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Estimation of Soil Loss by USLE Model in Upper Part of Dwarakeswar River Using Geoinformatics

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A R T I C L E I N F O

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A B S T R A C T

Soil conservation planning often requires estimates of soil erosion at a catchment or regional scale. Predictive models such as Universal Soil Loss Equation (USLE) and its subsequent Revised Universal Soil Loss Equation (RUSLE) are useful tools to generate the quantitative estimates necessary for designing sound conservation measures. This study focuses on the calculation of erosion using the Revised Universal Soil Loss Equation (RUSLE). All parameters are calculated on the base of remote sensing data. First to understand the relationships between plateau buildings related to climatic factors and erosion, while the second goal is to produce a precise erosion risk map for the whole region which is observed in this study. The result advocates for check dam construction at selected sites. Whereas the check dam sites are selected by analyzing the information experienced through analyzing the maps and imageries with RS &GIS techniques.

1. Introduction

RUSLE is a computation method which may be used for site evaluation and planning purposes and to aid in the decision process of selecting erosion control measures. It provides an estimate of the severity of erosion. It will also provide numbers to substantiate the benefits of planned erosion control measures, such as the advantage of adding a diversion ditch or mulch (Ekanayake and Dayawansa 2003). For example, a diversion may shorten the length of slope used in calculating a LS factor. Also, the application of mulch will break raindrop impact and reduce runoff (Jain et al. 2007).

The Revised Universal Soil Loss Equation (RUSLE) has improved the effects of soil roughness and the effects of local weather on the prediction of soil loss and sediment delivery. The importance of estimating erosion and sediment delivery has long been recognized to minimize the pollution by sediments as well as the chemicals carried with soil particles (Sharma et. al 2002). The visual effects of erosion include rills and gullies and sediment blockages found in culverts or drainage ditches. A well planned and engineered erosion control and/or water management plan will alleviate many concerns about construction site erosion and potential pollution. The Universal Soil Loss Equation (USLE) was developed by Weischmeier

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and Smith (1978), is the most widely used erosion prediction method.

Erosion is a natural geological phenomenon resulting from the removal of soil particles by water or wind, transporting them elsewhere, while some human activities can significantly increase erosion rates (2). One of the most widely applied empirical models for assessing the sheet and rill erosion is the Universal Soil Loss Equation (USLE).

2. About the study area

The upper part of Dwarakeswar river basin situated mainly in the part of Puruliya & Bankura district of West Bengal state (Fig: 01). This area contains Para. Hura, Kashipur, Raghunathpuer-1, Santuri blocks of Puruliya and Indpur, Chhhatna, Bankura blocks of Bankura district. This area is bounded on the north &northeast by the Bankura &Bardhaman district which is separated by damodar river .In the southeast lies Bankura & Medinipur district, while the entire southern &western parts are bounded by Puruliya district. The total geographical area of the study area is 135375 hectors.the area is included in the survey of

