Original Research Article

Morphometric Analysis Using Geospatial Techniques: A Case study from Halayapura Micro-Watershed of Tumkur District, Karnataka

ABSTRACT

Geospatial technique were used for land and water management action plan for Halayapura micro watershed in Tumkur district of Karnataka. Arc GIS software was used in evaluation of morphological characteristics in micro-watershed. The present study reveals that drainage pattern was dendritic with trunk order 4. The area, maximum length and width of the micro-watershed are 503 ha, 4.40 km and 2.20 km, respectively. The mean value of bifurcation ratio was 2.5 it indicates micro-watershed has been suffered less structural disturbance. The value of drainage density 0.851 km km^{-2} which indicated that the region is having permeable subsoil material. The value of form factor indicates micro-watershed is approaching towards elongated shape of watershed. The recharge factor found is 7% and utilizable groundwater is 41.7 mm (70% of 59.6 mm recharge estimated). This means the total available water resource combining the soil moisture store and utilizable runoff plus recharge is 256.0 mm. Currently about 19.4% of the utilizable runoff is being used and 9% of runoff excess is promoting by harvesting and conservation structures

INTRODUCTION

India covers 329 m ha of geographical area, which makes up 2.40 per cent of the world's land area and provides $1/25^{th}$ of the world's water supply. The total useful water resources of the country are estimated at 1086 km^3. The National Commission for Integrated Water Management Growth estimated the average annual drainage flow in Indian river systems at 1953 km^3 and the accessible annual surface water in India is 690 km^3. Estimated potential natural groundwater recovery from rainfall in India is 342.43 km^3, which constitutes 8.56 per cent of the country's total annual rainfall. The annual potential groundwater recharge enrichment from canal irrigation scheme estimated to be nearly 89.46 km^3.

Total water resources in seven river basin regions are about 7663 TMC. Currently 58 per cent of water sources occur in west flowing rivers where, a larger percentage of water could not be harnessed for any effective use. It is estimated that in the state only 1695 TMC of surface water could be economically utilizable for irrigation purpose.

In case of ground water, it has been predicted that 485 TMC of groundwater is available in the state. However, the allocation of groundwater and the usage for irrigation is not consistent across the state. A substantial amount of groundwater is found in the coastal areas, which cannot

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be effectively utilized. The surface water capacity of Karnataka is approximately 102 km^3, of which about 60 per cent is from the rivers flowing west, while the remaining comes from the rivers flowing to the east. The total annual yield of the Karnataka Rivers was estimated to be approximately 3475 TMC.

For instance, morphometric analysis of watershed b can be integrated with other natural resource information layers like, land use/land cover, wastelands, forest, villages, slope, *etc*. and generate statistics for the required hydrologic units. This information could be used to prioritize the watersheds, preparing priority location plans and select them for treatment on a scientific basis more accurately within a short period. GIS can be used for watershed prioritization, preparing resource action plans, suggesting suitable sites for groundwater recharge, getting natural resources and socio-economic information.

MATERIALS AND METHODS

The study area is a part of the Southern Transition Zone of Karnataka. December is the coldest month with mean daily minimum temperature of 18.30º C, while May is the hottest month with mean daily maximum temperature of 38.10º C. Relative humidity of over 87 per cent is common during monsoon period. The Survey of India (SoI) toposheet 4B3C5N1a of 1:50,000 scale with a contour interval of 20 m were used for the analysis of watershed characteristics namely, drainage pattern, network, contours, hydro geomorphological units and land use/ land cover respectively. ArcGIS is a software for creating, viewing, querying, editing, composing and publishing maps. The development of GIS data in the desired format is complex in nature particularly for hydrological analysis. ArcGIS 10.4 version was used to prepare the map layout and to get good output, which was easy to work and integrate the different feature class maps in a single layer.

Morphometry is the measurement and mathematical analysis of configuration of the earth's surface and the shape and dimensions of its landforms. It includes, the analysis on systematic description of the watershed geometry and its stream channel system to measure the linear, aerial and relief aspects of the drainage network. Morphometric analysis was carried out using topographical map of 4B3C5N1a. As per integrated missions for sustainable development (IMSD) guidelines, land use map, soil map, runoff potential map, stream order map, permeability map and slope maps are used for identifying the suitable sites for water harvesting structures by overlaying. Overlaying of these maps are done by using "Intersect" from "Overlay" option of "Analysis Tools" in ArcGIS. Percolation pond is normally suggested for recharging aquifer and used where surface storage is available for a restricted period. The required site conditions are having high permeability with higher stream order.

