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MORPHOMETRIC ANALYSIS: A CASE STUDY OF HIRANYAKESHI WATERSHED, BELAGAVI KARNATAKA

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ABSTRACT: In this present study, remote sensing and GIS techniques have been used to update drainage and surface water sources, evaluate linear, relief and aerial morphometric parameters and prioritize the watersheds of the Hiranyakeshi watershed Belagavi district Karnataka. A detailed study used SRTM data (from the USUS website) and Topographical maps for preparing digital elevation models (DEM) and GIS is used in the evaluation of morphometric parameters. Quantitative Morphometric analysis has been carried out for the Hiranyakeshi watershed. In this paper, there are 10 morphometric parameters computed for linear aspects. The drainage density of the watershed is 3.78 km/km2. This indicates the fine presence of permeable subsurface formation. This study will help people to utilize resources for sustainable development of the watershed and it will be useful for planning rainwater harvesting, soil and water conservation measures, watershed management and development.

Key words: - Remote sensing and GIS, Hiranyakeshi watershed, Morphometric Analysis..

INTRODUCTION :

Morphometric analysis requires measurement of linear features, gradient of channel network and contributing ground slopes of the drainage basin. 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). Most previous morphometric analysis are based on arbitrary areas or individual channel segments. Using watershed as a basic unit in morphometric analysis is the most logical choice. In fact, they are the fundamental units of the fluvial landscape and a great amount of research has focused on their geometric characteristics, including the topology of the stream networks and quantitative description of drainage texture, pattern and shape. The morphometric characteristics at the watershed scale may contain important information regarding its formation and development because all hydrologic and geomorphic processes occur within the watershed (Singh, 1992).

Morphometry is the measurement and mathematical analysis of configuration of the earth surface, shape and dimensions of its landforms (Clarke, 1973). 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. Morphometric analysis provides quantitative description of the basin geometry to understand initial slope or inequalities in the rock hardness, structural controls, geological and geomorphic history of drainage basin (Strahler, 1964). The goal of the study is to establish quantitative, rather than qualitative relationships between geomorphic processes and landforms.

The quantitative analysis of morphometric parameters is found to be of immense utility in river basin evaluation, watershed prioritization for soil and water conservation and natural resources management at watershed level. 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). The influence of drainage morphometry is very significant in understanding the landform processes, soil physical properties and erosional characteristics. Drainage characteristics of many river basins and sub basins in different parts of the globe have been studied using conventional methods (Horton, 1945; Strahler, 1957, 1964). Geographical Information System (GIS) techniques are now a days used for assessing various terrain and morphometric parameters of the drainage basins and watersheds, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information. In the present study, stream number, stream order, frequency, density and bifurcation ratio are derived and tabulated on the basis of areal and linear properties of drainage channels using GIS based on drainage lines as represented over the topographical maps (scale 1:50,000).

The quantitative morphometric analysis of the drainage basin is considered to be the most satisfactory method because it enables us:

i. to understand the relationship between different aspects of the drainage pattern of the same drainage basin;

ii. for comparative evaluation of different drainage basins developed in various geologic and climatic regimes and

iii. to define certain useful parameters of drainage basins in numerical terms.

RS and GIS techniques have already been used for assessing various terrain and morphometric parameters of the drainage basins and watersheds, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information particularly for the feature identification and the extraction of information for better understanding. In the present study, the GIS analysis techniques are used to evaluate linear, relief and aerial morphometric parameters of the watersheds for the future developmental planning of the area.

One of the advantages of the quantitative analysis is that many of the watershed parameters derived are in the form of ratios or dimensionless numbers, thus providing an effective comparison irrespective of scale (Ravikumar 2001). The morphometric analysis of a watershed is the measurement of linear aspects of the drainage network and areal aspects of the watershed.

STUDY AREA:

The study area is the Hiranyakeshi watershed situated in Belagavi district lies geographically between $74^0$27’ to $76^0$37’ East longitude and $16^0$3’ to $16^0$13’ North latitude with a watershed area of 478.15.km2. Relief from 608m to 913m (As per CARTODEM).Fig.1 shows the location map of the study area delineated based on topography and drainage pattern to understand the hydrological process of the basin. The drainage pattern is coarse texture and dendritic drainage pattern at the watershed level. The annual average rainfall of the area is 758mm. The principal soil types are Shallow to very deep black soils, Red loamy soils, Lateritic soils. For the delineation of the watershed for the study area for hypsometric analysis, CARTODEM with 30m resolution (www.bhuvan.nrsc.gov.in) is delineated using ArcGIS Software.

