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Remote Sensing and GIS technique with Gardes equation for estimation of sediment yield

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Abstract: Sediment is naturally occurring material created due to process of weathering, erosion and transported by action of wind, water, ice and force of gravity on the particle. Sediment is important problem created in reservoir, dam or other storage structure and river. As sediment load increases, the capacity of storage structure or river reduces. Recently in India, draught occurs in most of region due to less rainfall. At such a condition if water stored is reduced due to sediment accumulation in storage or river then in future, it will become difficult to survive also. Hence, sediment estimation is important study to avoid sediment yield in storage structure.

In present research study, the estimated sediment yield by using Garde's equation was obtained for 2002-03 and 2008-09 were 12.37 and 14.82 t/ha/yr respectively. Increase in sediment yield from 2002-03 to 2008-09 were 2.45 t/ha/yr. Though there was small amount of increasing sediment yield, further watershed management is necessary to avoid increasing sediment yield in future. Land use land cover changes represent the changes in area under various land use land cover categories, which helps to decide importance of watershed development planning.Land use land cover (LULC) map was obtained for year 2002-03 and 2008-09 by using visual image interpretation method (by using RS and GIS). Waste land is increased by 15.55 per cent, agriculture land increased to a very less extent 0.18 per cent and forest land is reduced by 2.69 per cent, therefore the increased estimated sediment yield was observed to the extent of 2.45 t/ha/yr in six years i.e. from 2002-03 to 2008-09. To reduce the rate of increase of sediment yield, the agriculture land needs to be increased by decreasing the waste land.

Keywords: Sediment yield, Land Use Land Cover, USLE, Vegetative Cover Factor and Drainage density etc.

INTRODUCTION

Sediment is naturally occurring material created due to process of weathering, erosion and transported by action of wind, water, ice and force of gravity on the particle. Sediment is important problem created in reservoir, dam or other storage structure and river. As sediment load increases, the capacity of storage structure or river reduces. Recently in India, draught occurs in most of region due to less rainfall. At such a condition if water stored is reduced then in future, it will become difficult to survive also. To avoid such condition sediment estimation is important study to avoid sediment yield in storage structure. As sediment created in upland areas and collected it in plane area which situated at lower elevation than upland areas, erosion occurs at greater rate than sediment rate. Hence both soil erosion and sediment yield has great importance in river morphology (Garde *et. al.* 1987).

This equation is commonly used for estimation of annual sediment yield which is derived by using data obtained from catchment situated in India (Garde*et al.*1987). It is used for various purpose. It is used for determined the sediment yield from a catchment with a grid or cell-based approach along with a GIS(Kothyari and Jain 1997). It used for

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deciding soil conservation measures which is required for the watershed and conversion of wasteland into cropped land and the construction of check dams at study area if necessary (Sekhar and Rao 2002). It is also used for the assessment of sediment yield by using two approaches i.e. (i) relationship between suspended sediment load and discharge and (ii) empirical relationship (Jain *et al.* 2003).

The parameters in the Garde's equation like rainfall, drainage density, and slope are more or less similar to the USLE's R, L, S parameters. USLE equation did not mention the geological condition of an area but that is so important for the erosion factor calculation. In Gardes equation, the vegetal cover factor (F_c) represents the geographical condition of the area. Hence Gardes equation is correct for estimation of sediment yield.Land use land cover changes represent the changes in area under various land use land cover categories, which helps to decide importance of watershed development planning. Hence land use land cover change study is necessary for watershed development.

MATERIAL AND METHODS

Study Area

Present research was conducted on Sonwal watershed, located in Shahadataluka of Nandurbar district, Maharashtra. The watershed occupied 99.34 Km^2 area of Nadurbardistrict. The latitude and longitude of Sonwal watershed is 74° 53´ to 74°75´ N and 21°54´ to 21°62´ E. The temperature of this area is varied from 48 °C to 9 ° C. The watershed received 552 mm average rainfall per year.