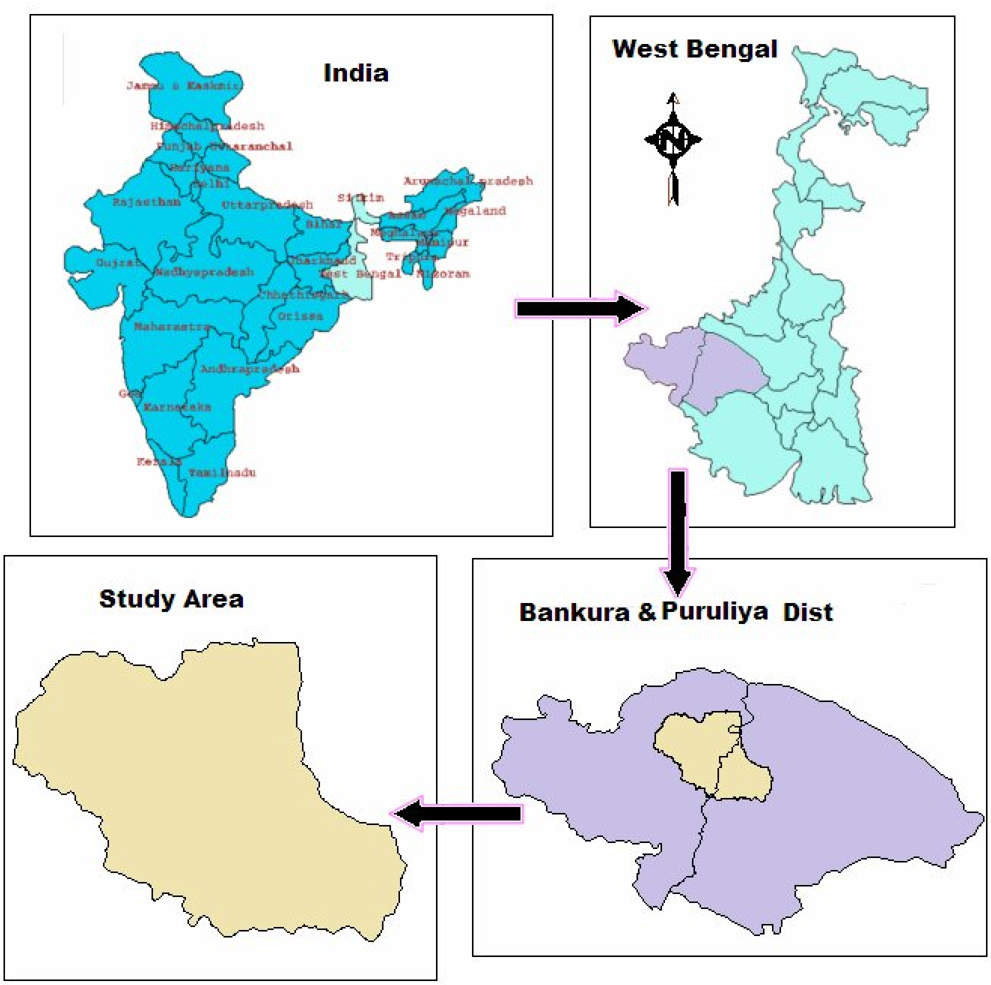

Fig. 1 Location of study area.

India toposheet numbers 73-I /11; 73-I/12; 73-I/15; 73-I/16; 73-M/4 and 73-M/3.
The latitude, & longitudinal extension of the area is 86°31'03.68"E to 87° 02' 45.81"E longitude and 23° 31 '38.68" N to 22° 57 ' N latitude.

Soil type (Fig: 02) will help determine how much water reaches the river. Certain soil types such as sandy soils are very free draining and rainfall on sandy soil is likely to be absorbed by the ground (Sarangi et al. 2000). However, soils containing clay can be almost impermeable and therefore rainfall on clay soils will run off and contribute to flood volumes. After prolonged rainfall even free draining soils can become saturated, meaning that any further rainfall will reach the river rather than being absorbed by the ground.

2.2 Drainage

The river originates from (Puruliya dist.) western upland of chhotonagpur plateau region to and flow almost parallel to each other carrying seasonal flow of water & meets Damodar River. The river Dwarakeswar is flowing from northwest to southeast of the study area. The study area drainage pattern in dendrite drainage pattern, here sub stream meet with mainstream at right angle (Fig: 03).We see 6th sub watershed in the study area. The total area of river watershed 135375 hectors and the length of river is around 80.249 km. Beko Nadi & Dudhbhariya Nala are the prominent tributaries of the Dwarakeswar river.

