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Sediment Yield Estimation and Soil Conservation Measures for Agrani River Basin Using Geospatial Techniques

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Abstract

Sedimentation reduces the capacity of the reservoir and it is the important concern for watershed management. This paper presents the computation of sediment yield of Agrani River basin of Sangli and Belgavi districts in Maharashtra and Karnataka, India using RS and GIS techniques. The land use/land cover (LULC) map of the study area was prepared by supervised classification using satellite imagery of IRS P6 LISS III and ERDAS-imagine v 9.1 image processing software. 26.67% of the area is occupied by agricultural land, 20.37% area covers forest land, 27.06% area of fallow land. Meteorological parameters such as average annual rainfall and mean annual temperature are then used to calculate amount of sediment yield in the reservoir. Garde model was used for determination of annual sediment yield. Mean annual runoff and sediment yield for investigating area is 19.30 million m^3 and 0.0897 million m^3/year, respectively. With very fine drainage texture, drainage density in the study area is 1.88 km/km^2.

Keywords: DEM, Garde Model, Sediment yield, Soil conservation, RS and GIS

1. Introduction

Sedimentation of reservoirs built for purposes including hydroelectric generation, irrigation, water supply for domestic and industrial needs has been a topic of concern all over the world. Normally the reservoirs are designed t o accommodate the estimated rate of sedimentation (Bali et.al 1977). For water allocation and demand-supply management studies need surface runoff and sediment yield information, in addition useful life span of reservoir (Abhijit Zende et.al 2014). Remote Sensing and GIS techniques are new methods to evaluate sediment yield which gives a great accuracy of results and spatial data within time. Sedimentation reduces the capacity of the reservoir progressively which is the great concern for water management. During heavy rains the whole river basin transfers certain amount of sediment eroded from the catchment area. Subsequent deposition of soil erosion in catchment areas of reservoir have its double effect, productiveness of the reservoir soils is reduced, and sediment deposition in reservoirs can affect their performance through damage to valves and conduits, storage capacity losses, changes in water quality and reduced flood attenuation. Dhruvanarayana and Rambabu (1983) have estimated that in India about 5,334 Mt (16.4 t ha^{-1}) of soil is detached annually; about 29% is carried away by river into the sea and 10% is deposited in reservoirs resulting in the considerable loss of the storage capacity. For detail study of reservoir sedimentation, soil conservation planning strategies, river morphology, design of efficient erosion control structures and water quality modeling measurement of sediment yield is essential on catchment. In India due to shortage of sufficient funds computation of sediment yield through gauging stations is very inadequate (Kothyari 1996, 1997). Under this situation, for assessing sediment yield by ungauged basins sediment yield measurement models are very useful. The amount of sediment yield from the catchment outlet depends upon many factors such as by topography, hydro metrology, lithology of the area and land-use land-cover pattern of the region.

For assessing soil erosion from the watershed, several empirical models based on the geomorphological parameters were developed in the past to quantify the sediment yield (Jose and Das 1982). Several other methods such as Sediment Yield (Dabral et al. 2008) Index method proposed by Bali and Karale (1977) and Universal Soil Loss Equation (USLE) given by Wischmeier and Smith (1978) are extensively used for prioritization of the watersheds. The USLE has been widely applied at a watershed scale on the basis of lumped approach (Williams and Berndt 1972) to catchment scale (Jain and Kothyari (2000). To measurement the storage capacity of the reservoir there are several techniques used, method proposed by Garde and the parameters evaluated using Remote Sensing and GIS is used for the estimation of sediment yield, which depends on mean annual precipitation (P), catchment area (A), Land slope (s), mean annual runoff (Q), drainage density (Dd) and Vegetative cover factor (Fc) for the basin. Agrani river basin of Sangli and Belgavi district in Maharashtra and Karnataka, India. Therefore, in present study, sediment yield in Agrani River basin of Sangli and Belgavi districts in Maharashtra and Karnataka, India is evaluated by Garde model and suitable sites for soil conservation measures are suggested using RS and GIS techniques.

2. Materials and Methods

2.1 Data Collection

Meteorological data, i.e. rainfall and temperature for the Agrani river basin were collected from the Jal-Vidynan Bhavan, Nashik, Maharashtra, India. Geocoded False Colour Composite (FCC) of the Indian Remote Sensing satellite (IRS) P6, Linear Imaging Self-Scanning (LISS) III on January, 2012, on 1:50000 scale. The Survey of India topographical sheets (E43U10, E43V1, E43U9, E43O16, E43U14, E43U13, E43P4, 47 P/2) were obtained from, Pune. Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) was used to prepare the DEM.

