Soil Erosion Estimation of Sitla Rao Sub Watershed Using RS & GIS Technology

R.D. Doi[1], Shashikant[2], Pallavi Singh[3]

Professor, University of Rajasthan- Jaipur.
JRF, Haryana Space Application Center (HARSAC)
Student, University of Rajasthan- Jaipur

ABSTRACT – Soil erosion is a serious environmental problem in Sitla Rao sab watershed. Soil erosion modeling, described here, is based on the methods explained (Morgen, 1986; Morgen and Finney, 1984). The model tries to encompass some of the recent advances in understanding of erosion processes. The model separates the soil erosion process into a water phase and a sediment phase. It considers soil erosion to result from the detachment of soil particles by raindrop impact and the transport of those particles by overland flow. Sloping areas in the buffer and transition zone can be categorized as fragile areas. Erosion would normally be expected to increase in slope steepness and slope length as a result of respective increase in velocity and volume of surface runoff. It is also clear that surface runoff quantum is dependent on rainfall amount. It is indicated that 'in Sitlarao sub-watershed good correlation was found between annual rainfall and elevation differences i.e. r value of 0.743 (Shrestha, 1997, p. 333)'. Slope steepness and slope length are dominating factors for controlling stream velocity and run off respectively. The ancillary data contours, slope, aspect, numbers of rainy days, soil map, land use/land cover and LISS-3 digital data are used to estimate the erosion. The western part of the study area is characterized by the lowest soil loss. In central path of the study area there are also certain pockets with lower soil loss. Movement of a cursor in raster map provides significant varying values.

Key words: - Soil erosion, erosion model, digital elevation model and ILWIS.

1. INTRODUCTION

The main factors causing soil erosion are climate, soil, vegetation, topography and man. These vegetation & to some extent soil and the topography may be controlled. The climatic factors and also the topographic and soil factors are beyond the power of man to control. The raindrops that fall on the bare soil are the initiation for soil erosion. Falling raindrops disturb the aggregated soil particles.

Slow and steady erosion year after year in each monsoon deprives the soil of its nutrients. Soils represent a storehouse of available nutrients held in their exchange complex. The living microorganisms, which perform many nutrient transformations like nitrification, ammonification and mineralization, are all lost, leaving the land poorer. Water soluble nutrients are also lost, leaving the land very poor. All this gradually mark the soils depleted in their nutrients and fertile topsoil, which perhaps took years to build up. 'The soils are degrading, at a rate much faster than their natural regeneration or resilience (Sehgal et al, 1997. p. ix)'. Remote sensing with aid of the Geographic Information System (GIS), by creating much more homogeneous polygons, has dependable accuracy for evaluation of models.

2. STUDY AREA

Sitla Rao Sub-watershed is coded 2C6C1s (Govt. of India, 1990, Plate 14). It is located in the western part of Doon valley, Dehradun District, newly created Uttrakhand State of in India. The sub watershed belongs to the Asan river system which is a tributary of Yamuna River. as indicated in Sitlarao FCC (Figure 1.1). The study area lies approximately between latitudes 30^0 24' 43" N to 30^0 29' 04" N and longitudes 77^0 45' 35" E to 77^0 57' 40" E covering 57.48 km^2 (Figure 1.2). The area is characterized by having east-west oriented mountain range belonging to the Meso Mountains of the Indian Himalayas, a chain of erosional hills, extensive piedmont and river valleys. A base map for the study area has also been generated for ready reference. The area is characterised by having East-West oriented mountain range belonging to the Middle Mountains of Indian Himalayas, a chain of erosional hills, extensive piedmont and river valleys. The altitude varies from 440 to 2300 m asl. The climate is characterised by hot summers and cold winters. The rainfall varies from 1600 to 2200 mm, depending on elevations, most of which falls in the rainy season (June-August). Land cover/land use is characterised by forest, grazing land and agriculture. In the lower elevation forest type is dominated by sal trees (*Shorea robusta*) while in the higher elevations the forest is of mixed type. Main crops are rice, wheat, maize and sugarcane.

