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Drainage Basin Analysis of Ilkalhalla Sub-Basin of Bagalkote and Koppal District, Karnataka

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ABSTRACT

In the present investigations, morphometric analysis of Ilkalhalla Sub-basin of Bagalkote and Koppal district, Karnataka was carried out using remote sensing and geographical information system to study various characters of basin mainly linear, aerial and relief aspects. ArcGIS software was used to digitize the drainage network of the basin. IHSB is of the highest order of VI and has been further categorized into four watersheds. IHSB has dendritic to sub-dendritic drainage pattern with average bifurcation ratio (3.75) suggesting that the basin is not influenced by any structural distortions. Based on elongation ratio value (0.53) of IHSB, it implies the sub-basin to be elongated in shape. Based on drainage density (1.94) and stream frequency (2.18) values it indicates the sub-basin to have gentle slope, moderate to highly subsurface and low run-off. Ruggedness number value (0.13) it emphasis, basin to be less prone to erosion. The proper analysis of various morphometric parameters with the aid of RS and GIS was found to be very much beneficial in understanding, planning, sustainable development and management of any river basin.

Keywords Basi nanalysis, IlkalhallaSub-basin, Karnataka, RS and GIS, Granites.

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INTRODUCTION

Appropriate use of water resources both surface and subsurface in terms of quality and quantity is very important for agricultural practices and development. Further with the ever increasing and need for rural and urban development groundwater regime is under serious threat. Water resources in many parts of the country is being over exploited while there is no recharge due to erratic rainfall due to which ground and surface water is depleting at alarming rates. Therefore, there is need for proper and detailed understanding of the water resources both surface and subsurface. This can be achieved by studying the morphometric characteristics of basin.

Many geoscientists throughout the world have worked on this subject for different climate and terrain conditions. Using both conventional and remote sensing and GIS based studies. Morphometry is the measurement and mathematical analysis of the configuration of the earth surface, shape and dimensions Clarke *et al.*(1966). A detailed morphometric analysis is of great help in understanding the drainage network and evaluating its effect and influence on landforms and other features Horton(1945), Leopold *et al.* (1956), Strahler (1964), Umrikar (2017).

In the last decade and more the application of remote sensing and GIS based studies for morphometric analysis is higher as the satellite images covers larger area and are updated one as compared to conventional ones. Many studies have been covered around the world by different researchers by coupling RS and GIS for morphometric studies Sameena *et al.*(2009),Mishra *et al.*(2011),Magesh *et al.*(2012), Singh *et al.*(2013), Jasmin *et al.*(2013), Asode *et al*. (2016).

