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MORPHOMETRY OF BUGGAVANKA WATERSHED IN KADAPA, ANDHRA PRADESH, INDIA USING SPATIAL INFORMATION TECHNOLOGY

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ABSTRACT

Water is the most essential element of life on Earth. The demand for water is increasing manifold with population explosion and rapid growth of all sectors of economy. Sustainable development is need of the hour and watershed forms the basic unit in water resource planning particularly in Semi Arid Tropics. Channel Morphometry, by the measurement of various stream attributes, gives holistic idea of a watershed. An attempt is made to study the Morphometry of morsel "Buggavanka" a seasonal tributary to Pennar river basin. "Bugga" stands for "Spring" and "Vanka" for "Stream" in vernacular language Telugu. The stream traverses several villages and Kadapa town in Andhra Pradesh before joining the main river. Spatial Information Technology plays an important role in geosciences for its effective, accurate and quick processing techniques. The basis of the study is SOI Toposheets (1979) on 1:50,000 Scale. The Buggavanka watershed morphometric parameters are determined, generated and computed using ERDAS and ArcGIS softwares. The Buggavanka stream travels from South to North for about 57.947 Km encompassing the watershed area 724.73Km^2 with a perimeter of 134.105 Km. The stream provides much of irrigation and drinking water to the villages within watershed area directly or indirectly. Simultaneously a pump house within the riparian part of the stream supplies drinking water to the major part of the Kadapa town. The ground water distribution in the study area is not uniform and it depends on the drainage pattern. The watershed region has high relief in the upper reach and nearly plain in the lower reach. Buggavanka watershed drainage pattern is sub-dendritic to dendritic type.

KEYWORDS: Morphometry, Watershed, Buggavanka, Spatial Information Technology

INTRODUCTION

"Water" is one of the five basic elements of life out of ***pancha bhuta*** i.e. air, water, earth, fire and sky on the earth is the most essential element of life. Water on earth goes through a gigantic Hydrological cycle of conversation to gaseous form by evaporation and coming down again to earth as rainfall. The demand for water is increasing in geometric progression all along the population growth (Gupta and Deshpande, 2004). Watershed and its runoff is an important hydrological variable in water resources application and Management of Watersheds.

The runoff is carried by various types of streams on the surface of the Earth. These streams are very short lived compared to perennial rivers providing uneven distribution of ground water within the watershed. There are few researches on the morphometric characteristics of ephemeral streams in general and no study has been done so far on morphometric characteristics of Buggavanka in particular. Most of the downstream section the study part is situated in the urban area, Kadapa town.

This study will serve as a database for those who want to further study to see the influence of change in watershed morphometric parameters on the hydraulics and channel processes of the main channel through time and space. Hence the morphometric characteristics of seasonal stream, Buggavanka are elaborately extracted using Spatial Information

Technology. Quantitative analysis of various morphometric parameters provides to understand its role in the watershed and water resource management.

A major emphasis in geomorphology over the past several decades has been on the development of quantitative physiographic methods to describe the evolution and behavior of surface drainage networks (Horton, 1945; Leopold, 1956; Abrahams, 1984). The source of the watershed drainage lines has been discussed since they were made predominantly by surface fluvial runoff and have very important climatic, geologic and biologic effects (Pareta, 2004;).

The morphometric charecteristics or the watershed scale may contain important information regarding its formation and development because all hydrologic and geomorphic processes occur within the watershed (Singh&Singh, 1997). Morphometric analysis of a watershed provides a quantitative description of the drainage system, which is an important aspect of the characterization of watersheds (Strahler, 1964). Spatial Information Technology is order of the day in geosciences.

The tools are used for assessing various terrain and morphometric parameters of the watershed. The Morphometric parameters include Linear and Areal aspects. GIS environment available in ArcGIS provides suitable alternatives for efficient management of large and complex databases. It is powerful and flexible as the tools help in quick, effective, accurate and integrating spatial data. Watershed monitoring and management is found to be cost and time effective with the usage of the capabilities of a Spatial Information Technology.

STUDY AREA

The study area falls under Semi Arid Tropics in India which is characterized by varied rainfall in time and space under the influence of the vagaries of monsoons. The area is situated south of Kadapa including the town, in Andhra Pradesh and is covered in the SOI, Toposheets 57J10, 57J11, 57J14, 57J15 and 57J16 on 1:50000 scale. The Buggavanka watershed area is 724.73Km^2 and located between 14^{0}12’15”N & 14^{0}33’16”N Latitudes and 78^{0}38’17E & 78^{0}57’52”E. The highest relief is 818 meters which is associated with Palakonda Hills i.e., upper reach in the south and the lowest 119 at the confluence of Pennar river in the north. The stream headways are in Palakonda Hills and the mainstream is about 57.947 Km long. It is joined by seven small tributaries finally to feed Pennar River Basin. The Buggavanka stream traverses many villages within watershed providing drinking water and irrigation facilities either directly or indirectly.

