Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 13	No. 2	pp. 297-302	2014

Original Research Paper

Prioritizing Subwatersheds from Drainage Morphometric Parameters for Erosion Studies in Chitravathi Watershed, Chickballapur District, Karnataka

T. Mahadevaiah and B. K. Narendra*
Deptt. of Civil Engg., B. G. S. Institute of Technology, B. G. Nagara-571 448, Nagamangala Taluk, Mandya Dist., Karnataka, India (*Principal)

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 11-9-2013
Accepted: 19-11-2013
Key Words:
Chitravathi watershed
Soil erosion
Drainage morphometry

ABSTRACT

Assessment of soil erosion in a watershed is important to take measure to control it. This paper presents the result of drainage morphometry approach to understand the status of erosion and deposition in the Chitravathi watershed. The study of drainage morphometry leads to an understanding of the dissection of the area, which in turn helps in deciphering the erosion condition. Soil erosion status in the subwatersheds of Chitravathi watershed is prioritized using drainage morphometric parameters.

INTRODUCTION

Soil erosion is one of the most serious environmental problems, as it threatens agricultural and natural environment. According to the global assessment, 1.9 billion hectares of land is affected by soil degradation worldwide (Anonymous 1974). Scientific management of soil, water and vegetation resources on watershed basis is, therefore, very important to arrest rapid siltation of rivers, lakes and estuaries.

Srinivas et al. (2002) have assessed soil erosion of Nagpur district, India, using USLE. They express that the assessment of soil erosion for a large area such as district can be deduced by deterministic relationship of complex factors such as rainfall erosivity, soil erodibility, slope and land use/land cover. Morgan-Morgan-Finney (MMF) model (1984) for soil is an empirical model to predict annual soil loss from field sized areas on hill slopes. Behera et al. (2005) have used MMF model to study the soil erosion of Song sub watershed in the Himalayan belt, India. Khan et al. (2001) have prioritized watershed based on sediment yield index (SYI). Suresh et al. (2004) have computed the drainage morphometry of subwatersheds of Terai watershed at the foot hills of the Himalaya, India. Chandramohan et al. (2002) have attempted to estimate the soil erosion using USLE for a drainage area in Koppal district in Karnataka state.

This paper presents the result of drainage morphometry approach to understand the status of erosion and deposition in the Chitravathi watershed.

The study area, Chitravathi watershed, is an undulating terrain with steep slopes, and there exists the problem of soil erosion. Many tanks in the study area are silted up and their live capacity is reduced to a great extent.

In the present study, Chitravathi watershed is further divided into 10 subwatersheds and their drainage morphometry is computed to understand the basin geometry. Further, based on drainage morphometric parameters, the subwatersheds are prioritized for soil and water conservation.

DELINEATION OF DRAINAGE NETWORK

The drainage networks of the 10 subwatersheds of the study area are delineated using the Survey of India (SOI) topographic sheets numbered 57G/14, 57G/15 and 57G/10 of 1:50000 scale. The drainage lines are digitized using GIS software. The different orders of the streams are given different identification, and the length and numbers of different orders are computed using GIS software. The basin perimeter and basin areas are also computed using the GIS software. A map showing different orders of the subwatersheds of the Chitravathi watershed is depicted in Fig. 1.

MORPHOMETRIC CHARACTERISTICS

Quantitative description of the geometry of a watershed is known as 'morphometric analysis'. It includes the measurement of linear, aerial and relief aspects of the drainage basin. The knowledge of drainage basin characteristics is an important prerequisite to evaluate the basin hydrology and characterize sediment erosion. The quantitative analysis of