Data used in the study

The data required for study as follows

- Digital imagery data : Landsat 7 for year 2002-03 and 2008-09
- Mean annual rainfall (mm) for year 2002-03 and 2008-09
- Monthly rainfall data (mm) for year 2002-03 and 2008-09
- Survey of India toposheet (1: 50,000) (Toposheet No. 46 K/10)

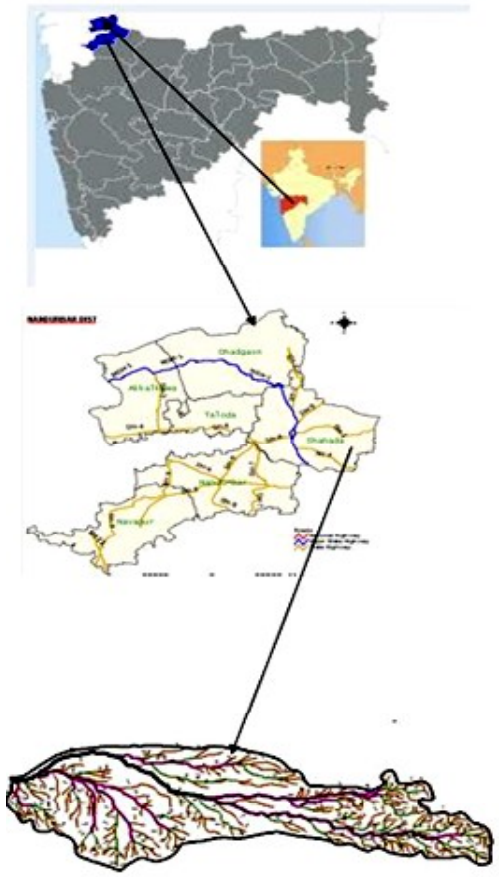

Figure 1: Location of study area

METHODOLOGY

Garde's Equation

This equation was developed from observations of 50 catchment areas placed all over India. This sediment yield equation is dependent not only on catchment area, but also on other parameters like slope, drainage density, annual rainfall and vegetal cover factor. The sediment yield equation developed by (Garde*et al.* 1987) used by (Upadhyay*et al.* 2012) is as under

$$V_{SAB} = 1.182 \times 10^{-6} \times A^{1.03} \times P^{1.29} \times S^{0.08} \times D_d^{0.40} \times F_c^{2.42} \quad (1)$$

Where,

V_{SAB} = Sediment yield in (Mm^3 /year),

A = Watershed area (km^2),

P = Annual precipitation (mm),

S = Average watershed slope (m/m),

D_d = Drainage density (km^{-1}) and

F_c = Vegetative cover factor.

Annual precipitation (A)

Rainfall data for the year 2002-03 and 2008-09 was taken from Hydrology Project (Surface water) Water Resource Department, Govt. of Maharashtra, Nashik.

Preparation of land use/land cover map

Now a day, LULC map has large scope for scientific research, planning, development and management of watershed area. LULC map distributed area according to various type of land use and land cover i.e. urban, forested, waste land, water body and agriculture, etc. They required only remotely sensed satellite imagery. After supervised, unsupervised and visual image classification operation in Arc GIS software, the different classes obtained with different colour, which become helpful for analysis of research work. In present study, visual image classification was used for preparation of LULC map.

Calculation of vegetative cover factor (Fc)

Using this method Garde *et al.* (1987) prepared an iso erosion factor curves map for the whole India. The vegetative cover factor equation developed by (Garde*et al.* 1987) used by (Upadhyay*et al.* 2012) is as under

$$F_c = \frac{0.8F_A + 0.6F_G + 0.3F_F + 0.1F_W}{A} \qquad (2)$$

Where,

F_A = Area under Agriculture land (km^2),

F_G = Area under Grass land (km^2),

F_F = Area under Forest area (km^2),

F_w = Area under Waste land (km^2) and

A = Total watershed area.

Drainage density (D_d)

The drainage density is the ratio of total channel length to the area of the watershed. A drainage map of the study area (the Survey of India toposheet at a scale of 1:50,000) was used for drainage map preparation and calculating the drainage density. The ArcGIS Software was used to draw the different order streams and calculate the length which directly gives the drainage density.