In the present investigation, Ilkalhalla Sub-Basin

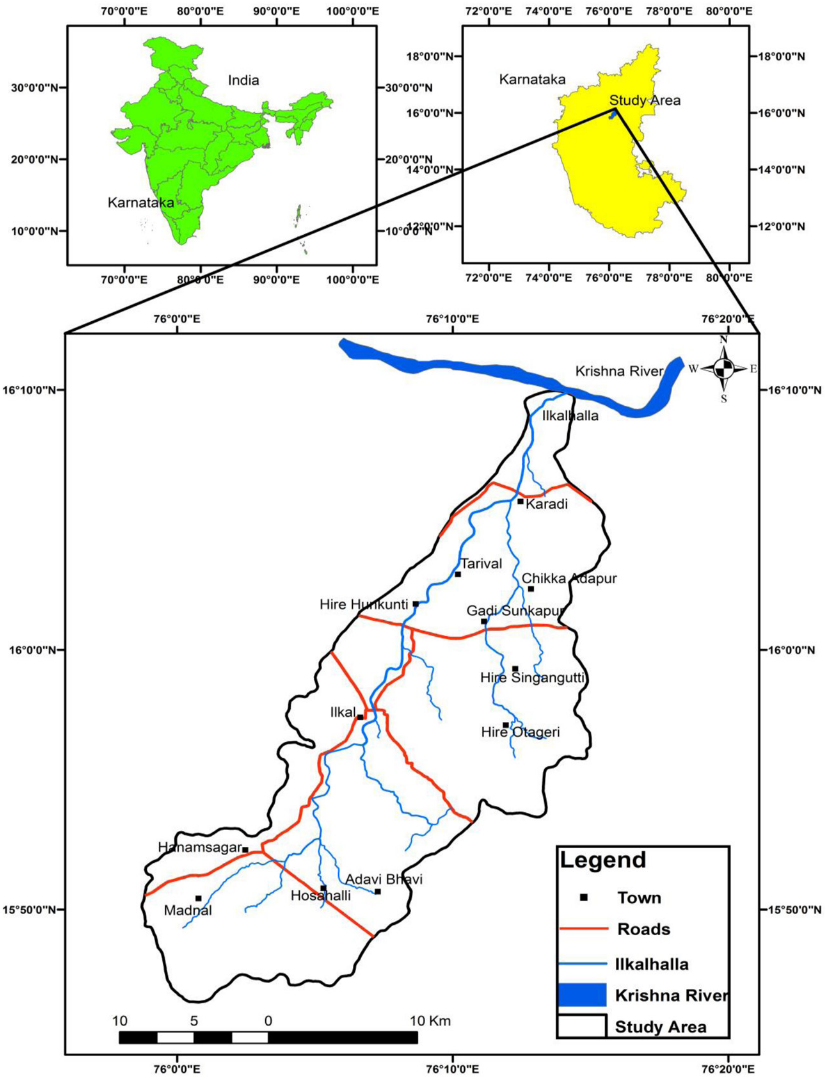

Fig. 1. Location map of Ilkalhalla Sub-basin.

(IHSB) which falls in one of the hard rock region of Karnataka was undertaken to study its morphometric characteristics using toposheets, remote sensing and GIS tools. Ilkalhalla Sub-basin is located majorly in Bagalkote district while some part lies in Koppal district of Karnataka (Fig. 1). It is one of the tributary of River Krishna which originates near Islampur village of Bagalkote district and traverses down till Yelbenchi village of Koppal district. The IHSB is located between 76^{o}5'00" to 76^{o}15'00" N latitudes and 16^{o}10'00" to 16^{o}48'00" E longitudes and covered in Survey of India toposheet numbered- 56D/04, 56D/08 and 57A/01 with an areal extent of 548 km^2. Physiographically, the lowest and highest elevations are 393m and 647m respectively. The basin forms part of Northern Maidan region with semi-arid type of climate. The mean annual rainfall is about 633mm. Geologically, the area is predominantly covered by varieties of pink and grey granites followed by meta-sediments and meta-volcanics. Basic dykes intrude the granites. Black cotton soil and red loamy soil are the major soil types in the study area.

MATERIALS AND METHODS

Survey of India toposheets of 1:50,000 scale and remote sensing data were used to delineate and digitize the Ilkalhalla Sub-basin. ESRI's Arc GIS (Ver-10.3) software was used for the scanned toposheet to georeference it to WGS Datum, Universal Transverse Mercator (UTM) Zone 43N Projection. Digit elevation model (DEM) was generated using Shuttle Radar Transmission Mission (SRTM) data of 30 arc second which was downloaded freely from USGS Earth Explorer website. Based on the capabilities of arcgis software different parameters were derived, some by computation and other parameters by direct tool processing. Further, these parameters are largely categorized into three aspects for better understanding and detailed study of basin viz., Linear, Areal and Relief aspects.

RESULTS AND DISCUSSION

Linear morphometric parameters

Stream order, stream number and stream length

Delineation of drainage boundary and stream orders was designated using Strahler's (1957) method. Ilkalhalla sub-basin has the highest order of VI with dendritic to sub-dendritic drainage pattern. IHSB comprises of 917 streams of first order, 212 of second order, 47 of third order, 12 of fourth order and 4 streams of fifth order (Fig. 2). The sub-basin is further divided into four sub-watersheds viz., IHSB-I, IHSB-II, IHSB-III and IHSB-IV (Table 1). The frequency and concentration of streams is increasing with decreasing stream order.

First Law of Stream Numbers states that stream number decreases with increase in stream order of any basin which holds good for IHSB and its sub-watersheds. Further, it also conforms Horton's (1945) Second Law of Stream Length which states length of stream segments decreased with an increase in stream order. It is also noted that, the change in order and size of the basins mainly depends on physiographic and structural conditions of the region Sreedevi *et al.* (2009).