2.2 Study Area

Agrani River Basin (Figure 1) is located in the western Maharashtra, India. Agrani river basin lies between 16°39'24" N to 17°19' 25"N Latitude and 74°40'16" E to 75°13'20" E longitude. The study area, i.e. Agrani River basin, is part of Sangli and Belgavi districts encompassing an area of about 1930 km^2. The basin length is about 97 km and perimeter is 249 km^2. It originates from the Western Ghats at an altitude 885 m and confluence point is Hulga Bali at Altitude 549 m. The study area comes under the semiarid region of the state of Maharashtra and Karnataka. The rainfall stations are Kavthe Mahankal, Vita, Miraj, Tasgaon, Jath, Madabhavi, and Atpadi. The annual rainfall is about 466.63 mm and more than 80% occurs mainly during the monsoon season, i.e. from June to September.

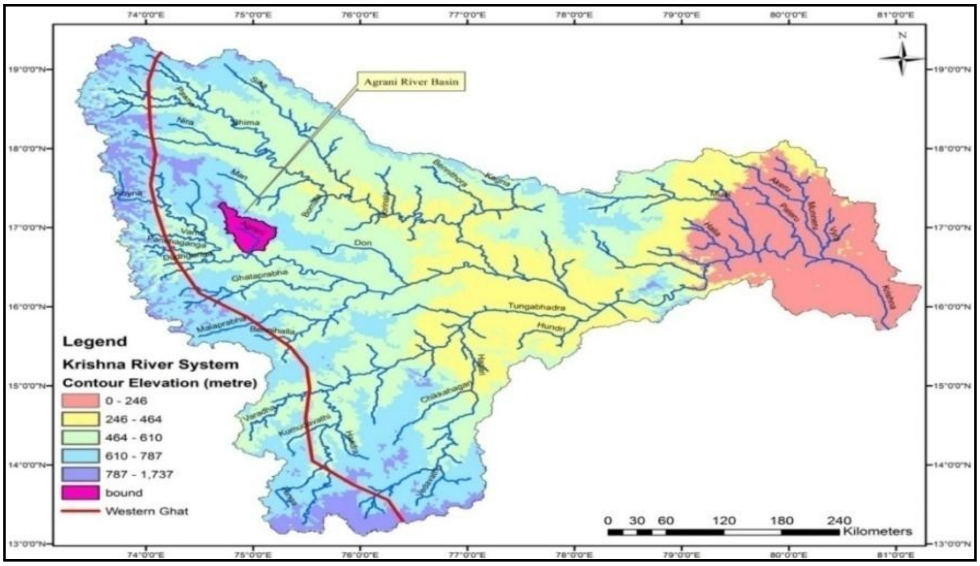

Figure 1 Location map of study area includes of upper Krishna basin

2.3 Preparation of Land Use/Land Cover Map

Multi spectral classification of satellite imagery IRS-P6 LISS III was used to prepare the land use/land cover map of the study area. Producing thematic maps of the land cover from remotely sensed data multi spectral classification techniques are useful. The multi spectral classification consist of the different land use/land cover types, namely forest, fallow land, agricultural land, rocky land, open scrub land and water- body. For this study, the supervised classification for the IRS-P6 LISS III multi spectral image was proceed by using ERDAS 10 software.

