Morphometric analysis using remote sensing and GIS technologies in the Vangira Watershed, Solapur Region, Maharashtra, India

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ABSTRACT

Morphometry is the dimension and mathematical estimation of earth's surface, form and the measurement of the landforms. The study of morphometric analysis tied with remote sensing and Geographical Information System techniques assess different precious parameters for the watershed improvement plan of severely drought prone vangira watershed (75^0 42' to 75^0 55'E and 17^0 48' to 17^0 56'N) of Solapur district. The area shows a dendritic drainage pattern which is characteristic of a massive hard rock terrain. The basin is indicated by values of form factor, circulatory ratio, elongation ratio, mean bifurcation ratio, drainage density and drainage texture of the catchment area. The present research work revealed the Linear aspects including the measurement of linear features of drainage such as stream order, stream length, Mean stream length, stream length ratio, bifurcation ratio, mean bifurcation ratio, length of overland flow, basin perimeter, basin length. The areal aspects such as Basin Area (A), Drainage Density (D_d), Drainage Frequency (F_s), Infiltration Number (I_f), Drainage Texture (D_t), Form Factor Ratio (R_f), Elongation Ratio (R_e) and Circulatory Ratio (R_c) were studied. The relief aspects such as Basin Relief (H), Relief Ratio (R_f), Channel Gradient (C_g), Basin Slope (S_b) etc. were also studied. The study will be supportive to understand hydrological behaviour of the basin and water storage purpose of the society.

Keywords: Morphometric analysis, watershed, RS and GIS, drought.

INTRODUCTION

Water is known as the liquid for sustenance of life. All living beings are depending on water, without which no life exists on the earth. Earth has plentiful water due to the presence of Hydrological Cycle on it, but most of it is unfit for living beings use and consumption. The study of the watershed morphometric analysis provides the beneficial parameters for the assessment of the ground water potential zones, identification of sites for water harvesting structures, water resource management, runoff and geographic characteristics of the drainage system. The morphometry is related to quantitative measurement and generalization of land surface geometry. In geomorphology 'morphometry may be defined as the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimensions of its landforms' (Clarke, 1966).The Morphometric analysis consists of linear, aerial and relief aspects. For the present study Remote Sensing and Geographical Information System (GIS) tools are used for managing and analyzing the spatially distributed information. The present research work was undertaken to describe the drainage, topography over drainage shape, area, shape perimeter, drainage streams, stream length, and Stream hierarchy-network etc. by using the morphometric analysis or quantitative analysis. It is used to minimize the watershed related issues and depictions of the watershed topography. So this study would help to better plan ultimate for land use/land cover, agricultural practices.

Study area

Study area lies between latitude17^0 48' to 17^0 56'N and longitude 75^0 42' to 75^0 55'E (Fig.1).Rainfall all over the district is uncertain and scanty with an annual average of 625 mm. The geology of study area is characterized by the Deccan volcanic basalts. Ground water in Deccan Traps mostly occurs in the weathered and fractured parts down to 10-15m depth (CGWB, 2013).