The major part of Kadapa town depends on this stream as means of domestic and drinking water supply by the local governing bodies through pump houses in its riparian part. This area receives rainfall from SW Monsoon and the rainiest months are July and August. However it receives winter rainfall under the influence of cyclonic activity in Bay of Bengal during the post monsoon season. The southern portion of the study area is hilly terrain. The climate is medium to dry with mean annual temperature of 32^{0}C.

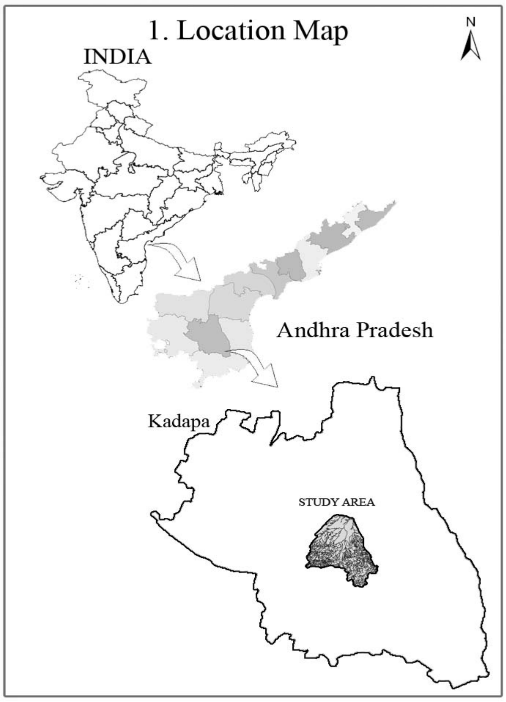

Figure 1

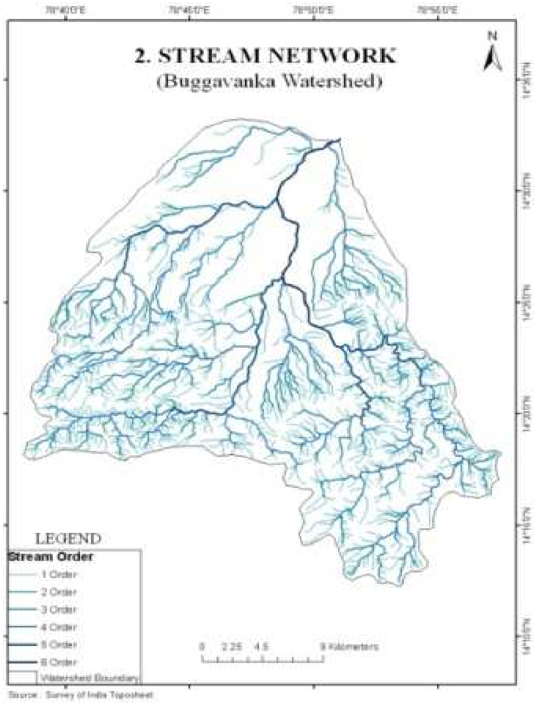

Figure 2

MATERIALS AND METHODS

Data used for the generating morphometric parameters are Survey of India Toposheets (1:50,000) No. 57J10, 57J11, 57J14, 57J15 and 57J16. ERDAS and ArcGIS are used to process the data and generate the stream attributes of the Buggavanka watershed. The broad methodology followed in generating the spatial data is illustrated in the flowchart, Figure 3. The basic channel parameters thus generated in GIS Environment after quality checks are reported using Report tool in ArcGIS. This input is taken for statistical analysis for evolving other morphometric parameters. The methods adopted for morphometric parameters of Buggavanka watershed and their results are tabulated in Table 1. Linear aspects and Table 3. Areal aspects. The linear aspects of the Morphometry include Stream Order (u), Number of Streams (N_u), Stream Length (L_u) and Bifurcation Ratio (R_b). The areal aspects of the drainage basin are Drainage Density (D), Stream Frequency (F_s), Texture Ratio (T), Basin Length (L_b), Elongation Ratio (R_e),Circularity Ratio (R_c) and Form Factor Ratio (R_f).