Slope map and stream slope (S)

Stream slope was calculated by dividing the total fall between the end points of the main stream by its length.

RESULTS AND DISCUSSION

Land use and land cover

Land use/ land use map for Sonwal watershed was used to represent the classification of land in various categories viz. forest, wasteland, water bodies and resident land, which is depicted in Table1.

Change detection of land use/ land cover

Land use/ Land cover change indicates the impact of the developmental activities in the watershed. Comparison of change in statistics of two different years 2002-03 and 2008-09, changes are given in the Table 1.

The area under agriculture land for year 2002-03 was 70.71km^2 and the area under agriculture land for year 2008-09 was 70.84 km^2 with per cent change (increase) of 0.18 in 2008-09 over 2002-03. The area under forest land for year 2002-03 was 21.93 km^2 and the area under forest land for year 2008-09 was 21.34 km^2 with per cent decrease of 2.69 in 2008-09 over 2002-03.

The area under waste land for year 2002-03 was 2.70 km^2 and the area under waste land was 3.12 km^2 with per cent increase of 15.55 in 2008-09 over 2002-03. The area under resident land for year 2002-03 was 1.15 km^2 and the area under resident land was 1.24 km^2 with per cent increases of 7.82 in 2008-09 over 2002-03.

The area under waterbody for year 2002-03 was 2.85 km^2 and the area under waterbody was 2.80 km^2 with per cent decrease of 1.75 in 2008-09 over 2002-03.

Calculation of vegetative cover factor (Fc)

The value of Fc factor was calculated by putting values of area under forest land (km^2),

Table 1
Land use/land cover statistic in 2002-03 and 2008-09 of Sonwal Watershed

Sr. No	*Land use categories*	*Year 2002-03 Area (km²)*	*Year 2008-09 Area (km²)*	*Per cent Change in LULC*
1	Agriculture land	70.71	70.84	0.18
2	Forest land	21.93	21.34	-2.69
3	Resident land	1.15	1.24	7.82
4	Waste land	2.70	3.12	15.55
5.	Waterbody	2.85	2.80	-1.75
6.	Grass land	0	0	*
	Total	99.34	99.34	

* There was no area under grass land in the year 2002-03 and 2008-09

(-) Sign indicates reduction in area.

