The Pharma Innovation Journal 2021; 10(11): 402-406

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(11): 402-406

www.thepharmajournal.com
Received: 10-08-2021
Accepted: 16-10-2021

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Evaluation of geo-morphological characteristics of Hebbur sub watershed Karnataka, India

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Abstract
Land and water are the two basic natural resources essential for survival of humankind on the earth. The present study was carried out for Hebbur sub watershed of Tumkur district Karnataka. The total area of sub watershed was found to be 1591.2 ha and lies between 76˚59´ to 77˚07´ East longitudes and 13˚08´ to 13˚11´ North latitudes. Further, the geo-morphological characteristics of watershed have been studied using GIS technique and the drainage pattern of the study area was found to be dendritic with trunk order stream as number 4.

Keywords: Watershed, GIS, geo-morphology

Introduction
Irrigation engineers and geo hydrologists are more familiar with the term catchment than with the term watershed. Until 1950 the technique was limited to specific regions such as soil eroded area. To support the likely rise in population and provide a better level of living, serious consideration should be given to the soil and water conservation as well as its management. Natural resource planning, assessment, management and utilization, particularly soil and water, are most important at local level.

The development of morphometric techniques are significant step in the quantitative analysis of geometry of the drainage basin and their networks, as it aids in characterizing the drainage network, comparing the characteristics of different drainage networks and evaluating the effects of parameters such as lithology, rock structure, rainfall, etc. Morphometry is the science of measuring and analyzing of configuration of earth surface, shape and size of its landforms. The idea of integrated watershed development refers to the development and management of the watershed resources in order to produce higher production that can be sustained without depleting the natural resource or by creating ecological imbalances. Precise and dependable production is critical for developing strategies for watershed planning and management.

In semi arid and arid locations, watershed management studies are necessary for preserving limited water resources, because surface water resources are scarce in most regions and groundwater recharge in these locations is solely dependent on rainfall. To understand the rainfall recharge mechanism and estimate groundwater budgets at the watershed level, it must be first comprehend the morphometric parameters at the basin level.

Morphometric investigations in For prioritization and implementation of the soil and water conservation measures in the drainage basin, physiographic information like watershed slope, drainage divide location, stream network configuration, stream length and geo morphologic parameters such as shape factor, relative relief, bifurcation ratio, circulatory ratio and drainage density are required.

Materials and Methods
Study area
The study area is part of the Hebbur sub watershed in Tumkur district, Karnataka state, covering an area of 1591.2 ha is located at North latitude 13°8' and 13°11' and East longitude 76°59' and 77°07' with an average altitude of 822 m above mean sea level (MSL) and study area located in the southern region of Tumkur district boundary. The location map of the study area is shown in Figure 1.