METHODOLOGY:

The base map of the study area is prepared from SOI Toposheets. The drainages are delineated from using CARTODEM Data. The drainage map of the study area is shown in Fig no 2. The morphometric parameters are calculated using standard methods. The basic parameters like watershed area, stream length, stream number and basin length are calculated in the GIS platform. The applied parameters are calculated using standard formulae (Table 1). The spatial distribution of selected morphometric parameters is prepared using the GIS tool.

RESULTS AND DISCUSSIONS :

Basic Parameters: The basic are discussed below.

Area (A): The area of each micro-watershed was measured. The total area of the watershed is 478.15km2.

Perimeter (P): It is the total length of the drainage basin boundary. The perimeter of watershed is 122Km.

The Basin Length (L): It is maximum length of the basin measured parallel to the main stream. The basin length of watersheds is 23.78Km.

Stream Order (Nu): Stream order is assigned based on a hierarchical ranking of streams. The Strahler's method was applied for stream ordering. The 323 first order, 154 second order, 83 third order, 37 four fourth order, 1 fifth order streams, 1 sixth order streams order, total 599 streams are observed in the watershed.

Stream Length (Lu): The number of drainages of different stream orders in a micro-watershed was counted and their lengths were measured. The 273.39 of first order, 118.72Km of second order, 60.60Km of third order, 25.42Km of fourth order, 26.48Km of fifth order, 2.48Km of sixth order, total 507.09Km length of streams are observed in watershed.

Derived Parameters: The derived morphometric parameters are computed through standard methods (Table No: 2) and are discussed below.

Linear Parameters :

Bifurcation Ratio (Rbm): Bifurcation ratio (Rb) is the ratio of the number of streams of a given order to the number of streams of the next higher order (Schumm 1956). Rbm suggests the complexity and degree of dissection of a drainage basin. The bifurcation ratio of the watershed is 4.952.

Stream Frequency (Fs): It is the total number of stream segments of all order per unit area (Horton 1932). The stream frequency of the watershed is 1.25. Stream frequency is inversely related to permeability, infiltration capacity and directly related to the relief of watersheds.

Texture Ratio (T): The drainage texture is the total number of drainages of all orders per perimeter of that watershed (Horton, 1945). It depends on climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development of a basin (Smith, 1954). The drainage texture of the watershed is 2.64.

Shape Parameters

Circulatory Ratio (Rc): Circularity ratio is the ratio of the area of the basin to the area of the circle having the same circumference as the perimeter of the basin (Miller 1953, Strahler 1964).It is mainly concerned with the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin (Rudraiah et al. 2008). The Rc of the watershed is 0.274. Higher Rc is indicative of circular shape of the watershed and of the moderate to high relief and permeable surface (Sadaf et al. 2014).

Form Factor (Rf): It is be defined as the ratio of basin area to square of the basin length (Horton 1932). The higher values of form factors have high peak flows of shorter duration and low values of form factor have lower peak flow for shorter duration. The Form factor of the watershed is 0.48.

Elongation Ratio (Re): Schumn (1956) defined Re as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. The watersheds show lower Re values which are high susceptible to erosion and higher values are indicative of high infiltration capacity and low runoff. Generally it varies from 0.6 to 1.0 depends upon climate and geology. The elongation ratio of the watershed is 2.871.

Compactness Coefficient (Cc): This is expressed as a ratio between the length of the drainage basin boundary (the perimeter) and the perimeter of a circle with the same area. The Compactness Coefficient of a watershed directly related to the infiltration capacity of the watershed (Sadaf et al. 2014). The Cc of the watershed is 0.051.

Relief Parameters

Relief (Z): The elevation difference between the highest and lowest points on the valley floor of a watershed is known as the total relief of that watershed. There is direct relationship between the relief and channel gradient and also a correlation between hydrological characteristics and the relief ratio of a drainage basin (Schumn, 1956).