Mean stream length (Lsm)

Mean stream length (Lsm) is defined by Strahler

Table 1. Linear parameters calculated for Ilkalhalla Sub-basin.

U	Nu	Lu	Rb	Lsm	Rl	ρ	Lg
1	917	638	4.33	0.69	0.31	0.07	
2	212	200	4.51	0.94	0.50	0.11	
3	47	99	3.92	2.10	0.57	0.14	
4	12	56	3	4.66	0.73	0.24	0.26
5	04	41	4	10.25	0.78	0.20	
6	01	32	-	32.0	-	-	
Total	1193	1066	3.75 (Avg)	43.95 (Avg)	0.58 (Avg)	0.15 (Avg)	

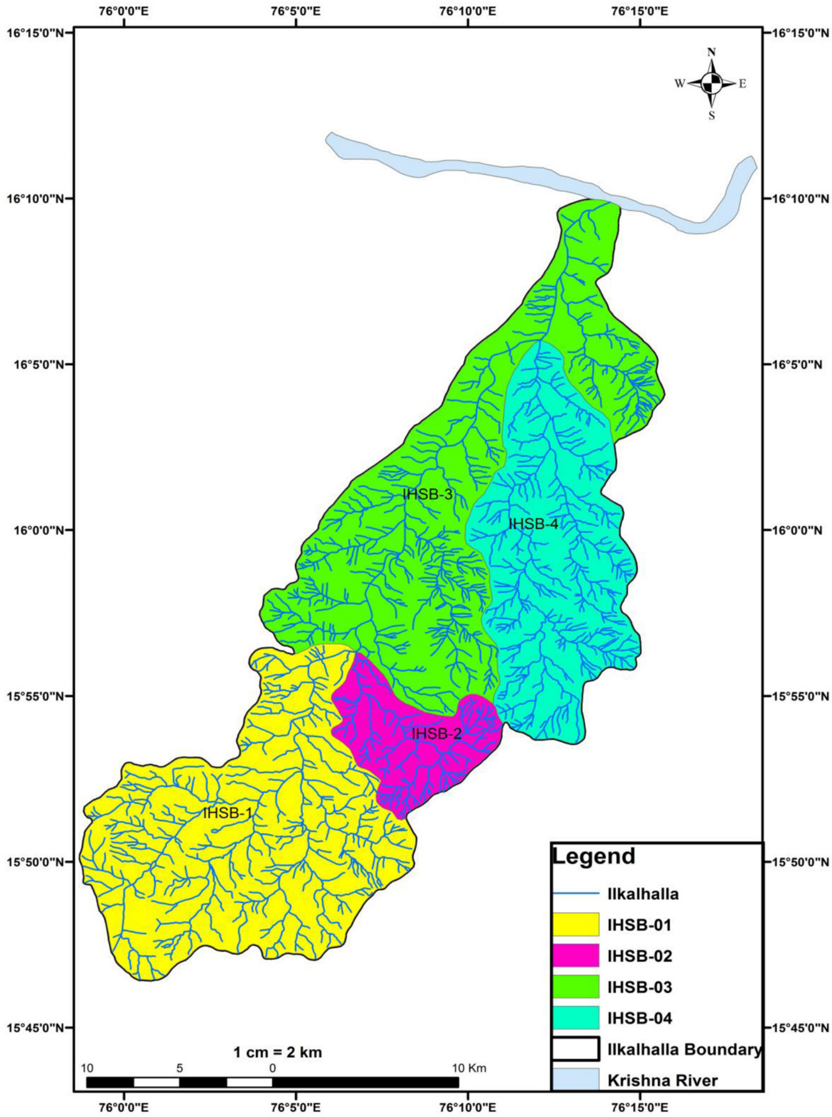

Fig. 2. Drainage network map of the Ilkalhalla Sub-basin (IHSB).

