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Determination of Morphological Parameters of a Watershed Using Remote Sensing and GIS

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ABSTRACT: In the present study, an attempt has been made to determine morphological parameters of Kesinga watershed falling in Odisha state. Remote Sensing (RS) coupled with Geographical Information System (GIS) technique has proved to be an effective tool in drainage delineation and their morphometric analysis. For detailed study, DEM of area has been extracted from SRTM 90 m which was downloaded from USGS Earth Explorer used for delineating watershed boundary and geographical information system (GIS) was used in evaluation of linear aspects of morphometric parameters. The Kesinga watershed covers an area of 11,773.1 km^2 in the districts of Nuapada, Balangir, Kalahandi and Nabarangpur (Odisha) and Raipur (Chattisgarh).The geographical information systems (GIS) analysis was made for the said themes using the Arc GIS –ArcMap10.3. The Kesinga watershed was found to be the fifth order basin. The present study aims to determine the morphometric characteristics of the watershed basin and it has been determined by applying GIS techniques. Strahler‘s method has been employed to find the fluvial characteristics of the study area. The morphometric properties determined for this area and for it will be useful for the efficient planning of water harvesting and groundwater projects on watershed basis.

Key Words: Watershed, Remote Sensing, GIS, Morphometric characteristics

I. INTRODUCTION:-

Watershed is an ideal unit which allows surface run off to a defined channel, drain, stream or river at particular point. It is a separating boundary of a drainage basin and termed it as a catchment (Chow, 1964). The response of a particular watershed to various hydrological processes and its behaviour depends upon certain physiographic, hydrological and geomorphological parameters. The size can be varying from fractions of hectares to thousands of kilometres. Modern technologies like Geographic Information System (GIS), Remote Sensing have got significant importance over the last decade in their applications in hydrology. DEMs provide good terrain representations which will helps in watershed modelling. The advantage of DEM is that, it can be used to derive flow networks and then automatically generate watershed boundaries for a given outlet points using GIS technology. So DEM becomes the essential component in process of watershed delineation. Nowadays many researchers have used remote sensing (RS) data and geographical information system (GIS) for determining various parameters such as stream orders, basin area ,perimeter of basin ,length of drainage channels ,drainage density (Dd); drainage frequency ,bifurcation ration (Rib), texture ratio (T) and circulatory ratio (Rc) (Kumar et al 2000). Quantitative morphometric characterization of a watershed is considered to be the most suitable method for the planning as well as its management because it enables us to understand the relationship among different aspects of the drainage pattern and also to make a comparative evaluation of different drainage basins, developed in different geologic and climatic regimes (Pingale S. M. et al.). Analysis of drainage based on morphometric parameters is very important for watershed planning because it gives an idea about the basin characteristics. Based on the morphometric analysis, the quantitative description of the drainage system can be provided and which is an important aspect of the characterization of watersheds (Strahler, 1964). In the present study the DEM data used for delineating the boundary of watershed automatically in the scale of 1:50000 using ArcSWAT tool in Arc map 10.1. Arc GIS is powerful software for analysing, visualizing and updating the geographical information to create

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quality presentations that brings interactive mapping and analysis.

Geomorphological analysis will helps to understand the hydrological system of watershed which is useful for taking different management strategies.

II. MATERIALS AND METHODS:-

2.1 Study Area

The Kesinga watershed covers an area of 11,773.1 km^2 in the districts of Nuapada, Balangir, Kalahandi and Nabarangpur (Odisha) and Raipur (Chattisgarh). It is located in between the Latitude-Longitude range of 19^0 46' North, 82^0 03' East and 20^0 22' North, 82^0 09' East (Fig.1). The maximum and minimum elevations in the area are 166 m and 1095 m above mean sea level. The major river flowing through this watershed is Mahanadi River. Average annual rainfall is about 2084.0 mm.