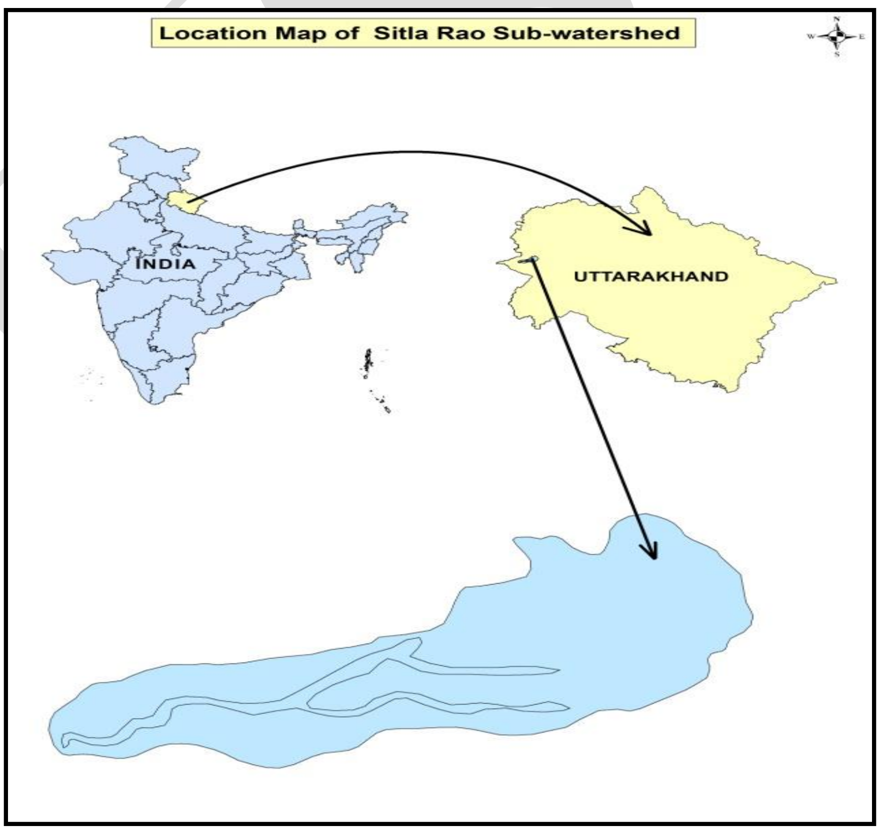

Figure: 1. Location map of Study area

3. MATERIALS AND METHODOLOGY

Satellite Image of IRS-D1 LISS-III (acquired on 2001) and Survey of India toposheets (53F/15) mentioned above of 1:50,000 scale as collateral data. Ancillary Data like Contours, Slope, Aspect, Internal Relief, Rainfall, Number of Rainy Days, Soil Map, Soil Unit Attributes, Land Use/Land Cover Attributes are used.

The Survey of India (SOI) toposheets for the study area have been procured, scanned and geometrically rectified so that each point represents correct geographical coordinates. Satellite Images of IRS-P6 LISS-III have been georeferenced with respect to toposheets and mosaiced. Land use/land cover classes were delineated on screen by digitizing using the Integrated Land and water information system (ILWIS Academic 3.2) software based on visual interpretation keys. A day intensive field checking effort was made in order to collect ground truth information by the three member group.

Sufficient ground truths were collected by traversing from west to east, south to north, east to west and north to south directions forming a rectangular path in the study. Garmin GPS instrument was also used to ensure the precise location in the field. Afterwards necessary corrections were done for the doubtful classes adopting supervised classification. Thus a final land use/land cover map outcome is obtained for Sitlarao sub-watershed including non spatial attribute statistics. A flow diagram of methodology is also given (Figure 1.2).

