Mini Watershed Characterization and Prioritization using Spatial Information Technology (SIT): A Case Study of Kansachara Sub-watershed, West Bengal

Kartic Bera[1] and Dr. Jatisankar Bandyopadhyay[2]
[1.] Research Scholar and [2.] Assistant Professor
Department of Remote Sensing & GIS,
Vidyasagar University, Paschim Medinipur, Midnapore – 721102.
E-mail: 4kbrsgis@gmail.com., jatiban@gmail.com

Abstract

In the present study, prioritization of sub-watershed was carried out on the basis of morphometric parameters using Geoinformatics in Kansachara sub-watershed, right hand side tributary of Dwarkeswar river in Bankura & Puruliya districts, West Bengal. Prioritization of watershed involve holistic integrated techniques of morphometric parameters, like stream order, stream length, mean stream length, stream length ratio, bifurcation ratio, drainage density, stream frequency, etc. For this analysis, satellite imageries of high resolution IRS-P6 LISS-III, SRTM and different hydrogeo-morphological units have been delineated. The compound parameter values are calculated and prioritization rating of six mini watersheds in Kansachara sub-watershed has been done. The morphometric investigation suggests that the sub-watershed is covered with fractured, resistant, high infiltration soil. The studies conclude that spatial information technology proved to be an inexpensive tool in morphometric analysis.

Introduction

Spatial Information Technology (SIT), Remote Sensing (RS), Geographical Information System (GIS) and Global Positioning System (GPS) have provided important tools (Rao et.al, 2010) for morphometric analysis and watershed prioritization studies in a meaningful way. Development of a drainage system and the flowing pattern of a river over space and time are influenced by several variables such as linear, relief and arial aspects of fluvial originated drainage basin (Rekha et. al., 2011; Singh, 2011). Linear parameters analysis includes Stream order (U), Stream length (Lu), Mean stream length (Lsm) and Bifurcation ratio (Rb). Relief parameters analysis includes Basin relief (Bh), Relief ratio (Rh) and Ruggedness number (Rn). Whereas arial parameters comprises of Drainage density (Dd), Stream frequency (Fs), Texture ratio (T), Form factor (Rf), Circulatory ratio (Rc), Elongated ratio (Rc), Length of overland flow (Lof) and Constant channel maintenance (C). Many works have been reported on morphometric analysis (Horton-1945; Smith- 1950; Strahler-1957) and the use of remote sensing and GIS in morphometric analysis by other authors like, Krishnamurthy and Srinivas (1995); Srivastava & Mitra (1995); Agarwal (1998); Biswas et. al. (1999); Chakraborty *et.al*, (2002); Rao *et.al,* (2006); Thakkar *et.al,* (2007); Christopher *et.al,* (2010); Rekha *et.al,* (2011); Kumer *et.al,* (2011); Singh (2011); Pal *et. al,* (2012). In the present study, morphometric analysis and prioritization of miniwatersheds are carried out for six mini watersheds of Kansachara sub watershed under Bankura and Puruliya districts of West Bengal, using Spatial Information Technology.

Study area

The Kansachara sub watershed is a major tributary of Dwarakeswar river covers an area of 113.21 km^2. The study area geographically located between 23^{0}20$^/$ N to 23^0 30$^/$ N latitude and 86^0 45$^/$ E to 86^0 55$^/$ E longitude and between four blocks under Bankura & Puruliya districts of West Bengal (Fig. 1). The relief undulations of the area are varied between 120m to 300m with gentle gradient from east to west. The dominated geological formation of the area comprises Archaean Dharwarian rocks and is an extension of peninsular

