IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 17, Issue 6 Ser. III (Nov. – Dec. 2020), PP 45-55
www.iosrjournals.org

Morphometric Analysis and Change Detection Analysis of Vrishabhavathi River basin using Remote sensing and GIS

Bipin Anand[1], Charan SN[2],Girija H[3],Jithin P Sajeevan[4]
[1,2,3]*Department of Civil, SJC institute of technology ,Chikballapur. India*
[4]*Research Scientist, LRDC,Bengaluru, India*

Abstract: *Remote Sensing(RS) and Geographical Information System (GIS) has become an effective tool in delineation of drainage pattern and water resources management and its planning.In the present study, morphometric analysis of the Vrishabhavathi river basin has been carried by using earth observation data and GIS techniques. The morphometric analysis was performed using ArcGIS to understand the nature, landscape development and hydrologic responses of Vrishabhavathi watershed. The drainage network shows that the terrain exhibits dendritic drainage pattern.The CARTOSAT and LISS(III) (SRTM) data is used for the morphometric analysis of the watershed to derive linear, relief, and aerial aspects.Spatial analysis is performed using ENVI for change detection studies in the basin to understand the effect of urbanization. Strahler's stream ordering techniques and analysis were followed for advanced analysis.From the analysis, it can be concluded that remote sensing techniques and GIS tools prove to be a competent tool in morphometric analysis. These studies are very useful for sustainable urban planning and also for land, water, and soil resource management in the watershed area.*

Keywords: *GIS,Spatial Analysis, Remote Sensing, Morphometric Analysis, Vrishabhavathi Watershed*

Date of Submission: 01-12-2020 Date of Acceptance: 15-12-2020

I. Introduction

Morphometric properties of a drainage basin are quantitative attributes of the landscape that are derived from the terrain or elevation surface and drainage network within a drainagebasinand it has its application in many studies like estimation of runoff, flood discharge, groundwater recharge, sediment yield soil as well as water conservation[12].The various morphometric properties depend on several aspects like geology, tectonics, vegetation and climate etc. 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. The drainage characteristics reflect the influence of variation of these determinants such as topography, climate and geology from place to place[8]. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface shape and dimension of its landforms. A watershed is a natural or disturbed system that functions in a manner to collect, store, and discharge water from a common outlet, such as a larger stream and lakes.

II. Study Area

Vrishabhavathi Watershed is a constituent of Arkavathi River Basin, Bangalore Urban and Ramanagara District and covers an area of 381.465 Km² lying between latitudes 12° 44' 37'' to 13° 2' 31'' N and longitudes77° 23' 14'' to 77° 34' 59" E(fig.1).Vrishabhavathi River is a tributary of the large Arkavathy River, which in itself is one of the tributaries of the River Cauvery Vrishabhavathi River originates from Peenya industrial area with an altitude of 930.25 m above mean sea level.As per the historical data received from the IMD(Indian Meteorological Department) normal annual rainfall received by the study area is 831mm. The total extent of the study area is 481.70 Sq. Km.

