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Research Paper

Morphometric Analysis of Watershed in Jaisinghnagar Area Shahdol District, Madhya Pradesh Using Remote Sensing and GIS Techniques

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Abstract :
The paper deals with Morphometric analysis of four watershed carried out using Remote Sensing and GIS techniques. GIS and image processing techniques can be employed for the identification of morphological features and analyzing properties of basin. All the sub-watershed show dendritic to sub dendritic drainage pattern with moderate drainage texture. The morphometric parameters of basin can address linear, areal and relief aspects. The complete morphometric analysis of drainage basin indicates that the given area is having good groundwater prospect. The Present study deals mainly with the geometry more emphasis being placed on the evaluation of morphometric parameters such ad stream order(Nu), Stream Length (Lu),bifurcation ratio(Rb), Drainage density(D), Stream Frequency (Fs), Circularity ratio(Rc) and form factor ration (Rf). The analysed morphometric parameters indicate that the area is immense scope for construction of artificial recharge structures.

Keywords: *Geographical information system, Remote Sensing, Morphometric analysis.*

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I. Introduction:

Remote sensing and GIS Techniques are the proven efficient tools in the delineation of groundwater potential of the area updating and morphometric analysis of drainage basin. The drainage basin analysis is important in any hydrological investigation like assessment of groundwater potential and groundwater management, various important hydrological phenomena can be correlated with the physiographic characteristic of drainage basin such as size, shape, slop of drainage area, drainage density, size and length of the tributaries etc. (Rastogi et al.,1976). Remote sensing data can be used in conjunction with conventional data for delineation of ridgelines, characterization, priority evolution problem identification assessment of potentials and management needs, identification of erosion prone areas, evolving water conservation strategies, selections of sites for check dam and reservoirs etc (Dutta et al.2002). Morphometric analysis provides quantitative description of the basin geometry to understand initial slope or inequalities in the rock hardness, structural controls, recent diastrophism geological and geographic history of drainage basin (Staler, 1964). Lower order tributarics show dendrite drainage whereas higher order drainage has parallel to sub-parallel pattern. Hills are covered by moderately dense forest. Bedding planes and weathered pediments are favourable for the groundwater exploitation (Tiwari et al. 2010).

The groundwater occurs in both semi confined and confined conditions. Morphometric analysis requires measurement of linear features. Gradient channel network and contributing groundwater slopes of the drainage basin (Natutical,1994). Nag (1998) carried out Morphometric analysis of chaka sub- basin in purulia district, while Nage and Chakraborti(2003) have carried out development of drainage network in hard rock area. Srinivas(2004); Chopara(2005); Sharma et al.(2008); Tiwari et al.(2011). The drainage basin has been seen as the fundamental hydrologic and geomorphic areal unit. Singh et al. (2023) GIS-based morphometric analysis with emphasis on hypsometric appraisal for sub-watershed prioritization: a case study of the Shyamari River Basin, Central India. Si et al. (2024) Mapping gray and white matter volume abnormalities in early-onset psychosis: an ENIGMA multicenter voxel-based morphometry study. We dealing with the water with in watershed the main source of water are due to precipitation. The water as pears water concern with respect to precipitation even though we classify in terms of watershed or particular river basin or drainage basin.

Study Area:

The study are is located in Jaisinghnagar block of Shahdol district. Hydtogeologicaly, the area is classified as Gondwana Supergroup of sediments which is unconsolidated soft sandstone and sandy. The area is covered by alluvial sandy/silty clay and course sand. The area of study lieas in North-western part of Shahdol district, a part of survey of India. Toposheets 64 E/S and 64 E/6. The area is limited by latitudes $20^0 30'$ to $24^0 55'$ N and longitudes $81^0 15'$ to $81^0 30'$E. The area enjoyes subtropical climate with extreames of temperature and dryness. The average rainfall is about 1100mm. The rock formations occurring in the area are boulder bed sandstones, shales, clays, limestone, coal seam. These rock formations are almost horizontal or having dip varying from 5^0 to 8^0 due south.

II. Methodology:

The topographical map was georeferenced and digitized using Arc GIS (ver.9.3) software and the attributes were assigned to create the digital database and morphometric analysis. The morphometric analysis can be achieved through measurements of Linear, areal and relief aspects of basin and slope contribution (Nag and chakarabrthy,2003). In present study, morphometric analysis and priorization of basin of basin is based on the integrated use of remote sensing and GIS technique. The remotely sensed data is geometrically rectified with respect to survey of India (SOI) Topographical maps at 1:50000.