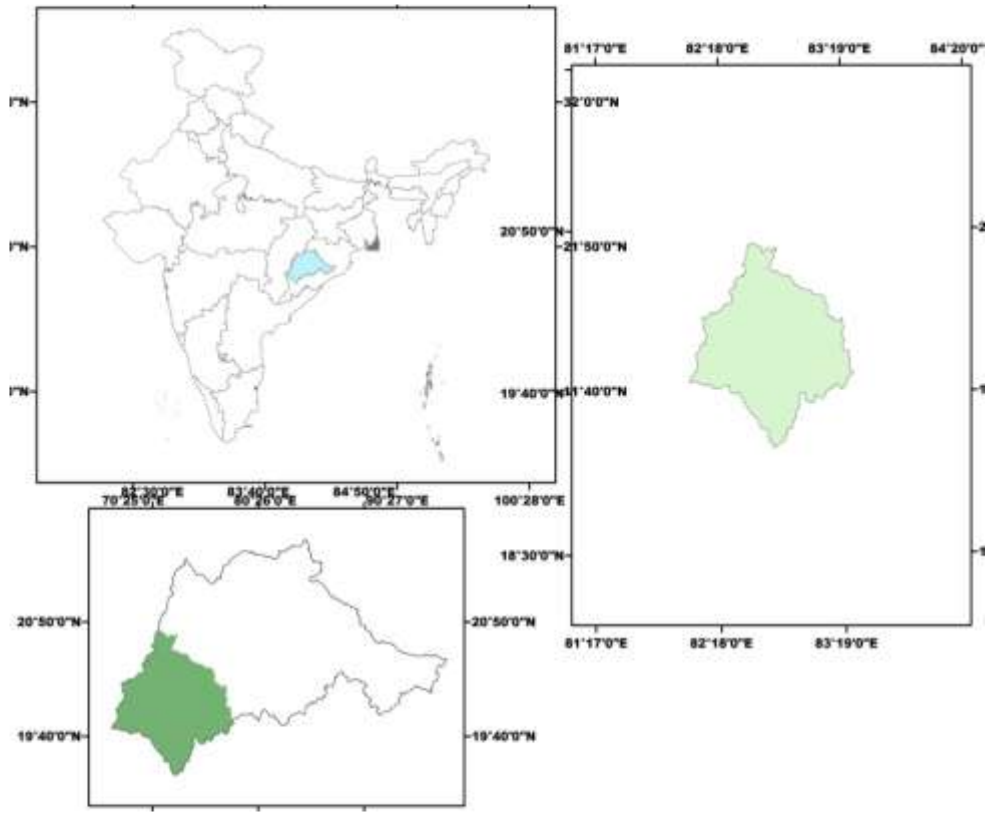

Fig.1. Location map of Kesinga Watershed

Data Used

The soil erosion map of the Kesinga watershed was prepared by using RUSLE model. To calculate various parameters of RUSLE supplementary data like rainfall data of 10 years has been taken from the Special Relief Commission (SRC) Odisha website. LU/LC map of the study area obtained in the scale of 1:250000 from NRSC, Hyderabd. Soil Texture map shown in Fig.2 have been obtained from FAO soil map and K factor was calculated. DEM of area has been extracted from SRTM 90 m which was downloaded from USGS Earth Explorer. The DEM data used for delineating the boundary of watershed automatically in the scale of 1:50000 using ArcSWAT tool in Arc map 10.1also LS factor has been calculated using the same DEM.

III. METHODS

Attempts were made to delineate watershed by using ArcGIS 10.1 and find the morphological parameters with the help of materials collected. Methods are taken with a view to fulfil the objectives of this study.

3.1 Delineation of watershed

ArcSWAT tool in ArcGIS was used for digital demarcation of the watershed boundary. DEM of the study area for the year 2014 (resolution 90 m) were loaded in ArcGIS window. The DEM should be protected from geographic coordination system to projected coordination system (WGS 1984 UTM Zone 45 N) using data management tool from Arc tool box. The process of delineation using ArcSWAT tool comprises the creation of new project setup initially after that clicking was made on the watershed delineation menu and then automatic watershed delineation was selected from that. A dialogue box for watershed delineation will automatically come after selecting the automatic watershed delineation. DEM of the study area was loaded from the disk for calculating flow accumulation. After importing the DEM the process comprises of giving flow accumulation threshold area, creating stream and network, manually editing outlet and giving definition for the whole watershed outlet, calculating sub basin parameters, and finally watershed delineation. The watershed boundary will be delineated automatically by doing this operation.

3.2 Delineation of streams

ArcSWAT tool in ArcGIS was used for digital demarcation of the watershed boundary. DEM of the study area for the year 2014 (resolution 90 m) were loaded in ArcGIS window. The DEM should be protected from geographic coordination system to projected coordination system (WGS 1984 UTM Zone 45 N) using data management tool from Arc tool box. The process of delineation using ArcSWAT tool comprises the creation of new project setup initially after that clicking was made on the watershed delineation menu and then automatic watershed delineation was selected from that. A dialogue box for watershed delineation will automatically come after selecting the automatic watershed delineation. DEM of the study area was loaded from the disk for calculating flow accumulation. After importing the DEM the process comprises of giving flow accumulation threshold area, creating stream and network, manually editing outlet and giving definition for the whole watershed outlet, calculating sub basin parameters, and finally watershed delineation. The watershed boundary will be delineated automatically by doing this operation.