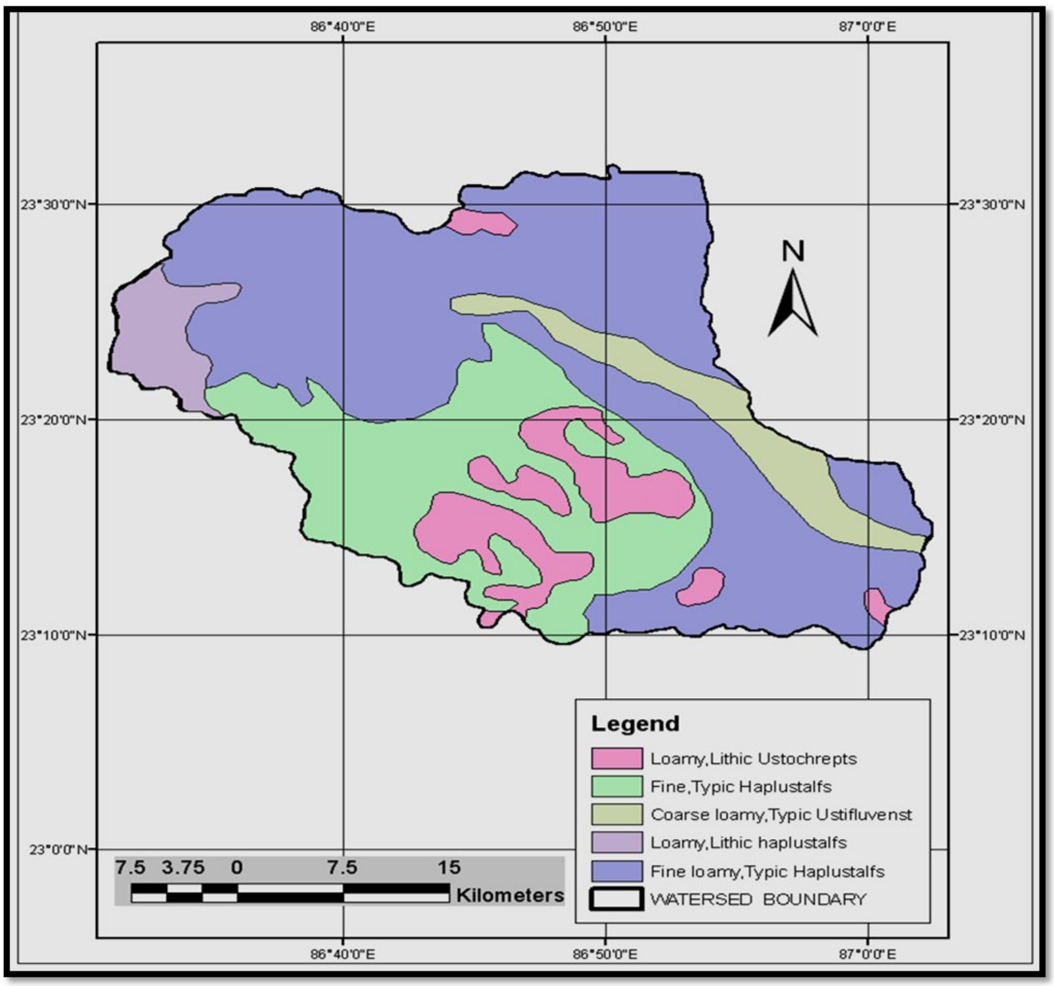

Fig. 2 Study area Soil Map.

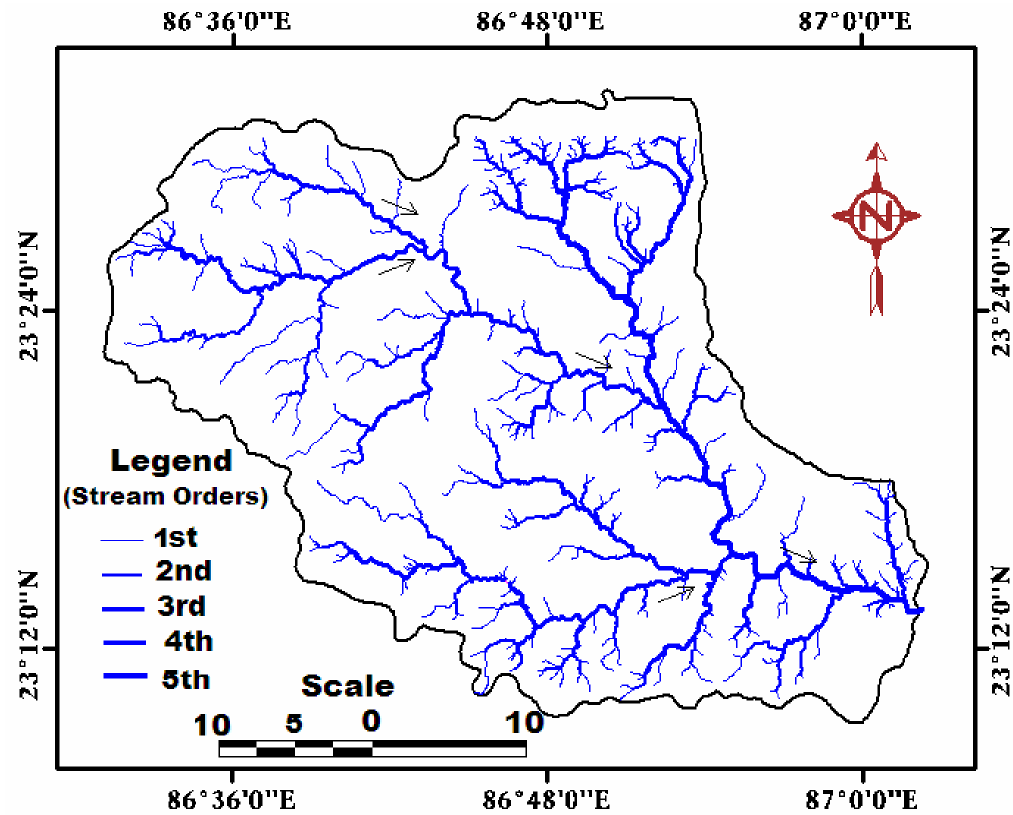

Fig. 3 Study area Drainage Map.

2.3 Slope Aspects

Slope aspect map (Fig: 04) is typically created by GIS analysts. They are often created with publicly available elevation data, which, in many cases, does not provide the detail or currency needed for accurate slope / aspect analyses.

Aspect maps (Fig: 04) enable you to quickly evaluate the slope and aspect of the terrain for a variety of applications, such as: 1. Examining the steepness and /or direction of slope. 2. Determining the speed and direction of runoff from snow melt. 3. Estimating rain (or, in some cases, chemical spills or leaks) run-off and direction. 4. Identifying areas at risk for landslides, avalanche, wildfires, and other hazards. 5. Distinguishing sites with maximum or minimum sun exposure. 6. Identifying possible suitable landing sites for emergency response helicopters.

2.4 Soil & Water Conservation

Gully erosion is evident in the most of the areas. As a part of mechanical measure of soil and water conservation practice construction of the eastern embankments of the composite types across the gully beds at suitable location may be taken up to collect and store the runoff for during stress period for optimum growth of crops for homestead uses, fisheries etc. Beside the water storage tanks will function as infiltration tanks to maintain the sub surface moisture storage capacity. They are simple structure & may be constructed as apart of soil conservation work across gullies (Wani et al. 2002).