(1964) as characteristic property related to the size of network components and its contributing basin surfaces. In the present study, the Lsm of VI order is 32 km (Table 2). Further, it is also noted that mean stream length of any given order is greater than that of the next lower order and less than that of its next higher order. Lsm of sub-watershed's (IHSB- I, II, III and IV) are 0.27, 0.24, 0.18 and 0.25 respectively (Table 2).

Stream length ratio (Rl)

The Rl has an important relationship between the surface flow discharge and erosional stage of the basin. Rl for IHSB varies from 0.31 to 0.78. This variation of Rl in the increasing order suggests mature stage of geographic development (Singh *et al.* 1997). The mean Rl for the study area as a whole is 0.58 while that of the sub-watersheds IHSB-I to IHSB-IV varies

Table 2. Linear parameters calculated for sub-watersheds (IHSB-I, II, III, IV).

Watershed	U	Nu	Lu	Rb	Lsm	Rl	ρ	Lg
	1	269	193	4.08	0.72	0.43	0.11	
	2	66	83	4.71	1.26	0.43	0.09	
IHSB-I	3	14	36	3.50	2.57	0.69	0.20	0.27
	4	04	25	-	6.25	0.52	-	
	5	01	13	-	-	-	-	
	6	-	-	-	-	-	-	
	1	92	47	3.54	0.51	2.76	0.78	
	2	26	17	2.89	0.65	2.13	0.74	
IHSB-II	3	09	08	4.50	0.89	1.60	0.36	0.24
	4	02	05	2.00	2.50	0.56	0.28	
	5	01	09	-	9.00	-	-	
	6	-	-	-	-	-	-	
	1	92	47	3.54	0.51	2.76	0.78	
	2	26	17	2.89	0.65	2.13	0.74	
IHSB-III	3	12	33	4.00	2.75	2.75	0.69	0.18
	4	03	12	-	4.00	-	-	
	5	-	-	-	-	-	-	
	6	01	33	-	-	-	-	
	1	233	156	4.57	0.67	3.25	0.71	
	2	51	48	4.25	0.94	2.18	0.51	
IHSB-IV	3	12	22	4.00	1.83	1.57	0.39	0.25
	4	03	14	3.00	4.67	0.74	0.25	
	5	01	19	-	19.0	-	-	
	6	-	-	-	-	-	-	

from 0.43 to 4.63 respectively (Table 1). Further, it is observed that the Rl between successive stream orders does not vary much which may be due to homogeneity of topographic conditions.

Bifurcation ratio (Rb)

Bifurcation ratio (Rb) reflects the complexity and degree of dissection of a drainage basin (Strahler 1964). The lower values of Rb are indicative of less structural disturbance and not much of distortion in drainage pattern while high values are indicative of geological disturbances and complexities (Nag *et al.* 2003). Rb values of IHSB vary from 3.0 to 4.51 with an average of 3.75.These variations may be due to

Table 3 Areal and relief parameters calculated for IHSB.

Parameters	IHSB	IHSB-I	IHSB-II	IHSB-III	IHSB-IV
A	548	190	42	132	127
P	135	67	31	50	56
L	49	27	10	18	32
Ff	0.22	0.26	0.42	0.39	0.12
Rc	0.38	0.53	0.55	0.67	0.51
Re	0.539	0.57	0.731	0.719	0.397
K	3.44	3.01	1.87	1.99	6.33
Cc	1.627	1.37	0.43	0.65	0.625
Dd	1.94	1.84	2.04	2.80	2.03
Fs	2.18	1.86	3.10	3.08	2.36
Dt	4.23	3.43	6.34	8.65	4.82
Di	1.12	1.01	1.51	1.10	1.16
C	0.51	0.54	0.49	0.36	0.49
H	254	171	100	185	164
Rr	0.0051	0.0063	0.010	0.010	0.005
Rn	0.13	0.32	0.20	0.52	0.33
Mrn	0.015	0.3923	0.488	0.509	0.46

lithological development/disturbances of a drainage basin and due to structural complexities. The mean Rb values calculated for sub-watersheds IHSB-I, II, III and IV are 4.07, 3.22, 4.81 and 3.95 respectively (Table 2). These values of Rb indicate that in IHSB, the structural control over the development of drainage network is not as pronounced as the geomorphic control.

