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Morphometric Analysis Of Erravankapalli Watershed Using Remote Sensing And Gis Techniques, Nallamada Mandal, Anantpur District, Andhra Pradesh, India

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Abstract: *Geographical information system (GIS) has emerged as an efficient tool in delineation of drainage pattern and ground water potential and its planning. GIS can be employed for the identification of morphological features and analyzing properties of Erravanka palli watershed. The morphometric parameters of basin can address linear, areal and relief aspects. The present study deals mainly with the geometry, more emphasis being placed on the evaluation of morphometric parameters such as stream order (Nu), stream length (Lu), bifurcation ratio (Rb), drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circularity ratio (Rc),and form factor ratio (Rf) etc.. Study area is Palavayi basin, geographically located between 76° 30', 76° 40' E longitudes, and 19°30', 19°45' N latitudes located in Anantapur district of Andhra Pradesh state in India. The GIS based Morphometric analysis of this drainage basin revealed that the Erravanka palli watershed is 5th order drainage basin and drainage pattern mainly in sub-dendritic to dendritic type thereby indicates homogeneity in texture and lack of structural control. Total number of streams is 449, in which 294 are first order, 100 are second order, 38 are third order, 11 are fourth order streams and 06 are fifth order. The length of stream segment is maximum for first order stream and decreases as the stream order increases. The drainage density (Dd) of study area is 160^2 km. This study would help the local people to utilize the resources for sustainable development of the basin area.*

Keywords: *Drainage morphometry Erravankapalli watershed, SOI Toposheets, ArcGIS 10.2.1.*

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I. Introduction:

The morphometric analysis is done successfully through measurement of linear, aerial, relief, gradient of channel network and contributing ground slope of the basin (Nautiyal 1994; Nag and Chakraborty, 2003; Magesh et al. 2012b). A widely acknowledged principle of morphometry is that drainage basin morphology reflects various geological and geomorphological processes over time, as indicated by various morphometric studies (Horton 1945; Strahler 1952, 1964; Muller 1968; Shreve 1969; Evans 1972, 1984; Chorley et al. 1984; Merritts and Vincent 1989; Ohmori 1993; Cox 1994; Oguchi 1997; Burrough and McDonnell 1998; Hurtrez et al. 1999). It is well established that the influence of drainage morphometry is very significant in understanding the landform processes, soil physical properties and erosional characteristics. Geomorphology is concerned with the surface features of the earth. For the purpose of study it is essential that this surface is reduced in some rational way to a system of smaller units. Before 1945, in accordance with the general trend landscape was generally divided regionally into areas sharing the same principal geomorphic features. W.M. Davis (1889) recognized the unitary character of the drainage basin, but tended to distinguish stage of evolution as the basis of his field study. Drainage basins differ enormously in size vary from large with a complex network of tributary rivers, to a tiny catchment area drained by a single stream. Thus an area enclosed by a major watershed may have within it a number of separate distinct catchment areas of varying sizes, but all contributing as part of the same main drainage system. The channels of the drainage network and the landforms they drain are bound together in a close causal relationship in which any long term change in the discharge characteristics of the streams will ultimately result in modification of the areas between them (Patrick Mc Cullagh, 1983). Drainage basin is generally regarded as the most satisfactory basic unit for study. It is an aerial unit defined by characteristics that can be measured quantitatively, thus providing an objective basis for analysis, comparison and classification. Morphometry may be defined as the numerical systematization of landform elements measured from the topographical maps provides the real basis of quantitative geomorphology. Emanuel De Martonne (1934) in his 'Trait de Geographic Physique' adopted the expression morphometry and defined it as the numerical systematization of the forms of the land relief as it can be interpreted from a topographic map. In any landform context the main aspects of the landform features which provide the differentiating characteristics and which can be studied from a topographic map (Hammond, 1954) are the area (surface arrangement), altitude, relief and volume (vertical dimension), profile (vertical arrangement of the surface), texture (horizontal dimension) and slope (deviation of the surface from horizontal). According to Clarke (1967), morphometry is defined as the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimensions of its landforms. A quantitative statement of the geomorphic characteristics of a drainage basin towards a qualitative inference of the hydraulic nature of the basin assumed considerable importance towards the middle of this century. An exhaustive study of the development and geometry of streams has been made by Horton (1945). Evaluation of geomorphic factors and their mathematical relationships to hydrology was delayed by lack of quantitative methods and procedures for measuring geomorphic characteristics. Much impetus, however, was given to fluvial morphometry by Horton (1945) and suggested methods of quantitative analysis of drainage features. Accurate prediction of stream flow under given precipitation conditions has been a goal toward which hydrologists have struggled. The present study was undertaken in an effort to establish mathematical relationships between quantitative geomorphic factors of a watershed and stream-flow characteristics. The remote sensing technique is the convenient method for morphometric analysis as the satellite images provide a synoptic view of a large area and is very useful in the analysis of drainage basin morphometry. The fast emerging spatial information technology, remote sensing, GIS, have effective tools to overcome most of the problems of land and water resources planning and management rather than conventional methods of data process (Rao et al. 2010).