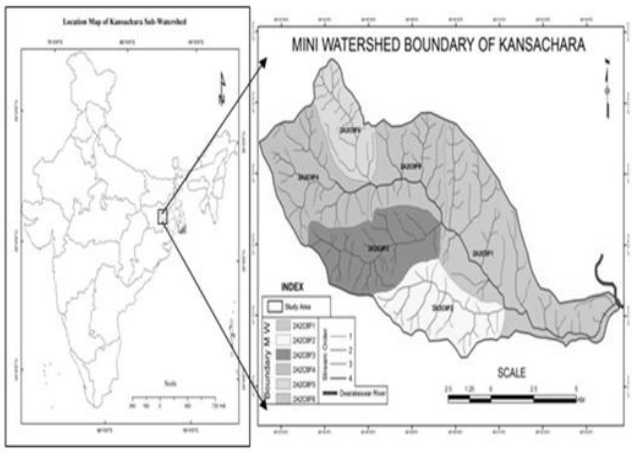


Fig. 1: Location map

mass of Chhotonagpur plateau. The climate conditions of the area are of tropical dry sub humid with normal rainfall ranging from 1100 mm to 1400 mm and also mean temperature ranges from 12^0 in winter to 46^0 C in summer.

The most part of land use is under agricultural fallow whereas some part of the area is covered by the forest mainly in the middle part of sub watershed. The drainage network of the watershed is thin and not well developed having dendritic to sub-dendritic pattern.

Materials and Methods

For the purpose of the watershed prioritization of Kanschara sub-watershed under study, a drainage map was prepared with the help of IRS P6 LISS-III image and SRTM database (Fig. 2). The flow accumulation from the SRTM DEM of drainage network was carried out using Arc GIS (9.3) software and then overly on image in ERDAS Imagine (9.0) software. The stream ordering is carried out following Strahler law, 1964. The detailed information of morphometric parameters in watershed is measured with the help of Arc GIS (9.3) software up to mini watershed level. The calculation of morphometric parameters (Linear, Relief and Arial) was made using formula given in the Table 01. The prioritization was carried out by assigning ranks to the individual indicators and a compound value (Cp) was calculated. Watersheds with highest Cp were of low priority while those with lowest Cp were of high priority. Thus an index of high, medium and low priority was produced. The various indicators which have been used in the prioritization of watersheds are described in Table 06 (Kanth *et.al.,* 2012).

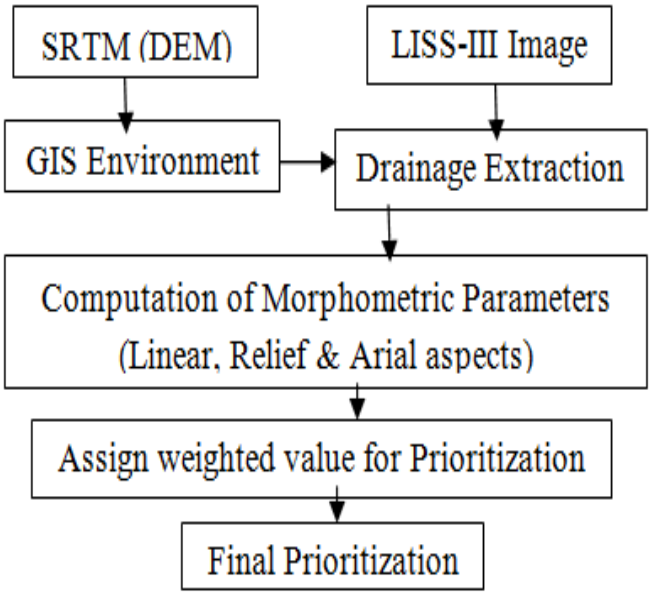


Fig. 2: Flow chart of the work

Result and discussion

The drainage line and boundary of the Kansachara sub watershed is prepared using the spatial analysis tool. The highest stream order of the study area is four. The six mini watershed areas are varying from 10.56 to 35.18 $km^{2.}$ This watershed prioritization is depending on the various morphometric parameters.

***Morphometric* Analysis:** The study 6 mini watershed carried out has been divided into three sections, deals with applicability of Liner aspects (Table 02) of study area. The second parameter deals with the relief aspects (Table 03) of watershed. The third section deals with aerial aspects (Table 04) for prioritization of watersheds.