2.5 Geology

The dominant geological formation of the study area comprises Archaean Dharwarian rocks and is an extension of peninsular mass of chhotonagpur plateau. There are two shear zones

(i) South Puruliya shear zone WNW – ESE trending tectonically distributed shear zone and (ii) North Puruliya shear zone ,there are numerous lineaments picked up by remote sensing Apart from the whole districts our study area chiefly constitute of Granite genesis migmatite , Mica schist, Amphibolites & hornblende schist also Intrusive granites (Kuilapal, Manbhum and other granites).

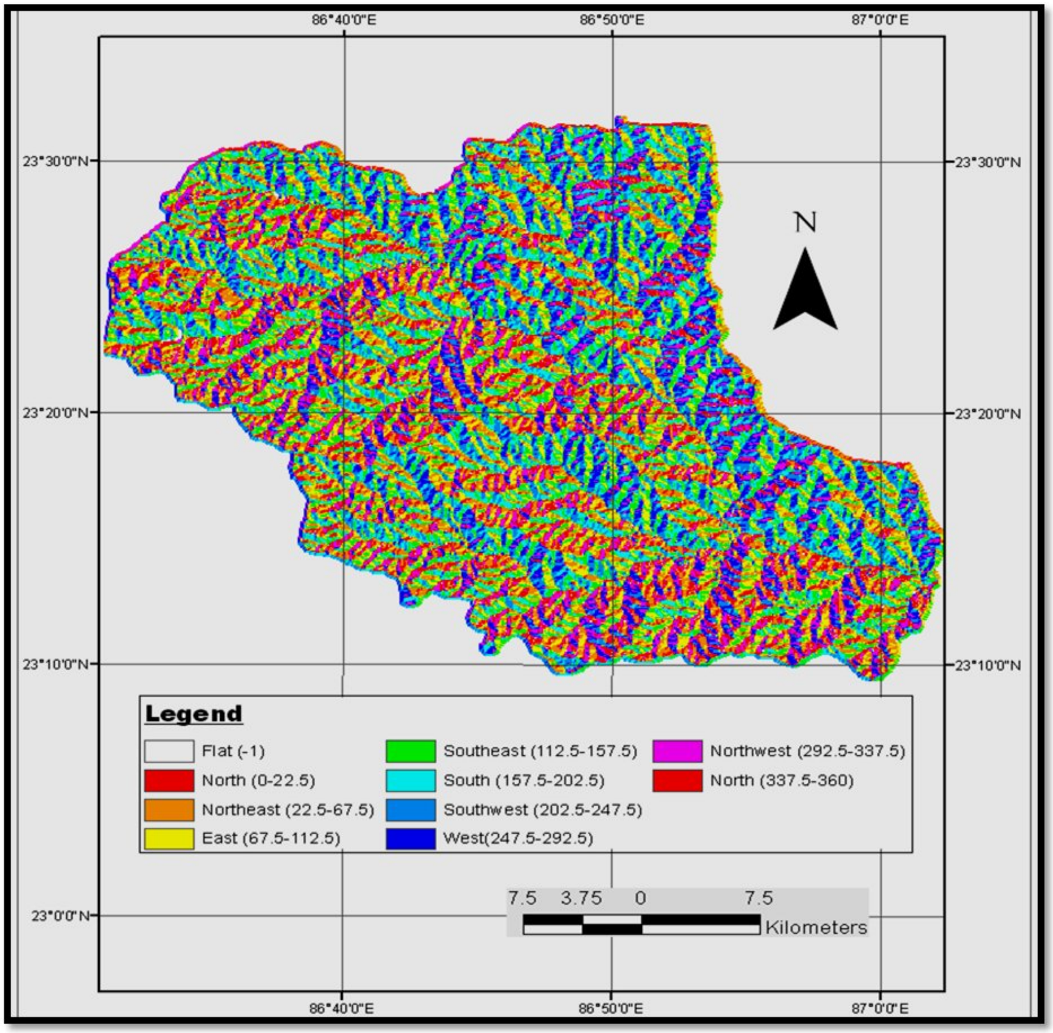

Fig. 4 Study area Slop and Aspect Map.

2.6 *Climate*

The climate of the district is of tropical dry sub-humid with normal annual rainfall ranging from 1100 mm in the western part and 1400mm in the eastern part .The mean daily temperature ranges from 12^{0}c (in winter) to the maximum 46^{0}c (in summer) The variations in the number of rainy days &soil moisture limitations are common. Severe drought periods lasting for weeks adversely affect the crop growth & yields during main cropping Kharif season.