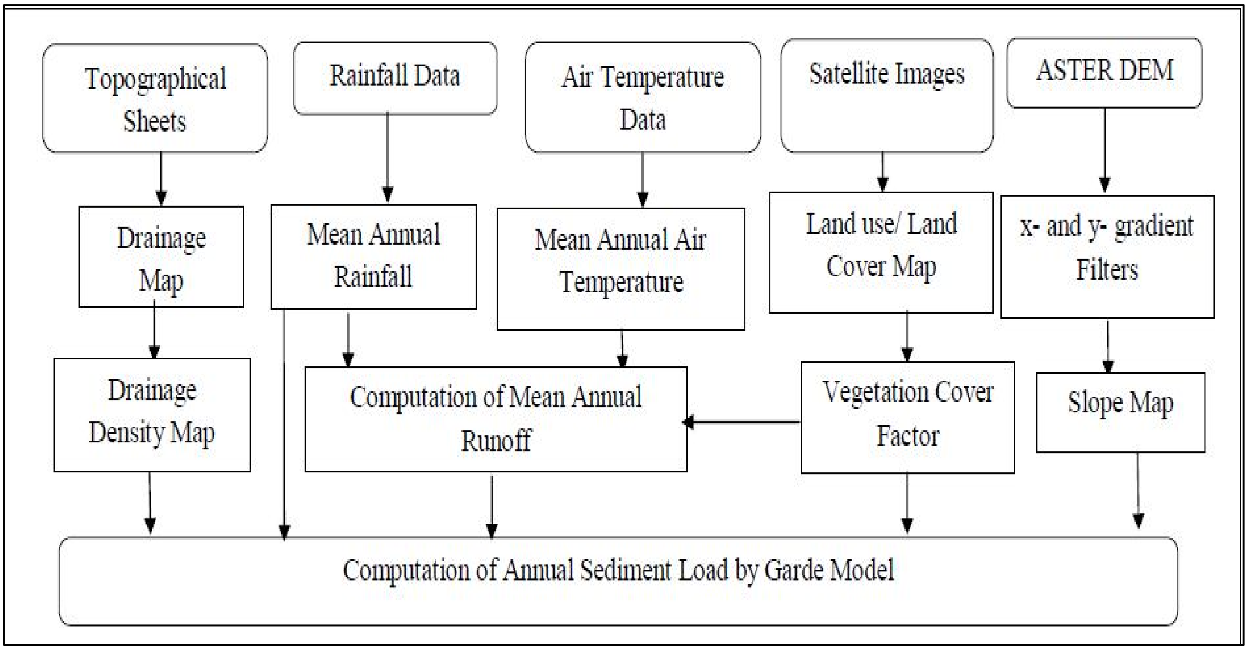

Figure 2 Flowchart illustrating procedure for quantification of sediment yield by Garde Model

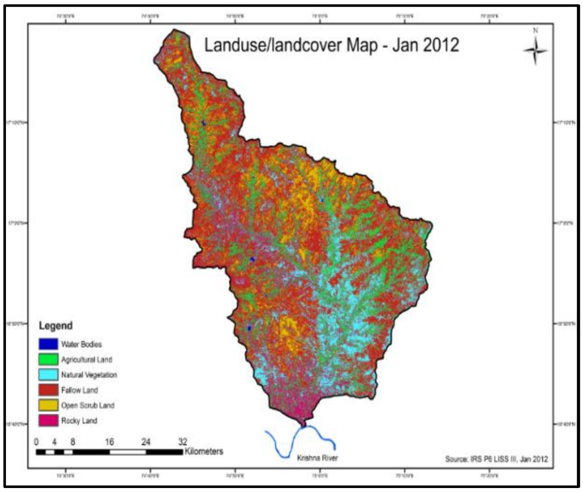

Figure 3 LU/LC map of Agrani river basin

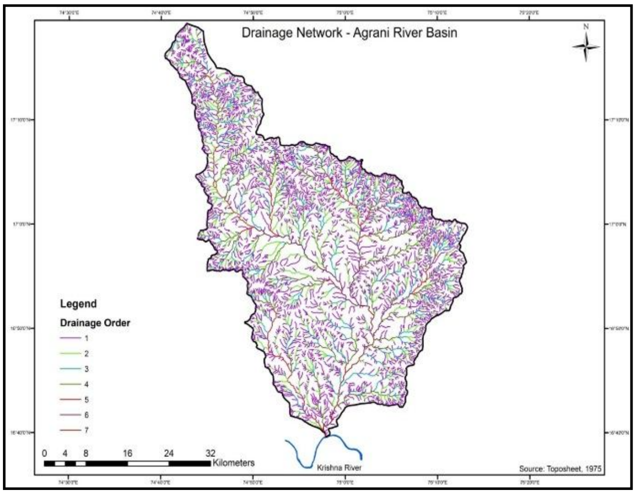

Figure 4 Drainage network of Agrani river basin

2.4 Estimation of Mean Annual Runoff

2.4.1 Computation of Vegetative Cover Factor (F_c)

The vegetative cover factor was computed from the following equation (Garde et al. 1983).

$$Fc = \frac{0.2F_1 + 0.2F_2 + 0.6\,F_3 + 0.8\,F_4 + F_5}{F_1 + F_2 + F_3 + F_4 + F_5} \qquad (1)$$

Where, F_1 = area under reserved and protected forest in km^2, F_2 = unclassified forest area in km^2, F_3 = agricultural land in km^2, F_4 = Open scrub land in km^2 and F_5 = Fallow land in km^2.