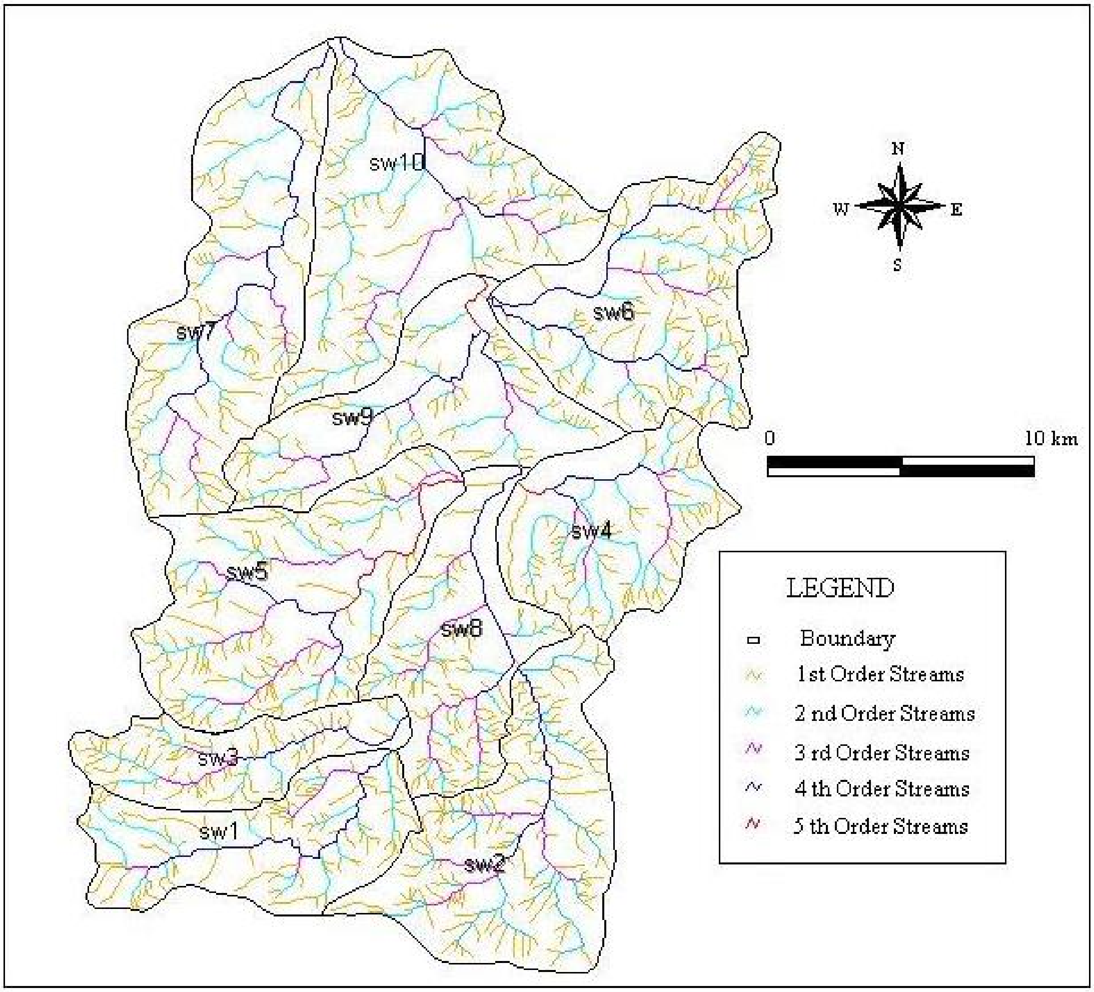

Fig. 1: Drainage network and the subwatersheds of Chitravathi watershed.

the drainage network proposed by Horton (1945) has been worked out in detail by Strahler (1957).

LINEAR ASPECT

Stream order, stream length, mean stream length, stream length ratio and bifurcation ratio are linear aspects that were determined and results are given in Tables 1, 2 and 3.

Stream order: The designation of stream orders is the first step in drainage basin analysis and is based on a hierarchic ranking of streams.

Stream length: The number of streams of various orders in a subwatershed is counted and their lengths from mouth to drainage divide are measured with the help of GIS software. The stream length (Lu) has been computed based on the law proposed by Horton (1945) for all the 10 sub-watersheds. Generally the total length of stream segments is maximum in first order streams and decreases as the stream order increases.