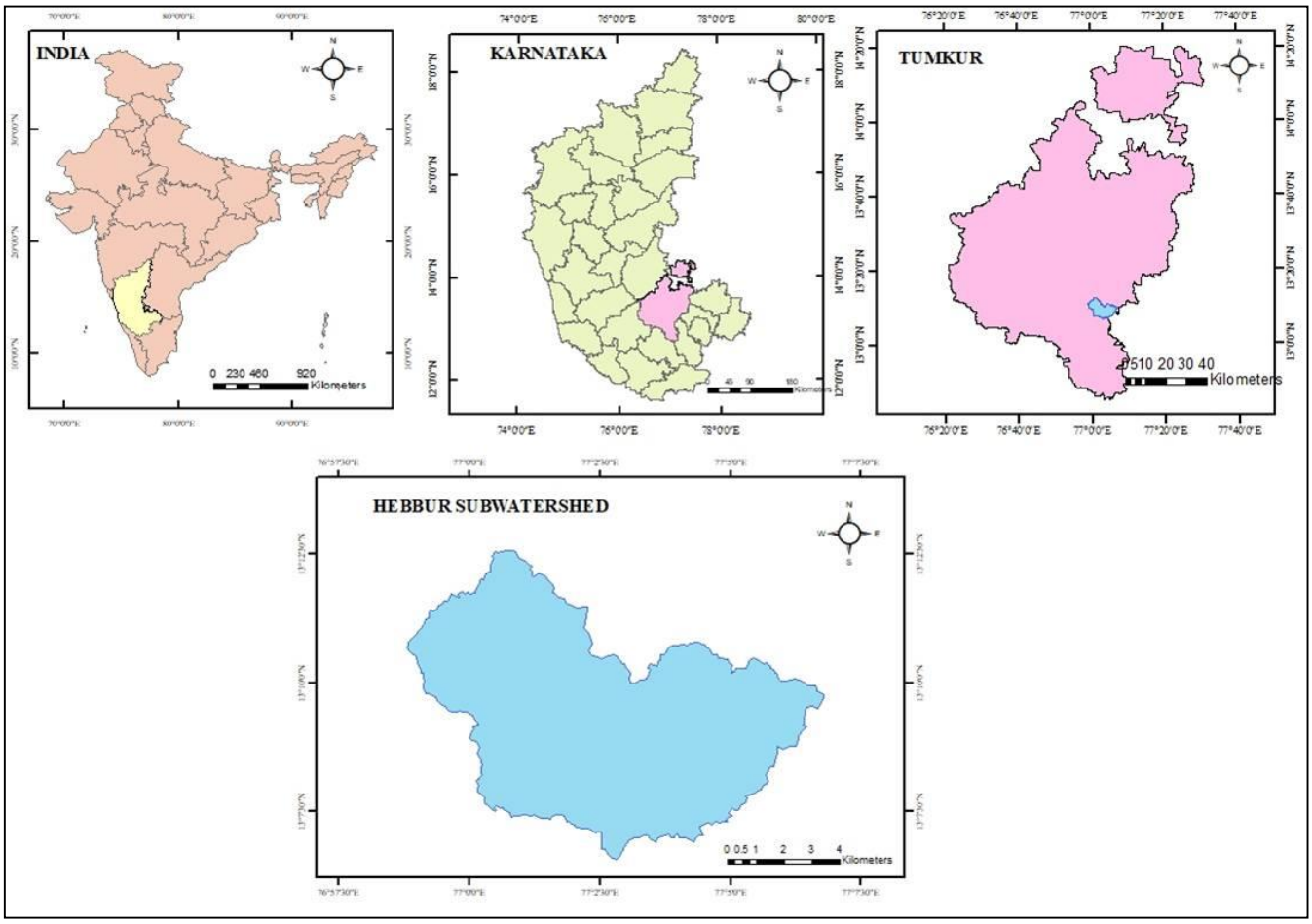

Fig 1: Location map of Hebbur sub watershed

Climate

The study region of Tumkur district is located in southern region of Karnataka, which come under drought region of Karnataka and falls within the semi arid region. The district climate ranges from mild to severe with pleasant winters and hot summers. The coldest month is December with an average daily low temperature of 21.6°C, while the hottest month is May with an average daily high temperature of 33.8°C. In May, the day time temperature frequently reaches 35.1°C. During the monsoon season relative humidity levels of above 75% are frequent. During the months of June and July wind velocity reaches to11 kmh^{-1}. The average annual of district is rainfall is 832.4 mm.

Geology

Tumkur district is situated on the arechaean complex and the geology of the area is fairly simple. The crystalline schist comes from the southern extension of the well-defined Chitradurga schist belt of the Dharwar system, which are the archaean complex. The schist belt is made up of basic and intermediate volcanic rocks such as chloritic schist, micaceous schist, quartzite, limestone and ferruginous quartzite.The new granites form a well defined narrow range of hills in the south eastern areas of Tumkur district.

Data collection and software used

Data collection

Toposheets: For the examination of watershed characteristics, such as drainage pattern, road network, built up land, contours, hydro geomorphological units, and land use/land cover, the SoI toposheet 57 A/5 of 1:50,000 scale with a contour interval of 10 m was utilised.

Satellite data

The IRS (Resourcesat-2) LISS-III satellite picture of 23.5 m resolution dated 17th November 2019 was downloaded from the BHUVAN official website by selecting "Bhuvan data archive" and entering extreme limits longitude and latitude values in the website (http://bhuvan.nrsc.gov.in).

Software used

ArcGIS 10.1 version

The generation of GIS data in the desired format particularly for hydrological study is complex. To evaluate geo morphological characteristics the ArcGIS 10.1 version software is used.