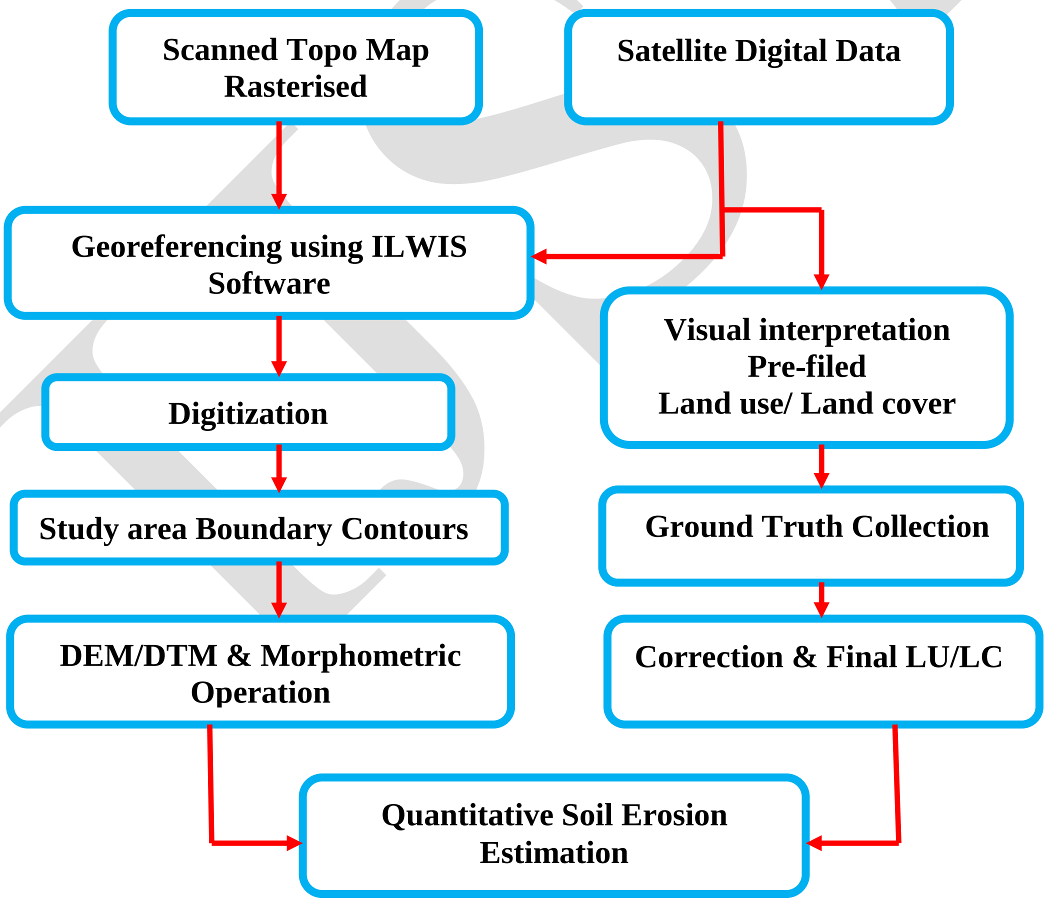

Figure: 2. Methodology Flow Chart

4. SOIL EROSION ESTIMATION

Even soils appearing similar are not only variable at surface but are much variable vertically in third dimension - the depth, which is the main seat of production. They vary greatly in their morphological, physico-chemical and biological properties. In spite of all these estimates it is difficult to estimate erosion precisely. These factors are found in different activities and locations within catchments. There are various types of factors affecting soil erosion are illustrated (Figure 3).