Landsat TM & Landsat ETMt imagery acquired in 2008,2010 was used for pupation of drainage captured from survey of India (SOI) topographical maps. standard image interpretation characteristics such as tone, texture, shape, size, pattern and association along with sufficient ground truth and Local knowledge were used to finalize these maps.

III. Result And Discussion:

In the present morphometric analysis of the parameters, namely stream order, stream length bifurcation ratio, relief ration drainage texture from factor, circulatory and elongation ratio, area, perimeter length and width of all the sub- watershed have been carried out using the mathematical formulae given in the table 1 and their results are summarized in table 2.

Morphometric analysis of basin:

The following paragraphs describe the physical meaning of various morphometric parameters. Further values of these parameters are obtained as per methods proposed by various researchers for the study area and indicated in respective description.

(A) **Liner Aspects:** The Linear aspect of morphometric analysis of basin include stream order, stream length, main stream length, stream length ration and bifurcation ratio.

Stream order: The properties of the stream networks are very important to study basin characteristics (Strahler, 2002). Drainage pattern of stream network from the basin have been observed as mainly of dendritic type which indicates the homogeneity in texture and lack of structural control. The designation of stream order is the first step in drainage basin analysis it is based on hierarchic ranking of streams proposed by Strahler(1964). Strahler's system, which is a slightly. The sub-watershed range from 26.5 to 42.5 respectively. The mean stream length of stream increases with increase of the order.

Stream Length Ratio (RL): The stream length ration can be defined as the ration of the mean stream length of given order to the mean stream length of next lower order and has an important relationship with the surface flow and discharge(Horton,1945). The RL values between streams of different order in the basin reveal that there are variation in slop and topography.

Bifurcation Ration (Rb): bifurcation ratio (Rb) may be depend as the ratio of the number of stream segments of given order to the number of segments of the next higher order(Schumn1956). Horton(1945) considered the bifurcation ratio as an index of relief and dissections. Strahler(1957) demonstred that the bifurcation ratio shows a small range of variation for different regions or different environmental conditions, expect where the geology dominates. Table 2 show that mean bifurcation(Rb) of the watershed are 4.24 and 16.39 usually these values are common in the area where geologic structures do not exercise a dominant influence on the drainage pattern.

(B) **RELIEF ASPECTS:** The relief aspect determined include relief= ratio, relative relief and ruggedness number.

Relief ratio(Rn): The relief ration(Rb) is ratio of maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line (Schuman,1956). The Rn normally increases with decreasing drainage area and size of watershed of a given drainage basin(Gottschalk,1964) relief ratio measures the overall steepness of a drainage basin and is an indicator of the intensity of erosion process operation on slope of the basin(Schuman,1956) in the present study, Rb range from 0.006 to 0.038.

Relative relief(Rbb): This term was given by Melton(1957) in the present study area it is obtained by visual analysis of the digital elevation model prepared from SRTM data.

Ruggedness number (Rn) : It is the product of maximum basin relief(H) and drainage density(Dd) where both parameters are in the same unit an extreme high value of ruggedness number occurs when both variables are large and slope is steep(strapler,1956). The value of ruggedness number in present basin is 0.063 (Schuman,1956).

(C) **ARIAL ASPECT :** It deals with the total area projected upon a Horizontal plane contribution overland flow to the channel segment of the given order and includes all tributaries of lower order it comprises of drainage density, drainage texture, stream frequency, from factor, circularity ratio, elongation ratio and length of overland flow.

Drainage Density(Dd): Horton (1932), introduced the drainage density (Dd) is an important indicator of the liner scale of land elements in stream eroded topography it is the ratio of total channels segment length. It is calculated for all order within a basin to the basin area, which is expressed in terms of km/km^2.