Delineation of watershed

The basin divide ridge lines will separate the adjacent basins by a function of decreasing elevation or slope and were used divide the adjacent watershed. The boundary line was created where the two streams meet and join their upper stream in different directions. The topographical sheet was scanned, registered and geo-referenced to the World Geodetic System WGS 1984 Geographic Coordinate System (GCS) and projected to the UTM (Universal Transverse Mercator) 43 N zone during the delineation process. The map was registered, geo referenced and digitized for building topology in ArcGIS software, all the streams inside the basin border were digitized.

Morphological characteristics of Hebbur sub watershed

It involves a systematic description of the watershed geometry and its stream channel system in order to measure the linear, areal and relief features of watershed. The topographical map of 57 A/5 was used to perform morphmetric analysis. Assigning stream orders, counting stream numbers according to stream orders, measuring stream lengths according to stream orders, measuring basin area, perimeter, maximum length of basin, maximum width of basin, drainage density, form factor, drainage texture, length of overland flow, circulatory ratio, elongation ratio, relief ratio and time of concentration were parts of the research.

The total drainage pattern of the watershed is governed by surface morphological features. The interplay of rainfall characteristics with various watershed parameters such as area, shape, slope, length of distinct streams and contour details results in drainage or runoff from the watershed, which is largely time invariant. Slope features may alter slightly as a result of watershed development activities such as land leveling, grading and the construction of soil and water conservation structures, among other things. These characteristics are useful in prioritizing watershed development work and choosing priority watersheds for applying various treatments to prevent runoff and soil erosion through appropriate conservation measures.

Linear aspects of the drainage network

The linear aspects *viz*., stream number (N_u), stream order (U), average basin width (B), basin length (L_b), mean stream length ($\bar{L}_u$), stream length (L_u), bifurcation ratio (R_b) and stream length ratios (R_L) were determined.

Areal aspects of the drainage network

The study provides a description of the arrangement of areal elements, primarily watershed shape, which affects stream flow hydrographs and peak flow, such as drainage area, form factor, drainage density, stream frequency, drainage texture, elongation ratio, circulatory ratio, compactness co-efficient, texture ratio, ellipticity index and length of the overland flow were calculated.

Relief aspects of drainage network

Maximum watershed relief (H), relative relief (R_R), ruggedness number (Rn), relief ratio (Rr), and time of concentration (Tc) were calculated.

Results and Discussion

Soil and water conservation planning is critical for preserving this two important natural resources *viz*., soil and water needed to sustain life. The research was carried out to assess the geomorphological characteristics of the Hebbur sub watershed in Tumkur district and to plan soil and water conservation measures.

Watershed delineation

The boundary of the Hebbur sub watershed was delineated using a 1:50,000 scale toposheet from the Survey of India. ArcGIS 10.1 version was used to delineate the boundary. The total area and perimeter of watershed were determined to be 1591.2 ha and 16.19 km respectively. The watershed length, width and perimeter were determined to be 5.10, 3.12 and 16.91 km respectively. The watershed outlet connects to Kerebandi playa tank.

Morphological characteristics of watershed

Morphological characteristics provide basic information for understanding the drainage basin slope, difference in rock hardness, structural control, geological and geomorphological features of watershed [16]. The geomorphic study of the drainage basin aims to collect accurate data on measurable features of the stream network.

Linear Aspects of the drainage network

According to the results, the watershed have 4th order stream and the drainage pattern is dendritic. The watershed maximum length and width were found out to be 5.10 km and 3.12 km respectively. The number of streams for the first, second, third and fourth order streams was determined to be 36, 9, 3 and 1 respectively. The cumulative stream lengths for the first, second, third and fourth order streams were given to be 30.04, 10.77, 3.90 and 2.17 km respectively as shown in Table 1.

By digitizing the stream networks with ArcGIS software, the stream lengths of different orders and their respective mean stream lengths were determined. Another important property of the drainage network is the bifurcation ratio (R_b), which reflects the watershed geological and tectonic characteristics. The bifurcation ratio (R_b) values from 1st to 2nd, 2nd to 3rd and 3rd to 4th order streams were 4, 3 and 3, respectively and the mean of bifurcation ratio was 3.34 as shown in Table 2. The values of stream length ratio (R_L) for 2nd to 1st, 3rd to 2nd and 4th to 3rd order streams were found to be 1.45, 1.08 and 1.67 respectively as shown in Table 3.

