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MORPHOMETRIC ANALYSIS OF SINA WATERSHED IN MADHA TAHSIL, SOLAPUR DISTRICT, MAHARASHTRA.

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Abstract

Assessment of the morphometric parameters involves preparation of drainage networks maps ordering of the various streams, measurements of catchment area, perimeter, relative relief, and relief ratio, length of drainage channels, drainage density, drainage frequency, bifurcation ratio, texture ratio, circulatory ratio and constant channel maintainers which helps to understand the natures of the drainage properties of basin. Morphometric parameters could be used in many of the watershed based application like terrain analysis, delineations of geomorphological features, quantitative geomorphology, pedo-geomorphological studies, land degradation studies, watershed prioritization, calculating flow direction, calculating flow accumulation assessment of runoff and top soil loss, hydro geomorphology, estimate peaks runoff rate, delineation of groundwater potential zone, flood zone and mapping etc.

Remote sensing and geographical information systems (GIS) techniques are being effectively used in recent times in determining the quantitative description of basin geometry (Biswas et all, 1999; Ready et all, 2002; Vijith and Satheesh, 2006). The high resolution of remote sensing data couples with topographical data analysis procedure have made satellite data based morphometric analysis highly effective tool to understand and manage natural resources.

For the present study, systematic description of the geometry of a drainage basin and its stream channel system requires measurement of linear aspects and of drainage network, aerial aspects of the drainage basin and relief aspects of channel network. This type of study is known "Planimetry" which means measurement in a single plane

Keyword: *Morphometric analysis, Sina watershed, GIs, Remote sensing, Data management tool(DMT)*

1.Introduction

The drainage basin is the response slope, bedrock, lithology and climate of that region which determines the characteristics of basin. Hence quantities analysis and them inter relationship are important to support decision for various themes. The methods of quantitative analysis of drainage basin was developed by Horton and modified by staller in conventional means but recently geographic information system and satellite remote sensing is a complete tool to Analyse to update and to correlate the measurement with periodic changes. Therefore, the results are more realistic and the time consuming. This study is to evaluate the nature of the drainage basins and relationship with characters of the terrains and for deriving means to conserve and manage natural resources and combating natural hazards. The study is soused on lined, aerial and Relief aspects of the catchment area using geographic information system tools.

Remote sensing and geographical information systems (GIS) techniques are being effectively used in recent times in determining the quantitative description of basin geometry (Biswas et all, 1999; Ready et all, 2002; Vijith and Satheesh, 2006). The high resolution of remote sensing data couples with topographical data analysis procedure have made satellite data based morphometric analysis highly effective tool to understand and manage natural resources. The analysis of satellite data in conjunction with drainage morphometry improves the capability in delineation of geological and landform unit (Reddy and Maji, 2003).It also helps in identification of drainage channel which are attend by natural force or human induced activities. The generated geo-coded resource database at watershed level in geographic information system (GIS) provides an excellent mean of storing, retrieving and analysing spatial information.

2.Study Area:

Location and Accessibility: Madha Taluka is one of the 11 tehsils of Solapur District in the Indian state of Maharashtra. It belongs to Pune Division .It is located 70 KM towards NorthWest from district headquarters Solapur. This technique has been attempted in the present investigations in the Sina River Basin. The study area in Sina River Basin of Solapur district. The Survey of India (1:50,000) Toposheets number 47 0/5, 47 0/9, 47 N/8 and 47 N/12 provides the topographic coverage of the study area. The watershed area of Sina River Basin is 666.16 sq km.

Geology:

From the accompanying map showing the regional geological setting, it will be seen that the area includes Deccan trap lava flows and they have assumed a great importance in Indian stratigraphy because of the great variety of rock types, complex structural features. The study area shows the basaltic lava flows which represent the peripheral portions of the Deccan traps. They occupy the western, central and southern India. The traps are divided into three main divisions, viz, the upper, the middle and the lower with the inter – trapping beds at the base . They are generally composed of fine grained compact basalts which at places are vesicular and amygdaloidal, amygdales containing secondary minerals like zeolites and different from the silica. However, in some places the basaltic flows are intercalated with ash beds, volcanic breccia‟s and acid and intermediate differentiate like rhyolites and andesite, Deccan traps considered to be theolelitics plateau basalts.