2.4.2 Computation of annual runoff (R_m)

Garde et al. (1983) model is developed for Indian catchments, which is an empirical runoff computation model and is defined below

$$R_m = \frac{Fc^{0.49}\,(P_m - 0.5\,T_m)^{0.59}\,(P_m - 0.5\,T_m)}{26.5} \qquad (2)$$

Where, R_m = mean annual runoff in cm, P_m = mean annual precipitation in cm, F_c = vegetative cover factor obtained from land use/land cover map and T_m = mean annual temperature in degree centigrade.

2.4.3 Computation of Sediment Yield (V_{sy})

The Garde et al. (1983) model is expressed below:

$$V_{sy} = 1.182 \times 10^{-6} \times A^{1.03} \times P^{1.129} \times Q^{0.29} \times S^{0.08} \times {D_d}^{0.40} \times {F_c}^{2.52} \qquad (3)$$

Where, V_{SY} = mean annual sediment yield in mm^3/year, A = basin area in km^2, Q = mean annual runoff in million m^3, S = mean basin slope, D_d = drainage density in km km^{-2}, Fc = vegetative cover factor and P = mean annual precipitation in cm. A complete flowchart for computation of mean annual sediment yield by Garde model using remote sensing and GIS techniques is shown in Figure 2.

3. Results and Discussion

The study area involves the total number of six different land use/land cover types, namely forest, fallow land, agricultural land, rocky land, open scrub land and water- body. The basin creates different land use/ land cover shown in (Figure 3) of about 26.67% of the area is covers agricultural land, 20.37% are a occupied by forest land, 27.06%area of fallow land, 7.98% area covers open scrub land and remaining 17.89% of the area is occupied by others such as water body and rocky land. The slope map of the study area is shown in Figure 6. The slope in the study area can be divided into six classes: (a) 0–3%, (b) 3–5%, (c) 5–8%, (d) 8–15%, (e) 15–30%, and (f) >30%. It can be seen from that the lowest slope (0–1%) specifies flat water surface of waterbodies in the study area. High slope classes (i.e. 6–15%, 15–30%, >30%) exists in the form of stretched strips along the hills lying along the boundaries of the study area. Drainage map of the study area is shown in (Figure 4). The drainage pattern analysis indicates that the area is covered by a dendritic pattern of drainage which shows that rocks in the study area are homogeneous and uniformly resistant to water flow. Total length of all the drainage streams in the study area measured by using GIS is 3642.37 km and the area of the basin is 1930 km^2. Thus, the drainage density in the study area is 1.88 km km^{-2} (Figure 5). The drainage density is an inverse function of permeability. Actually, the less a rock is permeable, the less the infiltration of rainfall, which conversely tends to be concentrated in surface runoff. This gives origin to a well-developed and fine drainage system.