Table 1: Stream order and its mean stream lengths of Hebbur sub watershed

Parameters	Stream order (U)				Total
	I	II	III	IV	
No. of streams	36	9	3	1	49
Cumulative stream length, km	30.04	10.77	3.90	2.17	46.88
Mean stream length, km	0.83	1.20	1.30	2.17	5.50

Table 2: Bifurcation ratio of Hebbur sub watershed

Stream order (U)	No. of streams	Bifurcation ratio (R_b)
I	36	4
II	9	3
III	3	3
IV	1	-
Mean	-	3.34

Table 3: Stream length ratio of Hebbur sub watershed

Stream order (U)	Mean stream length, km	Stream length ratio (R_L)
I	0.83	-
II	1.20	1.45
III	1.30	1.08
IV	2.17	1.67
Mean	1.37	1.40

Relationship between stream number and stream order

The number of streams in each order were counted and recorded in Hebbur sub watershed as given in Table 1. To investigate geometric property, the logarithm of stream number (ordinate) as a function of stream order (abscissa) was plotted using Horton's law. Figure 2 shows the regression value (R_2 = 0.998) with a logarithmic trend line.

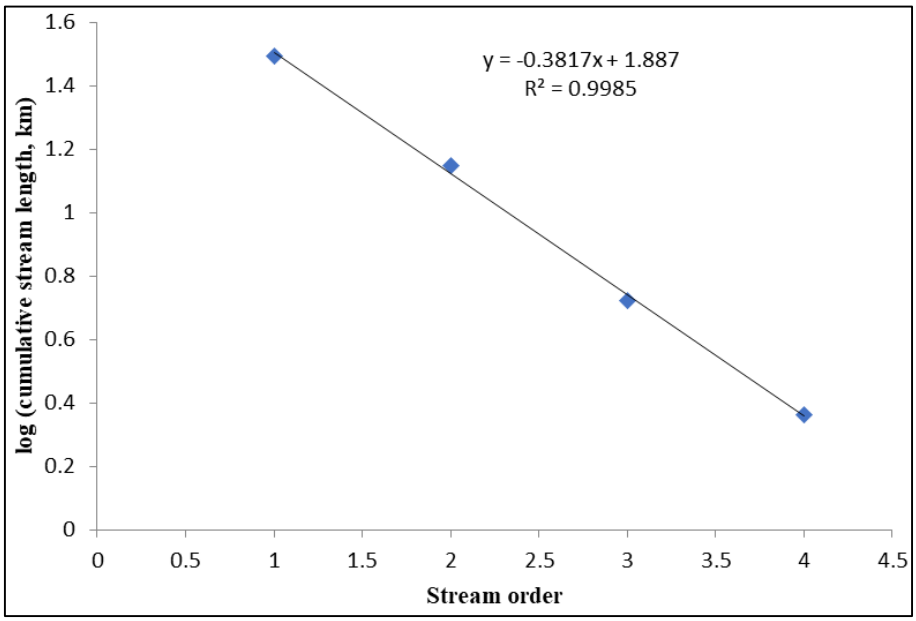

Fig 2: Regression of logarithm of stream number and stream order

Relationship between cumulative (total) stream length and stream order

The present study attempted to establish a relationship between the cumulative stream length and stream order (U). To determine the correlation, the logarithm of cumulative stream length was plotted as the ordinate and the stream order (U) as the abscissa, plotted on standard log paper to investigate the geometric property. Figure 3 shows the regression value (R_2 = 0.989) with a logarithmic trendline.