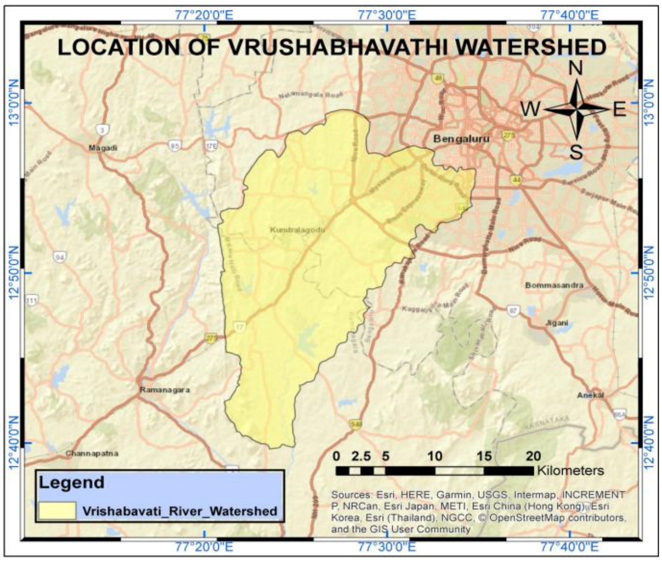


Fig.1 Map of study area

III. Geology ,Geomorphology and Soil

Geological setup of the study area is not very complex. It is due to the repeated tectonic disturbances caused by different orogenic cycles. Valdiya(1980) carried out extensive geological and structural mapping in the area. Broadly, there are eight geomorphic units based on geological groups exposed in the area (a) Ridges (b)Inselberg (c)Pediment (d) Residual Hills (e) Waterbody (f)Structural Hills (g)Valley (h)Plains.The major rock types are granite, granodiorite, amphibolites, metapelitic schist and migmatites.Barring the alluvial deposits along the river courses and flood plains, the entire area is covered by hard rocks. The main rock types are amphibolites, phyllites, gneisses of varying degree of metamorphism along with granite intrusive and schists.There are mainly four types of soil based on texture, group, family, series and order of soil classification, in the study area (a) Fine soil (b) Clayey skeletal soil (c) Sandy Skeletal soil and (d) Loamy skeletal soil The topography is highly undulating and geological formations are moderately to steeply dipping.

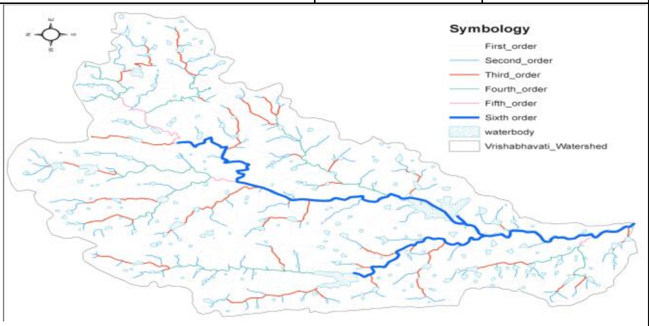
IV. Methodology

In this case study we delineated the Vrishabhavathi river and its watershed using state of the art remote sensing and GIS tools.The data sources have been collected using CARTOSAT DEM 3 and LISS(III) Satellites. Processing of this case study has been carried out by Georeferencing, Digitalization, Classification and Morphometric analysis of the study area using ArcGIS software.The major part of the area is covered under Survey of India (SOI) Toposheet numbers 57H/5, 57H/6, 57H/9 and 57G/12 on 1:50,000 scale were used for preparation of base map.Later we Identified the lithological and structural characteristics of the study area using remote sensing data and software packages.We set up statistical relationships between morphological parameters, effect of urbanisation and change detection analysis[8]using vegetative and built-up index from the year 2015-2020 in the study area with standard buffer zones[26] for the various stream orders as the detection area. Determining the stages of geomorphic development of drainage basins falling in the area measures have been suggested for conservation and sustainable watershed development in the study area[10].Data used for hypsometric analysis analysis were CARTOSAT DEM 3 and the elevation map was classified into 20 equal intervals . GIS function for hypsometric analysis[21] was used to compute relative elevation and corresponding area. Hypsometric curve was generated using the hypsometric function proposed by Pike and Wilson ,1971[22] that represents the hypsometric integral as an area under the curve.

V. Result

Table.1 Morphometric Parameters

A. Linear Morphometric Parameters			B.Aerial Morphometric Parameters		
Parameters	**Formula**	**Reference**	**Parameters**	**Formula**	**Reference**
Stream Order (U)	Hierarchical rank	Strahler (1964)	Stream Frequency (Fs)	Fs=Nu/A	Horton (1945)
Stream Number (Nu)	Nu = N1+N2+…Nn	Horton (1945)	Drainage Density (Dd)	Dd=Lu/A	Horton (1945)

Stream Length (Lu)	Length of the stream	Horton (1945)	Channel Maintenance (C)	C=1/Dd	Schumm (1956)
Mean stream length(Lsm)	Lsm = Lu/Nu	Strahler (1964)	Infiltration Number (If)	If = Fs * Dd	Faniran (1968)
Stream Length Ratio (Rl)	RL = Lu / Lu-1	Horton (1945)	Length of Overland Flow (Lg)	Ls=1/2Dd	Horton(1945)
Bifurcation ratio (Rb)	Rb = Nu / Nu+1	Schumm (1956)			
Basin shape/Shape factor ratio (Bs)	Bs=Lb2/A	Horton (1945)			
RHO coefficient	RHO =RL/Rb	Horton (1945)			