The digital elevation model (DEM) of the area was generated to deduce the morphometric parameters like drainage basin area, drainage density, drainage order, relief and network diameter in GIS environment. Combination of the remote sensing satellite data and hydrological and spatial analysis in GIS environment is made easy to identify and discriminate the drainage area (Pirasteh et al.2010). The geographic and geomorphic characteristics of a drainage basin are important for hydrological investigations involving the assessment of groundwater potential, etc. The present study aims at using the remote sensing and GIS technology to compute various parameters of morphometric characteristics of the Erravankapalli watershed. This is in consonance with the latest developments and researches as cited above.

II. Study Area:

Erravankapalli watershed is Nallamada mandal, Anantapur District, Andhra Pradesh state between lies longitude 77° 35 ' 00" to 77° 46 ' 00" latitude14 °30' 00" to 14 °35' 00" watershed area around 160 ^{2} km. One Mandal is covered namely Nallamada. The Study area is mostly Pediplain terrain land and eastern part is covered with residual hills, denudational hills and some pediments are there. Anantapur district area experiences semi-arid climate, the summer is very hot and the Mercury rises to + 420 Celsius. Winter is pleasant; night temperature is about 130 Celsius to 150 Celsius. Average rainfall per annum 550 mm.

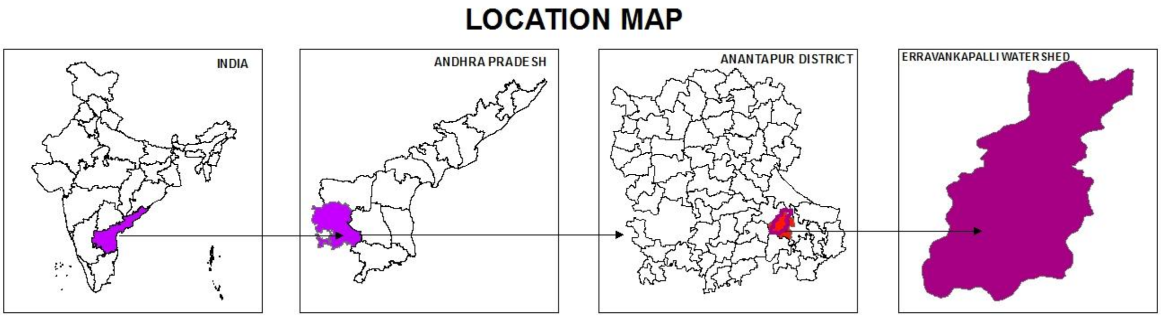

Fig. 1. Location map of Erravankapalli watershed,Nallamada mandal Anantapur District, A.P.