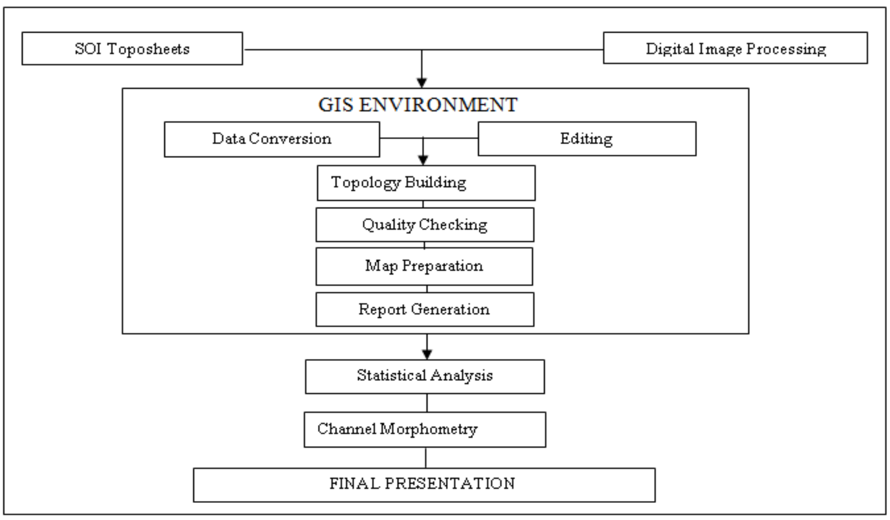

Figure 3: Flow Chart Showing the Broad Methodology

RESULTS AND DISCUSSIONS

Morphometry is the measurement and mathematical analysis of configuration of Earth surface, shape and dimensions of its landforms. The main purpose of the work is to discover holistic stream properties from the measurement of various stream attributes. The quantitative drainage analysis is done aspect wise such as linear and areal aspects. The linear aspects are tabulated in Table 1.

Table 1: Linear Aspects of Buggavanka Watershed

Stream Order u	Number of Streams N_u	Total Length of Streams in Km L_u	Bifurcation Ratio R_b	
1	1055	712.931	1st / 2nd Order	4.37
2	241	263.750	2nd / 3rd Order	3.82
3	63	159.842	3rd / 4th Order	4.84
4	13	93.183	4th / 5th Order	2.60
5	5	52.387	5th / 6th Order	5.00
6	1	22.945	-------	-------
Total	**1378**	**1,305.038**	**Mean Bifurcation Ratio**	**4.12**

Stream Order (u)

The first step in morphometric analysis is designation of stream orders. The stream ordering is done by adopting Strahler method (1964). In this method of stream ordering the headway streams are designated as 1st order, when two 1st order streams join to form 2nd order, where two 2nd order streams to form 3rd order and so forth. The highest order of main trunk stream is 6 i.e., Buggavanka stream (Figure 2) and measures 57.947 Km.

Number of Streams (N_u)

The study area is traversed by a total of 1,378 streams, out of which 1055 are of 1st order, 241 are of 2nd order, 63 are of 3rd order, 13 are of 4th order, 5 are of 5th order and the culminating in the form of one 6th Order stream. (Table 1). The streams of 1st order account for 76.56% followed by 17.48%, 0.04%, 0.009% and 0.003% for 2nd, 3rd, 4th and 5th Orders. The numbers of order of stream in this watershed decreases downstream in accordance with Horton's law of stream numbers. Majority of the 1st order streams are found in the upper reach of the Buggavanka stream.

Stream Length (L_u)

The stream length is calculated by adopting Horton's method. The surface runoff or the overland flow to a great extent is influenced by the stream length. The length of the stream is inversely proportional to the slope gradient, i.e., the smaller stream length is characteristic of relatively steep slope and finer texture where as longer lengths of the streams are generally indicative of gentle slope gradient. A cursory glance at Table 1 reveals that the total length of streams in 1st order is maximum and it decreases as the stream order increases.

Length, Mean Length and Length Ratio of Streams

The Stream length of 1st, 2nd, 3rd, 4th, 5th and 6th order is 712.931 Km, 263.750 Km, 159.842 Km, 93.183 Km, 52.387 Km and 22.945 Km respectively (Table 1). The total stream length of 1st order is far greater than the rest of the streams. Generally, the total stream length of different orders decreases with increasing order of the stream numbers and is in accordance with Horton's "Law of stream lengths". Streams do exhibit their increasing length with the decreasing slope from south to north in the Buggavanka watershed. The mean values of stream length are shown in Table 2.

Stream length ratio (R_l) of the Buggavanka watershed is calculated by dividing mean length of the stream (L_u) with specific order to the mean length of the next lower order stream (L_u-1). The value ranges between 1.46 to 2.82. The ratio between 2nd and 1st order streams is 1.61 shows that most of the first order streams are in upper reach of the channel governed by the rich relief parameter.