3.Aim and Objectives

1. To determine different geomorphic and morphometric parameters of the basin.
2. To find out inter relationship between various parameters.
3. To assess the watershed characteristics of the study area.

4.Methodology and data used

Application of geographic Information system (GIS) in Geo morphometry:

The morphometric analysis is quantitatively done is the (ARC GIS 10.0) which is a powerful tool and it is advanced very easily measuring basin length, basin, area, automatic creating of drainage network, stream order, stream length, circular area of basin etc. Shows how to use in the creation of basin, delineation of drainage network, stream length, flow direction and stream orders. Using Arc GIS technique the work of mapping, statistics, analysis, displaying the data and output is done. In the process of morphometric analysis Arc GIS tools like analysis tools (AT), conversion tools (CT) data management tools (DMT), Geo statistical tools (GT) and spatial analysis tools (SAT) etc. are used. Using all the tools, morphometric analysis of Sina River Basin is carried out quantitatively using Arc GIS 10.0software.

4.1.Methodology:

i) Data Preparation:

The major goal of the study is to develop a viable methodology for producing geographic information system (GIS) data model for drainage morphometric analysis to discover holistic stream properties from the measurement of various stream attributes using Arc Gis software. The required necessary data sources for morphometric analysis were carried out through the use of survey of India (SOI) Toposheets of the area. The Toposheets were geometrically rectified and georeferenced by taking ground control points (GCPs) by using UTM projection and WGS 84 datum further, all the geocoded images were mosaic using ERDASimagine 2011 image processing software. After that digitization work has been carried out for entire analysis of the basin for morphometric analysis using Arc GIS10.0 software.

ii) Data analysis in geographic Information system (GIS):

The order was given to each stream by following Horton (1969) stream ordering technique. The parameters like the number and length of stream of each different orders, drainage area, basin perimeter and basin length were calculated using Arc GIS software (10.0). From the above parameters drainage density drainage frequency, shape, form factor, circulatory ratio, elongation ratio etc. we calculated. The methodology adopted for the compotation of morphometric parameters is given below. With the help of covers ion tools in the Arc tool box; the data is converted into raster to vector form. Coverage tools and personal geo database tools were used in the area to estimate stream length. Topology tool was used to edit he line errors like polygon, point and node of overlapping and gap for accuracy. With the help of data management tools projection and transformation was made by registering of raster image with satellite image and topographical map. After this process bifurcation ratio, form factor, elongation ratio, drainage density, drainage frequency, steam frequency and drainage texture were analysed. The drainage basin analysis was arried out quantitatively aspects wise such as linear aspects, aerial aspect and relief aspect. I the linear aspects, stream order stream length, bifurcation ratio, mean stream length, stream length ratio and mean stream length ratio were analysed. In aerial aspect Basin area, drainage density, drainage frequency, infiltration number, drainage texture, form factor ratio, elongation ratio, circulatory ratio was calculated. In relief aspects basin relief, relief ratio, dissection Index, channel gradient and basin slope were analysed. The method of calculation and the procedure involved in estimating each parameter is briefly descried.

iii) Data used:

Toposheets The study area in Sina River Basin of Solapur district. The Survey of India (1:50,000) Toposheets number 47 0/5, 47 0/9, 47 N/8 and 47 N/12 provides the topographic coverage of the study area. The watershed area of Sina River Basin is 666.16 sq km.

4.2.ANALYSIS AND INTERPRETATION

Morphometric analysis:

According to Clarke (1966), morphometry is the measurement and mathematical analysis of the configuration of the earth surface, shape and dimension of its landform. The morphometric analysis is carried out through measurement of linear, aerial and relief aspects of the basin and slope contribution. Linear Aspects:

Linear aspects of basin are related to the channel pattern of drainage network where in topological characteristics of stream segment are analysis. The drainage network which consist of all the segments of stream of a particular river, is reduced to the level of graphs, where stream junction acts a points (junction) become links or lines where in the number of all segment are counted their hierarchical order are determined, the length of all steam segments area measured and their different inter relationship are studied. Linear aspects include the measurement of linear features of drainage such as stream order, Mean stream length, stream length ratio, bifurcation ratio, mean bifurcation ratio, stream length, length of overland flow, basin parameter, basin length.