2.7 *Land Use / Land Cover*

Land use is the surface utilization of all the development and vacant land on a specific point, at a given time and space. This leads on back to the village from and the farmer to the field gardens, pastures, fallow and forest and to the isolated farmstead. The difference between the land uses and the land utilization is important. Land use is the use actually made of any parcel of land, house, and apartments. And industrial locations are land use categories, where as the term residential, industrial and agricultural refers to a system of land utilization implying roads, neighborhood retail and service activities as well as location of industry and carrying of agricultural pursuits. In a rural areas tree crop and corn crop would identify the land use.

The most part of land use map we see the agricultural fallow land, here one time of year cultivation is occurred. The southwestern western and southeastern part thin forest are present. Here also shows existing

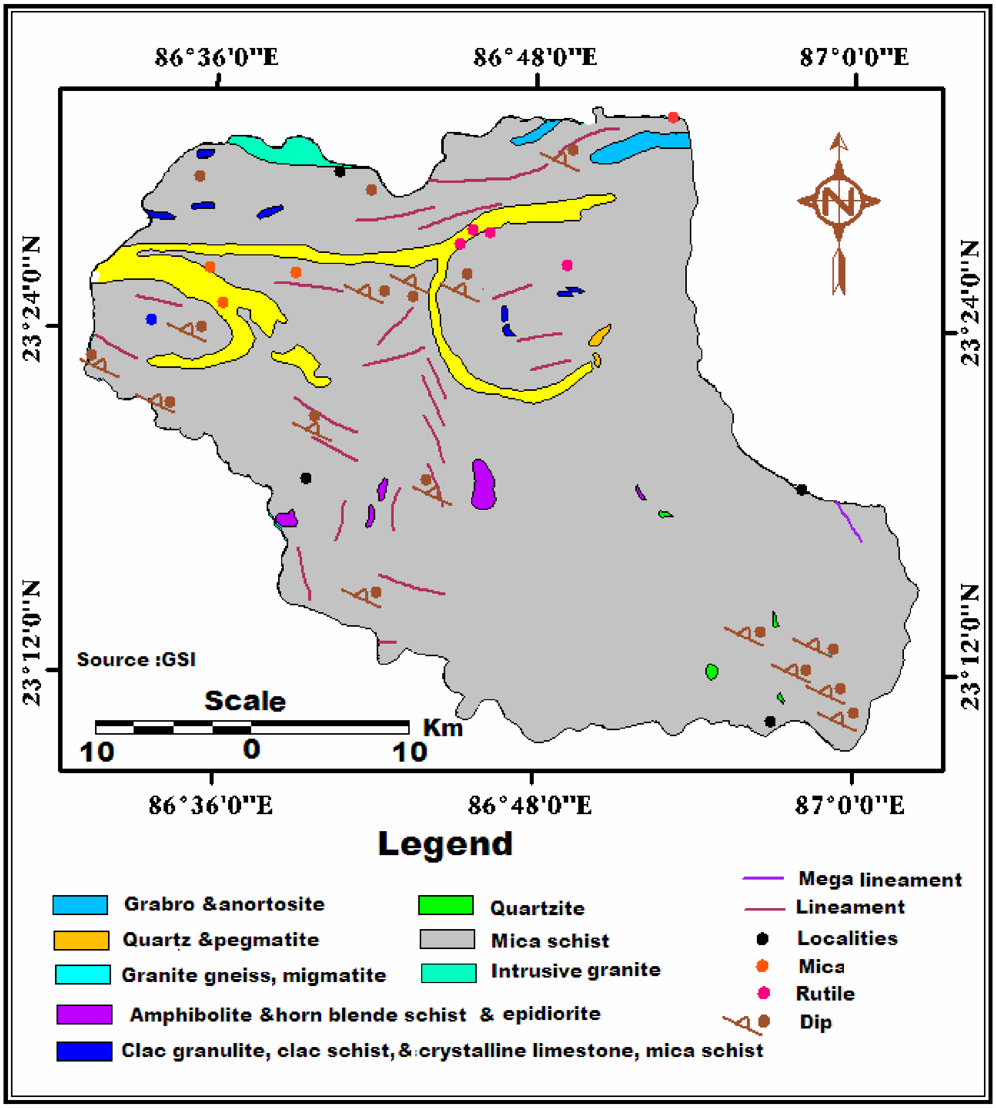

Fig. 5 Study area Geology Map.

agriculture, open fallow land. And also covered wetland, sand few portion of the study area. Here huge amount gully erosion is present. Southeastern rail way pass through the eastern part. Here different type of metal led & un-metal roads are present.

3. Aim and objectives

In the purpose of better management of water resource the present study consider the following objectives.

- Identification of DWARAKESWAR watershed (upper parts) in its division in 6th sub watershed.
- The studies of physical attribute mainly relief, drainage climate, water availability soil and geology.
- To analyzed the land use character in relation to physical attribute.
- To distribute land use among the sub watershed and their areal distribution
- To classify the stream according to drainage order followed by Strahler's.
- Finally to prepare management plan with special reference to the construction of check dam.