2.1. Physiography and Drainage:

The study area is located in Erravankapalli Watershed, Anantapur District, Andhra Pradesh state. The terrain consists of denudational hills and valleys, Corstone-Tor Composites with highest elevation of 554 m on the eastern side and undulating plains, shallow to moderately weathered pediplains on the western part with an elevation of 840 m. On the eastern side of the area, a joint controlled second order stream, with rectangular drainage pattern is flowing along NNE-SSW direction, conforming to the major lineament trend. There are few first order drainages which feeds two reservoirs, located at the southern boundary of location. The lithology of the study area is pink (Orthoclase feldspar) and grey (Plagioclase feldspar) granite of Archaean age. The weathered zone thickness ranges between 10-30 m along East and central part of the study area.

III. Methodology:

Erravankapalli sub basin drainage network and assigning the stream order from a published Survey of India (SOI) topographic map and from geo referenced satellite data for a large area is a time taking tedious exercise. To over- come this problem, automatic extraction techniques have been used for evaluating the morphometric parameters of a basin, i.e., extraction of River basin/watershed boundary and extraction of drainage/stream network from the Erravankapalli sub basin using Senthinel Satellite Data in conjunction with geo coded standard false colour composite remote sensing satellite data (SENTHINEL? of 2017) and georeferenced SOI toposheets of 1972 (57F/15, 57F/16, 57J/03and 57J/04 having 1:50,000 scale) and using ARC GIS-10.2.1 software'. The extracted basin and stream networks are projected to the regional projection (WGS-1984, UTM zone 44 N). A detail of Flow chart of morphometric analysis is given Fig. 2.

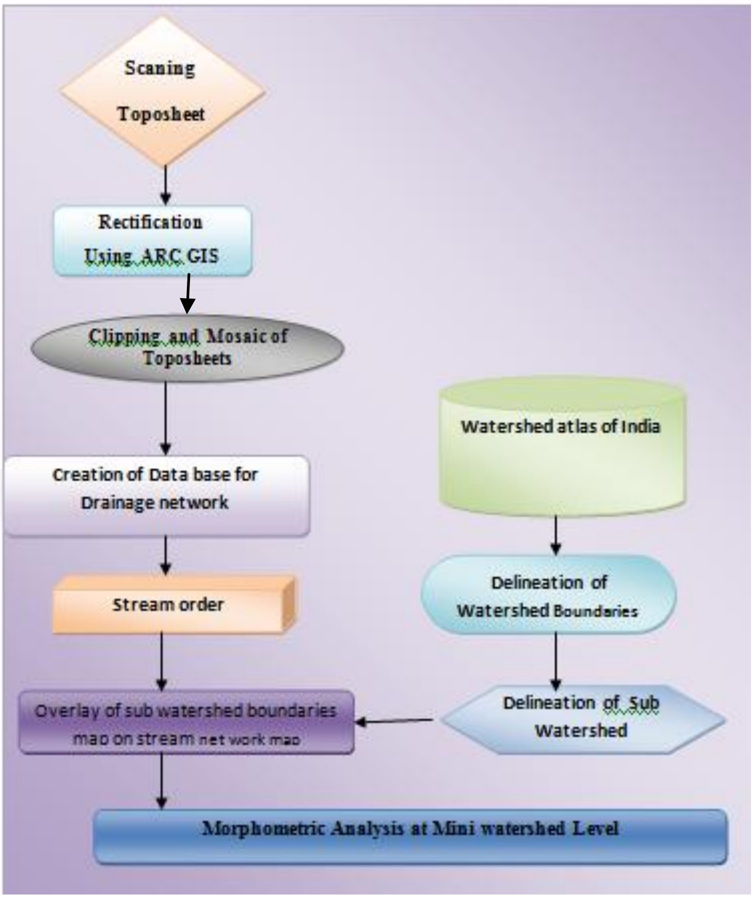

Fig. 2. Flow chart of Morphometric analysis Erravankapalli watershed.