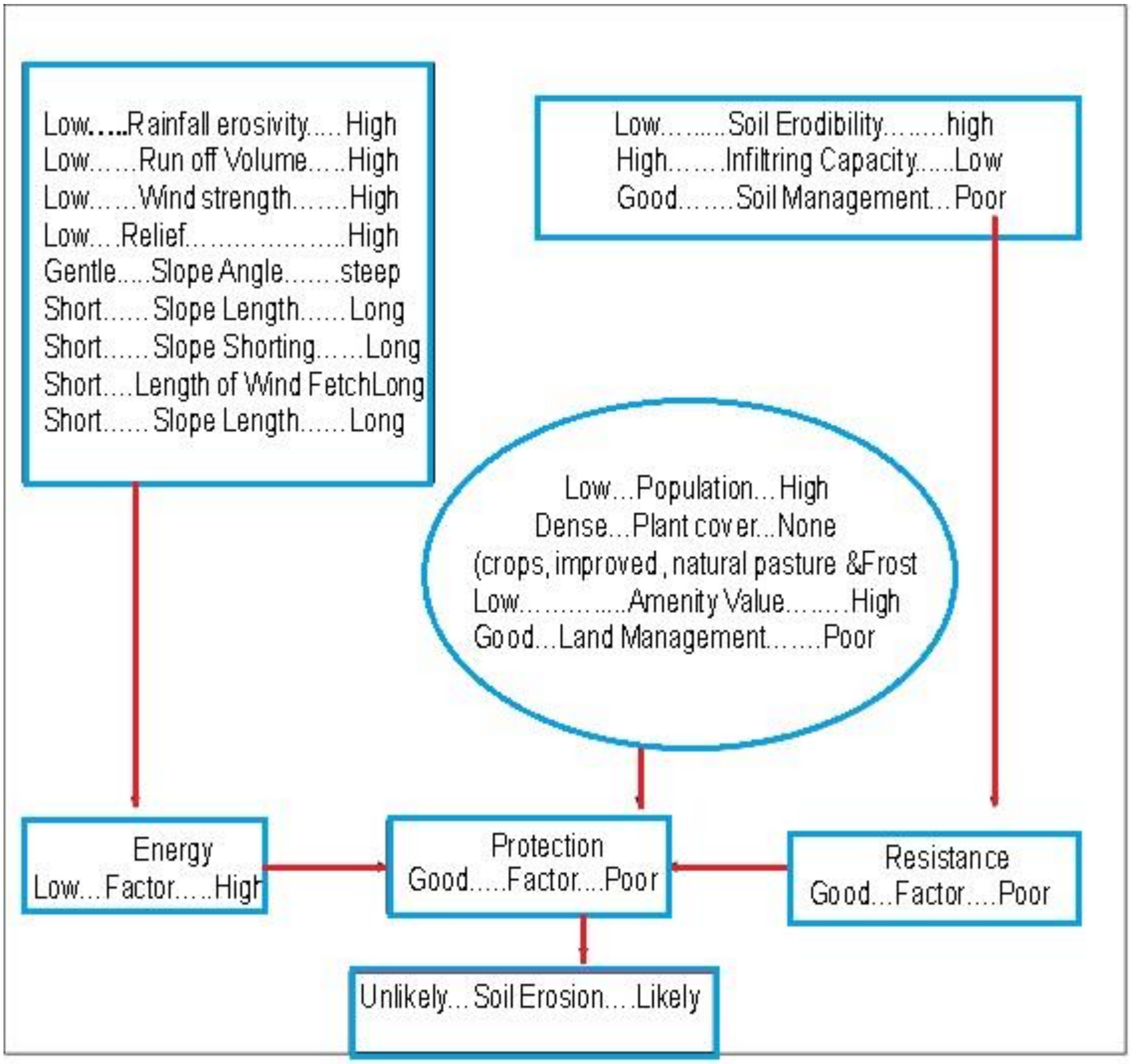

Figure: 3 Soil Erosional General Model (After Singh 1998, p.62)

Soil unit attributes as well as land use/land cover attributes have been utilized which are given in the table1 and 2 respectively. The inputs which have been used in estimating soil loss considering parameters of both water and sediment phases as indicated in the beginning of this chapter. The outputs generated are pertaining different variables as shown indicated (Figures 4 Rainfall, 5 Kinetic Energy of Rainfall, 6 Ratio of Actual to Potential Evopotranspiration, 7

Percentage of Rainfall, 8 Soil Bulk Density, 9 Soil Loss (kg/m^2/annum and 10 Soil Loss (Tonnes /Hact./annum)
Finally, soil loss has been estimated which is being indicated in kg/m^2/annum as well as in tones/hectare/annum. In order to estimate soil loss in kg/m^2/annum and tones/hectare/annum the following have been applied and figure are obtained.
Kinetic energy of rainfall (E) in j/m^2 is dependent on the amount of annual rain (R) and the rainfall intensity (I). It can be derived by the following equation:

