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A GIS based assessment of Morphometric analysis of Lingasugur Taluk in Raichur District, Karnataka, India

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Abstract— In the present paper, an attempt has been made to study drainage morphometric of Lingasugur Taluk, Karnataka, India. It lies of Latitude 16°03′ 50″ to 16°21′ 35″ and Longitude 76° 20′ 30″ to 76°45′50″. The total study area consists of 1965.75Sq.Km. Geologically, the area is situated in the northern part of Hutti Schist Belt with some metavolcanics and metasediments of Eastern Dharwar Craton. For the present study we used ASTER-DEM data for the understanding and preparation of essential maps for the analysis. The Arc GIS software (Version: 10.4.1) is used. The present evaluation consist of linear, areal and relief aspects of morphometric analysis. The analysis has revealed that, Drainage Pattern is Dendritic to Sub-dendritic in nature. Mean Bifurcation ratio suggests that the drainage pattern is not much influenced by geological structure. Drainage density (Average value -1.66) indicated clearly that the subsurface is permeable. The length of overland flow indicates low relief. Calculated Circulatory ratio (0.15 to 0.29) and elongation ratio (0.006 to 0.013) suggest that the sub-basins are in elongated shape within the boundary. Relief Ratio (0.0037 to 0.0056) shows major portion of the area is having gentle slope. Hence the groundwater recharge scheme is recommended for proper management of water resources. The overall analysis depicts extraction of river basins in the administrational boundary of Lingasugur Taluk, Karnataka, India.

Keywords— GIS, Lingasugur Taluk, Morphometry, etc

1. INTRODUCTION

Morphometric analysis represents the topographical expression of the basin geometry to understand its slope, area, shape, length, or inequalities in the rock hardness, structural controls, recent diastrophism, geological and geomorphic history of the drainage basin [28]. There are basically three vital aspects as linear aspect, areal aspect and relief aspect used for the analysis of the morphometric characteristics of the basin. Linear aspect is the single dimensional parameters gives information about parameters like stream order, stream number and bifurcation ratio. Areal aspect deals with parameters like: drainage density, drainage texture, stream frequency, circularity ratio and form factor which are two dimensional parameters. Relief aspect is the three dimensional aspect which deals with the parameter like total relief, relief ratio and slope. The drainage pattern characteristics of various basins have been studied using conventional methods in earlier times [9], [14], [21], [23], [25].

In the recent years, the analysis of morphometric parameters has gained increasing attention after the advent of tools such as Remote Sensing and Geographical Information System (GIS) [10], [13], [16], [15], [18], [19], [22], [24] [29], [30]. The GIS tools helps in various manners as to identify the drainage network with the help of Digital elevation model (DEM), also can give quantitative description of geometric characteristics which includes topology of stream network, computation of relief characteristics, drainage pattern and drainage texture. Therefore, morphometric analysis has concluded that, remote sensing has emerged as a powerful tool in analyzing the drainage morphometry [15][19]. There is no published literature available on the morphometric analysis of Lingasugur taluk, Karnatak State using RS and GIS techniques. Hence, the present study has been undertaken.

1.1. STUDY AREA

The study area comprises of administrational boundary of Lingasugur Taluk of Raichur District, Karnataka state, India and it lies in between North Latitude 16°03′ 50″ and 16°21′ 35″ and East Longitude 76° 20′ 30″ and 76°45′ 50″ which fall in the Survey of India Toposheet- 56D/7, 56D/8, 56D/11, 56D/12, 56D/15, 56D/16, 57A/4 and 57A/9. The total study area consists of 1965.75 sq. Km. and three Sub-basins have been identified based on water divide concept namely Sub-basin I, Sub-basin II and Sub-basin III (Fig.03). The Sub-basin I lies in the northern part of the study area belongs to Krishna river basin where as other two sub-basins belongs to river Tungabhadra, which lies in the southern part of the study area.

Physiographically, the study area is located in the northern plateau region of Karnataka state which is drought prone and falls in one of the arid tract of the country. Rainfall being uneven and uncertain renders the area liable to effects of drought frequently. The normal Annual rainfall of the area is 608mm. The climate of study area is semi-arid and falls under northeastern dry agro climatic zone. During summers the day time temperature often touches 45°c. In the study area, three important types soils are noticed i.e., clayey skeletal soils, clayey soils and loamy soils.