The drainage density, indicates the closeness of spacing of channels. Thus providing a quantitative measure of the average Length of stream channel for the whole basin. It has been observed from drainage density measurement made over a wide range of geologic and climate type that a low drainage density is more likely to occur in region and highly resistant of highly permeable subsoil material under drainage density is the resultant of weak or impermeable subsurface. Material is the resultant and mountainous relief it is affected by factors which control the charactertic length of the stream like resistance to weathering. Low drainage density leads to fine drainage texture(Strahler,1964). Sub-watershed with drainage density values of 1.59 and 2.47 respectively. The moderate drainage density indicates the basin is highly permeable subsoil and vegetative cover (Nag,1998).

Stream Frequency(Fs): Stream frequency (Fs) is expressed as the total number of stream segments of all order per unit area(Hurton,1932). Table 2 shows close correlation with the drainage density values of sub-watersheds indicating the increase in with respect to in increase in drainage density.

Drainage Texture: Drainage texture ration (T) is the total number of stream segments of all orders per parameter of that the area(Horton,1945). It depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relies and stage of development. Smith(1950) has classified drainage density in to five different texture i.e. coarse (C2), Coarse(2-4) moderatge(4-6). fine (6-8) and very fine(>8). In the present study sub- watershed have moderate drainage texture as their drainage densities are 1.59 and 2.47 respectively.

From Factor: From factor(Ft) is defined as the ratio of the basin area to square of the basin length. This factor indicates the flow intensity of a basin a defined area(Horton,1945). The form factor value should be always less than 0.057(The value corresponding to a perfectally circular basin). The smaller the value of the from factor, the more elongated will be the basin. Whereas with high from factors experience larger peak flows of shorter duration, coheras elongated watersheds with low from factors experience lower peak flows of longer duration. The from factor(Ff) value for study area is 0.046 and 0.075 indicating elongated basin with lower peak flows of longer duration than the average.

Circulatory Ration (Rc): Circulatory ratio is the ratio of the area of a basin to the area of circle having the some circumference as the perimeter of the basin(Miller,1953) it is influenced by the length and frequency of streams, geological structures Land use/ land cover, climate and slop of the basin. In the present case circulatory ratios for sub- watershewd are 0.295 and 0.473 significance indicating that the area is chara-cherized by high relief and the drainage system is structurally controlled.

Elongation Ration: Schumn(1956) defined elongation ratio as the ratio of dimeter of a circle of the same area as the drainage basin and the maximum length of the basin values of Elungation ration (Re) generally very from 0.6 to 1.0 over a wide variety of climate and geologic types. Re values close to unity correspond typically to regiuns of low relief, where as values in the range 0.6 to 0.8 are usually associated with high relief and steep ground in to three categories namely(a) circular(>0.9),(b) oval(0.9-0.8), (c) less elonated (<0.7). The Re for the sub-watershed varies between 0.039 to 0.076 indicates sub watersheds to be elongated with high relief and steep slope.

Lenght of overland flow: The length of overland flow(Lg) is the length of water over the ground surface before it gets concentrated in to definite stream channel (Horton,1945). Lg is one of the most important independent variables affecting hydrologic and phyisographic development of drainage basin. The length of over land flow is approximately equal to the half of the reciprocal of drainage density. This factor is related inversely to the average slop of the channel and is quiet synonymous with the length of dheet flow to a large degree Table 2 reveals that Lg is 0.795 and 1.235 sub-watersahed respectively.

Constant of channel maintence (C): Schuman (1956) used the inverse of drainage density as the property termed constant of stream maintenance c. This constant, in units of square feet per foot has the dimension of length and therefore increases in magnitude as the scale of the land-form unit in creases. The values of c as 0.50

and 0.628 mean the on average 0.542 Sq. Ft. Surface of needed in basin for correlation of one linear foot of the stream channel.

IV. **CONCLUSION:**

Remote sensing coupled with GIS techniques have proved to be an efficient tool in drainage delineation and from the morphometric analysis of two sub-watersheds. Bifurcation ratio, Length ratio and stream order of basin indicates that the basin is fourth order basin with dendritic type of drainage ratio circulatory ratio and elongation ratio shows that texture of basin is moderate and shape of basin almost elongated. The complete morphometric analysis of drainage basin indicates that the given area is having good groundwater prospect. The formula used for evaluating morphometric parameter are tabulated in table1. Result of this analysis are tabulated in table2.

