLARATION OF INTEREST STATEMENT

None

REFERENCES

[1] Carvalho, D.F., Durigon, V.L., Antunes, M.A.H., Almeida, W.S., & Oliveira, P.T.S. (2014), "Predicting soil erosion using RUSLE and NDVI time series from TM Landsat 5." *Pesq. agropec. bras., Brasília*, v.49, n.3, p.215-224, mar. 2014. doi:10.1590/S0100-204X2014000300008.

[2] Uddin, K., Murthy, M.S.R., Wahid, S.M., & Matin, M.A. (2016), "Estimation of Soil Erosion Dynamics in the Koshi Basin Using GIS and Remote Sensing to Assess Priority Areas for Conservation." *PLoS ONE* 11(3): e0150494. doi: 10.1371/journal.pone.0150494.

[3] Pancholi, V.H., Lodha, P.P, & Prakash, I. (2015), "Estimation of Runoff and Soil Erosion for Vishwamitri River Watershed, Western India Using RS and GIS." American Journal of Water Science and Engineering 2015; 1(2): 7-14.

[4] Jain, M.K., & Kothyari, U.C. (2000), "Estimation of soil erosion and sediment yield using GIS." *Hydrological Sciences-Journal-des Sciences Hydrologiques*. 45(5) October 2000.

[5] Rahaman, S.A., Aruchamy, S., Jegankumar, R., & Ajeez, S.A. (2015), "Estimation of annual average soil loss, based on RUSLE model in Kallar watershed, Bhavani basin, Tamil nadu, India." ISPRS Annals of the Photogrammetry, *Remote Sensing and Spatial Information Sciences*, Volume II-2/W2, 2015.

[6] Parmar, S. (2018), "Sediment Yield Estimation Using SAGA GIS: A Case Study of Watershed – 63 of Narmada River." *JASC: Journal of Applied Science and Computations*, Volume 5, Issue 9, September/2018, ISSN NO: 1076-5131.

[7] Gitas, I. Z., Douros, K., Minakou, C., Silleos, G.N., & Karydas, C.G. (2009), "Multi-temporal soil erosion risk assessment in N. Chalkidiki using a modified USLE raster model." *EARSeL eProceedings* 8, 1/2009.

[8] Sreenivasulu, V., & Pinnamaneni, U.B. (2008), "Sediment yield estimation and prioritization of watershed using remote sensing and gis." International Archives of the Photogrammetry, *Remote Sensing and Spatial Information Sciences*, Volume XXXIX-B8, 2012.

[9] Horvat, Z. (2013), "Using Landsat Satellite Imagery to Determine Land Use/Land Cover Changes in Međimurje County, Croatia." *Hrvatski Geografski Glasnik* 75/2, 5 – 28(2013).

[10] Javed, A., Tanzeel, K., & Aleem, M. (2016), "Estimation of Sediment Yield of Govindsagar Catchment, Lalitpur District, (U.P.), India, Using Remote Sensing and GIS Techniques." *Journal of Geographic Information System.* 2016, 8, 595-607.

[11] Prasannakumar, V., Vijith, H., Abinod, S., & Geetha, N. (2012), "Estimation of soil erosion risk within a small mountainous sub-watershed in Kerala, India, using Revised Universal Soil Loss Equation (RUSLE) and geo-information technology." *Geoscience Frontiers* 3(2) (2012) 209e215.

[12] Dubey, S.K., Sharma, D., & Mundetia, N. (2015), "Morphometric Analysis of the Banas River Basin Using the Geographical Information System, Rajasthan, India." *Hydrology* 2015; 3(5): 47-54.

[13] Rudraiah, M.S.G., & Srinivas, V.S., "Morphometry using Remote Sensing and GIS Techniques in the Sub-basins of Kagna river basin, Gulburga district, Karnataka, India." *Indian Society Remote Sense*. 36:351–60.

[14] Parmar, S. (2019), "Morphometry Analysis Using SAGA GIS: A Case Study of Watershed – 63 of Narmada River, Gujarat, India." *Journal of Engineering Research and Application*, Issue 2 (Series -II) Feb 2019, doi: 10.9790/9622- 0902023951.

[15] Narendra, K., "Morphometric Analysis of River Catchments Using Remote Sensing and GIS (A Case Study of the Sukri River, Rajasthan." *International Journal of Scientific and Research Publications*." Volume 3, Issue 6, June 2013 1 ISSN 2250-3153.

[16] Swatantra, K.D., Sharma, D., & Mundetia, N., "Morphometric Analysis of the Banas River Basin Using the Geographical Information System, Rajasthan, India." *Hydrology 2015*; 3(5): 47-54, Published online October 9, 2015. doi: 10.11648/j.hyd.20150305.11.

[17] Joshi, V., Susware, N., & Sinha, D. (2016), "Estimating soil loss from a watershed in Western Deccan, India, using Revised Universal Soil Loss Equation." *Landscape & Environment* 10 (1) 2016. 13-25.

[18] Uddin, K., "Estimation of Soil Erosion Dynamics in the Koshi Basin Using GIS and Remote Sensing to Assess Priority Areas for Conservation." *PLoS ONE* 11(3): e0150494. doi: 10.1371/journal.pone.0150494.

[19] Asawa, G.L. (2005), *Irrigation and Water Resources Engineering.* (Newagepublishers ,1 January 2005)

[20] Gajraj, S. (2012), *GIS in water resources engineering*. (Publisher: SBS Publisher & Distributors Edition: 2012)

[21] Garg, S.K.(1973), *Hydrology and Water Resources Engineering*. (Khanna Publishsers-Delhi; Twenty Third edition 1973)