Length of overland flow (Lg)

Chorley (1969) defined length of overland flow (Lg) as most dominant hydrologic and morphometric factor in the development of drainage network and is a measure of stream spacing degree of dissection and is approximately one half the reciprocal of drainage density. Lg value for the present study as a whole is 0.26 while it varies from 0.18 to 0.27 for the four sub-watersheds (Tables 2 and 3). These values imply that the IHSB has low relief.

Areal morphometric parameters

Area (A), perimeter (P) and length (L)

Area of IHSB is 548 km^2 with basin perimeter of 135 km and has a basin length of 49 km. The four sub-watersheds viz. IHSB-I, II, III and IV have areas 190, 42, 132 and 127 respectively (Table 2).

Form factor (Ff)

Horton (1932) defined form factor (Ff) as the ratio of the area of the basin and square of basin length. The value of form factor largely describes its shape as high value of Ff indicates circular basin while lower values indicates elongated basin (Horton 1945). Low Ff value of IHSB (0.22) indicates the basin to be elongated while it varies from 0.12 to 0.42 for the four sub-watersheds (Table 3). From the study, it was found that the IHSB is elongated in shape.

Circulatory ratio (Rc)

Circulatory ratio (Rc) is defined as the ratio of basin area to the area of circle having the same circumference as the perimeter of the basin. It mainly deals with the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin.Rc value of the IHSB (0.38) indicates the basin is not circular in shape while the range of values for the four sub-watersheds varies from 0.51 to 0.67 (Table 2), indicating the Ilkalhallasub-basin to be elongated in shape.

Elongation ratio (Re)

Elongation ratio (Re) is expressed as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. In general the value of Re varies between 0.6 and 1 over a wide variety of climate and geologic conditions. Re value for the IHSB is 0.53which indicates high relief and steep slope while it varies from 0.39 to 0.73 for the four sub-watersheds (Table 2). This indicates that, IHSB is less elongated in shape.

Lemniscate ratio (K)

Chorley (1957) expressed the lemniscate's (K) value to determine the slope of the basin and for estimation of drainage shape and defined it as the degree of actual basin form to the pure lemniscates form measured by a lemniscate ratio (K) to the ratio of perimeter of basin. K value for IHSB is 3.44 which indicates that the watershed occupies the maximum area in its regions of inception with large number of streams of higher order while it varies from 1.87 to 6.33 for the four sub-watersheds (Table 2).

Compact coefficient (Cc)

Cc as the ratio of perimeter of watershed to circumference of circular area, which equals the area of the watershed. Further, Cc is independent of size of watershed and dependent only on the slope (Zavoianu 1985). The computed value of Cc for the entire study area is 1.62 while it varies from 0.43 to 1.37 for the watershed WS-I, II, III and IV (Table 2).

Drainage density (Dd)

Dd is defined as the length of streams per unit area divided by the area of the drainage basin (Horton 1932). Dd tends to be high in an area of weak or impermeable subsurface with sparse vegetation and high relief (Nag *et al* 2003). Further, Strahler (1956 and 1964) stated that, Dd depends upon the geologic and climatic factors and increases as the individual drainage unit proportionality decreases. Dd can be used as a better quantitative expression for the dissection and analysis of landform (Melton 1957). Dd value for the present study as a whole is 1.94 km/km2 which indicates moderate to high permeable, sparse vegetation and moderate relief while it varies from 1.84 to 2.80 for the four sub-watersheds (Table 2). Therefore, the study area falls in the category of low drainage density indicating highly permeable subsurface and coarse texture.

Stream frequency (Fs)

Horton (1945) defined stream frequency (Fs) as the ratio between the total number of segment cumulated for all orders within a basin to the basin area. Stream frequency is influenced by the rock structure, soil property, vegetation cover and rainfall. According to Melton (1957), low value of stream frequency (1 to 3.5) indicates the stream or channel being controlled by fractures and high stream frequency (4 to 10) indicates a more slope from surface runoff. Accordingly, Fs of the present study as a whole is calculated to be 2.18 indicating good subsurface recharge conditions. Further, it varies from 1.86 to 3.10 for the four sub-watersheds (Table 2). Thus, low values of Fs indicate gentle slope and high permeable rocks, thus low run-off and high infiltration.