	Morphometric Parameters	Methods	References
LINEAR	Stream order (U)	Hierarchical order	Strahler, 1964
	Stream length (Lu)	Length of the stream	Horton, 1945
	Mean stream length (Lsm)	Lsm = Lu/Nu where, Lu=Stream length of order 'U' Nu=Total number of stream segments of order 'U'	Horton, 1945
	Stream length ratio (Rl)	Rl=Lu/Lu-1; where Lu=Total stream length of order 'U', Lu-1=Stream length of next lower order.	Horton, 1945
	Bifurcation ratio (Rb)	Rb = Nu/ Nu+1; where, Nu=Total number of stream segment of order'u'; Nu+1=Number of segment of next higher order	Schumn,1956
RELIEF	Basin relief (Bh)	Vertical distance between the lowest and highest points of watershed.	Schumn, 1956
	Relief ratio (Rh)	Rh=Bh/Lb; Where, Bh=Basin relief;Lb=Basin length	Schumn, 1956
	Ruggedness number (Rn)	Rn = Bh × Dd Where, Bh =Basin relief; Dd=Drainage density	Schumn, 1956
ARIAL	Drainage density (Dd)	Dd = L/A where, L=Total length of streams;A=Area of watershed	Horton, 1945
	Stream frequency (Fs)	Fs = N/A where, N=Total number of streams; A=Area of watershed	Horton, 1945
	Texture ratio (T)	T = N1/P where,N1=Total number of first order streams; P=Perimeter of watershed	Horton, 1945
	Form factor (Rf)	$Rf=A/(Lb)^2$;where, A=Area of watershed, Lb=Basin length	Horton, 1932
	Circulatory ratio (Rc)	$Rc=4\pi A/P^2$;where, A=Area of watershed, π=3.14, P=Perimeter of watershed	Miller, 1953
	Elongation ratio (Re)	$Re=2\sqrt{(A/\pi)}/Lb$;where, A=Area of watershed, π=3.14, Lb=Basin length	Schumn,1956
	Length of overland flow (Lof)	Lof = 1/2Dd where, Dd=Drainage density	Horton, 1945
	Constant channel maintenance (C)	Lof = 1/Dd where, Dd=Drainage density	Horton, 1945

Table 1: Methods of calculating morphometric parameters

Linear aspects

The linear parameters namely stream order, stream length, mean stream length, stream length ratio and bifurcation ratio are calculated (Table 2) by using selected formula. Stream order (U): The stream order (u) is extracted from SRTM DEM by Arc Info 9.3 based on the hierarchic ranking of streams by strahler-1964 (Table 1). After extraction, drainage pattern compared and edited based on IRS LISS-III satellite image. From the drainage line it is observed that the maximum frequency is in case of first order (Table 2) of six mini watersheds. It is also observed that there is a decrease in stream frequency as the stream order increases (Vittala S. *et.al,* 2004). Stream length (Lu): Stream

lengths are automatically calculated by the software in attribute table by Horton, 1945. Mean stream length (Lsm) is calculated according to Strahler-1964 formula. Stream Length Ratio (RL): RL is defined as the ratio of the mean length of the order to previous order by Horton's methods 1964. Bifurcation ratio (Rb) is used to express the ratio of the number of streams of any select order and next higher order (Schumn, 1956).