3.3Quantitative Morphometry

Morphometric analyses of the watershed were done. The linear, areal and relief aspects of the watersheds extracted from SRTM DEM have been carried out using the standard mathematical formulae and the details are given in the Table 1.Systematic details of the geometry of a drainage basin and its stream channel requires measurement of linear aspects of the channel network and contributing ground slopes.

Table 1.Linear morphological parameters of a watershed

Sl. No.	Parameters	Formula	References
1	Stream order (U)	Hierarchical rank	Strahler (1964)
2	Stream number (Nu)	No of streams	Horton (1945)
3	Stream length (Lu)	Length of the stream (kilometres)	Hortan (1945)
4	Mean stream length (L_{sm})	L_{sm} = Lu/Nu Lu = Total stream length of order u Nu = Total no. of stream segments of order u	Strahler (1964)
5	Bifurcation ratio (Rb)	Rb = Nu/(Nu + 1) Nu = Total no. of stream segments of order u Nu + 1 = Number of segments of the next $(u+1)^{th}$ order	Schumn (1956)
6	Mean bifurcation ratio (R_{bm})	Average of bifurcation ratios of all orders	Strahler (1964)

IV. RESULTS AND DISCUSSION

To achieve the aim of the present research, DEM from the Shuttle Radar Topographic Mission (SRTM) downloaded to extract all possible morphological parameters of the catchment in the area. Further morphological parameters in linear aspects of sub watersheds in the study area were done.

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4.1 Delineation of watershed

Boundary of the Kesinga watershed delineated with the help of ArcSWAT tool in ArcGIS. The area of the basin was found to be 11773.1 km^2 with a perimeter of 902.9 km and having 29 sub-basins. The delineated watershed was shown in Fig.2

Fig.2. Watershed delineation of Kesinga watershed

4.2 Delineation of streams

The Study area found to be watershed of fifth order. The detailed description about the streams will be discussed in coming sections. The stream order map was shown in Fig.3.

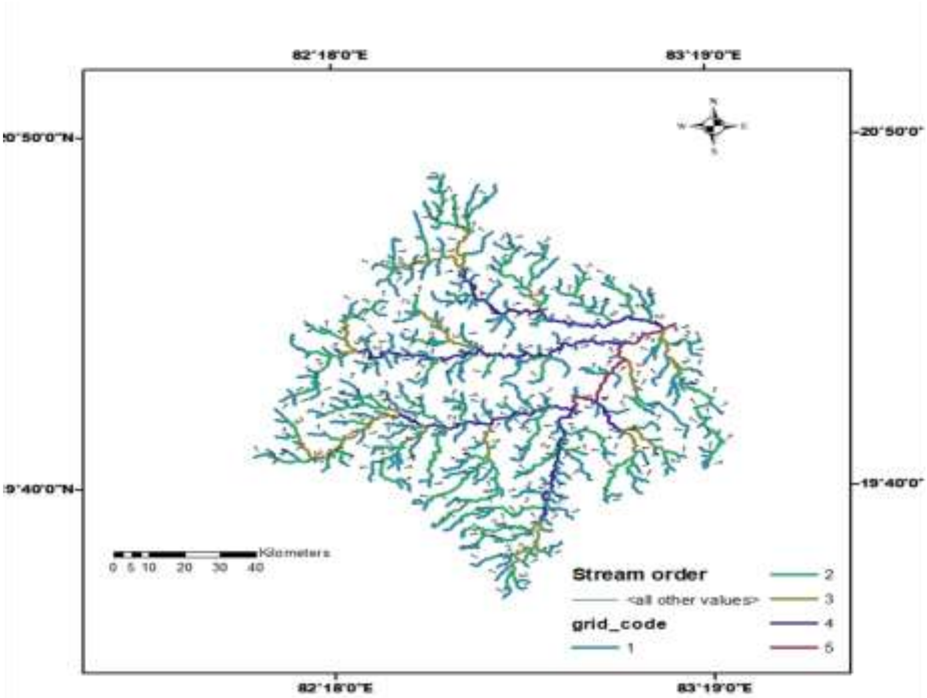

Fig.3. Stream order map of Kesinga watershed

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4.3 Morphological parameters of watershed

Systematic description of drainage basin geometry and its stream channel requires linear aspects measurements and contributing ground slopes.