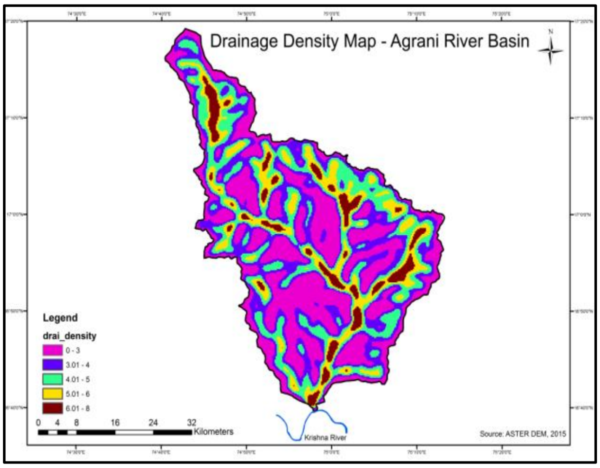

Figure 5 Drainage density of Agrani river basin

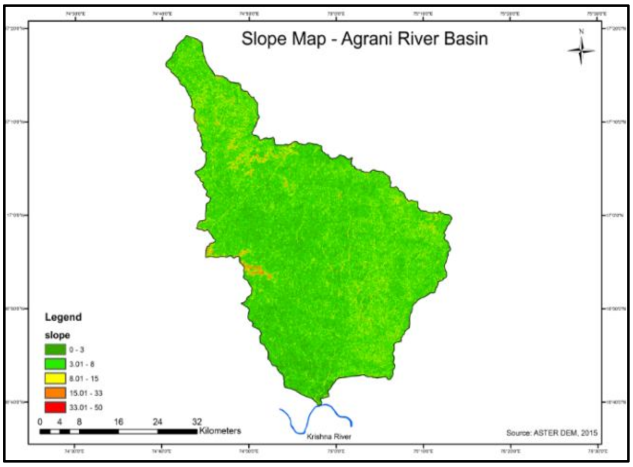

Figure 6 Slope Map of Agrani river basin

3.1 Annual Sediment Yield

It is estimated from the land use/land cover map that out of total area of the Agrani River basin (1930 km^2), forest area comprises 393.16 km^2, agricultural land 501.8 km^2, open scrub land 154.16 km^2, fallow land 522.41, rocky land 339.10and waterbodies 6.17 km^2. Therefore, F1=393.16, F2=0, F3=501.8, F4=154.16 and F5=861.51. Substituting these values of five variables in Eq. 1, the values of vegetative cover factor, Fc is 0.714. The mean annual rainfall, P and mean annual temperature, Tm over a period of 18 years (1998– 2015) in the study area are 12.06 cm and 25.78°C, respectively. By substituting the values of P, Tm and Fc in Eq. 2, mean annual runoff is calculated to be 0.023 cm. Annual runoff in million m3 is given by $Q = R_m \times A$, where A is the area of the basin (i.e. 1930 km^2). Thus, mean annual runoff, Q for the study area is 44.39 million m^3. The values for the parameters given in Eq. 3 pertaining to the present study are: A=1930 km2, P=12.06 cm, Q=44.39 million m^3, S=4.298, D_d= 1.88km km^{-2} and Fc = 0.714. Substitution of these values in the Eq. 3 results the sediment yield of the basin that is V_{SY}=0.0897 million m3/year. Thus, the sediment yield from the Agrani river basin is 89799.08 m^3/year.

3.2 Sites for Soil Conservation Measures

Contour bund, MI tank, check dam, KT weir etc. these are the area measures for controlling the soil erosion Contour bund cannot be proposed in the study area as subsurface formations are rocky in nature, and therefore, the subsurface formations have low infiltration and percolation rates. It results in prolonged holding of water on the upstream side and consequently crops are damaged. Among all soil erosion measures, check dams are most popular and widely constructed structures in the semi-arid regions of Rajasthan. The check dams are small-scale silt control structures built across lower order streams in order to prevent silt transportation. Check dams are most-effective when a number of tributaries carrying sediment drain into the reservoir. Sites for construction of check dams in the study area were identified by using Boolean logic analysis over slope map and drainage map. The drainage pattern and the slope of the basin were carefully studied. It was attempted that the sites should be on 2nd or 3rd order stream. Finally, check dams were located where the surface topography is fairly level after a steep slope. A total number of 18 sites were identified in the study area, with low (1–4%) to moderate (4–6%) slopes and locations of these sites are shown in (Figure 7). The location map of the proposed check dam sites is very useful for planning and designing of soil conservation structures in the study area.