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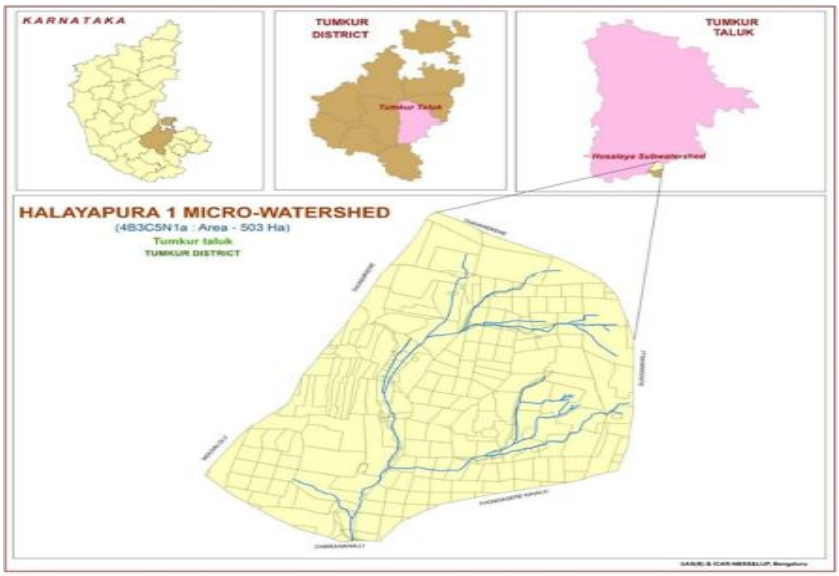

Fig. 1 .Location map of Halayapura micro watershed

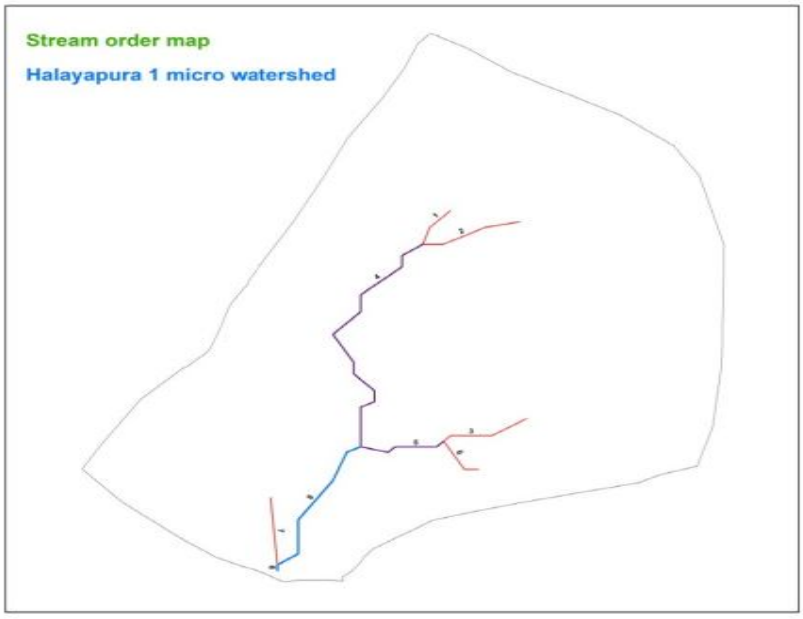

Fig.2 Stream order map of Halayapura micro-watershed

Table.1 Equations adopted for estimating the morphometric analysis

Linear Aspects			
Sl. No.	Parameter	Equations	Reference

	Bifurcation ratio (R_b)	$R_b = \frac{N_u}{N_{u+1}}$ Nu = Number of streams of the given order Nu+1 = Number of streams of the next higher order	Schumn (1956)
Aerial aspects			
	Stream frequency (S_f)	$S_f = \frac{Nu}{A}$ N_u = Number of streams of order u A = Area of basin km^2	Horton (1945)
	Drainage Density (D_d)	$D_d = \frac{N_l}{A}$ N_1= Length of streams of all orders A= Area of the basin	Horton (1932)
	Shape factor (S)	$S = \frac{L^2}{A}$ S= Shape factor in km A= Area of the basin km^2	Horton (1932)
	Form factor (R_f)	$R_f = \frac{A}{L_b^2}$ A = Area of watershed, km^2 L_b = Length of basin, km	Horton (1932)
	Elongation ratio (R_L)	$R_L = \left(\frac{1}{L_b}\right)\sqrt{\frac{A}{\pi}}$ L_b= Main channel length A = Area of the basin	Schumn (1956)
	Circulatory ratio (R_f)	$R_f = \frac{4\pi A}{P^2}$ A= Area of basian km^2 P= Perimeter of bas in km	Miller (1953)
	Length of overland flow (L_f)	$L_f = \frac{0.5}{D_d}$ L_f = Length of overland flow D_d = Drainage density	Horton (1945)
	Drainage texture (D_t)	$D_t = \frac{N_u}{P}$ N_u= Number order of stream u P = Perimeter of basin in km	Horton (1932)
Relief Aspects			
	Infiltration number (In)	$I_n = D_d * S_f$ D_d =Drainage density S_f =Stream frequency	Faniran (1968)

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	Constant of channel maintenance (C_c)	$C_c = \frac{1}{D_d}$ C_c = Constant channel maintenance D_d = Drainage density	Schumn (1956)
13	Basin relief (R_b)	R_b E_{max} = Maximum elevation, E_{min} = Minimum elevation	Strahler (1952),
14	Relief ratio (R_r)	$R_r = \frac{R_b}{L}$ R_b = Basin relief L= Channel length in km	Schumn (1956)

RESULTS AND DISCUSSION

The experiment is conducted as per the experimental plan as detailed under materialsand methods. The results of the experiment are detailed further under the following titles.