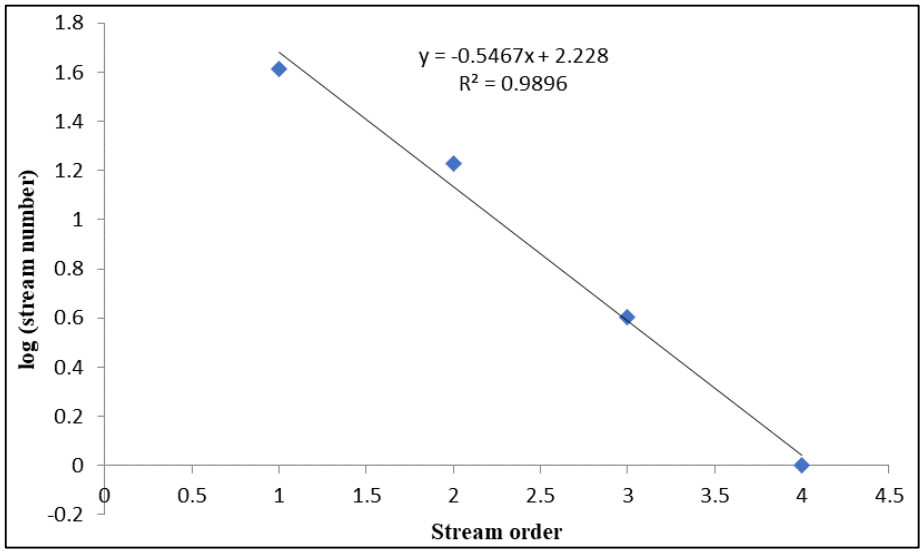

Fig 3: Regression of logarithm of cumulative stream length and stream order

Areal aspects of the drainage network

The drainage density (D_d) value was found to be 3.32 km km^{-2} as shown in Table in 4.4, which falls within the range of 2.49 to 3.37 km km^{-2}, indicating that the area has moderately textured subsoil strata and good vegetation cover (Mallik *et al.* 2011) [6]. The drainage texture (Dt) value was determined to be 3.32 km^{-1}, indicating the watershed has coarse drainage texture (Smith, 1950).

The value of a stream frequency was found to be 3.95 km$^{-2.}$ The circulatory ratio (R_c) and elongation ratio (R_e) were calculated to be 0.69 and 0.88 respectively. The elongation ratio (0.88), compactness coefficient (C_c), texture ratio (R_t), ellipticity index (E_i) and length of overland flow (L_g), which were determined to be 1.06, 0.41, 1.20 and 0.15 km respectively. The texture ratio was found to be (0.41). The length of the overland flow is the distance that water travels over land before it is concentrated into definite stream channels and is equal to half of drainage density (Horton, 1945). The length of overland flow is inversely proportional to the average channel slope. Table 4 shows the various areal aspects of drainage network.

Relief aspects of drainage network

Maximum watershed relief (H), relief ratio (R_r) and relative relief (R_R), were estimated to be 98 m, 0.019 and 0.005, respectively, indicating that the watershed has a low relief value. The presence of base rocks exposed in the form of a small ridges and mounds with a lower degree of the slope is indicated by a lower relief ratio value (Praveen *et al.* 2012). When these properties were added together, the ruggedness number was calculated and determined to be 0.32. The time of concentration for the current study was 497 minutes,

indicating that time required for water to travel from the remotest part of the watershed to its outlet. Table 45shows the various relief aspects of drainage network.

Table 4: Areal aspects of Hebbur sub watershed

Sr. No.	Areal aspects	Value
1	Drainage area (A), ha	1591.2
2	Basin length (L), km	5.10
3	Basin width (B), km	3.12
4	Basin perimeter (P), km	16.91
5	Form factor (R_f)	0.60
6	Drainage density (D_d), km km^{-2}	3.32
7	Drainage texture (D_t), km^{-1}	3.32
8	Stream frequency (F), km^{-2}	3.95
9	Circulatory ratio (R_c)	0.69
10	Elongation ratio (R_e)	0.88
11	Compactness coefficient (C_c)	1.06
12	Ellipticity index (E_i)	1.20
13	Texture ratio (R_t)	0.41
14	Length of overland flow (L_g), km	0.15

Table 5: Relief aspects of Hebbur sub watershed

Sr. No.	Relief parameters	Value
1	Maximum watershed relief (H), m	98
2	Relative relief (R_R)	0.005
3	Relief ratio (R_r)	0.019
4	Ruggedness number (R_n)	0.325
5	Time of concentration (T_c), min	497

Conclusion

The Hebbur sub watershed is of 4th order type and the pattern of drainage is dendritic, indicating textural homogeneity and a lack of structural control. A low Bifurcation ratio (3.55) shows that the watershed has less structural disturbance and the drainage pattern has not changed due to structural disturbance. The drainage density was found about 3.32 km km-2, which ranges between 2.0 to 4 km km-2, indicating that the region has coarse drainage texture and the value of the stream frequency was found about 3.95 km-2 which indicates the study basin has high stream frequency.The highest watershed relief (H), relative relief (RR) and relief ratio (Rr) were found to be 98 m, 0.005, and 0.019, respectively. This indicates a low relief value. The low relief value is primarily because of the resistant basement rock foundation.

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