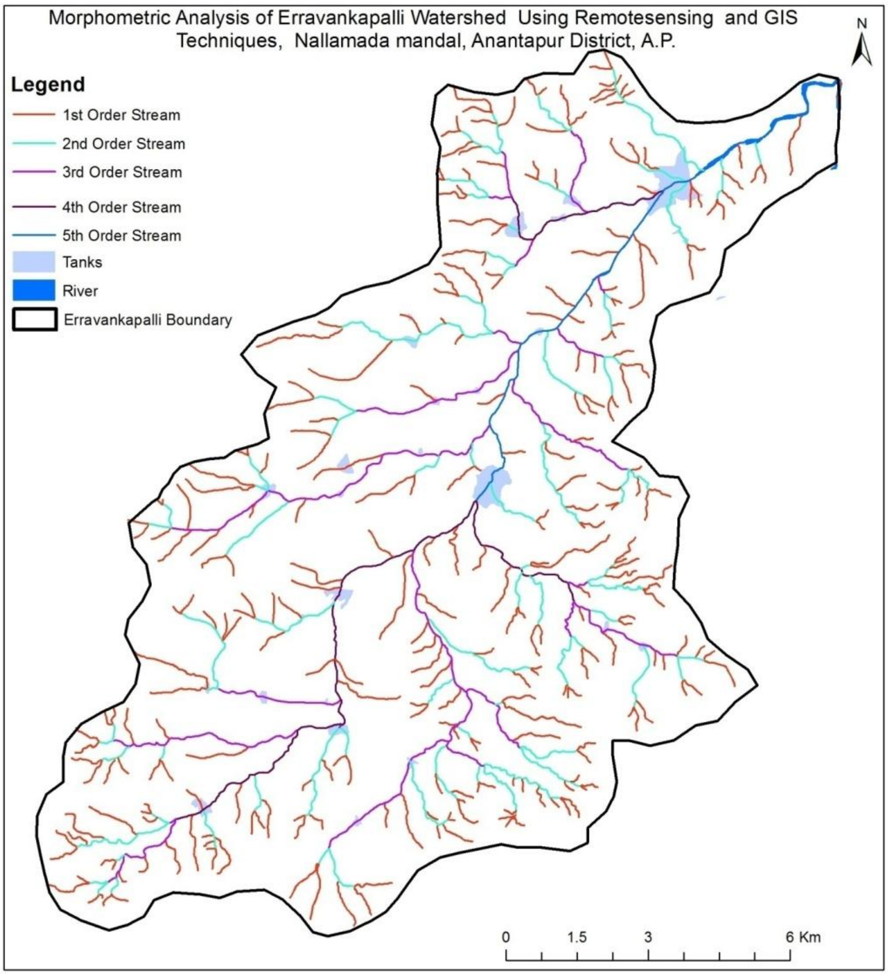

Fig. 3. Drainage pattern and their order identified from the Erravankapalli watershed.

3.1. Stream Order (Nu):

In the drainage basin analysis the first step is to determine the stream orders. In the present study, the channel segment of the drainage basin has been ranked according to Strahler's stream ordering system. According to Strahler (1964), the smallest fingertip tributaries are designated as order 1. Where two first order channels join, a channel segment of order 2 is formed; Where two of orders 2 join, a segment of order 3 is formed; And so forth. The trunk stream through which all discharge of water and sediment passes is therefore the stream segment of highest order. The study area is a 5th order drainage basin (Fig.3). The total numbers of 449 streams were identified of which 294 are 1st order streams, 100 are 2nd order, 38 are 3rd order, 11 in 4th order, 06 are 5th order streams. Drainage patterns of stream network from the basin have been observed as mainly dendritic semi dendritic type which indicates the homogeneity in texture and lack of structural control. This pattern is characterized by a tree like or fernlike pattern with branches that intersect primarily at acute angles. While in some parts of the basin represent parallel and radial pattern types indicating that the topographical features are dipping, folded and highly jointed in the hilly terrain. The properties of the stream networks are very important to study the landform making process (Strahler and Strahler, 2002).

3.2. Bifurcation Ratio (Rb):

The term bifurcation ratio (Rb) is used to express the ratio of the number of streams of any given order to the number of streams in next higher order (Schumn, 1956). Bifurcation ratios characteristically range between 3.0 and 5.0 for basins in which the geologic structures do not distort the drainage pattern (Strahler, 1964). Strahler (1957) demonstrated that bifurcation ratio shows a small range of variation for different regions or for different environment dominates. The mean bifurcation ratio value is 0.99813 for the study area which indicates that the geological structures are less disturbing the drainage pattern.