4.2.1.Stream order:

The first step in drainage basin analysis is designation of stream orders, following a system introduced into the United State by Hoston (1956) and slightly modified by strahler (1964) assuming that one has available drainage network map including all intermittent and permanent flow lines located in clearly defined villages, the smallest fingertip tributaries are designated as order 1 (fig). Where two first order channels join, a channel segment of order 2 is found and so forth. After the drainage network elements have been assigned their order numbers the segment of each order are Page 17 counted to yield the number Nu of segments of the given order u. The stream order is a measure of the degree of stream branching with in a basin. Earth length of streams indicated by its order.

Stream number:

The count of stream channel in its order is known as stream number. The number of stream segments decreases as the order increases. The higher amount stream order indicates lesser permeability and infiltration Stream number is directly proportional to size of contributing watershed to cannel dimensions. It is obvious that the number of stream of any given order will be fewer than for the net lower order but more numerous than for the next higher order. The number of stream decreases as the stream order increases. The stream number shows stream number usually decreased in geometric progression as the stream order increase. In the present study the order wise stream numbers estimated are given in the table no 1.

4.2.2.Stream lengths:

Mean stream length (Lsm) of a stream channel segments of order u is a dimensional property revealing the characteristics size of components of a drainage network and its contributing basin surfaces. Channel length is measured with the help of Arc GIS software directly from the stream order map. To obtain the mean stream length of channel (Lsm) of order u, the total length is divided by the number of streams segment Nu of that order; thus.

Lsm=Lu/Nu Where,

Lu= Total stream length of all orders

Nu= Total number of stream of all orders

The mean stream length is presented in table. It is seen that Lsm value exhibits variation from 0.64 to 1.99. It is observed that Lsm values of Sina River Basin indicate that Lsm of the given order is greater than that of the lower order stream length shows linear graph when plotted against stream order which shows stream number usually decreases in geometric progression as the stream order increases

4.2.3.Mean Stream Length:

According to Strahler (1964), the mean stream length is a characteristics property related to the drainage network and its associated surface. The mean stream length (Lsm) has been calculated by dividing the total stream length of order „u‟ and number of stream of segment of order „u‟. It is calculated by the formula

Mean Stream Length (Lsm) = Lu / Nu Where,

Lu = Total stream length of Order „u‟.

Nu = Total no. of stream segment of order „u‟.

4.2.4.Stream length ratio:

Stream length ratio (RL) is defined as the average length of stream of any order to the average length of stream of the next lower order and it is expressed as

RL= Lu/Lu-1

Where Lu= Total stream length of all orders

Lu-1= Total stream length of its next order.

The length ratio RL in the basin area is ranging from 0.37 to 0.52.

4.2.5.Bifurcation ratio:

The bifurcation ratio (Rb) is defined as the ratio of number of the stream segments of given order to the number of segments of the next higher order (scheme, 1956)It is calculated by Rb=Nu/Nu+1

Where Rb= Bifurcation ratio

Nu= Total number of streams of all order

Nu + 1= Number of segment of next higher order.

Strahler (1957) demonstrated that bifurcation ratio shows a small range of variation for different regions or for different environment except where the power full geological control dominates. Bifurcation ratio is mainly controlled by the basin shape and is not only influence the landscape and morphometry but also control the surface runoff.

4.2.6.Mean Bifurcation Ratio:

The mean bifurcation ratio may be defined as the average of bifurcation ratio of all orders and all sub – watershed fall under normal basin category (Strahler,1957).

Mean bifurcation Ratio (Rbm) = Average of bifurcation ratio of all order.

4.2.7.Length of overland flow:

The length of overland flow defined as "the mean horizontal length of flow path from the divide to the stream in a first order basin and is measure of stream spacing and degree of dissection and is approximately one half reciprocal of drainage density. It is one of the most important morphometric variables which affect the hydrological and topographical development of basin. It is calculated by the formula. Lg= ½ D.