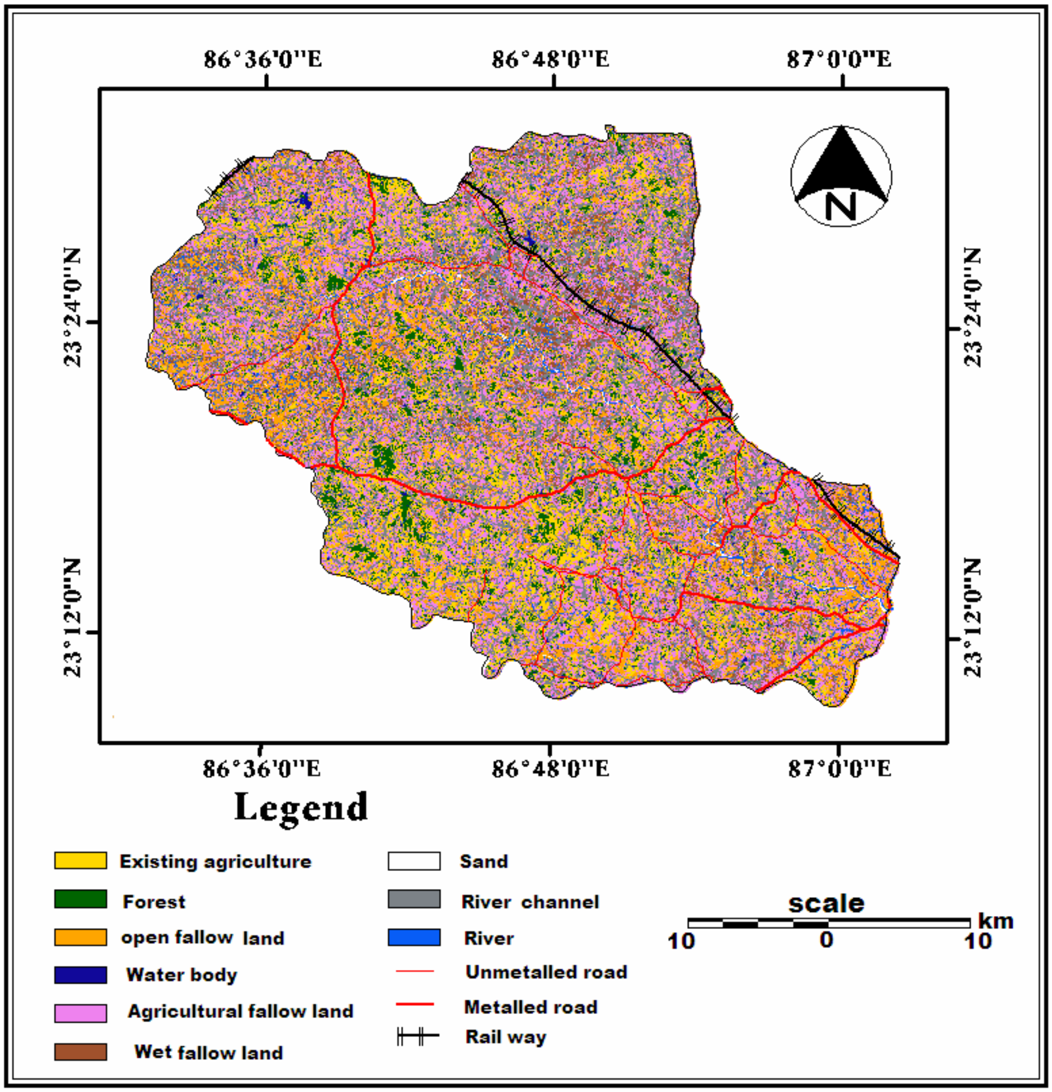

Fig. 6 Study area Land use/Land cover Map.

Table 1: Data and Data Sources

Data	Source	Use for
73-I/11, 73-I /11; 73-I/12; 73-I/15; 73-I/16; 73-M/4; 73-M/3;	SOI- Kolkata	Forest, Contour & Settlement
Geology map	GSI- Kolkata	Soil & Geology
SATALLITE IMAGE		Land Use/ Land Cover
SRTM		Drainage, DEM, Slope

Soil erosion measurement using Satellite data processing
UNIVERSAL SOIL LOSS EQUATION (USLE) $A = R \times K \times LS \times C \times P$

4. Data and methodology

UNIVERSAL SOIL LOSS EQUATION (USLE) $A = R \times K \times LS \times C \times P$

A represents the potential long term average annual soil loss in tons per acre per year. This is the amount, which is compared to the "tolerable soil loss" limits.

R is the rainfall and runoff factor by geographic location as given in Table 02, *R factor Dat*a. The greater the intensity and duration of the rain storm, the higher the erosion potential. Select the R factor from Table 02 based on the county and corresponding station where the calculation is to be made.

K is the soil erodibility factor. (See Table 3, *K Factor Dat*a). It is the average soil loss in tons/acre per unit area for a particular soil in cultivated, continuous fallow with an arbitrarily selected slope length of 72.6 ft. and slope steepness of 9%. K is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. Texture is the principal factor affecting K, but structure, organic matter and permeability also contribute.