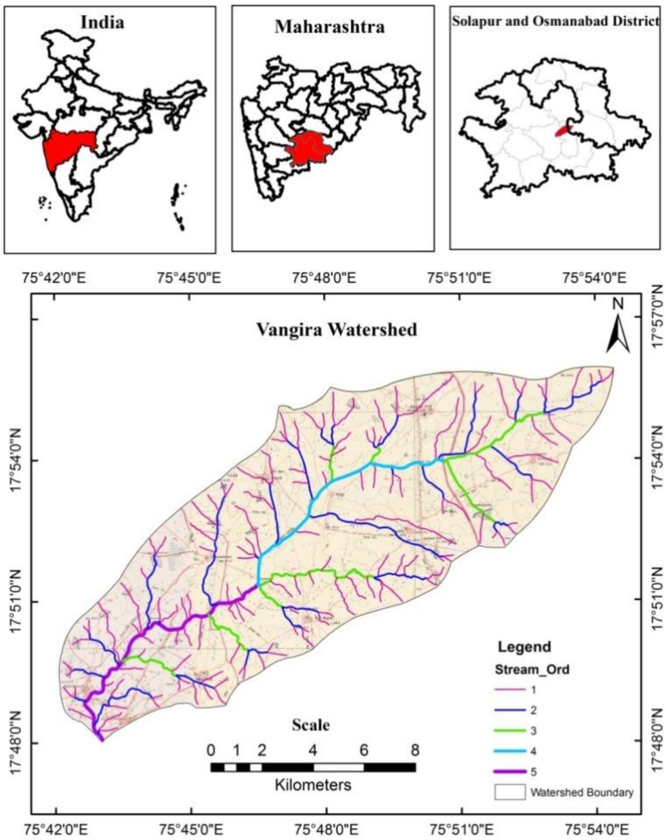

Fig 1: Location map of the Study area

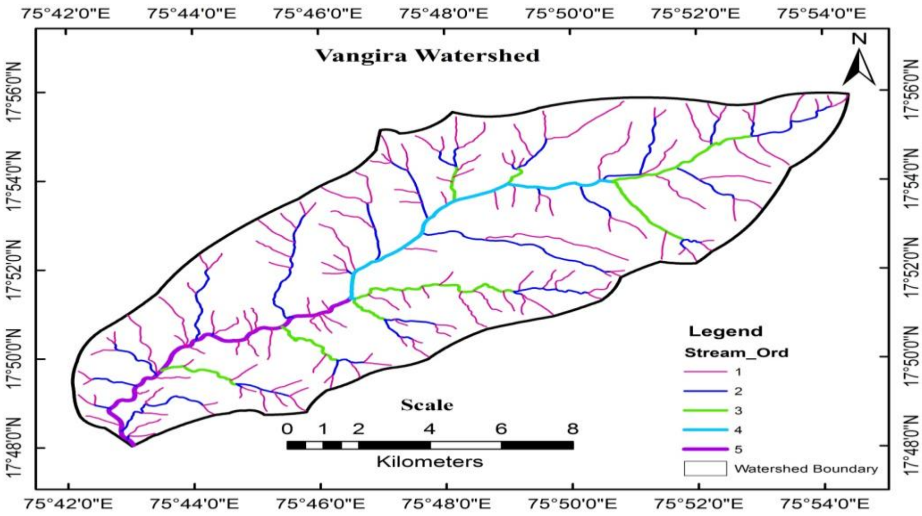

Fig 2: Drainage Map of the Study area

METHODOLOGY

Morphometric analysis is considered the best method for isolation of problem through which precise descriptions of the geometry of landforms could be harnessed as data could be collected, organized, analysed and visualized using remote sensing integrated with GIS techniques to resolve the given application complexity. The drainage map was prepared using SOI toposheet number 47O/9 and 47O/13 on 1:50,000 scale. The Topomaps were scanned and projected for delineating the required features. The Digitized maps were updated with the help of satellite imagery using ArcGIS software. In the present study area dendrite drainage pattern was present (Fig 2).

DATABASE AND METHODOLOGY

Morphometric analysis, which is all about exploring the mathematical relationships between various stream attributes, used to compare streams and to identify factors that may be causing differences. The term Morphometry is derived from a Greek word, where “morpho” means earth and “metry” means measurement, so together it is measurement of earth features. This is an important factor for planning any watershed development. Morphometric analysis also provides description of physical characteristics of the watershed which are useful for environmental studies, such as in the areas of land use planning, terrain elevation, soil conservation and soil erosion. Morphometric analysis for the present study was grouped into three classes such as linear aspects, areal aspects and relief aspects (Table 2).

Linear Aspects: Linear aspects contain the measurements of linear featuresof drainage such as stream order, stream length, stream length ratio, length of overland flow, bifurcation ratio, etc. The linear characteristics of the drainage basin are discussed below.

Stream orders: The first step in drainage basin analysis is designation of stream orders, following a system introduced into the United States by Horton (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 valleys, the smallest fingertip tributaries were designated 1storder (Fig. 2) where two first order channels join, a channel segment of order 2nd was found and where two of order two joins, segment of order 3rd was formed and so forth. The trunk stream through which all discharge of water and sediment passes is therefore the stream segment of highest order. Usefulness of the stream order system depends on the premise that, on the average, if a sufficiently large sample is treated, order number is directly proportional to size of the contributing watershed, to channel dimensions and to stream discharge at that place in the system. Because order number is dimensionless, two drainage networks differing greatly in linear scale can be compared with respect to corresponding points in their geometry through use of order number. After the drainage network elements have been assigned their order numbers, the segments of each order are counted to yield the number *Nu* of segments of the given order *u*.

Bifurcation Ratio: 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 the next higher order (Schumn, 1956). The bifurcation ratio, for a given density of drainage lines, is very much controlled by basin shape and shows a very little variation in homogeneous bedrock from one area to another (Chorley et al., 1984). The bifurcation ratio will not be precisely the same from one order to the next because of the possibility of variations in basin geometry and the lithology, but tends to be a constant throughout the series. 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). The lower bifurcation ratio values are characteristics of the watershed, which has suffered less structural disturbances and the drainage pattern has not been distorted by the structural disturbances. The bifurcation ratio is also indicative of shape of the basin (Table 1).