Table 2: Linear Aspects

M.W.C	Parameter	I Order	II Order	III Order	IV Order
2A2C8F1	Stream order (U)	42	10	1	1
	Stream length (Lu)	31051	15668	2035	13054
	Bifurcation ratio (Rb)	4.2	10	1	_
	Mean Stream Length (Lsm) M	739.3095238	1566.8	2035	13054
	Stream length Ratio (RL)	0.504589224	0.129882563	6.414742015	-
2A2C8F2	Stream order (U)	26	7	1	-
	Stream length (Lu)	14576	9006	6077	-
	Bifurcation ratio (Rb)	3.714285714	7	-	-
	Mean Stream Length (Lsm) m	560.6153846	1286.571429	6077	-
	Stream length Ratio (RL)	0.617864984	0.674772374	-	-
2A2C8F3	Stream order (U)	29	8	1	-
	Stream length (Lu)	21351	6340	6570	-
	Bifurcation ratio (Rb)	3.625	8	-	-
	Mean Stream Length (Lsm)	736.2413793	792.5	6570	-
	Stream length Ratio (RL)	0.296941595	1.036277603	-	-
2A2C8F4	Stream order (U)	27	8	3	1
	Stream length (Lu)	19418	7128	3781	652
	Bifurcation ratio (Rb)	3.375	2.666	3	-
	Mean Stream Length (Lsm) M	719.1851852	891	1260.333333	652
	Stream length Ratio (RL)	0.367082089	0.530443322	0.172441153	-
2A2C8F5	Stream order (U)	19	3	1	1
	Stream length (Lu)	15840	2155	4556	1564
	Bifurcation ratio (Rb)	6.333	3	1	-
	Mean Stream Length (Lsm)	833.6842105	718.3333333	4556	1564
	Stream length Ratio (RL)	0.13604798	2.114153132	0.343283582	-
2A2C8F6	Stream order (U)	22	5	1	1
	Stream length (Lu)	16285	5291	1487	5301
	Bifurcation ratio (Rb)	4.4	5	1	-
	Mean Stream Length (Lsm)	740.2272727	1058.2	1487	5301
	Stream length Ratio (RL)	0.324900215	0.281043281	3.564895763	-

Relief aspects (Ra)

Relief aspects is another important parameter for prioritization of watershed. Element of the relief aspects i.e Basin relief (Bh): According to Schumn-1956, basin relief is the vertical distance between the lowest and highest point of watershed. That is calculated by detailed contour values of mini watersheds generated from SRTM data by using Arc GIS (9.3) software. Relief ratio (Rh) is computed based on the law proposed by Schumn,1956 for the entire six mini watersheds (Table 3).

Ruggedness number (Rn): The ruggedness number is calculated by multiply of basin relief and drainage density, formulated by Schumn, 1956. Table 3 shows the RA values of mini watersheds.

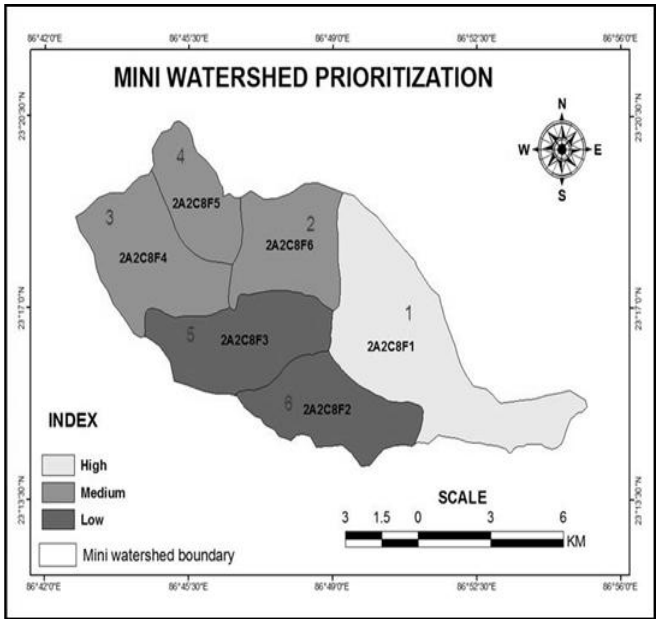
Table 3: Relief Aspects

Mini watershed code no.	Basin Relief (Bh)	Relief ratio (Rh)	Ruggedness number (Rn)
2A2C8F1	58	3.232169729	101.8716681
2A2C8F2	20	0.913264089	38.33397958
2A2C8F3	44	2.150346131	82.75149586
2A2C8F4	48	2.209564471	79.15005057
2A2C8F5	36	1.657173354	82.16354344
2A2C8F6	34	1.661631101	64.39906511