3.3. Stream Length (Lu):

Stream length 364 is one of the most significant hydrological features of the basin as it reveals surface runoff characteristics streams of relatively smaller lengths are characteristics of areas with larger slopes and finer textures. Longer lengths of streams are generally indicative of flatter gradients. Generally, the total length of stream segments is maximum in first order streams and decreases as the stream order increases. The 534 number of streams of various orders in the basin are counted and their lengths from mouth to drainage divide are measured with the help of GIS software. Plot of the logarithm of stream length versus stream order showed the linear pattern which indicates the homogenous rock material subjected to weathering erosion characteristics of the basin. Deviation from its general behavior indicates that the terrain is characterized by variation in lithology and topography.

3.4. Areal Aspects of the Drainage Basin:

Area of a basin (A) and perimeter (P) are the important parameters in quantitative morphology. The area of the basin is defined as the total area projected upon a horizontal plane contributing to cumulate of all order of basins. Perimeter70.06 km is the length of the boundary of the basin which can be drawn from topographical maps. Basin area is hydrologically important because it directly affects the size of the storm hydrograph and the magnitudes of peak and mean runoff. It is interesting that the maximum flood discharge per unit area is inversely related to size (Chorley, et al., 1957). The aerial aspects of the drainage basin such as drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circularity ratio (Rc) and form factor ratio (Rf) were calculated and results.

3.5. Drainage Density (D):

Horton (1932), introduced the drainage density (D) 2.0717 km^2 is an important indicator of the linear scale of landform elements in stream eroded topography. It is the ratio of total channel segment lengths cumulated for all orders within a basin to the basin area, which is expressed in terms of mi/sq. mi or km/sq. km. The drainage density indicates the closeness of spacing of channels,

$$\text{Drainage Density (Dd)} = Lu/A$$
$$= 331.485/160 = 2.0717$$

3.6. Basin Area (A):

The area of the Erravankapalli basin 160 km^2 is another important parameter like the length of the stream drainage. Schumm (1956) established an interesting relation between the total Erravankapalli basin areas and the total stream lengths, which are supported by the contributing areas. The author has computed the basin area by using ArcGIS-10.2.1 software, which is 160 Sq Kms.

3.7. Basin Perimeter (P):

Basin perimeter is the outer boundary of the Erravankapalli basin that enclosed its area. It is measured along the divides between watersheds and may be used as an indicator of basin size and shape. The author has computed the basin perimeter by using ArcGIS-10 software, which is 68 Kms.

3.7. Elongation Ratio (Re):

Schumm (1956) used an elongation ratio (Re) defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. It is very significant index in the analysis of basin shape which helps to give an idea about the hydrological character of a drainage basin. Values near to 1.0 are typical of regions of very low relief (Strahler, 1964). The value Re of the study area of is 0.56 indicates that the low relief of the terrain and elongated in shape.

$$Re = D/L$$
$$= 1.128\sqrt{A}/L$$
$$= 1.128 * \sqrt{160}/20$$
$$= 0.71341$$

IV. Conclusion and Discussion:

The study is primarily based on published and derived data. For the analysis of the drainage characteristics and relief, intensive use has been made of Topographical sheets on 1: 50,000 scale published by the Survey of India. The quantitative analysis of the morphometric characteristics of the watershed includes Stream Order, Stream Length, Bihrcation Ratio, Drainage density, Stream frequency, Relief ratio, Elongation ratio and Circularity ratio. Erravankapalli watershed comprises a catchment of about 160 km2. The drainage pattern is characterised by irregular branching of tributaries in many directions with an angle less than 90". The dendritic pattern of drainage is observed which is a characteristic feature of regions occupied by mainly Hornblende – biotie Gneissic rocks (Thornbury, 1969).

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