Mean stream length: According to Strahler (1964), the mean stream length is a characteristic property related to the drainage network and its associated surfaces. The mean stream length has been calculated by dividing the total stream length of order 'u' and number of streams of segment of order 'u'. It is noted from Table 1.2 that Lsm varies from 0.13 to 18.68

Stream length ratio: Stream length ratio is the ratio of the total length of the one order to the next lower order of stream segment.

Bifurcation ratio: The term Bifurcation ratio (Rb) is the ratio of the number of stream segments of given order to the number of segments of the higher order (Schumm 1956). Horton (1945) considered the bifurcation ratio as an index of relief and dissections. In the present study, the higher values of Rb indicate strong structural control on the drainage pattern while the lower values are indicative of sub-

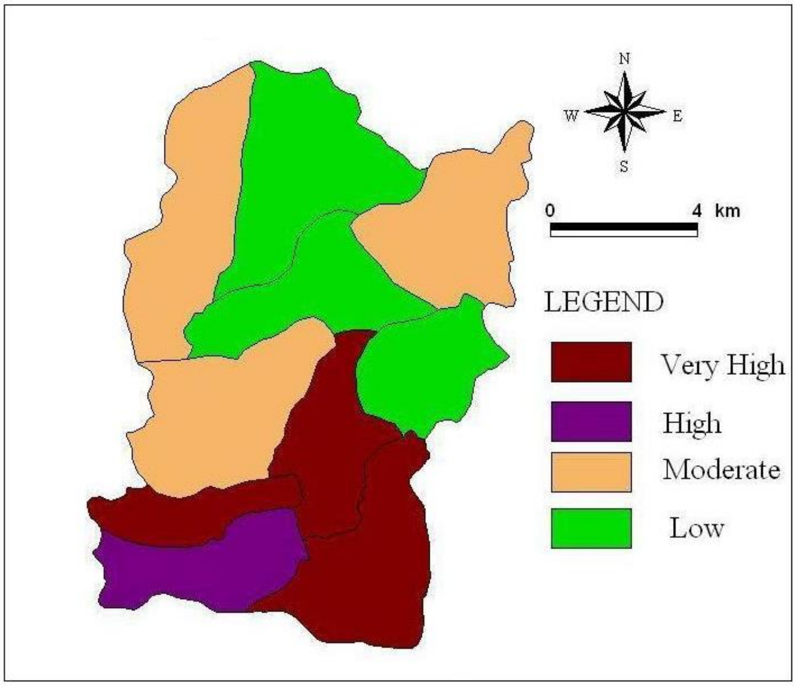

Fig. 2: Subwatersheds prioritization for erosion.

watersheds that are not affected by structural disturbances.

AERIAL ASPECT

Different morphometric parameters like drainage density, texture ratio, stream frequency, form factor, circularity ratio, elongation ratio and length of overland flow have been discussed in detail and are presented in Table 3.

Drainage density: High drainage densities usually reduce the discharge in any single stream, more evenly distributing run-off and speeding run-off into secondary and tertiary streams.

The drainage density varies between 4.73 and 8.61 km/km^2 indicating high drainage density (Table 3). In the present case it is suggested that this high drainage density indicates that the region has less permeable subsoil and less vegetative cover and erosion is more.

Stream frequency: Horton (1932) introduced the term stream frequency (Fs), which is the total number of stream segments of all orders per unit area. Hypothetically, it is possible to have the basin of same drainage density differing in stream frequency and basins of same stream frequency differing in drainage density.

Table 3 shows Fs for all sub-watersheds of the study area. It is noted that the Fs exhibits positive correlation with the drainage density values of the subwatersheds indicating the increase in the stream population with respect to increase in drainage density.