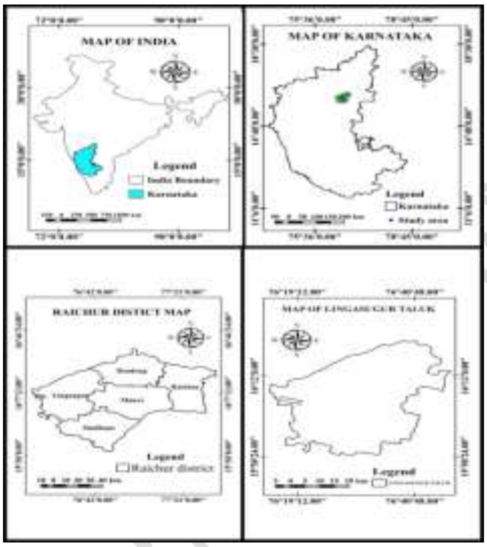

Fig. 01: Location map of the study area

1.2. GEOLOGY

The area under investigation constitute part of the late Archean Hutti Maski greenstone belt, is located in the northern part of eastern Dharwar craton(EDC). The study area predominantly composed of granitoids which intrude the dominant sequence of metavolcanics and minor association of metasediments. At some places discontinuous narrow dolerite (diabase) dykes intrude the pink porphyritic granite.

2. Methodology

Base map was prepared with the help of Survey of India toposheets of the scale 1:50,000. Toposheets numbers used are as follows 56D/7, 56D/8, 56D/11, 56D/12, 56D/15, 56D/16, 57A/4 and 57A/9. The ASTER-GDEM (Advanced Space borne Thermal Emission and Reflection Radiometer - Global Digital Elevation Model) (Fig.2) was used subsequently. ASTER is a good choice for this study because of its free availability, easy processing in GIS environment and nearly equal accuracy as SRTM [6], [7], [11]. The Arc GIS software (Version-10.4) have been used for digitization and computational purposes and also for output generation of maps. Survey of India toposheets have been used for the reference while creating maps and digitizing too. Map finalization, quality checking of the final maps, ground truthing and database organization is done as per NRSA standards.

This is a special case of calculating morphometric parameters on the basis of Administration boundary instead of drainage basin boundary. Thus the drainage network has been created by taking into account of surrounding drainage basins also then the present study area was extracted so that ground truthing of ordering the streams remain unchanged to the natural scenario. The morphometric characteristics of the three sub-basin have been studied using the conventional methods [9], [27].

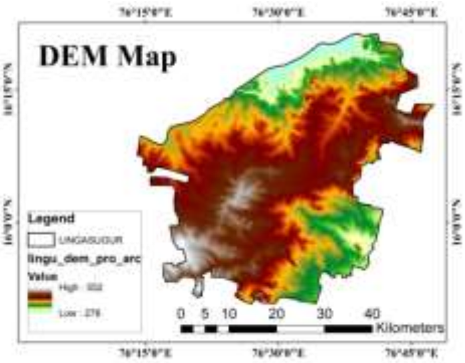

Fig. 02: DEM map of the study area

3. MORPHOMETRY

In the present study morphometric analysis of the parameter of all the sub-basins have been carried out using the mathematical formula suggested by [9], [21], [27] and their summarized results are shown in the Table 1, Table 2 and Table 3. The sub-basins show slight differences in their stream networks and flow characteristics. Drainage pattern of the study area shows dendritic to sub-dendritic pattern at higher elevation. In the study of morphometry three aspects are considered i.e., Linear, Areal and Relief aspects.