Constant Channel Maintenance ©: It is the inverse of drainage density as a property to define term constant channel maintenance (Schumn, 1956). It defines the number of sq. ft of a watershed surface required to sustain one liner feet of channel. The value of C for the study area was 0.68 (Table 2). Thus the SWS were under the influence of high structural disturbance, low permeability, steep to very steep slope and high surface runoff.

Relief aspect: Relief is the elevation difference between the highest and lowest point on the valley floor of the region. The relief measurements like relief ratio, basin length and total relief have been carried out

Relief ratio: The maximum relief to horizontal distance along the longest dimension of the basin parallel to the principle drainage line is termed as relief ratio (Schumn, 1956). Relief ratio has direct relation between the relief and channel gradient. The relief ratio normally increases with decreasing drainage area and size of the watersheds of a given drainage basin (Gottschalk, 1964). In the study area, the value of relief ratio is 2.43(Table 2).

Aerial aspects: Aerial aspects include different morphometric parameters, like drainage density, texture ratio, stream frequency, form factor, circulatory ratio, elongation ratio and length of the overland flow. The values of these parameters are presented in Table 2 and interpreted below.

Drainage Area (Au): The entire area drained by streams or by streams pattern in such way that all streams flow originating in the area is discharged through a single outlet is termed as the Drainage Area. The given study, an area considered for work was measured to be 152.4 square km.

Drainage density (Dd): It is measured as a sum of the channel lengths per unit area and obtained by dividing the total stream length by total area of the basin. Drainage density is controlled by the type of formations in the basin areas with impervious formations will have higher drainage density than those with pervious formations (Manjare et al., 2014). In an area with high precipitation, the run-off results in more surface drainage channels. So the amount of precipitation along with vegetation & rainfall absorption capacity of soils influences the rate of surface run-off affecting the drainage texture of an area. In general low drainage density is favoured in regions of high resistant or highly permeable sub soil materials, under dense vegetation cover and where relief is low. High drainage density is favoured in regions of weak or impermeable surface materials, sparse vegetation, and mountainous relief. The drainage density is governed by the factors like rock type, run off intensity, soil type, infiltration capacity and percentage of rocky area. The drainage density in watershed of the study area is 1.45per km^2

Stream frequency /Channel frequency: The total number of stream segments of all orders per unit area is known as stream frequency (Horton, 1932). It is noted Fs value of the basin of the study area is 1.19**(**Table 2). It is also seen that the drainage density values of the sub-basins exhibits +ve correlation with the stream frequency suggesting that there is an increase in stream population with respect to increasing drainage density.

Table 1: Drainage Basin Morphometry Worksheet of the Vangira Watershed.

Sr.No.	Variable	Vangira Watershed
1	Area (km^2)	152.4
2	Perimeter Length (km)	57.98
3	Gradient (longest path)	29.45
4	Drainage Pattern (Name)	Dendritic
5	Number of 1st Order Streams (no.)	138
6	Number of 2nd Order Streams (no.)	33
7	Number of 3rd Order Streams (no.)	8
8	Number of 4th Order Streams (no.)	2
9	Number of 5th Order Streams (no.)	1
10	Order of Master Stream	5
11	Length of 1st Order Streams (km)	126.02
12	Length of 2nd Order Streams (km)	52.30
13	Length of 3rd Order Streams (km)	22.05
14	Length of 4th Order Streams (km)	10.11
15	Length of 5th Order Streams (km)	11.15
16	Sum of all Stream Lengths (km)	221.63
17	2nd Order Bifurcation Ratio (No.1st/No.2nd)	4.06
18	3rd Order Bifurcation Ratio (No.2nd/No.3rd)	3.67
19	4th Order Bifurcation Ratio (No.3rd/No.4th)	2.67
20	5th Order Bifurcation Ratio (No.4th/No.5th)	1
21	Mean of Bifurcation Ratio	2.84

Drainage texture: It is the total number of stream sequence of all orders per perimeter of that area (Horton, 1945). It is one of the important concepts of Geomorphology which means that the relative spacing of drainage lines are numerous over impermeable areas than permeable areas. According to Horton (1945), infiltration capacity as the single important factor which influences drainage texture & considered drainage texture which includes drainage density & stream frequency. The value of drainage texture ratio of study area is 3.13 (Table 2). According to Smith (1950) there are five different classes of drainage texture based on drainage density. The drainage density less than 2 indicates very coarse, between 2 & 4 is related to coarse, between 4 & 6 is moderate, between 6 7 8 is fine whereas above 8 is referred as very fine drainage texture. Watershed coarse drainage texture indicating softer & more permeable rock formation.