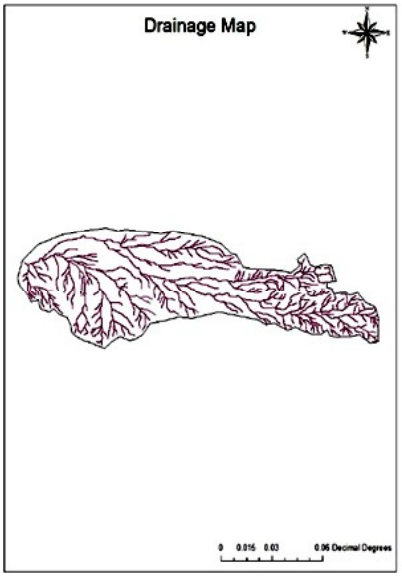

Figure 2: Drainage map of Sonwal watershed

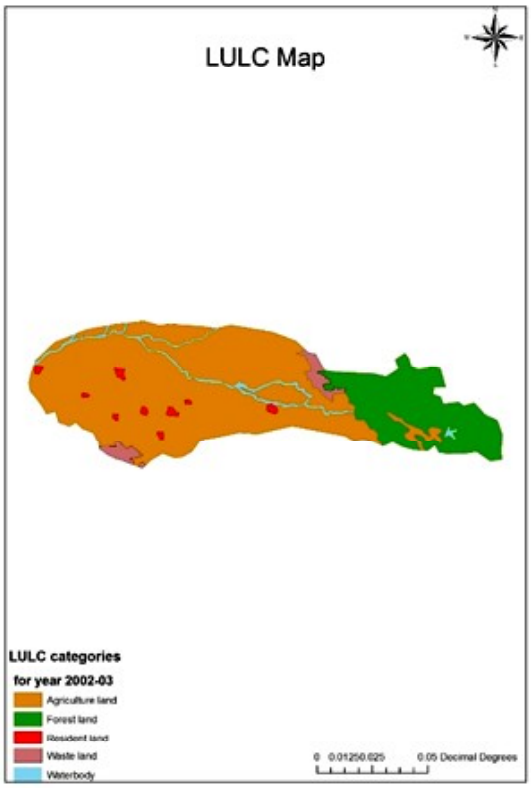

Figure 3: Land use land cover map of Sonwal watershed foryear 2002-03

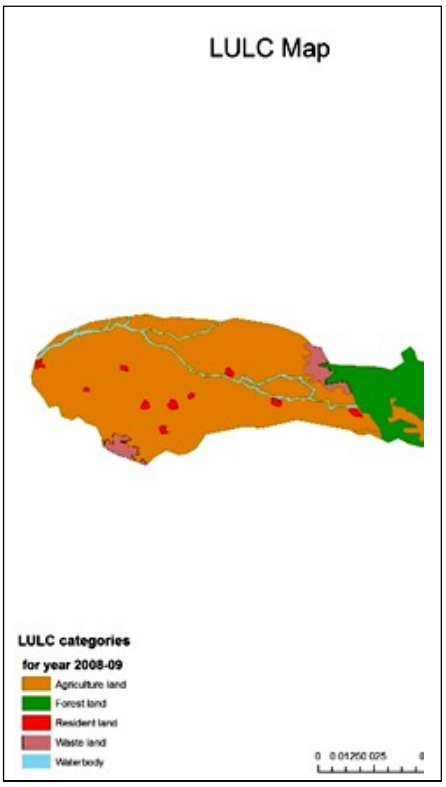

Figure 4: Land use land cover map of Sonwal watershed for year 2008-09

agriculture land (km²), grass land (km²) and waste land (km²) in equation (2). These areas were calculated using LULC map (Fig. 3 and Fig. 4). The value of Fc for year 2002-03 was 0.638 and for year 2008-09, 0.638.

Drainage density (D_d)

The length of watershed was taken from drainage map using attribute table in ArcGIS software. As shown in Fig. 2, the length of watershed basin was found to be 305.356 Km. The area of the Sonwal

watershed was 99.34 Km^2. Therefore, the value of D_d was 3.073 Km^{-1}.

Slope map and stream slope (S)

The length of main stream was 22.24 Km and the total fall between the ends points of the main stream, 177 m.Therefore, the stream slope of the watershed was 0.00796 m/m.

Sediment yield estimation using Garde's equation

After putting all values (Fc, D_d, S, A, P) in equation (1), sediment yield for year 2002- 03 was 12.37 t/ha/yr and for year 2008-09, 14.82 t/ha/yr.

Change detection in sediment yield estimation using Garde's equation

The estimated sediment yield for the watershed for year 2002-03 using Garde's equation was found to be 12.37 t/ha/year. The sediment yield for the watershed for year 2008-09 was found to be 14.82 t/ha/yr. As depicted in Table 2, the sediment yield was increased from 2002-03 to 2008-09 by 2.45 t/ha/yr.

Table 2
Increase in sediment yield in 2008-09 over 2002-03 ofSonwal watershed using Garde's equation.

Year 2002-03	*Year 2008-09*	
Sediment yield (t/ha/ year)	*Sediment yield (t/ha/ year)*	*Increase in Sediment yield in 2008-09 over 2002-03 (t/ha/year)*
12.37	14.82	2.45

CONCLUSIONS

Based on the results of the study, conclusions obtained are as follow

1) Waste land is increased by 15.55 per cent, agriculture land increased to a very less extent 0.18 per cent and forest land is reduced by 2.69 per cent, therefore the increased sediment yield was observed to the extent of 4.34 t/ha/yr (73.80 %) in six years i.e. from 2002-03 to 2008-09.To reduce the rate of increase of sediment yield, the agriculture land need to be increased by decreasing the waste land.
2) The estimated sediment yield using Garde's equation shows the increasing sediment yield from 2002-03 to 2008-09. Hence, the watershed development programme needs to be implemented effectively to reduce sediment yield.

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