3.1. LINEAR ASPECT

Linear aspects contain single dimensional parameters. Linear parameters have direct relationship with erodability [17]. The parameters like stream order, stream length, bifurcation ratio, mean stream length and mean stream length ratio comes under Linear aspects of morphometry.(Table no 1)

3.1.1. Stream Order (U)

Stream ordering is the pioneer step of drainage basin analysis. It is referred to the determination of the hierarchical position of a stream within drainage basin. It has been carried out based on the method proposed by Strahler [27]. The first ordered streams are the pure contributories which joins together to form second order streams. Similarly, third ordered have the first and second ordered streams as their tributaries and so on. Streams order influences the size of contributing drainage area, channel dimension and stream discharge at that place in the drainage system. The highest stream order in the Sub-basin I is 7, Sub-basin II is 5 and Sub-basin III is also 5.

3.1.2. Stream number (Nu)

The count of stream channels in its order is known as stream number [9]. The higher amount of stream order indicates lesser permeability and infiltration. Frequency of the stream decreases with the increase of the order of the stream. The numerical count of the streams including all the stream orders in the entire study area is 4843 further divided as 2872, 1394 and 577 streams according with Sub-basin I, II and III respectively.

Fig. 03: Drainage Map of the Study area

3.1.3. Stream length (Lu)

In the drainage basin, stream length (Lu) is defined as the total length of every stream of each and every order respectively. Stream length of all sub-basins was measured using GIS softwares. The total stream length of the Study area is 3290.05 kilometers and that of the three sub-basin are 2000.53 kilometers, 905.36 kilometers and 384.22 kilometers respectively.

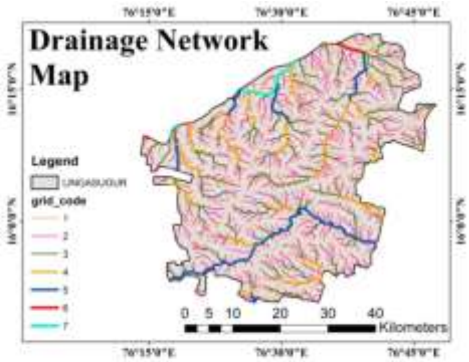

Fig. 04: Stream network Map of the study area

Generally the summation of streams length segments is maximum in the first order streams and further decreases as the stream order increases. However in case of Lingasugur Taluk area the segments of streams of various orders show variation from the generalized observation. This change may indicate flowing of streams from higher altitude, lithological in variations and moderate steep slopes[22].

3.1.4. Mean stream length (Lsm)

Strahler (1964) denominated the mean stream length as characteristic attribute related to the size of drainage network and its associated surface features. It is computed by dividing the total stream length by the number of streams. In the present study area, value ranges from 0.53 to 8.56 kilometers. The mean stream length also shows increasing value with respect to the increasing stream order. This anomaly may be due to variation in the topography and slope.

3.1.5. Stream length ratio (RL)

Stream length ratio may be defined as the ratio of the stream length of one order to stream length of previous lower order of stream segments. Variation of stream length from one order to another order indicate their stages as late or youth stage of geomorphic development of streams of present study area. During the study, it is found that the whole basins have the stream length ratio varies from 0.21 to 2.52.(Table 2)

3.1.6. Bifurcation ratio (Rb)

Bifurcation ratio is the numerical value of the ratio of stream number of one order to the stream number of the next corresponding higher order [21]. The Rb values are not same from one order to another. These differences are depending upon the Geological and Lithological development of the drainage basin [27].

The higher value of Rb indicate strong structural control in drainage pattern while the lower values of Rb are characteristics of the basin which have suffered less structural disturbances and drainage pattern has not been distorted because of the structural disturbances [15]. The bifurcation ratio of present analysis ranges from 2.06 to 4.0 (Table 3) and all sub-basins fall under normal category [28].

3.2. AERIAL ASPECT

Aerial aspect can be defined as the two dimensional property of the basin, which delineate area that contribute water from each stream segment. The aerial aspect constituents like drainage density, stream frequency, drainage texture, elongation ratio, circulatory ratio and form factor were calculated. (Table 5&6)

3.2.1. Drainage density

The drainage density indicates the closeness of spacing of channels or stream segments [8]. It is quantitavely represented as the total length of streams of all the orders per drainage area. Drainage density and Drainage texture has the inverse relation with each other, as one increases the other gets finer. High density is the resultant of impermeable sub-surface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture [27]. High density is the resultant of impermeable sub-surface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture [27].