Drainage texture: Drainage texture (Rt) is one of the important concepts of geomorphology which indicates the relative spacing of drainage lines. In the present study, the drainage density varies between 4.73 and 8.61 km/km^2, indicating moderate to very fine coarse drainage texture.

Form factor: According to Horton (1932), form factor (Rf) may be defined, as the ratio of basin area to square of the basin length. The form factor value varies from '0' in highly elongated shape to the unity i.e. '1' in perfect circular shape. Hence, higher the value of form factor more circular the shape of the basin and vice-versa. From Table 3, it is observed that the Rf varies between 0.20 and 0.71 and thus indicates that subwatershed 4 and 6 are circular in shape with higher value, whereas the remaining subwatersheds are elongated with lower values of form factor.

Circularity ratio: It is the ratio of the area of the basin to the area of the circle having the same circumference as the perimeter of basin (Miller 1953). The circularity ratio (Rc) is influenced by the length and frequency of the streams, geological structures, landuse/land cover, climate, relief and slope of the basin. In the present study, the Rc ranges from 0.44 to 0.73. High Rc indicates that they are more or less circular and are characterized by high to moderate relief, and drainage system is structurally controlled. The

Table 1: Stream order and stream length of subwatersheds of Chitravathi watershed.

Sub-Watershed	No. of streams 1st Order N1	2nd Order N2	3rd Order N3	4th Order N4	5th Order N5	Total no. of streams	Stream length (km) 1st Order L1	2nd Order L2	3rd Order L3	4th Order L4	5th Order L5	Total stream length (km)
SW1	87	21	4	1		113	155.35	57.12	14.45	18.68		245.6
SW2	135	29	7	1		172	285.38	89.93	22.84	7.3		405.45
SW3	67	11	2	1		81	90.05	32.73	5.84	6.11		134.73
SW4	65	16	4	2	1	88	97.81	53.44	19.23	7.79	1.22	179.49
SW5	110	27	8	2	1	148	180.84	78.49	46.58	7.22	7.00	320.13
SW6	125	32	6	2	1	166	185.36	108.53	27.54	23.42	0.13	344.98
SW7	78	21	5	1		105	139.97	64.44	22.36	16.52		243.29
SW8	93	22	6	1		122	129.52	54.79	27.52	8.52		220.35
SW9	65	19	7	2	1	94	115.05	65.82	27.97	15.54	2.15	226.53
SW10	103	25	5	1		134	180.61	93.54	27.92	8.25		310.32

Table 2: Linear aspects of subwatersheds of Chitravathi watershed.

Sub Water shed	Mean stream length 1st L1/N1	2nd L2/N2	3rd L3/N3	4th L4/N4	5th L5/N5	Bifurcation ratio (Rb) N1/N2	N2/N3	N3/N4	N4/N5	Mean Bifurcation ratio, Rbm	Stream length ratio L2/L1	L3/L2	L4/L3	L5/L4
SW1	1.79	2.72	3.61	18.68		4.14	5.25	4.00		4.46	0.37	0.25	1.29	0.00
SW2	2.11	3.10	3.26	7.30		4.66	4.14	7.00		5.27	0.32	0.25	0.32	0.00
SW3	1.34	2.98	2.92	6.11		6.09	5.50	2.00		4.53	0.36	0.18	1.05	0.00
SW4	1.50	3.34	4.81	3.90	1.22	4.06	4.00	2.00	2.00	3.02	0.55	0.36	0.41	0.16
SW5	1.64	2.91	5.82	3.61	7.00	4.07	3.38	4.00	2.00	3.36	0.43	0.59	0.16	0.97
SW6	1.48	3.39	4.59	11.71	0.13	3.91	5.33	3.00	2.00	3.56	0.59	0.25	0.85	0.01
SW7	1.79	3.07	4.47	16.52		3.71	4.20	5.00		4.30	0.46	0.35	0.74	0.00
SW8	1.39	2.49	4.59	8.52		4.23	3.67	6.00		4.63	0.42	0.50	0.31	0.00
SW9	1.77	3.46	4.00	7.77	2.15	3.42	2.71	3.50	2.00	2.91	0.57	0.42	0.56	0.14
SW10	1.75	3.74	5.58	8.25		4.12	5.00	5.00		4.71	0.52	0.30	0.30	0.00

Table 3: Areal aspects of subwatersheds of Chitravathi watershed.