E = R*(11.9 + 8.7* log (101))
For computing the rainfall energy, the rainfall map generated earlier in the exercise can be used. For rainfall intensity take the value of 25 mm/hr for Sitla Rao watershed and generate the rainfall energy map in map calculation
By typing the following command in the command line:

E = R*(11.9 + 8.7*log (25)

Estimation of the rate of soil detachment
Soil detachment is a function of soil detachability index defined as the weight of soil detached from the soil mass per unit of rainfall energy.
It can be computed by using following equation:

$F = K*(E*e^{(-0.05*A)}*1.0*10^{-3}$
Where F is the rate of soil detachment in kg/m^2, K is the detachment index and A is the Percentage rainfall contributing to permanent interception.
Q= R* exp (-Rc/Ro)
Where

Rc= 1000*MS*BD*RD*(t/Eo)*0.5

Ro = R/Rn

Where MS= Moisture Storage Capacity, BD = Soil Bulk Density, RD = Rooting Depth, Et/Eo= Ratio of actual to PET, R= Amount of Annual Rain, Rn= Number of days.

Estimation of transport capacity of overflow G is given by

G= C*Q^2.0* sin (S*10-3), where C is the crop cover management factor,

Q the volume of over land flow and S the topographic slope factor

The transport capacity of the overland flow can be rewritten as:

G= C*sq(Q)*sin(degrad (S))*0.001kg/m2

Soil loss is given by -Soil loss= min (G, F) kg/m2 /annum and Soil loss= min (G, F)*10 tons/hact/ annum