Table 2: Stream Length Ratio

Stream Order	Minimum Length (In Meters)	Maximum Length (In Meters)	Mean Length (In Meters)	Stream Length Ratio R_l	
1	139	4050	676	------	
2	85	6614	1094	2nd / 1st Order	1.61
3	148	10098	2537	3rd / 2nd Order	2.31
4	284	17648	7168	4th / 3rd Order	2.82
5	7195	17866	10477	5th / 4th Order	1.46
6	22945	22945	22945	6th / 5th Order	2.19

Bifurcation Ratio (R_b)

Bifurcation Ratio denotes the ratio of number of streams in a given order (N_u) to the number of streams in the next higher order (N_u+1). As seen from Table 1 Bifurcation ratios characteristically range between 2.6 and 5. The hypothetical minimum value of 2 is rarely approached under natural conditions. Abnormally higher bifurcation ratios might be expected in regions of steeply dipping rock strata where narrow strike valleys are confirmed between hogback ridges. The Mean Bifurcation Ratio of Buggavanka watershed is 4.2 and it indicates the watershed suffered less structural disturbances. The drainage pattern evolved is not a consequence of structures and small variations are due to different environments. Therefore the drainage pattern in the study area is sub-dendritic to dendritic.

Table 3: Areal Aspects of Buggavanka Watershed

Morphometric Parameters	Symbol/Formula	Adopted from	Result
Area (sq. km)	A		724.73
Perimeter (km)	P		134
Drainage Density (km/sq. km)	$D=L_u/A$	Horton, 1932	1.8
Stream Frequency	$F_s=N_u/A$	Horton, 1932	1.9
Texture Ratio	$T=N_1/P$	Horton, 1932	7.87
Basin Length (km)	L_b		41.26
Elongation Ratio	$R_e=2\sqrt{\frac{A}{\pi}}/L_b$	Schumm, 1956	0.73
Circularity Ratio	$R_c=4\pi A/P^2$	Miller 1953	0.5
Form Factor Ratio	$R_f=A/L_b^2$	Horton 1932	0.42

Areal Aspects of the watershed are the main component in Morphometric analysis. Therefore the areal aspects are calculated and summarized in Table 3. The details are thoroughly discussed subsequently based on the methods adopted and their relevance to the Buggavanka watershed.

Drainage Density (D)

Drainage density indicates the length of the stream per km^2 in the drainage basin. Various factors contribute to the variations in drainage density such as climate, type of rock, relief, infiltration capacity and vegetative cover. The drainage density in Buggavanka watershed is 1.8. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture (Strahler, 1964).

Stream Frequency (F_s)

Stream frequency is the total number of streams of all orders per unit area (Horton, 1932). The stream frequency of Buggavanka watershed is 1.9, which indicates positive correlation with drainage density value of the area i.e., increase in number of streams with respect to increase in drainage density.

Texture Ratio (T)

Texture ratio is the measure of the closeness of the channel spacing and related directly to the drainage density, also depends on underlying lithology, rate of infiltration and relief conditions. In Buggavanka watershed the texture ratio is 7.87 and categorized as fine to very fine in nature.

Basin Length (L_b)

There are several definitions defining the length of the basin. For Buggavanka drainage basin, the definition of Schumm (1956), is taken into consideration. According to him the basin length as the longest dimension of the basin parallel to the principal drainage line. The length of the basin is 41.26 Km.

Elongation Ratio (R_e)

Elongation ratio is related to the shape of any drainage basin. Schumm (1965) defined elongation ratio as "the ratio of diameter of a circle of same area as the basin to the maximum basin length". The elongation ratio in the present study is 0.73 which suggests that the Buggavanka watershed is less elongated.

Circularity Ratio (R_c)

Miller (1953) defined dimensionless circularity ratio as the ratio of the basin to area of the circle having the same perimeter as the basin. According to him, the circularity ratio of the basin ranges between 0 – 0.5 as strongly elongated and highly permeable homogenous geological material. The circularity ratio of the Buggavanka watershed is 0.5 which according to Miller's range indicates that the basin is less elongated, low discharge runoff.

Form Factor Ratio (R_f)

The stream discharge behavior is greatly affected by the form factor. The ratio of the basin area to the square of the basin length is called as form factor ratio (Horton, 1932). It is used as quantitative expression of the shape of basin form. The form factor ratio varies between 0.03 to 0.55 and in the present study it is recorded as 0.42.

CONCLUSIONS

Channel Morphometry of the Buggavanka watershed reveal that the drainage network is less controlled by the tectonic activity and the pattern is sub-dendritic to dendritic. Stream frequency of watershed revealed positive correlation with drainage density. Buggavanka watershed is less elongated and lack structural control. The variation in the Bifurcation ratio within the watershed is attributed to difference in topographic conditions and lithology. It is evident from the above that the Spatial Information Technology i.e., Remote sensing and Geographical Information system (GIS) are very effective tools in the study of drainage characteristics. Morphometric analysis of the drainage basin is of immense utility especially in the analysis of runoff, watershed prioritization and water resource management. It is therefore recommended to take detail study on the relation of morphometric parameters numerous lower order streams at micro watershed level.

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