Sub Water shed	Basin Area sq. km	Basin Length (km)	Perimeter (km)	Circularity Ratio (Rc)	Elongation Ratio (Re)	Form Factor Rf	Drainage Density (km/sq.km)	Stream Freque-ncy (Fs)	Compactness coefficient (Cc)	Texturte Ratio (Rt)
SW1	32.76	9.68	28.42	0.51	0.67	0.35	7.50	3.45	1.40	3.06
SW2	47.07	10.93	34.53	0.50	0.71	0.39	8.61	3.65	1.42	3.91
SW3	20.86	10.13	24.4	0.44	0.51	0.20	6.46	3.88	1.51	2.75
SW4	31.21	6.64	23.15	0.73	0.95	0.71	5.75	2.82	1.17	2.81
SW5	50.78	11.36	31.98	0.62	0.71	0.39	6.30	2.91	1.27	3.44
SW6	45.39	8.63	31.26	0.58	0.88	0.61	7.60	3.66	1.31	4.00
SW7	51.4	15.36	36.38	0.49	0.53	0.22	4.73	2.04	1.43	2.14
SW8	32.34	10.11	29.96	0.45	0.63	0.32	6.81	3.77	1.49	3.10
SW9	37.6	9.56	32.62	0.44	0.72	0.41	6.02	2.50	1.50	1.99
SW10	56.9	10.89	36.69	0.53	0.78	0.48	5.45	2.36	1.37	2.81

remaining subwatersheds with low Rc indicate that they are elongated.

Elongation ratio: Schumm (1956) defined elongation ratio (Re) as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. The Re of the subwatersheds of the Chitravathi watershed varies from 0.51 to 0.95. The lowest Re in case of subwatershed number 3 indicates high relief and steep slope, while very high values in subwatershed number 4 indicate that plain land with low relief and low slope. Further it reveals

Table 4: Prioritizing subwatersheds from drainage morphometric parameters.

S. No.	Rc	Rf	Re	Rb	Dd	Fu	T	Total	Average	Priority	Class
1	6	4	4	5	3	5	5	32	4.571	4	High
2	5	6	6	1	1	4	2	25	3.571	3	Very high
3	1	1	1	4	5	1	8	21	3.000	1	Very high
4	10	10	10	9	8	7	6	60	8.571	10	Low
5	9	5	5	8	6	6	3	42	6.000	6	Moderate
6	8	9	9	7	2	3	1	39	5.571	5	Moderate
7	4	2	2	6	10	10	9	43	6.143	7	Moderate
8	3	3	3	3	4	2	4	22	3.143	2	Very high
9	2	7	7	10	7	8	10	51	7.286	9	Low
10	7	8	8	2	9	9	7	50	7.143	8	Low

where Rc = Circularity ratio, Rf = Form factor, Re = Elongation ratio, Rb = Bifurcation ratio, Dd = Drainage density, Fu = Stream frequency, T = Texture ratio

that subwatershed number 4 is circular whereas the remaining subwatersheds are elongated in shape.

EROSION MODEL ADOPTED FOR THE STUDY

Biswas et al. (2002) have prepared the drainage map of Nayagram block of the Midnapore district, West Bengal from Survey of India topographical maps, and carried out morphometric analysis with GIS. Linear and aerial morphometrical aspects were computed and the subwatersheds were prioritized for water and soil conservation by giving hierarchical order to the aerial and linear morphometry parameters. The highest value of bifurcation ratio, drainage density, stream frequency, and texture ratio among 44 microwatersheds were given a rating of 1, the next highest value was given a rating of 2, and so on. The lowest value was rated last in the series of numbers. For the shape parameters (form factor, circularity ratio, and elongation ratio) the lowest value was given a rating of 1, the next lowest value was given a rating of 2, and so on. After the rating has been done, based on every single parameter, the rating values for every microwatershed were averaged to arrive at a compound value. Based on the average value of these parameters, the microwatershed having the least rating value was assigned the highest priority number of 1; the next highest value was assigned a priority number of 2 and so on. The microwatershed that got the highest value was assigned the last priority number. This method will not quantify the erosion, but it compares the erosion rate among the subwatersheds considered.