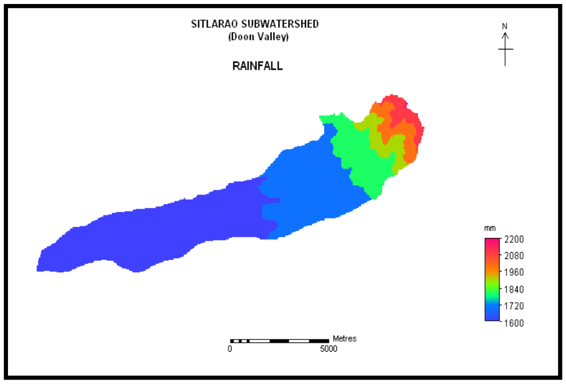

Figure: 4

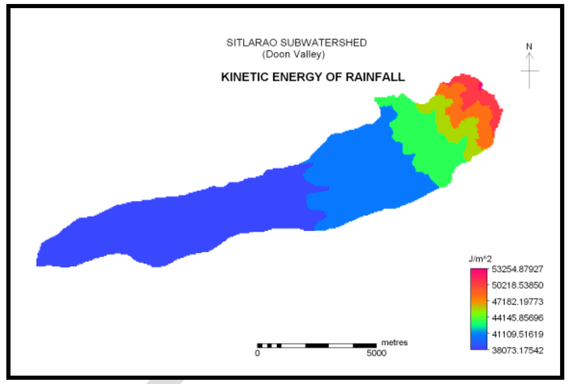

Figure: 5

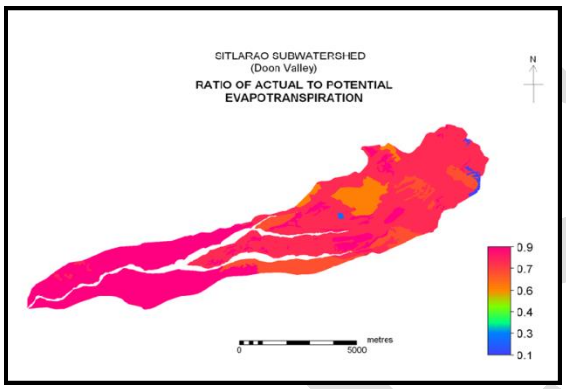

Figure: 6

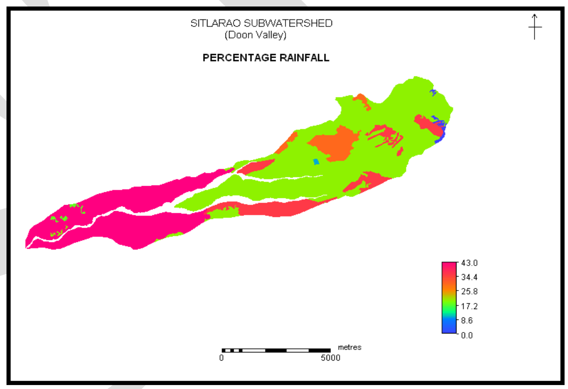

Figure: 7

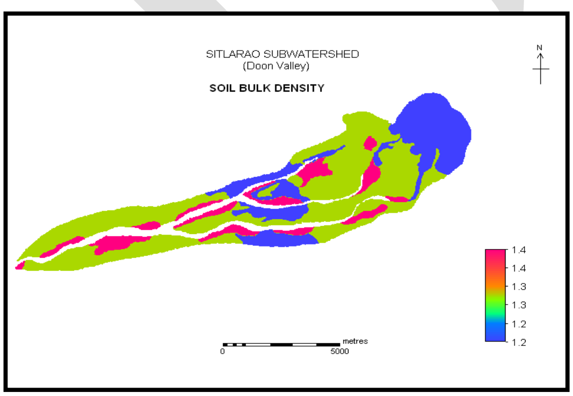

Figure: 8

Figure: 9

Issue 4 volume 4, July-August 2014
ISSN 2249-9954

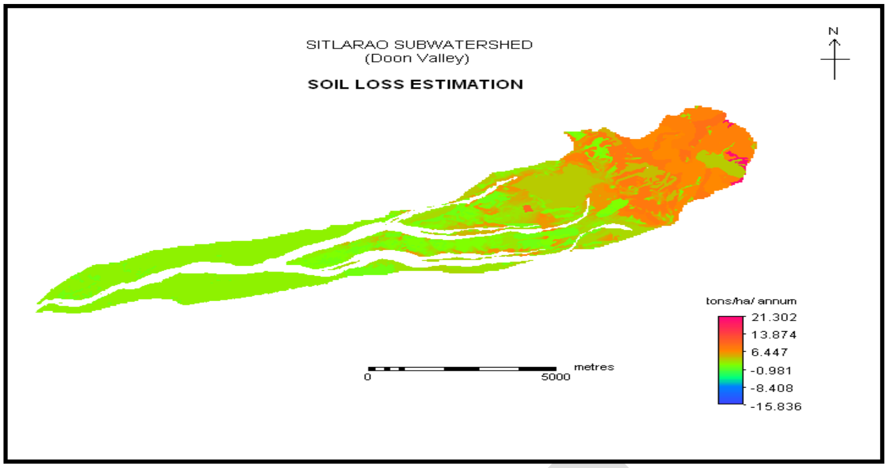

Figure: 10

Table 1. Soil attribute table, Sitlarao Sub watershed

Soil map unit	Area (m)	Drainage class	Surface texture	Soil depth class	pH (top soil)	Stoniness %	1s fact	Bulk (g/cm^3)	M storage capacity	K fact
H11	2.39	Well drain	Gravely loam	Shallow	6.6	40	4.0	1.3	0.18	0.45
H12	2.73	Well drain	Loam	Deep	6.5	20	4.3	1.3	0.18	0.50
H13	0.23	Well drain	Gravely loam	Deep	7.2	50	4.5	1.4	0.20	0.40
H21	2.87	Well drain	Loam	Deep	6.8	20	4.0	1.3	0.20	0.48
M1	1.1	Excellent drain	Gravely Sandy loam	Shallow	7.5	90	6.0	1.2	0.26	0.45
M2	6.0	Excellent drain	Gravely Sandy loam	Shallow	7.0	90	6.5	1.2	0.25	0.43
M3	0.57	Excellent drain	Gravely Sandy loam	Shallow	6.8	90	5.5	1.2	0.25	0.40
P11	2.15	Well drain	Gravely loam	Deep	6.8	35	3.5	1.4	0.18	0.35
P12	6.73	Well drain	Loam	Very deep	6.6	15	3.2	1.3	0.20	0.40
P21	4.35	Well drain	Gravely Sandy loam	Very deep	7.2	10	2.5	1.3	0.20	0.36
P22	5.26	Well drain	Sandy loam	Deep	7.4	5	2.6	1.2	0.28	0.38
V1	9.72	Well drain	Loam	Deep	6.8	0	1.2	1.3	0.20	0.41
V2	4.07	Excellent drain	Loamy sand	Deep	7.0	5	1.0	1.4	0.10	0.30
V3	0.63	Excellent drain	Sandy loam	Deep	6.8	40	1.5	1.2	0.15	0.35
River	6.0	-	-	-						
Total										