TABLE 1. Result and formula adopted for computation of morphometric parameters:

	Morphometric Parameters	**Formula/ Definition**	**Reference**
LINEAR	Stream order (U)	Hierchial rank	Strahler(1964)
	Stream Length(Lu)	Length of the Stream	Hortan(1945)
	Mean Stream Length (Lsm)	Lsm= Lu/Nu Where,Lsm = mean stream length of a given order Lu= Total stream length of order'U' Nu= Total number of stream Segments of order 'U'	Hortan(1945)
	Stream Length Ratio (RL)	RL= Lu/Lu-1 Wheere, RL Stream Length Ratio Lu= The Total stream lewngth of order'U' Lu-1= The Total stream length of its next loder order	Hortan(1945)
	Bifercation Ratio(Rb)	Rb= Nu/Nu+1 Where, Rb =Bifurcation ratio Nu= Total number of stream segment present in the given order Nu+1=Number of gegments of the next higher order	Schumn(1956)
	Mean bifurcation Ratio (Rbm)	Rbm =Average of bifurcation ratios of all order	Strahler(1957)
RELIEF	Basin Relief (Br)	Vertical distance between the Lowest and Highest points of basin	Schumn (1956)
	Relief Ratio(Rh)	Rh= BH/Lb where, Bh= Basin relief, Lb= Basin Length	Schumn(1956)
	Raggedness number(Rn)	Rn= BhxDd where, Bh = Basin Relief Dd= Drainage density	Schumn(1956)
AERIAL	Drainage Density (D)	D= Lu/A where, D= Drainage Density Lu = Total stream Length of all orders A= Area of the Basin(Km^2)	Horton (1932)
	Stream Frequency(Fs)	Fs=Mu/A where, FS = Stream Frequency Nu= Total no of Stream of all orders A= Area of the Basin(Km^2)	Horton(1945)
	Drainage Texture(Rt)	Rt= Nu/F where, Rt= Drainage Texture Nu= Total no of streams of all order P=perimeter of Basin	Horton(1945)
	Form Factor (CRt)	Fg= Nu/P Where, RF = Form Factor, A= Area of the Basin (Km^2)Lb^2= Square of Basin length	Horton(1932)
	Circularity Ratio(Rc)	Rc= 4 ЛA/P^2 where,A = Area of basin, Л=3.14, P= Perimeter of basin	Miller(1953)
	Elaongation Ratio(Re)	Re=2v(A/pi/Lb) where, Re= Elongation ratio A= Area of Basin(Km^2), Pi=Pi value i.e. 3.14 Lb= Basin Length	Schumn(1956)

	Length of overland(Flow) (Lg)	Lg= 1/2 Dd where, Lg= Length of overland floe, D= Dranage Density	Horton(1945)
	Constant Channel maintenence(C)	C= 1/Dd where, Dd= Drainage Density	Schumn(1956)

TABLE 2. Order number and Bifurcation ratio of streams in different watershed.

Watershed	Stream Order	No. of Streams	Bifurcation ratio	No. of Streams used	Product of Colum (3&4)	Watershed Mean
	(1)	(2)	(3)	(4)	(5)	(6)
SW-I	I	48				
	II	31	1.54	79	121.66	
	III	08	3.87	39	150.93	
	IV	01	8.00	09	72.00	
			13.41	**127**	**344.59**	**2.71**
SW-II	I	48				
	II	16	3.00	64	192.00	
	III	11	1.45	27	39.15	
	IV	01	11.00	12	132.00	
			15.45	**103**	**362.15**	**3.52**
SW-III	I	48				
	II	19	2.52	67	168.84	
	III	11	1.72	30	51.60	
	IV	-	0.00	11	0.00	
			4.24	**108**	**220.44**	**2.04**
SW-IV	I	94				
	II	41	2.29	135	309.15	
	III	10	4.10	51	209.10	
	IV	01	10.00	11	110.00	
			16.39	**197**	**628.25**	**3.18**
SW-V	I	63				
	II	21	3.00	84	252.00	
	III	06	3.50	27	94.50	
	IV	02	3.00	08	24.00	
			9.50	**119**	**370.50**	**3.11**

Table 3 Order, Length, Cumulative length and mean stream length of streams in different watershed.