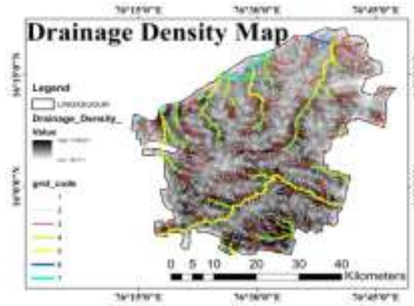

Fig.04: Drainage density map

The present drainage density of the study area are 1.69 Km^{-1}, 1.60 Km^{-1} and 1.71 Km^{-1} of the respective Sub-basin I, II, and III as shown in the Table 2 Indicates that sub-basins have highly resistant permeable subsurface material with intermediate drainage and low to moderate relief.

3.2.2. Drainage texture (Rt)

Drainage texture deduces the relative spacing of the drainage lines. It is an important concept of geomorphology [9] inferred that the drainage texture is the total number of segments of all the order per perimeter area of the basin. According to Smith [23], five classification have been made based upon drainage texture values so as drainage texture is called as very coarse when the drainage texture value is less than 2, between 2 and 4 is related to course texture, between 4 and 6 is moderate texture, between 6 and 8 is fine and greater than 8 is very fine texture. In the study area the drainage texture value ranges from 5.489 to 12.8877 (Table.4) indicating moderate to very fine drainage textures.

3.2.3. Stream frequency (Fs)

Stream frequency is calculated as the ratio of the total number of streams of all the orders in the basin to the total area of the basin. In the study area, the stream frequency is observed to be ranging from 2.46 to 2.56 Km^{-2}. Table 4 shows a positive correlation with drainage density values of all Sub-basins indicating the increase in stream population with respect to increase in drainage density.

3.2.4. Form factor (Ff)

Form factor is the numerical index [8], commonly used to represent different basin shapes. Smaller values indicate the elongated basin where as high form factor have high peak flows of shorter duration. In the present case all sub-basin have lower Form factor values 0.37, 0.7, 0.17 as in table table 3 indicating them to be elongated in shape and suggesting the peak flow of shorter duration.

3.2.5. Circulatory ratio (Rc)

Circulatory ratio is expressed as the ratio of the basin area to the area of circle having same perimeter as the basin [27]. It is influenced by the length and frequency of streams , geological structure, Land use / cover , climate , relief and slope of the basin. In the present study area, all the values are less than 0.5 (Table 3) representing the elongated shape. Diversity of slopes and relief of the area is the main cause for this anomaly.

3.2.6. Elongation ratio (Re)

Schumn [26] 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. A circular basin is more efficient in discharge of runoff than an elongated basin [22]. The value of Re varies from 0 (highly elongated in shape) to unity i.e., 1 (circular in shape). Elongation ratio of the present analysis is 0.0066, 0.0088 and 0.0132 of the respective sub-basins I, II and III, are indicative of elongated shape.

3.2.7. Length of overland flow (Lo)

According to Horton [9] and Schumn [21], the average length of overland flow is approximately half the average distance between stream channels and is therefore approximately equal to half of reciprocal of drainage density. It is one of the most important morphological variables; it affects hydrological and topographic development of the basin. The higher value of Lo is indicative of low relief, where as low value of Lo is indicative of high relief. The computed length of overland flow values of the study area are 0.0388, 0.0758 and 0.0910 indicating lower degree of slope and erosion.

3.3. RELIEF ASPECTS

Evaluations some of the relief factors of the sub basins is discussed and presented in the Table 7

3.3.1. Relief (M)

Relief is an important factor in understanding the denudational characteristics of the basin. Strahler (1952) depicted that the basin relief is the contour difference between the highest peak point and the lowest elevation point of the basin. Basin relief is an important factor in understanding the denudational characteristics of the basin. The maximum height see in Lingasugur Taluk area is 573feet above mean sea level and the lowest point is 276feet. Thus the total relief or relative relief is 297 feet.