C. Relief Morphometric Parameters			D. Geometric Aspects		
Parameters	Formula	Reference	Parameters	Formula	Reference
Basin Relief (R)	$R = H - h$	Hadley and Schumm (1961)	Length of the sub basin (Lb)	$Lb = 1.312 * A^{0.568}$	Kanth et al (2012)
Relief Ratio (Rh)	$Rh = H/Lb$	Schumm (1963)	Length area relation (Lar)	$Lar = 1.41 * A^{0.6}$	Hack (1957)
Relative Relief (Rhp)	$Rbp = H * 100/P$	Melton (1957)	Lemniscate (k)	$k = Lb^2/A$	Chorley (1957)
Ruggedness number (N)	$N = Dd * (H/1000)$	Strahler (1957)	Form factor ratio (Rf)	$Rf = A/Lb^2$	Horton (1945)

Table.2 Stream number

Stream order	Stream Order Number	Number	%of total	Logarithm
1	Number of first order streams(N1)	762	78.4	2.88
2	Number of first order streams(N2)	159	16.37	2.20
3	Number of first order streams(N3)	38	3.91	1.58
4	Number of first order streams(N4)	9	0.92	0.95
5	Number of first order streams(N6)	3	0.3	0.48
6	Number of first order streams(N5)	1	0.1	0.00
	TOTAL	972	100	8.09

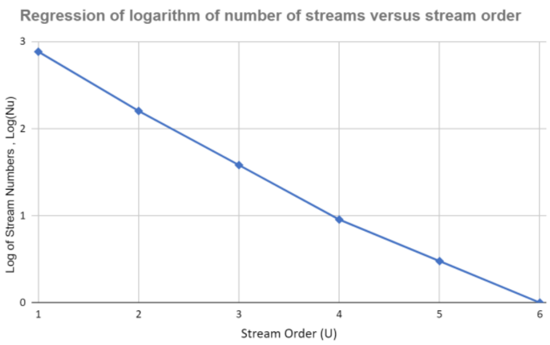


Fig.2 Plot of stream number vs stream order

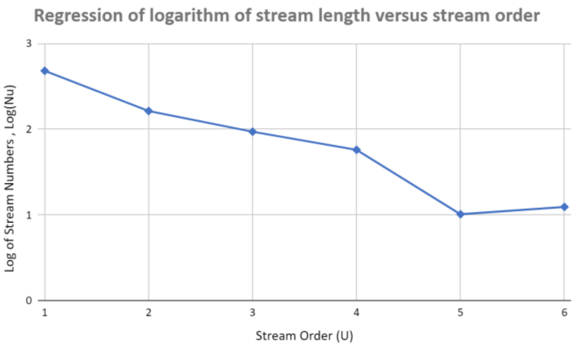


Fig.3 Plot of stream order vs Stream mean length

Table.3 Stream length

Stream order Length	Length	Mean stream	Cumulative mean	% of	Logarithm
Length of 1st order streams	480.23	0.63	0.63	58.77	2.68
Length of 2nd order streams	163.21	1.03	1.66	19.97	2.21
Length of 3rd order streams	93.60	2.46	4.12	11.45	1.97
Length of 4th order streams	57.56	6.40	10.51	7.04	1.76
Length of 5th order streams	10.20	8.40	18.91	1.25	1.01
Length of 6th order streams	12.42	12.42	31.33	1.52	1.09
TOTAL	817.21	31.33	67.16	100	10.73

Table 4: Morphometric parameters of Vrishabhavathi watershed

Watershed parameter	**Unit**	**Values**	**Watershed parameter**	**Unit**	**Values**
Length of Basin	km	37.227	Bifurcation ratio		4.049
Watershed area	Sq.km	481.706	Length ratio		0.654
Perimeter of watershed	km	120.84	Form factor		0.348
Highest stream order	No.	6	Circularity ratio		0.414
Length of watershed	Km	368.75	Elongation ratio		0.665
Maximum width of watershed	Km	43.05	Total Watershed relief	Km	0.29
Cumulative stream segment	Km	972	Relief ratio		0.0077
Cumulative Stream length	Km	817.21	Relative relief		0.0024
Length of overland flow	Km	0.299	Ruggedness number		0.485
Drainage density	Km/Sq.km	1.672	Shape factor ratio		2.887
Constant of channel maintenance	Sq.km/Km	0.59	Rotundity co efficient		2.268
Stream frequency	No./Sq.km	2.016	Length Area relation	Sq.km	42.556

i. Stream Order (U):A key step in the analysis of the water basin is to determine the stream orders, which reveal the superior relationship between the stream components, their connections, and the output from the supply areas. Stream order (U) is dimensionless, which can be used to compare the geometry of water supply networks on precise vertical scales.. Strahler [15] system has been followed because of its simplicity in the present study. Stream order of Vrishabhavathi river is 6.