Table no.1: Illustrates the calculation of Linear Aspects of drainage basin

Stream Order	Stream No. (Nu	Stream Length (Lu)	Mean Stream Length (Lsm)	Bifurcation Ratio	Stream Length Ratio	Mean Bifurcation Ratio (Rbm)	Length of Overland Flow
1	1117	745.81	0.66				
				3.91	0.37		
2	285	278.20	0.97				
				5.18	0.49		
3	55	136.81	2.48				
				5.00	0.52		
4	11	72.00	6.54			0.32	1.04
				3.66	0.49		
5	3	35.54	11.84				
				3.00	0.42		
6	1	15.07	15.07				
Total	1445	1283.47					

4.3.Aerial Aspect:

Arial aspects (Au) of a water shed of given order u is defined as the total area projected upon a horizontal plane contributing overland flow to the channel segment of the given order and includes all tributaries of lower order. Area of basin (A) and perimeter (p) are the most important parameters in quantitative morphology. The area of basin is defined as the total area projected upon a horizontal plane contributing to cumulate of all order of basins. Perimeter is the length of the boundary of the basin which can be drawn from topographical maps. The aerial aspects of the drainage basin such as drainage density (D), stream frequency (Fs), Drainage texture (Te) elongation ratio (Re), circulatory ratio (Rc), form factor ratio (Rf). Infiltration number were calculated and results have been given in table no 5.

Table no.2 Illustrates the Areal Aspects and formula

1	Basin Area (A)	Area from which water drains to a common stream and boundary determined by opposite ridges.
2	Drainage Density (Dd).	Dd = Lμ / A Where , Lμ = Total stream length of all orders. A = Area of the basin
3	Drainage Frequency (Fs)	Fs = Nμ / A Where , Nμ = Total no of streams of all orders. A = Area of basin.
4	Infiltration Number (If)	If = Dd * Fs Where, Dd = Drainage Density. Fs = Drainage Frequency
5	Drainage Texture (Dt)	Dt = Nμ / P Where , Nμ = No. of streams in a given order. P = Perimeter
6	Form Factor Ratio (Rf)	Rf = A / Lb Where , A = Area of basin. Lb = Length of basin.
7	Elongation Ratio (Re)	Re = √A / π / Lb Where , A = Area of Basin. Lb = Basin Length.
8	Circulatory Ratio (Rc)	Rc = 4πA / P2 Where, A = Area of Basin. P = Perimeter.

4.3.1.Drainage Density:

Horton (1932), introduced the drainage density (D) is an important indicator of the linear scale of land form element in stream eroded topography. It is the ratio of total channel segment length cumulated for all orders within a basin area, which is unpressed in term of 1.92 km sq. Km. It is expressed as,

Dd=Lu/A Where,

Dd= drainage density

Lu= Total stream length of all orders

A= Area of basin (km2)

The drainage density indicates the closeness of spacing of channels, thus providing quantitative measures of the average length of stream channel for the whole basin. If has been observed from drainage density measurement made over a wide range of geologic and climatic types that a low drainage density is more likely to occur in region of highly resistant of highly permeable subsoil material under dense vegetative cover and where relief is low. High drainage density is the resultant of weak or impermeable sub surface material, sparse vegetation and mountain relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture (strahaler 1964). Drainage density is controlled by the type of formation in basin areas with impervious formation will have higher drainage density than those with pervious formations (Gokhle, 2005). In the study area Drainage density is 1.92.The drainage density is governed by the factor like rock type, run off intensity, soil type, infiltration capacity and percentage of rocky area.

4.3.2.Drainage Frequency:

Horton (1932) introduced stream frequency (Fs) and it is defined as stream frequency which is the total number of stream segments of all orders per unit area. It can be expressed as

Fs = Nu / A

Where Fs = Stream Frequency

Nu = Total number of streams of all orders.

A = Area of Basin (Sq.km)

Hopefully, it is possible to have basins of some drainage density inconsistent stream frequency and basin of the same stream frequency differing in drainage density. The stream frequency of the study area is 2.16.