3.3.2. Relief ratio (Rr)

The ratio of maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line is termed as Relief Ratio [21]. The relief ratio normally increases with decreasing area and size of sub basins of a given drainage basin [31]. In the present study area, the values of relief ratio are very low ranging from 0.0037 to 0.0 056. The low value of the relief ratios indicate that the study area has resistant basement rocks of the basin and low degree of slope.

3.3.3. Slope (Sa)

The slope map represents change in surface contour value with respect to horizontal distance which can be expressed in degrees or percentages. It relates to geomorphic studies which reflect inevitable influence on drainage pattern and assist in understanding other hydrogeological characteristics. Raster DEM in a grid has each cell value referenced to a common datum[10]. Any two points are enough to find slope where the maximum difference is found and the gradient is determined [4]. The slope study is an important tool to determine the amount of runoff and the infiltration through soil towards the groundwater as recharge. The slope of the basins provides has an important role to control the run-off and hence the infiltration capacity of the soil. The range for slope map classification are based on Manjunatha Dalwai [13]., viz. 0-<1° (Nearly level), 1-<3° (very gentle), 3-<5° (Gently sloping), 5-<10° (Moderately sloping), 10-<15° (strongly sloping), 15-<35° (moderately to very steep) (Fig no. 05) The slope analysis provides data for planning ,settlement, modernization of agriculture, planning of engineering structures, morpho conservation practices etc [13], [20]. It is observed that most of the study area comes under gentle but a little undulating slope which is designated as ‘excellent’ category for favorable infiltration of groundwater due to sufficient time for percolation to the runoff water. The river basin is a good zone for check dam constructions etc.

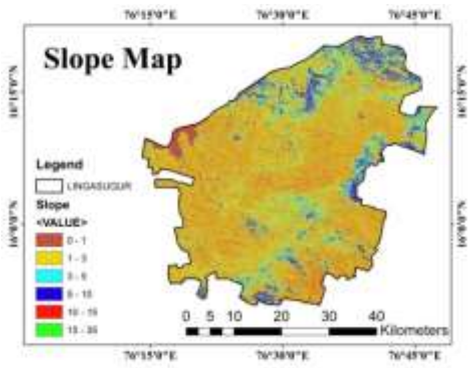

Fig. 05: Slope map of the study area

4. FORMULAE

<u>Morphometric Parameter formula With Reference</u>

<u>Stream order (Nu)</u>
Hierarchical rank Strahler (1964)

<u>Stream length (Lu)</u>
Length of the stream Horton (1945)

<u>Mean stream length (Lsm)</u>
Lsm = Lu/Nu Strahler (1964)

<u>Stream length ratio (RL)</u>
RL = Lu/Lu-1 Horton (1945)

<u>Bifurcation ratio (Rb)</u>
Rb = Nu/Nu+1 Schumn (1956)

<u>Mean bifurcation ratio (Rbm)</u>
Rbm = Average of bifurcation ratios of all orders Strahler (1957)

<u>Drainage Density (Dd)</u>
Dd = Lu/A Horton (1945)
Where A = Area of the basin (km2)

<u>Drainage texture (Rt)</u>
Rt = Nu/P Horton (1945)
Where P= Perimeter

<u>Stream frequency (Fs)</u> **Fs = Nu/A** Horton (1945)

<u>Form factor (Rf)</u>
Rf = A/Lb2 Horton (1945)
Where Lb2 = Square of the basin

<u>Circulatory Ratio (Rc)</u>
Rc = 4*Pi*A/p2 Strahler (1964)
Where Pi = Pi value i.e. 3.14

<u>Elongation Ratio (Re)</u>
Re = √(2/Lb)*(A/p) Schumn (1956)

<u>Length of overland flow (Lo)</u>
Lo = 1/Dd*2 Horton (1945)

Table.1: Linear Aspects of the study area

SUB BASINS	Stream Order(Nu)							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
I	1820	810	177	48	10	4	03	2872
II	877	401	94	15	7	--	--	1394
III	357	173	35	09	3	--	--	577

Table.2. Stream lengths of the respective stream numbers.