LS are the slope length-gradient factor. The LS factor represents a ratio of soil loss under given conditions to that at a site with the "standard" slope steepness of 9% and slope length of 72.6 feet. The steeper and longer the slope, the higher is the risk for erosion. Use Table 04, *LS* Factor Calculation or the "Equation for Calculating LS" included in this Factsheet to obtain LS.

C is the crop/vegetation and management factor. It is used to determine the relative effectiveness of soil and crop management systems in terms of preventing soil loss. The C factor is a ratio comparing the soil loss from land under a specific crop and management system to the corresponding loss from continuously fallow and tilled land. The C Factor can be determined by selecting the crop type and tillage method (Table 5A, Crop Type Factor and Table 5B, Tillage Method Factor respectively) that corresponds to the field and then multiplying these factors together. The C factor resulting from this calculation is a generalized C factor value for a specific crop that does not account for crop rotations or climate and annual rainfall distribution for the different agricultural regions of the country. This generalized C factor, however, provides relative numbers for the different cropping and tillage systems; thereby helping you weigh the merits of each system.

P is the support practice factor. It reflects the effects of practices that will reduce the amount and rate of the water runoff and thus reduce the amount of erosion. The P factor represents the ratio of soil loss by a support practice to that of straight-row farming up and down the slope. The most commonly used supporting cropland practices are cross slope cultivation contour farming and strip cropping (Table: 06, *P Factor Dat*a).

5. Results and discussion

The parameters (R, K, LS, C and P) are calculated for quantity of soil loss in per acre/ year.

$LS = 0.065+0.0456(\text{slope}) +0.006541(\text{slope})^{2](}$slope length/const)^{NN}

Slope length = length of slope (ft.)

Constant = 72.5 Imperial or 22.1 metric NN = see Table 04

Management Strategies to Reduce Soil Losses: The R factor for a field cannot be altered. The K Factor for a field cannot be altered. LS factor Terracing requires additional investment and will cause some inconvenience in farming. Investigate other soil conservation practices first. C factor, Consider cropping systems that will provide maximum protection for the soil. Use minimum tillage systems where possible. P factor, Use support practices such as cross slope farming that will cause deposition of sediment to occur close to the source (Ahmad and Verma 2013).

DWARAKESWAR UPPER CATCHMENT, CALCULATION OF SOIL EROSION USING USLE, $A = R \times K \times LS \times C \times P$

Rainfall and Runoff Factor (R)

Therefore the R factor is obtained in Table 1 from the Delhi weather station.

R factor = 100

Soil Erodibility Factor (K)

The sample field consists of fine Silt Clay Loam soil with average organic matter content. The K Factor is obtained from Table 2.

K Factor = 0.32

Slope Length-Gradient Factor (LS)

The LS factor calculated using "Equation" using the NN value in Table 3.

LS Factor = 1.4

Crop/Vegetation and Management Factor (C)

The sample field was plowed in the spring and grain corn was planted. The C Factor is obtained from the crop type factor (Table 4A) and the tillage method factor (Table 4B).

Crop Type Factor for grain corn = 0.4

Tillage Method Factor for No Tillage = 0.25

C Factor = 0.4 x 0.25 = 0.1

Support Practice Factor (P)

Cross Slope farming is used on this sample field. The P Factor was obtained from Table-5.

Table 2: R Factor Data

Weather Station	County	R Factor
Brantford	Brant	90
Delhi	India	100
Essex	Essex	110
Fergus	Dufferin, Wellington	120
Hamilton	Halton, Hamilton-Wentworth	100
Kingston	Frontenac, Lennox & Addington, Prince Edward	90
Kitchener	Waterloo	110
London	Lambton, Middlesex, Oxford	110
Mount Forest	Bruce, Grey, Halliburton,	90
Niagara	Niagara	90
Northern Ont.	Algoma, Cochrane, Kenora, Manitoulin, Parry Sound,Rainy River, Sudbury,Thunder Bay, Timiskaming	90
Ottawa	Glengarry, Lanark, Leeds, Nipissing, Ottawa- Carleton, Renfrew, Russell, Stormont	90
Prospect Hill	Huron, Perth	120
Ridge town	Kent	110
Simcoe	Haldimand / Norfolk	120
Toronto	Metro-Toronto, Peel, York	90

Note: any other counties not in this chart are assumed to have an R factor of 90.