Aerial aspects

Different morphometric parameters like drainage density, stream frequency, texture ratio, form factor, circulatory ratio, elongation ratio, length of overland flow and constant channel maintenance have been discussed in detail and are presented in Table 4. Drainage density (D): Horton (1945) has introduced drainage density, based on the total length of streams divided by area of the watershed. The highest value 2.282320651 in 2A2C8F5 mini watershed and lowest value 1.648959387 occurs in 2A2C8F4 and so on. Stream frequency (Fs): Stream frequency is the total number of stream segments of all orders per unit area flowed by Horton, 1945 (Table 1). Table 4 shows for all six mini watersheds Fs value. Texture ratio (Rt): Texture ratio deals with concepts of geomorphology. According to Horton, 1945, Rt is the total number of stream segments of all orders per perimeter of that area (Table 4). Form factor (Rf): Horton (1932) introduced form factor which is the area of watershed divided by basin length (Table 1). From Table 04, it is observed that the Rf varies between 0.357947617 (2A2C8F1) and 0.421579251 (2A2C8F5) and where as the remaining watersheds are extended with moderate values of form factor. Circulatory ratio (Rc): It is the ratio of the area of the basin to the area of a circle having the same circumference as the perimeter of the basin (Miller-1953) (Table 1). All mini watersheds under study, the Rc values ranges from 0.357947617 to 0.698137647 of 2A2C8F1 and 2A2C8F5 mini watersheds, respectively (Table 4).

Elongation ratio (Re): Schumn (1956) defined elongation ratio as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin (Table 1)



(Vittala *et.al,* 2004). In the study area, Re value is varying between 0.674959032 to 0.732499427 (Table 4). Length of overland flow (Lof): It is the length of water over the ground before it gets concentrated into definite stream channels (Horton, 1945) in Table 1. This factor basically relates inversely of the average slope of the channel and is quite synonymous with the length of sheet flow approximately equals to half of the reciprocal of drainage density (Horton, 1945). Constant channel maintenance (C): Channel maintenance method follows a constant as per Horton, 1945 (Table 1). The 'C' values ranges between 0.438150529 to 0.606443074 (Table 4).

Final Prioritization

Mini watershed wise total values of Morphomatric parameter are calculated then cumulative values often by using total values of morphometric parameter. After that weighted value are assign to each of the mini watershed according to the deferent morphometric morphometric parameters (La, Ra & Aa) calculated sum for final prioritization. The final priority classes are classified in three class i.e high, medium and low. The highest priority class under 2A2C8F1 mini watershed, 2A2C8F6, 2A2C8F4 & 2A2C8F5 mini watershed under medium and lowest priority value in 2A2C8F3 & 2A2C8F2, respectively.

Table 4: Aerial Aspects

Mini watershed code no.	Drainage Density (Dd)km/km2	Stream Frequency (Fs)	Texture ratio (Rt)	Form factor(Ff)	Circulatory ratio(Rc)	Elongation ratio (Re)	Length of overland flow (Lof)	Constant channel maintenance (C)
2A2C8F1	1.75640807	1.534531163	1.610819937	0.357947617	0.393649	0.674959032	0.284671887	0.569343774
2A2C8F2	1.916698979	2.197190633	1.786567221	0.400262782	0.537126648	0.7137404	0.260865167	0.521730335
2A2C8F3	1.880715815	2.085962354	1.930883516	0.391478071	0.591298421	0.705864589	0.265856221	0.531712443
2A2C8F4	1.648959387	2.07587627	1.969329958	0.389840488	0.602220501	0.704386699	0.303221537	0.606443074
2A2C8F5	2.282320651	2.271388246	1.739920964	0.421579251	0.698137647	0.732499427	0.219075264	0.438150529
2A2C8F6	1.89409015	1.936561331	1.660190968	0.402052209	0.616980548	0.715334056	0.263978987	0.527957975