Linear aspects of drainage network

After analysis it was found that, the micro-watershed has 3rd order trunk stream and type of drainage pattern was dendritic which indicates the homogeneity in texture and lack of structural control. Maximum length and basin width of micro-watershed was found to be 4.29 km and 2.20 km respectively. The values of linear aspects are given in Table 1. The stream length of different orders and respective mean stream lengths were found out by digitizing the stream networks using ArcGIS software.

The other important properties of linear aspects of drainage network are bifurcation ratio (R_b), which reflects about geological and tectonic characteristics of the watershed. The bifurcation ratio (R_b) value of the stream was found to be 2.5. Thus, the bifurcation ratio value was low indicating that, micro-watershed had suffered less structural disturbance and drainage pattern had not been distorted by structural disturbance.

The value of stream length ratio (R_L) is 1.218. Change in stream length ratio from one order to another order indicating their late youth stage of geomorphic development (Singh and Singh, 1997). The variation in stream length ratio was due to change in slope and topography. The other linear aspects of micro-watershed were main valley length and main stream length these characteristics were found out in ArcGIS software.

Aerial aspects of drainage network

Aerial aspects of drainage network include measurement of aerial elements such as drainage area, form factor, drainage density, drainage texture, stream frequency, circulatory ratio, elongation ratio, compactness co - efficient, ellipticity index, texture ratio and length of overland flows were represented in a systematic way. From the results, it was observed that, the value of form factor (R_f) was found to be 0.2721 (Table 2). An elongated basin with low farm

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factor shows flatter peak flow for longer duration.

The value of drainage density (D_d) was found to be 0.851 km km^{-2}. The value of stream frequency was found to be 1.78 km^{-2} which indicates the watershed is having impermeable subsurface material and sparse vegetation. Circulatory ratio (R_c) and elongation ratio (R_e) were found to be 0.786 and 0.872 respectively. Further, related to drainage density (D_d), the other morphological characteristic properties of drainage basin are Shape factor, texture ratio (R_t), and Length of overland flow (L_g) which were found to be3.67, 0.557 and 0.558km respectively.

Relief aspects of drainage network

The estimated value of Basin relief, Relative relief (R_R) and Relief ratio (R_r) were found to be 53 m, 0.59 and 0.018 respectively. Addition to these properties ruggedness number value was computed and it was found to be $4.505*10^{-5}$. For the present study the time of concentration is 48 min and it indicates more time is required for water to travel from the distant part of watershed to its outlet (Table 3).

Table 2. Linear aspects of drainage network

Sl no.	Parameters	Output
1.	Stream order	3
2.	Stream length	4.299 km
3.	Streams number	8
4.	Bifurcation ratio	2.5
5.	Stream length ratio	1.218
6.	Mean stream length	477.66 m

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Table 3. Aerial aspects of drainage network

Sl no.	Parameters	Output

1.	Drainage density (km $km^{-2)}$	0.851
2.	Stream frequency (km^{-2})	1.78
3.	Shape factor	3.67
4.	Circulatory ratio (R_c)	0.786
5.	Elongation ratio (R_e)	0.872
6.	Length of overland flow (L_g), (km)	0.588
7.	Form factor (R_f)	0.2721
8.	Texture ratio (R_t)	0.557

Table 4. Relief aspects of drainage network

Sl no.	**Parameters**	**Output**
1.	Basin relief, (m)	53
2.	Relative relief (R_R)	0.59
3.	Ruggedness ratio	$4.505*10^{-5}$
4.	Relief ratio (R_r)	0.018
5.	Time of concentration (T_c), (min)	48

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CONCLUSION

In the present study, an effort was made to highlight the use of remote sensing and Geographical Information System for the water resources conservation planning. Initially, watershed delineation was done using Arc-GIS 10.40 version then different geomorphological characteristics were found out, which includes basin area and perimeter, linear aspects, aerial aspects and relief aspects. The calculated values of morphological characteristics have been interpreted in terms of drainage basin characteristics.

Halayapura micro-watershed had 3^{rd} order trunk stream and drainage pattern was dendritic which indicates the homogeneity in texture and lack of structural control. The maximum length and width of the micro-watershed was found to be 4.40 km and 2.20 km respectively. The value of drainage density was found to be 0.854 km km^{-2} which indicates that, the region is having permeable subsoil material and good vegetation cover.The value of stream frequency was found to be1.78 km^{-2} which indicates, high discharge carrying capacity and greater erosion hazard.

Circulatory ratio (R_c) and elongation ratio (R_e) were found to be 0.786 and 0.872 respectively. The greater elongation ratio than circulatory ratio results in elongated formation of watershed than circular watershed. In the present study, the value of elongation ratio (0.872) indicates elongated shaped micro-watershed. The relative relief (R_R) and relief ratio (R_r) were found to be 0.59 and 0.018 respectively. This is an indication of low relief value. The low value of relief mainly due to the resistant basement rocks of the basin.

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