Table 2. Land use/ Land cover Attributes of Sitlarao Watershed

	Area	Percentage Area	Perimeter (m)	N Pol	C	P	RD	A	Et/Eo
Degraded Forest	25328698.7	44.1	146066.6	1.0	0.030	0.8	0.10	20	0.8
Dense Mix Forest	956340.1	1.7	15868.9	6.0	0.010	0.8	0.10	20	0.9
Dense Sal Forest	2762975.4	4.8	55612.0	26	0.004	0.8	0.10	20	0.9
Forest Blank	55931.0	0.1	965.0	1	1.000	1.0	0.08	10	0.2
Highly Degraded Slope	296133.3	0.5	8241.3	2	1.000	1.0	0.02	00	0.1
Intensive Cultivation	15835446.8	27.6	50486.4	2	0.300	0.6	0.07	43	0.9
Low intensity/Terraced Cultivation	2816028.3	4.9	15277.4	3	0.5..	0.7	0.05	30	0.6
Moderate Cultivation	5598562.9	9.7	46592.1	7	0.400	0.7	0.06	35	0.7
Orchard	79310.8	0.1	3049.6	3	0.007	0.8	0.10	20	0.9
Plantation	178900.2	0.3	5533.1	5	0.008	0.8	0.09	18	0.8
River	3567463.8	6.2	48639.4	1	0.000	?	?	?	?

5. RESULTS AND DISCUSSIONS

1. The western part of the study area is characterized by the lowest soil loss. In central path of the study area there are also certain pockets with lower soil loss. Movement of a cursor in raster map provides significant varying values.
2. By applying conversion formula for soil loss (i.e kg/m^2 = 10 tones/hectare) on the previous soil map as an input. The standard values in term of tones per hectare per annum vary between 0 to 213.02. It is clear that altitudinal increase has some bearing on increased soil loss but it may not be a general case as it could be perceived by the movement of cursor on raster map.
3. There is high spatial variability in soil loss in the study area because of the fact that varies water and sediment phase processes have their bearing on existing soil loss. It is interesting to note that nil soil loss is also found in some pockets
4. Interpretation could be improved after taking ground truths from the study area .The project has helped us in learning RS & GIS techniques for different type of applications. Deforestation is taking place and steep slopes are more vulnerable for soil loss.

References:-

[1]. Morgan, R.P.C, Morgan, D.D.V. and Finney, H.J. (1984). A predictive model for the assessment of soil erosion risk. J. Agric. Engng. Res., 30: 24253.
[2]. Shrestha, D. P. 1997. The integrated Land and Water Information System (ILWIS) Department – Applications Guide. ITC Enschede, The Netherlands, pp. 323-342.
[3]. Singh, S. 1998. Impact of Erosion on Agricultural Land Use and Land Suitability: A Case Study of Morel Dam Catchment (Rajasthan). Unpublished Ph. D Thesis, University of Rajasthan, jaipur.

[4]. Government of India 1995. Report of the High Level Committee on Wastelands Development. Dept. of Wastelands Development, Min. of Rur. Areas & Employment, New Delhi.
[5]. Morgan, R.P.C. (1986). *Soil erosion and conservation*. Longman Scientific and Technical, England. ISBN 0-582-30158-0. 298 pp.