Drainage density (D_d): Drainage density *(D_d)* is one of the important indications of the linear scale of landform elements in stream eroded topography. It is defined as the total stream length to the total area of watershed. The drainage density is expressed as km/Sq.km. It gives the mean length of the stream per unit area of the watershed. Drainage density varies inversely with the length of the overland flow, and therefore, it provides the indication of the drainage efficiency of the watershed. Drainage density is mathematically expressed as;

$$Drainage\ \text{density}(D_d) = \frac{\text{Total length of all streams in the watershed (km.)}}{Area\ \text{of the watershed (sq. km.)}}$$

where,

D_d= Drainage density (km/sq.km)

ΣL_u= total stream length of all orders (km)

A = area of watershed (sq.km)

The drainage density indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole basin. The lower value of drainage density influences greater infiltration and hence the wells in this region will have good water potential leading to higher specific capacity of wells. In the areas of higher drainage density the infiltration is less and surface runoff is more. The drainage density can also indirectly indicated groundwater potential of an area, due to its surface runoff and permeability.

CONCLUSION:

The present study demonstrates the effectiveness of RS and GIS technology in scientific decision-making in watershed management. According to the results of watershed falls under the high erosion category. The watershed shows a dendrite drainage pattern with a moderate drainage texture. Low bifurcation ratios indicate a normal basin category. Immediate soil conservatory measures are required for these watersheds. It will help the planners and administrators to construct water harvesting structures in this region. The present conceptual approach adopted in sustainable development planning is expected to provide a model methodology for other watersheds having similar topographical conditions.

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Table No 1: Morphometric Parameters of Hiranyakeshi watershed

Sl No.	Morphometric Parameter	Formula	References
1. 3	Bifurcation ratio (Rb)	Rb = Nu / (Nu + 1) Nu = Total no. of stream segments of order 'u'	Schumn (1956)
2. 4	Drainage density (Dd)	D = Σ Lu / A Σ Lu = Total stream length of all orders A = Area of the basin (km2)	Horton (1932)
3. 5	Stream frequency (Fs)	Fs = Σ Nu / A Σ Nu = Total number of streams of all orders	Horton (1932)
4. 6	Texture ratio (T)	T = Σ Nu /P Σ Nu = Total number of streams of all orders P= Perimeter of the basin	Horton (1945)
5. 7	Circularity ratio (Rc)	Rc = 4*π *A/P2 Where, Rc = Circularity ratio; π = 'Pi ' value i.e. 3.14;	Miller (1953)
6. 8	Form factor (Ff)	Ff = A/Lb2 Lb2= Square of the basin length	Horton (1932)
7. 9	Elongation Ratio (Re)	Re = 2 v (A / Pi) / Lb Where, Re = Elongation Ratio	Schumn (1956)
8. 10	Compactness Coefficient (Cc)	Cc= 0.2821 P/A	Gravelius (1914)

Table No 2: Linear aspects of Hiranyakeshi watershed

Streams	Stream order (NU) stream segment.	Stream Length (LU) km	Log of stream Segment (Nu)	Log of stream length(lu)	Mean stream length (Lsm) Lsm=Lu/Nu	Stream length ratio (RL) RL= Lu / Lu-1	Bifurcation Ratio (Rb = Nu / (Nu+1)	Cumulative Length (km)	Mean length Ratio	Drainage density (Dd) Dd=L/A (sqkm)
1	323	273.39	2.509	2.437	0.846	1.696	0.997	273.39	0	1.06
2	154	118.72	2.188	2.075	0.771	1.931	0.994	392.11	0.911	
3	83	60.6	1.919	1.782	0.73	2.278	0.988	452.71	0.947	
4	37	25.42	1.568	1.405	0.687	3.468	0.974	478.13	0.941	
5	1	26.48	0	1.423	26.48	3.365	0.5	504.61	38.538	
6	1	2.48	0	0.394	2.475	-0.649	0.5	507.09	0.093	
	599	507.09				12.088	4.952			

Table No: 3 Drainage density for different textures.