Watershed No	Stream Order	Total Stream Length (km)	Cumulative Length(km)	Total no of stream	Mean stream length(km)	Maximum length of Basin
	(1)	(2)	(3)	(4)	(5)	(6)
SW-I	I	28	28	48	0.58	26.5
	II	13	41	31	0.41	
	III	09	50	08	1.12	
	IV	03	23	01	3.00	
SW-II	I	37	37	48	0.77	32.5
	II	12	49	16	0.75	
	III	06	55	11	0.54	
	IV	00	55	01	00	
SW-III	I	23	23	48	0.47	27
	II	10	33	19	0.52	
	III	10	43	11	0.90	
	IV	00	43	00	00	
SW-IV	I	61	61	94	0.64	42.5
	II	21	82	41	0.51	
	III	18	100	10	1.80	
	IV	05	105	01	05	
SW-V	I	40	40	63	0.63	36.5
	II	40	50	21	0.47	
	III	05	55	06	0.83	
	IV	07	62	02	3.50	

Table 4 Morphometric analysis shape parameters of different watershed

Watershed	Drainage Density Dd=L/A	Length of Overland flow L of=1/2d	Drainage texture Rt=Nu/p	From factor(rf) $Rf=A/(Lb)^2$	Circularity Ration (Rc) $Rc= 4\pi A/P^2$	Elongation Ration $Re=2\sqrt{(A/\pi)}/LB$	Constant of Chanel Main

SW-I	2.00	1.00	3.320	0.075	0.473	0.061	0.50
SW-II	1.69	0.845	2.338	0.052	0.386	0.066	0.591
SW-III	1.59	0.795	2.888	0.058	0.465	0.076	0.628
SW-IV	2.47	1.235	3.435	0.058	0.295	0.039	0.404
SW-V	1.69	0.845	2.520	0.046	0.344	0.062	0.591
Total	**9.44**	**4.72**	**14.501**	**0.289**	**1.963**	**0.304**	**2.714**
Mean	**1.888**	**0.944**	**2.900**	**0.057**	**0.392**	**0.060**	**0.542**

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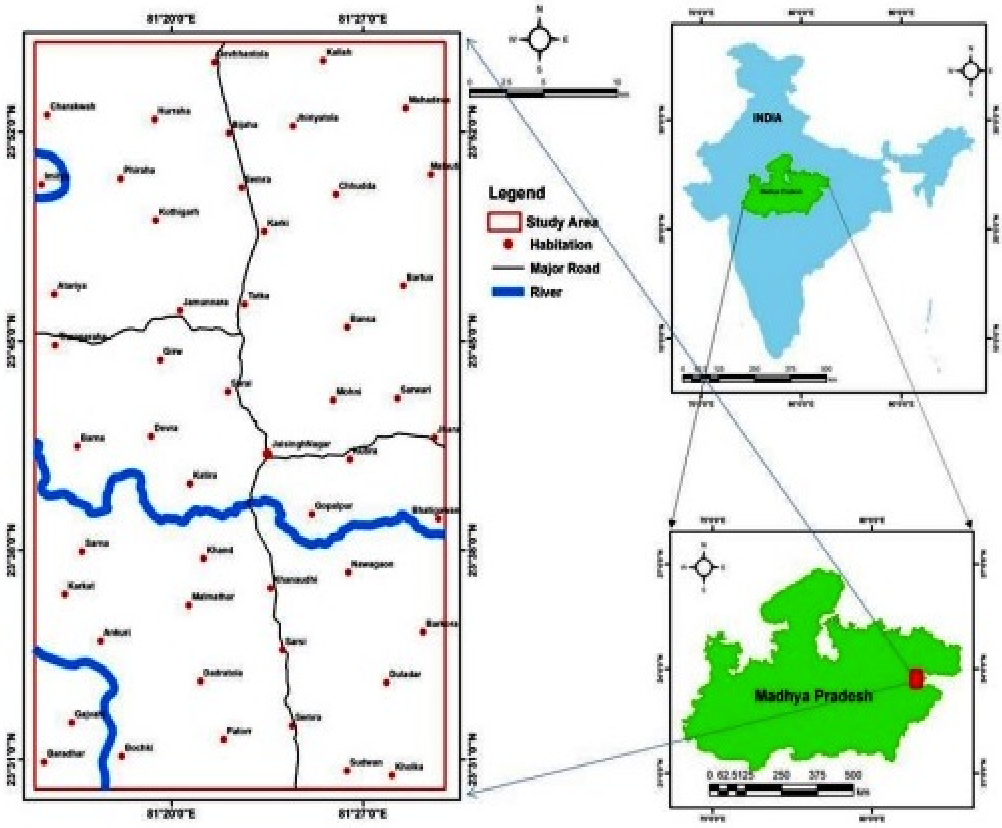