Table 3 : K Factor Data

Textural Class	Organic Matter Content		
	Average	Less than2 %	More than 2 %
Clay	0.22	0.24	0.21
Clay Loam	0.30	0.33	0.28
Coarse Sandy Loam	0.07	-	0.07
Fine Sand	0.08	0.09	0.06
Fine Sandy Loam	0.18	0.22	0.17
Heavy Clay	0.17	0.19	0.15
Loam	0.30	0.34	0.26
Loamy Fine Sand	0.11	0.15	0.09
Loamy Sand	0.04	0.05	0.04
Loamy Very Fine Sand	0.39	0.44	0.25
Sand	0.02	0.03	0.01
Sandy Clay Loam	0.20	-	0.20
Sandy Loam	0.13	0.14	0.12
Silt Loam	0.38	0.41	0.37
Silt Clay	0.26	0.27	0.26
Silt Clay Loam	0.32	0.35	0.30
Very Fine Sand	0.43	0.46	0.37
Very Fine Sandy Loam	0.35	0.41	0.33

Table 4 : NN Values

S	<1	1? slope<3	3? slope<5	? 5
NN	0.2	0.3	0.4	0.5

Table 5A : Crop Type Factor

Crop Type	Factor
Grain Corn	0.40
Silage Corn, Beans & Canola	0.50
Cereals (Spring & Winter)	0.35
Seasonal Horticultural Crops	0.50
Fruit Trees	0.10
Hay and Pasture	0.02

Table 5B : Tillage Method Factor

Tillage Method	Factor
Fall Plough	1.0
Spring Plough	0.90
Mulch Tillage	0.60
Ridge Tillage	0.35
Zone Tillage	0.25
No-Till	0.25

Table 6A : P Factor Data

Support Practice	P Factor
Up & Down Slope	1.0
Cross Slope	0.75
Contour farming	0.50
Strip cropping, cross slope	0.37
Strip cropping, contour	0.25

Table 6B : Soil Loss Tolerance Rates

Soil Erosion Class	Potential Soil Loss (tons/acre/year)
Very Low (tolerable)	<3
Low	3 – 5
Moderate	5 – 10
High	10 – 15
Severe	>15

P Factor = 0.75

Therefore,

A= R x K x LS x C x P

= 100 x 0.32 x 1.4 x 0.1 x 0.75

= 3.36 tons/acre/year (Metrication)

6. Conclusion

All the above analysis is for optimum development of land and water resources and to meet the basic minimum needs of people thereby improving their socioeconomic conditions. The information generated from such studies can be applied by decision makers and planners for sustainable development of any given watershed area.

The current work done was a macro analysis, and due time constraints as it was an academic project, ground truth or micro analysis for watershed could not be carried out. So it is advised to carry out a micro analysis supported by ground truthiness before implementation of these development plans.

Analysis of satellite imagery and other maps and collected information with RS & GIS techniques can yield better results, which can support decision for management. The present study reveals the character of upper DWARAKESWAR basin in the form of soil, relief, drainage, land use etc and other collected information about climate geology local problems etc are use for analysis with RS &GIS techniques. The result advocates for check dam construction at selected sites. Again the check dam sites are selected by analyzing the information experienced through analyzing the maps and imageries with RS &GIS techniques. Seven of such sites are initially selected with the mentioned (earlier) objectives, through farther detailed studies is needed before going to execution stage.

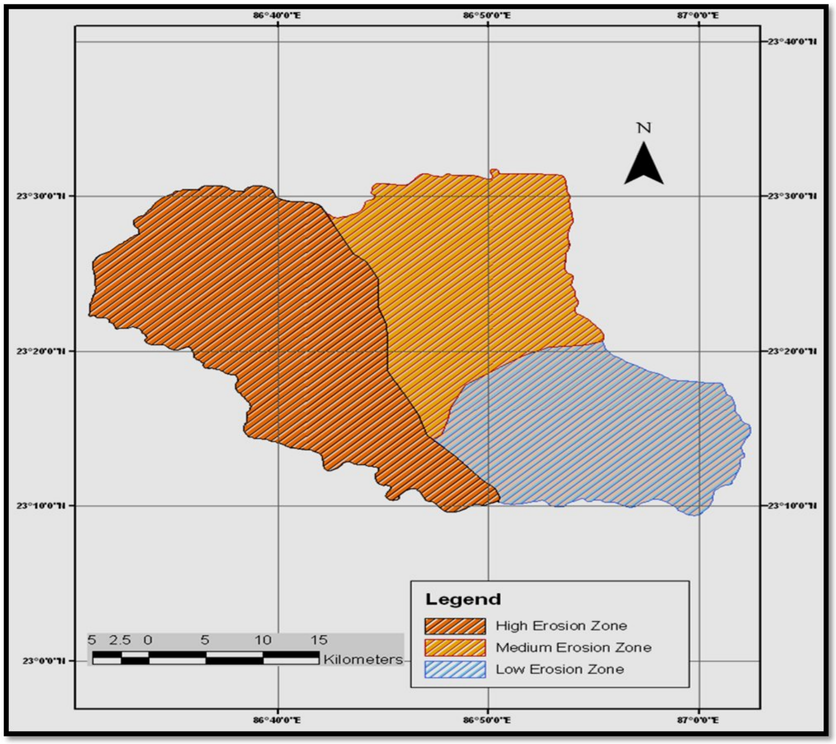

Fig. 7 Study area Soil Erosion Zone

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