Drainage density (km/Sq. km)	Textures
< 1.24	Very coarse
1.24-2.49	Coarse
2.49-3.73	Moderate
3.73-4.97	Fine
> 4.97	Very fine

Table.3: Result of morphometric analysis

Sl. No.	Parameters	Unit	Values (Hiranyakeshi Watershed)
1	Area	sq.km	478.15
2	Perimeter	km	122
3	Length of watershed	km	23.78
4	Width of watershed	km	26.56
5	Total no of segments	No.	599
6	Total length of stream segments	km	507.09
8	Highest order of stream	No.	6
9	Bifurcation ratio	---	4.952
10	Drainage density	km/sq km	1.06
11	Stream frequency	No./ km	1.25
12	Texture ratio	---	2.64
13	Circularity ratio	---	0.274
14	Form factor	---	0.48
15	Elongation ratio	---	2.871
16	Compactness coefficient	---	0.051

Fig no 1: Study Area map of Hiranyakeshi watershed

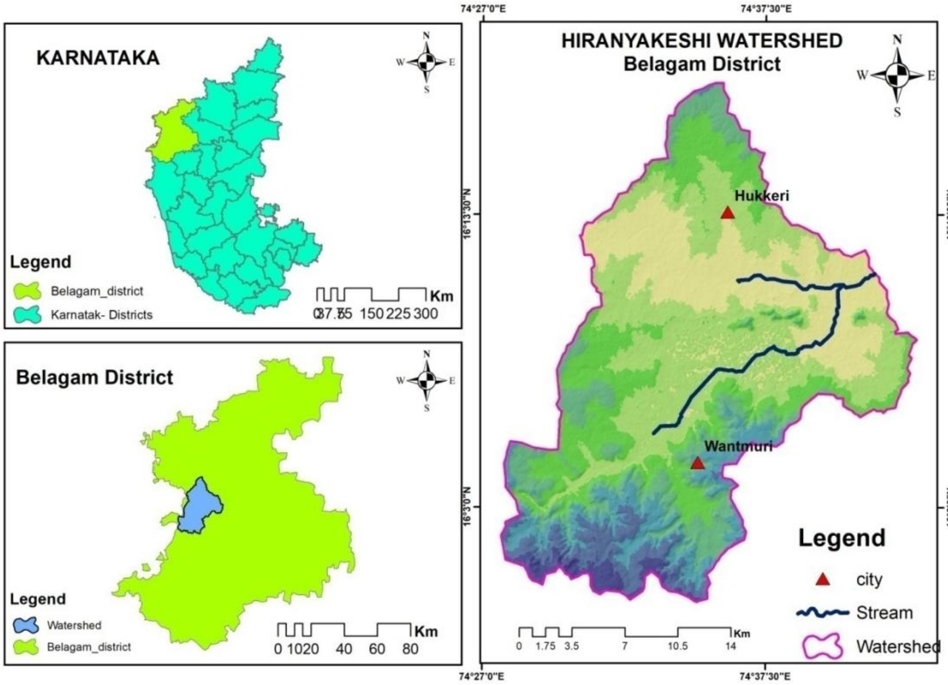

Fig no 2: the Drainage Map of Hiranyakeshi watershed

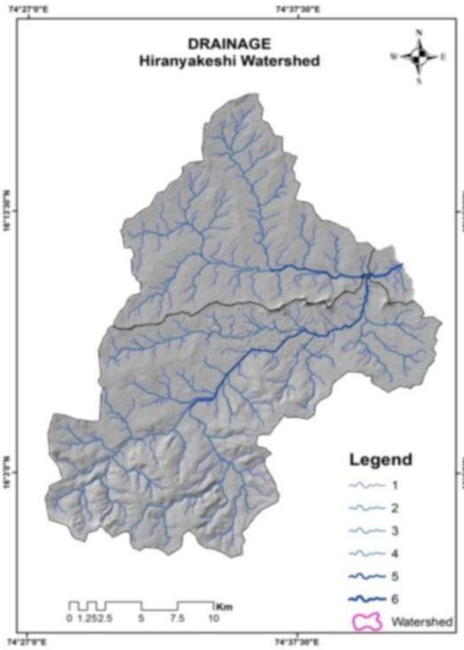

Fig no 3:No of stream segments on stream order for Hiranyakeshi watershed