4.3.3.Drainage pattern:

In the watershed, the drainage pattern reflects the influence of slope, lithology and structure. Finally, the study of drainage pattern presents some characteristic of drainage basins through drainage pattern and drainage texture. It is possible to deduce the geology of the basin, the strike and dip of depositional rocks, existence of faults and other information about geological structure from drainage patterns. Drainage texture reflects climate, permeability of rocks, vegetation and relief ratio etc. The dendritic drainage pattern of the study area.

4.3.4.Drainage Texture:

Drainage texture is also classified on the basis of density of analysis or texture. Drainage texture is the product of drainage density and stream frequency (Horton) 1945). It is expressed the same as drainage and classification is given below. High relief ratio brings high discharge of surface water in a short duration. Small relief ratio indicates the erosional development of the drainage basin. The value of drainage texture of the study area is 9.15and it shows the very worse grain drainage texture. The high value of drainage texture and lower value of Drainage density (1.92) indicates the presence of highly resistant permeable material with moderate to high relief.

Form Factor:

Form factor may be defined as the ratio of the area of the basin and square of basin length (Horton, 1932) . It can be formulated by

Rf = A / L

Where Rf = Form Factor

L = Total length of basin.

A = Area of basin.

The value of form factor would always be greater than 0.68 for perfectly circular basin. Smaller the value of form factor, more elongated will be the basin. The form factor of the study area is 0.24

4.3.5.Elongation Ratio:

Elongation ratio is the ratio of diameter of the circle of the same areas in the basin to the maximum basin length. It is expressed as

Re = 2 √ Aπ / Lb

Where Re = Elongation ratio.

A = Area of basin.

Lb = Basin length.

The elongation ratio of the study area is 8.05 and it generally shows the highly elongated shape. A circular basin is more efficient in the discharge of the run-off than an elongated basin (Singh and Singh, 1997).

4.3.6.Circulatory Ratio:

The circulatory ratio is mainly concerned with the length and frequency of stream, geological structure, land use / land cover, climate, relief and slope of basin. It is the ratio of the area of the basins to the area of circle having the same circumference as the parameter of the basin (Miller, 1953).

It can be expressed as

Rc = 4π A / P2

Where Rc = Circulatory Ratio.

A = Area of basin.

P = Perimeter of basin.

It is the significant ratio which indicates the stage of dissection in the study region. Its low, medium and high value is correlated with youth, mature and old stage of the cycle of the tributary watershed of the region and the value obtained. The circulatory ratio of the study area is 0.3

Table no.3: Illustrates the calculation of Areal Aspects of drainage basin

Sr .No	Morphometric Parameter	Symbols and Formulas	Results of the study Area
1	Basin Area (sq.km)	A	666.16
2	Basin Perimeter (km)	P	157.89
3	Drainage Density	Dd = Lu /A	1.92
4	Drainage Frequency	Fs = N / A	2.16
5	Infiltration Number	Dd * Fs	4.14
6	Drainage Texture	∑ Nu / P	9.15
7	Form Factor Ratio	Rf = A / (Lb)	2 0.24
8	Elongation Ratio	Re = 2√ (A / π) / Lb	8.05
9	Circulatory Ratio	Rc = 4πA / P2	0.33

5. Conclusion

The study reveals that Topo sheet data and GIS based approach in evaluation of drainage morphometric parameters and their influence on landforms, drainage characteristics at river basin level is more appropriate than the conventional methods. GIS based approach facilitates analysis of different morphometric parameters and to explore the relationship between the drainage morphometry and properties of landforms.

The morphometric analysis of the drainage network of the watershed show dendritic drainage texture. The bifurcation ratio in the watershed indicates normal watershed category and the presence of moderate drainage density suggesting that it has moderate permeable sub-soil, and coarse drainage texture. The value of form factor and circulator ration suggests that Sina River Basin is less elongated.

The drainage densities calculated for whole basin is 1.92 indicate that probability of branching. The variation of bifurcation ratio within the successive phase of drainage order could due to change irregularly and variation in a change of stream network and structural control of the basin.

GIS study allows consistent most accurate and most updated database on land resources. It has also been very useful in deriving geo morphometric parameters. In the present study GIS software are used to preparation of Base map & Drainage map of Sina River Basin.

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