Drainage texture (Dt)

Drainage texture (Dt) is one of the important drainage parameters in morphometric analysis which depend on numerous factors. It is the product of stream frequency (Fs) and drainage density (Dd). According to Smith (Smith 1954), drainage density is classified into five classes of drainage texture, i.e. very coarse (<2), coarse (2–4), moderate (4–6), fine (6–8) and very fine (>8) drainage texture. It is also called as infiltration number.In the present study, Dt value of IHSB is calculated as 4.23 and which falls under moderate texture category while the value of Dt varies from 3.43 to 8.65 for the sub-watersheds (Table 2).

Drainage intensity (I)

Drainage intensity (I) is the ratio of stream frequency (Fs) and drainage density (Dd). Drainage intensity gives an idea of rate of infiltration and permeability of subsurface and relief of a basin.The value of (I) for present study as a whole is 1.12.This low value of I indicates the basin is least affected by denudation. Further for the four sub-watersheds drainage intensity varies 1.01 to 1.51 (Table 2).

Constant channel maintenance (C)

Schumm (1956) defined constant channel maintenance (C) is the reciprocal of drainage density or inverse of Dd. C largely depends on duration of erosion and climatic regime, vegetation cover and relief. C value for IHSB is 0.51 while it varies from 0.36 to 0.54 km^2 for the four sub-watersheds (Tables 2 and 3). This indicates that the sub-basin has high permeability subsurface, low to moderate slope, less surface runoff and less structural disturbances.

Relief morphometric parameters

Basin relief (H)

Basin relief (H) is the difference in the elevation between the highest point of a watershed and the lowest point on the valley floor. It can be defined as the ratio between the total relief of a basin and the longest dimension of the basin parallel to the main drainage line. Basin relief favors the flood patterns and in the amount of sediment to be transported (Hadley 1961). Basin relief (H) of IHSB as a whole is calculated as 254 m while H for the four sub-watersheds is presented in Table 2.

Relief ratio (Rr)

Relief ratio (Rr) is the ratio of the basin relief to the basin length. It depends on the nature of rocks and slope of the basin. High values of relief ratio are characteristics of hilly region. Low values are characteristic of pediplains and valley (Schumm1956). Rr value of IHSB is 0.005 indicating moderate relief and slope while it varies from 0.005 to 0.0101 for sub-watersheds IHSB-I, II, III and IV (Table 2). These values of Rr indicates low to moderate relief and slope. This may be due to the resistant basement rocks of the basin and low degree of slope.

Ruggedness number (Rn)

Ruggedness number (Rn) of a basin is defined as the product of basin relief (H) and drainage density (Dd). The Rn value computed for IHSB is 0.13 implies the terrain is less prone to soil erosion and have intrinsic structural complexity (Strahler 1956) while it varies from 0.20 to 0.52 for four sub-watershed (Table 2).

Melton's Ruggedness number (Mrn)

Melton's Ruggedness number (MRn) is an index which represents the ruggedness of a relief within a watershed (Melton 1965).The Mrn value for the IHSB is 0.015 while it varies from 0.3923 to 0.5092 for four sub-watershed (Table 3) and it suggests that the basin is prone to debris flood wherein bedload component dominates sediment under transport (Wilford *et al.* 2004).

CONCLUSION

In the present study, application of RS and GIS was widely used over conventional method of quantitative analysis of basin. Ilkalhalla Sub-basin is a VI order stream with dendritic type of drainage pattern. The basin is elongated which is confirmed by assessing shape factors such as form factor, circularity ratio and elongation ratio. Based on bifurcation ratio value it was concluded the basin is less affected by structural disturbances. Further, the elongated shape of basin deciphers it is less prone to flood, low erosion and sediment transport facilities. The low value of drainage density implies that the area has less vegetation cover moderate to high relief. Further from the values of parameters such as stream frequency, drainage to be moderately permeable leading to high runoff. From the relief parameters also it is clear the basin is less affected due to flash floods and erosion. The morphometric studies carried out have highlighted useful information with respect to its hydrological characteristics and water resources. There is still further scope for development of the basin by constructing recharge and water harvesting structures at suitable sites.

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