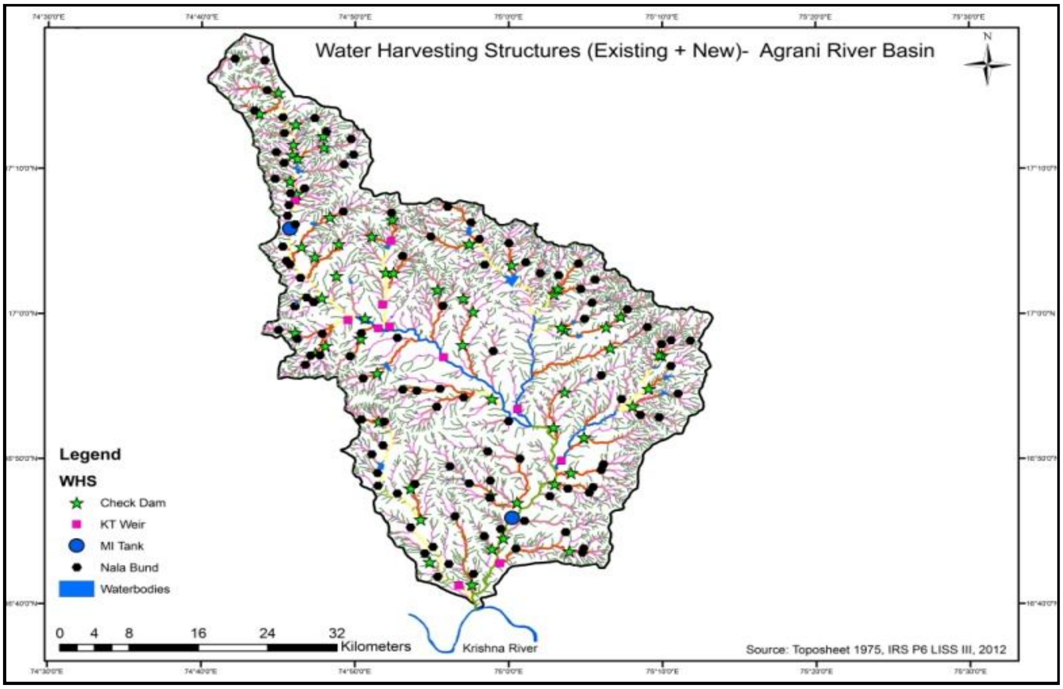

Figure 7 Water Harvesting Structure Map of Agrani River Basin

4. Conclusions

The land use/land cover map of the study area revealed that the highest proportion of the study area (i.e. 27.06%) is covered by fallow land. Major portion of the study area, i.e. 40% falls under 1–4% slope class and the mean stream slope is 0.0042. The drainage pattern is dendritic which shows that rocks in the study area are homogeneous and uniformly resistant to water flow. Total length of all the drainage streams in the study area is 3642.37 km and the mean drainage density is 1.18 km km^{-2}. The vegetative cover factor for the study area is 0.714 and the mean annual runoff is 19.30 million m^3. The Garde et al. model resulted in mean annual sediment yield in the study area as 89799.08 m^3/year. 59 suitable sites for construction of check dams are identified to check soil erosion in the study area by overlaying drainage map on the slope map, runoff of individual sub watershed.

References

1. Abhijit M. Zende., and R. Nagarajan. (2014). Sediment yield estimate of River basin using SWAT model in semi-arid region of Peninsular India, in Proceeding of IAEG XII Congress 2014, Engineering Geology for Society and Territory, Vol. 3, pp. 543-546.
2. Bali, Y. P., and Karale, R. L. (1977). A sediment yield index for choosing priority basins. IAHS-AISH Publication, 222, 180.
3. Dabral, P. P., Baithuri, N., and Pandey, A. (2008). Soil erosion assessment in a hilly catchments of north eastern India using USLE, GIS and remote sensing. Water Resources Management, 22, 1783–1798.
4. Dhruvanarayana, V. V., and Rambabu (1983). Estimates of soil erosion in India. Journal of Irrigation and Drainage, 109 (4), 419–433.
5. Garde, R. J., Rangaraju, K. C., Swamee, P. K., Miraki, G. D., and Molanezhed, M. (1983). Mathematical modelling of sedimentation process in reservoirs. Hydraulic Engineering, Report No. HYD 8304, University of Roorkee, India.
6. Jain M. K, and Kothyari U. C., (2000) Estimation of soil erosion and sediment yield using GIS. Hydrol Sci J 45(5), pp. 771–786
7. Jose, C.S., and Das, D. C. (1982). Geomorphic prediction models for sediment production rate and intensive priorities of watersheds in Mayurakshi catchment. Proceedings of the international symposium on hydrological aspects of mountainous watershed held at School of Hydrology, University of Roorkee, No 4–6, Vol. I, pp. 15-23.
8. Kothyari, U. C. (1996). Erosion and sedimentation problems in India. Proceedings of International Symposium on Erosion and Sediment Yield: Global and Regional Perspectives, Exeter, U.K., IAHS Publication No. 236, pp. 531–539.
9. Kothyari, U. C., and Jain, S. K. (1997). Sediment yield estimation using GIS. Hydrological Sciences Journal, 42 (6), 833–843.
10. Wischmeier WH, Smith DD (1978) Predicting rainfall erosion losses. USDA Agricultural Research Services handbook 537. USDA, Washington, DC, p 57.
11. Williams JR, Berndt HD (1972) Sediment yield computed with universal equation. J Hydraul Div 98, (12):pp. 2087–2098