ii. Stream Number (Nu): The characteristics of stream networks are very important in studying the process of geomorphology [15]. The total sum of the stream segment is known as the broadcast segment. The statistics of the stream order in the Vrishabhavathi basin are shown in Table 2. The median distribution number for the Vrishabhavathi basin is 38. The total log value is 8.09. The distribution order and the total number of stream segments in each stream order are shown in Table 2. The geometric relationship is shown in diagrams in the form of a straight line with a slight deviation from a straight line .The total length of individual stream segments for each order is the length of the distribution for that order. Smaller streams are characteristic of areas with large slopes, the length of the streams indicates soft gradients and where rock formation is not permitted [8]

iii.Stream length(Lu): In the Vrishabhavathi basin, the first-order streams are 0.6302 km long compared to the other orders. The length of the distribution of the various orders is presented in Table3

iv. Mean stream length (Lsm): Lsm values for Vrishabhavathi basin ranges from 0.630 to 12.42 km for L1to L6 (TABLE 3).Apparently, It means the length of the channel sections of a given order is greater than that of the next lower order but less than that of the next higher order.Generally, when order increases, the length of the wide streams is defined in nature. The channel length is a property and specifies the size of the stream network material components and their supply surface [31]. Table.3 shows that the total Lsm value of the basin is 31.33Changes in this value is an indication of changes in slope and density, also determining the age of basin [25].

v.**StreamLength ratio(RL)**:In this study, the RL ranged from 0.63 to 31.33Table 3 reveals that there is a variation of RL in the basin. The variability may be caused by changes in slope and frequency.This parameter shows a very significant relationship with the surface flow discharge, erosional and depositional stages of the basin.

vi.Bifurcation ratio(Rb): Horton (1945)[10] considered bifurcation ratio as an index of relief and dissection. According to Strahler (1957)[32], bifurcation ratio exhibits subtle fluctuation for different regions with varied environments except where powerful geological control dominates [19]. According to Schumm (1956)[28], bifurcation ratio is the ratio of number of stream segments of given order to the number of segments in the next order, it is dimensionless property and indicates the degree of integration prevailing between streams of various orders in drainage basin [16]. Strahler significantly marked that geological structures do not affect drainage patterns for bifurcation ratio in between 3.0 to 5.0. When the bifurcation ratio is low, there will be high possibilities of flooding as water will tend to accumulate rather than spread out [20]. Human intervention plays an important role in reducing the bifurcation ratio which in turn augments the risk of flooding within the basin, this was noted significantly by [20].Bifurcation ratio is the ratio of number of streams of order to the number of streams of higher order.The bifurcation ratio obtained using the formula is 4.049.

vii.Basin shape/Shape factor ratio: Basin Shape is the ratio of the square of basin length (Lb) to the area of basin (A).Vrishabhavathi Catchment has a Shape Factor of 2.886. This indicates that the basin is neither too elongated nor too circular. Hence the basin has moderate time of concentration of flood waters.

viii.Area(A) and Perimeter (P) of the basin: The area of the Vrishabhavathi basin determined by the series of terrain processing procedures in CARTOSAT DEM of 30m resolution is 481.70 sq.km. If the basin size is small, it is likely that rainwater will reach the main channel more rapidly than in a larger basin. Lag time will be shorter in the smaller basin, which is a key parameter for flood modeling purposes. Basin perimeter is the outer boundary of a watershed. The perimeter of the Vrishabhavathi basin is 120.83 Km.

ix.Length of the sub basin (Lb): Horton [10] defined basin length as the straight-line distance from a basin mouth to the point on the water divide intersected by the projection of the direction of the line through the source of the mainstream, parallel to the principal drainage line. The length of the Vrishabhavathi basin is 37.227km.

x.Length area relation (Lar): Hack [9] found that for a large number of basins, the stream length and basin area are related as Lar = 1.4*A^0.6. The length area relation of the Vrishabhavathi basin is 42.56 sq.km.

xi.Form factor ratio (Rf): Form factor is the numerical index [11] commonly used to represent different basin shapes. The value of form factor varies from 0.1 to 0.8. Smaller the value of form factor, more elongated will be the basin. The form factor obtained from analysis is 0.347.