4.3.1 Linear aspects

Linear aspects of the drainage basins are closely connected with the channel patterns of the drainage network and the topological characteristics of the stream segments in terms of open links of the network system are studied. Morphometric parameters for linear aspects calculated and were tabulated in Table 2

Parameters	Stream orders				
	I	II	III	IV	V
Stream Number (N_u)	404	78	16	5	1
Stream Length (L_u) (km)	1671.1	928.35	299.26	328.19	56.15
Mean Stream Length (L_{sm})	4.13	11.9	18.7	65.63	56.15
Stream Length Ratio (R_L)		II/I = 2.88	III/II = 1.57	IV/III = 5.51	V/IV = 0.85
Bifurcation Ratio (R_b)		I/II = 5.1	II/III = 4.87	III/IV = 3.3	IV/V = 5
Mean bifurcation ratio(R_{bm})	4.56				

Table 2. Morphometric parameters for linear aspects

4.3.1.1 Stream order

Identification of stream orders is the first step in drainage basin analysis and is based on a hierarchic ranking of streams. In this study, ranking of streams has done based on the method ofStrahler (1964). The order wise stream numbers and stream lengths of the -watershedwas given in Table 2. The highest stream order found to be 5th order. According to (Costa, 1987) higher stream order is associated with greater discharge, and higher velocity

4.3.1.2 Stream length

The length of each order was calculated and shown in Table 2. In general, the total length of stream segments is high in first order streams and decreases as the stream order increases. Here in this study also stream length was found to be decreased as order increases. Longer length of stream is advantageous over the shorter length, in that the former collects water from wider area and greater option for construction of a bund along the length; the lower stream lengths are likely to have lower runoff.This observation was justified by the report of Magesh (2012).

4.3.1.3 Stream number

The number of stream channels in a given order is known as stream number (Horton, 1945). Stream number of streams of any given order will vary inversely with stream order. A higher stream number is the indication of lesser permeability and infiltration. In Kesinga watershed also higher numbers of streams are found in first order and lesser in fifth order. Observation of the present study shows some similarities with the results obtained by (Afreedaet al., 2018).

4.3.1.4Mean stream length (Lsm)

It is a characteristic property related to the size of drainage network components and its contributing basin surfaces (Strahler, 1964). It was calculated by dividing the total stream length of order „„u"" by the number of streams of segments in the order (Table 2). Generally, Lsm of any given order is greater than that of the lower order and less than that of its next higher order. The values of Lsm were shown in the Table.2.

4.3.1.5 Stream length ratio (RL)

It is the ratio of the mean length of the one order to the next lower order of the stream segments (Horton 1945). The RL between streams of different order in the study area reveals that there is a different variation trend. This variation might be because of the changes in slope and topography, (Table 2). The value of stream length ratio varies from 0.85 to 5.51. These results are in agreement with the findings of Bansod (2018).Change in this value from one order to another showed that the early stage of maturity of the watershed.

4.3.1.6 Bifurcation ratio (R_b)

These may be defined as the ratio of the number of stream segments of given order to the number of segments of the next higher order (Schumm 1956). Strahler (1957) explained that the bifurcation ratio shows a small variation in different regions or different environmental conditions, exception in the case where the geology dominates .Mean bifurcation ratio of the study area is 4.56. Higher bifurcation value found between first and second order.It was seen that Rb is not the same from one order to its next order. These changes depend upon the geological and lithological development of the watershed.In general, the value of R_b normally varies in between 2 to 5 and tends to be more for elongated basins (Beaumont, 1975). Here the value is nearer to 5. An elongated basin is likely to have high R_b whereas a circular basin is likely to have low R_b (Patilet al., 2015).The analysis of bifurcation ratio value shows that the watershed possesses well developing drainage network as the bifurcation ratio ranges from 3.3 to 6.0 which in medium range. The watershed is neither elongated nor circular in shape. The shape of watershed is more or less like a polygon.

V. CONCLUSION

The aim of the study is to collecting, comparing, processing and analysing the DEM data in a GIS environment for delineation of watershed boundary and determination of morphological parameters of selected watershed in Odisha.Morphometric studies relating to the linear aspects of the selected watershed have been carried out using the standard mathematical formulae from the SRTM DEM. Linear aspects of the basins and the channel patterns of the drainage network are closely connected. Giving stream orders is the first step in drainage basin analysis and the highest stream order of the watershed is fifth order. The numbers of streams having different orders in a watershed was counted and length measured. The selected watershed do not show any variation from the general observation.ie, the stream length decreases with stream order. The stream length ratio of different streams orders in the study area discloses that there is a variation trend in the present watershed. This variation might be because of the changes in slope and topography of the area. The analysis of bifurcation ratio value shows that the watershed possesses well developing drainage network as the bifurcation ratio ranges from 3.3 to 6.0 which in medium range.

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