Fig.1 Location Map of Study Area

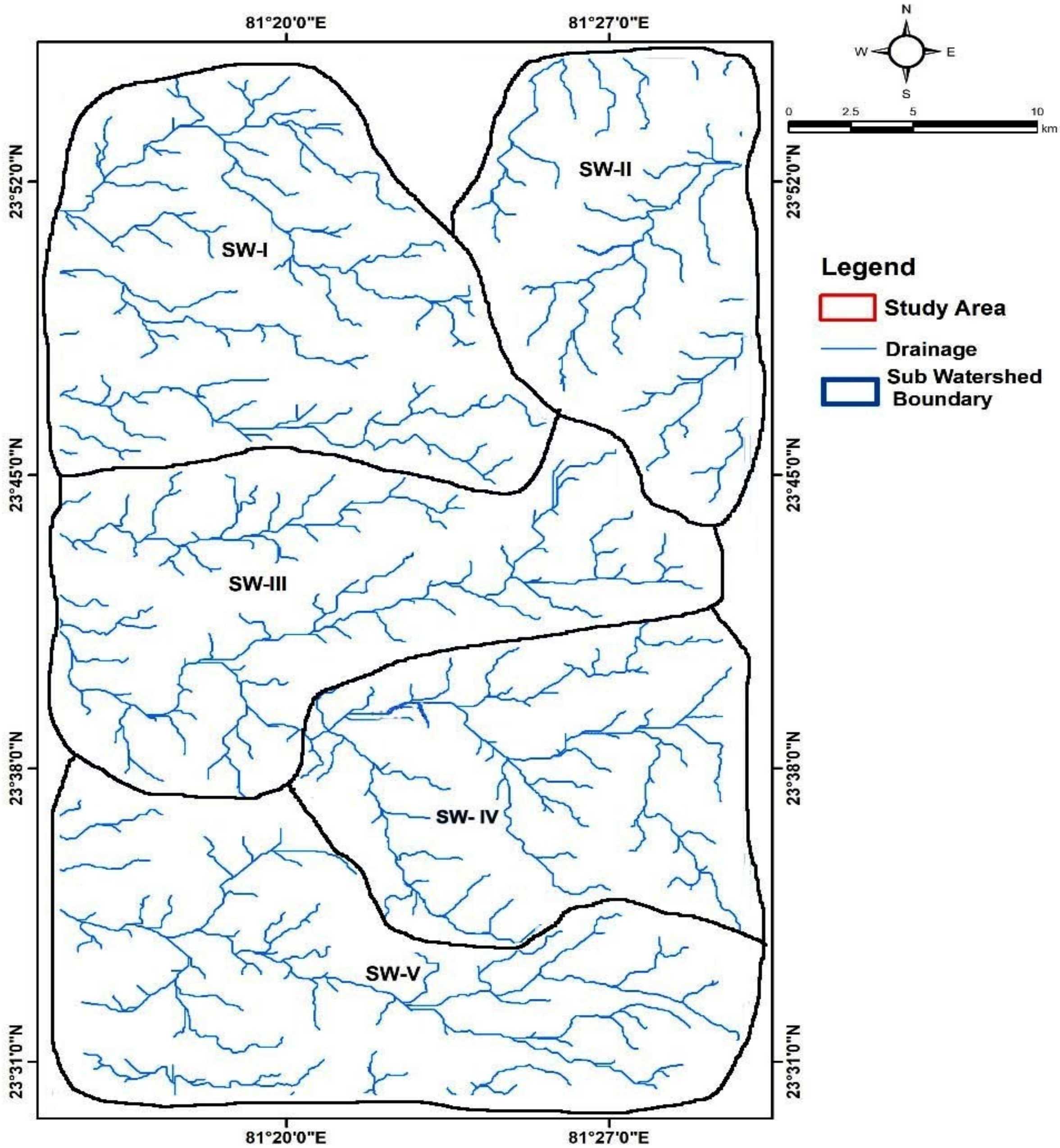

Fig.2 Watershed map of Study Area.