For prioritizing the subwatersheds of the Chitravathi watershed, the above methodology is adopted. The results are listed in Table 4. The subwatersheds are prioritized into four categories such as very high, high, moderate and low erosion prone areas. In the Table 4, average column, the maximum score is 8.571, minimum 3.0, mean 5.5 and the standard deviation is 1.299. Very high priority subwatersheds are having the value of 3.0 to 3.701, high 3.701 to 5.5, moderate 5.5 to 6.799 and low having values 6.799 to 8.571. The result is graphically shown in Fig. 2.

RESULTS AND CONCLUSIONS

The study of drainage morphometry leads to an understanding of dissection of the area, which in turn helps in deciphering the erosion condition, soil development and landuse pattern of an area, which is of utmost importance in prioritization of watersheds. Soil erosion status in the subwatersheds of Chitravathi watershed is prioritized using drainage morphometric parameters. Drainage morphometric parameters will not take into account the conservation techniques taken up. Hence, this method lacks to provide information on the current erosional status of the area.

REFERENCES

Anonymous 1974. Effects of man on the interface of the hydrological cycle with the physical environment, International Association of Hydrological Sciences, Publication No. 113, 157.

Behera Pallavi, Durga Rao, K.H.V. and Das, K.K. 2005. Soil erosion modeling using MMF model – a remote sensing and GIS perspective. Journal of the Indian Society of Remote Sensing, 33(1): 165-176.

Biswas Sujata, Sudhakar, S. and Desai, V.R. 2002. Remote sensing and GIS system based approach for watershed conservation. Journal of Surveying Engineering, 128(3): 108-123.

Chandramohan, T. and Dilip, G. Durbude 2002. Estimation of soil erosion using universal soil loss equation. Journal of the Indian Society of Remote Sensing, 30(4): 181-190.

Horton, R.E. 1945. Erosional development of streams and their drainage basins hydrophysical approach to quantitative morphology. Geol. Soc. Am. Bull., 56: 275-370.

Khan, M.A., Gupta, V.P. and Moharana, P.C. 2001. Watershed prioritization using remote sensing angeographical information system: A case study from Guhiya, India. Journal of Arid Environments, 49: 465-475.

Morgan, R.P.C., Morgan, D.D.V. and Finney, H.J. 1984. A predictive model for the assessment of soil erosion risk. Journal of Agricultural Engineering Research, 30: 245-253.

Schumn, S.A. 1956. Evolution of drainage systems and slopes in

Badlands at Perth Amboy, New Jersey. Geol. Soc. Am. Bull., 67: 597-646.

Srinivas, C.V., Maji, A.K., Obi Reddy, G.P. and Charry, G.R. 2002. Assessment of soil erosion using remote sensing and GIS in Nagpur District, Maharashtra for prioritisation and delineation of conservation Units. Journal of the Indian Society of Remote Sensing, 30(4): 198-212.

Strahler, A.N. 1957. Quantitative geomorphology of drainage basins and channel networks, In: V.T. Chow (ed.), Handbook of Applied Hydrology, McGraw Hill Book Company, New York, Sections 4-11.

Suresh, M., Sudhakar, S., Tiwari, K.N. and Chowdary, V.M. 2004. Prioritizatoin of watersheds using morphometric parameters and assessment of surface water potential using remote sensing. Journal of Indian Society of Remote Sensing, 32(3): 249-311.