Form factor: Form factor may be defined as the ratio of the area of the basin and square of basin length (Horton, 1932). The value of form factor would always be greater than 0.78 for a perfectly circular basin. Smaller the value of form factor, more elongated will be the basin. Rf values of the study area is 0.25 . The values in the watersheds indicated that they were elongated to sub-circular in shape.

Circulatory ratio: The circularity ratio is mainly concerned with the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin. It is the ratio of the area of the basins to the area of circle having the same circumference as the perimeter of the basin. In the study area, the Re value is 0.56 **(**Table 2). The watershed is elongated to sub circular in shape.

Elongation ratio: The elongation ratio values generally exhibit variation from 0.6 to 1.0 over a wide variety of climatic and geologic types. Values close to 1.0 are typical of regions of very low relief, whereas values in the range 0.6–0.8 are usually associated with high relief. In case of watershed the value considerably below 0.6 indicating very high relief. Elongation ratio is the ratio between the diameter of the circle of the same area as the drainage basin arid the maximum length of the basin. The elongation ratio value of the watershed is 0.57, indicated very high relief (Table 2).

Length of overland flow: The length of overland flow (Lg) approximately equals to half of reciprocal of drainage density (Horton, 1945). It is the length of water over the ground before it gets concentrated into definite stream channels.

This factor basically relates inversely to the average slope of the channel and is quite synonymous with the length of the sheet flow to the large degree. The Lg value of the study area is 0.73(Table 5). The values of Lg are low in all watersheds indicating overall high relief in area.

Table 2: Morphometric Parameters with formulae of the Vangira Watershed.

Sr. No.	Morphometric Parameters	Symbol/Formula	Observed Values	Reference
1		**Linear Aspects**		
1.1	Basin Perimeter (Km)	P	57.98	Schumn (1956)
1.2	Basin Length (Km)	Lb	24.74	Schumn (1956)
1.3	Main Channel Length (Kms)	CI	29.45	Strahler (1964)
1.4	Length of Overland Flow	Lg = 0.5*Dd	0.73	Horton (1945)
1.5	Bifurcation Ratio	Rb = Nμ / Nμ +1	2.27	Schumn (1956)
1.6	Mean Bifurcation Ratio	Rbm = Average of bifurcation ratios of all orders	2.84	Strahler& Chow (1964)
1.7	Constant Channel Maintenance	C=1/Dd	0.68	Schumn (1956)
2		**Areal Aspects**		
2.1	Basin Area (Km^2)	A	152.4	Strahler& Chow (1964)
2.2	Stream Frequency	fs = Nu/A	1.19	Horton (1932)
2.3	Drainage Density	Dd = Lu/A	1.45	Horton (1932)
2.4	Drainage Texture	Dt = Nu/P	3.13	Horton (1945)
2.5	Infiltration Number	If = Fs * Dd	1.74	Zavoiance (1985)
2.6	Form Factor Ratio	Rf = A/(Lb*Lb)	0.25	Horton(1945)
2.7	Circularity Ratio	Rc = 12.57*(A/P2)	0.57	Miller (1953)
2.8	Elongation Ratio	$Ra = (2/Lb)*(A/\Pi)^{0.5}$	0.56	Schumn (1956)
3		**Relief Aspects**		
3.1	Basin Relief	H = Z-z	60.00	Rudraiah et al. (2008)
3.2	Relief Ratio	Rf = H/Lb	2.43	Schumn (1956)
3.3	Basin Slope	sb = H/Lb	2.43	Miller (1953)

CONCLUSION

The drainage morphometric analysis of the study area reveals that the watershed can be characterized by elongation ratio, circulatory ratio and form factor. The result shows that the characterization of drainage on the basis of the parameters values. The few parameter values are considered here those are as a elongation ratio was 0.56which defines that the watershed is strongly elongated, circularity ratio was observed to be 0.57, it is also a evidence as strongly elongated watershed and again form factor also observed 0.25, this also indicate that it is elongated in shape and bifurcation ratio observed 2.84it indicate that the region is in flat in the landscape (shape). It inferences the flat region and elongated drainage basins with low form factor has a lower subsequent flow of larger durations. Generally the watershed topography formed due to rainfall, Slope and aspect so the watersheds have an infinite variety of shapes and the shape supposedly reflects the way that runoff will bunch up at the outlet. So the evaluated and analysed morphometric parameters such as area, length, stream pattern, flow direction, and perimeters all these are reflect the shape and topography of the given watershed. The scope of research work focuses on the management of Natural resources used in water conservation, such as primarily watershed evaluation, its characterization and drainage development etc. to avoid drought affected area for better agricultural practices.

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