SUB BASINS	Stream Length(Lu)							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
I	1080	455.2	241.7	150.9	46.7	7.3	18.5	2000.53
II	465.1	231.0	113.3	35.98	59.9	--	--	905.36
III	214.6	94.10	48.81	21.89	4.75	--	--	384.22

Table 3. Bifurcation ratio of the study area.

SUB BASINS	Mean Stream Length (Lsm) (Km)							Stream Length Ratio (Rl)					
	1	2	3	4	5	6	7	i	ii	iii	iv	v	vi
I	0.59	0.56	1.36	3.14	4.67	1.83	6.17	0.42	0.53	0.62	0.30	0.15	2.52
II	0.53	0.57	1.20	2.39	8.56	--	--	0.49	0.49	0.32	1.66	--	--
III	0.60	0.54	1.39	2.43	1.58	--	--	0.43	0.51	0.44	0.21	--	--

Table 4. Linear aspects as stream length ratio

Table 5. Areal aspects of the study area.

SUB BASINS	Perimeter (P)	Area of Basin $(Km)^2$	Basin length (Lb) km	Elongation Ratio (Re)	Length of over land flow (Lg)
I	223.03	1177.26	56.63	0.006637	0.0388
II	211.57	564.72	48.92	0.008266	0.0758
III	105.11	223.77	35.65	0.013288	0.0910

Table 6. Areal aspects of the study area.

SUB BASINS	Drainage density (Dd) (Km)	Drainage Texture(Km)	Stream frequency (Fs) (Km2)	Form factor (Rf)	Circularity ratio (Lo)
I	1.69	12.877	2.5439	0.3375	0.2974
II	1.60	6.588	2.4680	0.1764	0.1585
III	1.71	5.489	2.5780	0.1756	0.2545
Average	1.66	8.318	2.5299	0.2298	0.2368

Table 7. Relief aspects of the study area.

Sub Basin	Elevation in 'm'		Basin relief (H-h) (mts) (Rr)	Relative relief (H-h) (Km) (Rr)	Longest axis 'L' (Km)	Relief ratio (H-h/L) (Km) (Rh)
	Max 'H'	Min 'h'				
I	573	276	261	0.261	59.06	0.0044
II	552	339	213	0.213	56.88	0.0037
III	552	352	200	0.200	35.69	0.0056

SUB BASINS	Bifurcation Ratio (Rb)						Mean Bifurcation Ratio (Rbm)
	Rb1	Rb2	Rb3	Rb4	Rb5	Rb6	
I	2.24	4.57	3.68	4.80	2.50	1.33	3.186
II	2.18	4.26	6.26	2.14	--	--	3.71
III	2.06	4.94	3.88	3.00	--	--	3.47

5. CONCLUSION

Morphometric analysis of the Lingusugur taluk has been carried out to understand the drainage characteristics using Arc GIS Software and ASTER Digital elevation model (DEM). The total study area consists of 1965.75 sq.Km and it has been subdivided into three sub basins (Sub basin I, II and III). The morphometric analysis of drainage network exhibits dendritic to sub-dendritic drainage pattern with highest stream order of 7th, 5th and 5th of the respective sub-basin of I, II and III. Regional and local trends of geological setup are reflected in the variable orientation of streams of different order and variations in stream length ratio might be due to changes in slope and topography. The drainage density (Dd) of the study area reveals that the nature of subsurface strata is permeable as drainage density values are less than 5 which constitutes a coarse drainage and suggests being potential area to construct recharge structures. The mean bifurcation ratio (Rb) is ranging from 3.17 to 3.74 indicating the non-influential geological structure. Maximum stream order frequency is observed in case of first order streams and followed by second order streams. The values of form factor and circulatory ratio (Rc) suggest that the sub-basin II is elongated in shape whereas other two sub-basins are more or less circular. Elongation ratio (Re) shows that all sub basins possesses highly elongated in shape. The relief analysis with the relief ratio of 0.003 to 0.005 suggests that maximum of the area shows gentle slope. In the present study area the water resources are becoming scarce thus this exercise of calculating the attributes of the drainage basin to the administrational boundary of Lingasugur taluk plays a significant role in locating sites for artificial recharge structure useful for the operational boards and departments looking after the water management and its sustainable development.

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