Table 5: Final Prioritization

Mini watershed code no.	Total values of Morphometric parameter			Cumulative value of Morphometric parameter			Assign Weighted value			Total Weighted value	Prioritization Class	
	La	Ra	Aa	La	Ra	Aa	La	Ra	Aa			
2A2C8F1	155.46	163.1	7.17	3109.2	5436.67	89.63	1	6	6	13	**1**	High
2A2C8F2	83.58	59.24	8.34	1671.6	1974.67	104.3	4	1	3	8	6	Low
2A2C8F3	93.32	128.9	8.39	1866.4	4296.67	104.88	2	4	2	8	5	Low
2A2C8F4	83.6	129.35	8.29	1672	43.1167	103.63	3	5	4	12	3	Medium
2A2C8F5	68.76	119.82	8.8	1375.2	3994	110	6	3	1	10	4	Medium
2A2C8F6	80.52	100	8.02	1610.4	3333.33	100.25	5	2	5	12	2	Medium

aspects. Then total weighted value of each mini watershed is being calculated, finally prioritization class was made. This class is also verified using Land use / Land cover and considering the water scarcity in dry period of Bankura town Watershed prioritization is one of the most important aspects of planning for developments and management of natural resource. Remote sensing and GIS have proved to be efficient tool in drainage delineation and updating in the present study and this updated drainage has been used for the morphometric analysis. The variation of total value of Linear Aspects (La) is 68.76 to 155.46. Relief aspects (Ra) values varying 59.24 to 163.1, and Ariel aspects (Aa) varying 7.17 to 8.8. On the basis of above

References

1. Chakraborty, *et.al*. (2002). "Morphometric Analysis of a Watershed Using Remote Sensing and GIS - A Case Study" Jour. Agric. Physics, Vol. 2, No.1, pp. 52-56.
2. Christopher, *et.al. (*2010). "Hydrological Analysis of Onitsha North East Drainage Basin Using Geoinformatic Techniques", World Applied Sciences Journal 11 (10) p. 1297-1302.
3. Horton R. E (1945). Erosional development of streams and their drainage basins, hydrological approach to quantitative morphology, Bulletin of the Geological Society of America 56 276-370.

4. Kanth T.A *et.al*, (2012). “Morphometric analysis and prioritization of watersheds for soil and water resource management in Wular catchment using Geo-spatial tools” International Journal of Geology, Earth and Environmental Sciences, 2012 Vol. 2 (1) January-April, p.30-41.

5. Pal. B *et.al*, (2012). Morphometric and hydrological analysis and mapping for Watut watershed using remote sensing and GIS techniques, International Journal of Advances in Engineering & Technology, Jan 2012 p. 357-368.

6. Rao. K *et.al,* (2010). “Morphometric Analysis of Gostani River Basin in Andhra Pradesh State, India Using Spatial Information Technology” International Journal of Geomatics and Geosciences, 1(2) 2010. p.p 179-187.

7. Rekha *et.al*, (2011). “Morphometric Analysis and Micro-watershed Prioritization of Peruvanthanam Sub-watershed, the Manimala River Basin, Kerala, South India” Environmental Research, Engineering and Management, 2011. No. 3(57), P. 6 – 14.

8. Schumn, S A. (1956). Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey Geol Soc Am Bull., 67: 597-646.

9. Singh. V (2011). “Linear Aspect of the Maingra River Basin Morphometry, District Gwalior, Madhya Pradesh, India”. International Journal of Science and Advanced Technology, Volume 1 No 5 July 2011 p. 212-222.

10. Strahler, A. N. (1964). Quantitative geomorphology of drainage basins and channel networks, section 4II, In: Handbook of Applied Hydrology, edited by V.T. Chow, McGraw Hill, pp 439.

11. Thakkar A. *et.al*. (2007). “Morphometric analysis and prioritization of mini watersheds in Mohr watershed, Gujarat using Remote sensing and GIS techniques” Journal of the Indian Society of Remote Sensing, Vol. 35, No. 4, 2007 p. 313-321.

12. Vittala S. *et.al*, (2004). “Morphometric analysis of sub-watersheds in the Pavagada area of Tumkur district, south India using Remote sensing and GIS techniques” Journal of the Indian Society of Remote Sensing, Vol. 32, No. 4, 2004 p. 351-362.