xii.Elongation ratio (Re):Elongation ratio (Re) may be defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. The value of Re varies from 0 (in highly elongated shape) to unity i.e. 1.0 (in the circular shape). The elongation ratio calculated for the study area is 0.67.

xiii.Basin Relief (H): Basin relief is the elevation difference of the highest and lowest point of the valley floor. Basin Relief plays a significant role in landform development, drainage development, surface and subsurface water flow, permeability and erosional properties of the terrain.

xiv.Relief Ratio (Rh): In accordance with Schumm (1956)[28], the maximum relief to the horizontal distance along the largest dimension of the basin parallel to the principal drainage line is termed as relief ratio. It computes overall steepness of the drainage basin. Relief ratio is an indication of the intensity of the erosional process operating on the slope of the basin [29]. On the basis of work carried out by Schumm (1963), it is dimensionless height-length ratio equal to the tangent of angle formed by two planes cross at the mouth of the basin, one exhibits the horizontal and the other passes through the highest point of the basin [7]. When the basement rock of the basin is resistant and low degree of slope heralds or gives rise to low value of relief ratio [1]. Relief ratio is inversely proportional to the drainage area and the size of given drainage [5]. While high values are characteristic of hill regions low values are characteristic of pediplains and valleys.The relief ratio for the study area is 0.0078.

xv.Relative Relief (Rhp): Relative relief is defined as the ratio of the maximum watershed relief to the perimeter of the watershed. It is computed for the study area as 0.0024.

xvi.Ruggedness number (N): Strahler (1964)[31] defined Ruggedness number is the product of the watershed relief and drainage density and usually combines slope steepness with its length. High values of the ruggedness number in the watershed area because both the variables like relief and drainage density are enlarged. The Ruggedness number analyzed for the study area is 0.485.

xvii.Stream Frequency (Fs): Stream frequency is the sum of all stream segments of all orders per unit area [11]. Basically it depends upon the basin lithology and indicates distinctly the texture of the drainage network. Stream frequency is density serves as a tool in initiating erosional processes operating over an area; more precisely, in relation to stream orders and their characteristics provides data that elucidate the succession of relief development and degree of ruggedness in area [4]. It also acts as an index of various stages of landscape evolution. The influencing strands are rock structure, infiltration capacity, vegetation cover, relief nature, and amount of rainfall and subsurface material permeability. Hence, the low value of stream frequency exhibits presence of a permeable subsurface material.

Stream frequency is directly related to the lithological characteristics. The number of stream segments per unit area is termed as Stream Frequency (Fs) or Channel Frequency or Drainage Frequency. The drainage density computed is 2.016 No/Sq.km.

xviii.Drainage Density (Dd): Drainage density is the computation of the total stream length in a given basin area to the total area of the basin [27]. The measurement of drainage density is a useful numerical measure of landscape direction and runoff potential. It relates to the various aspect of landscape dissection such as valley density channel head source are climate and vegetation soil and rock properties relief and landscape evolution processes[29], [13]. Strahler,(1964)[31] distinctly observed that drainage density is directly proportional to basin relief. A high drainage density indicates weak basin and impermeable subsurface material with sparse vegetation and high relief. Whereas low drainage density manifests weak coarse drainage texture, high potential runoff and potential erosion of basin area [27]. The dissected drainage basin with a relatively rapid hydrology response to rainfall events, while low drainage density demonstrates poorly drained basin with a slow hydrological response. 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 drainage density obtained for the area is 1.672 Km/Sq.km.The drainage pattern for the present study area isdendritic. The dendritic pattern of drainage indicates that the soil is semi pervious in nature.The drainage pattern for the present study area isdendritic. The dendritic pattern of drainage indicates that the soil is semi pervious in nature.

xix.Drainage Pattern (Dp): In geomorphology, a drainage system is the pattern formed by the streams, rivers, and lakes in a particular drainage basin. They are governed by the topography of the land, whether a particular region is dominated by hard or soft rocks, and the gradient of the land.The drainage pattern for the present study area isdendritic.The drainage pattern shows a well integrated pattern formed by a mainstream with its tributaries branching and debranching freely in all directions. The dendritic pattern of drainage indicates that the soil is semi pervious in nature.

xx.Constant of Channel Maintenance (C): The inverse of drainage density is the constant of channel maintenance (C). It indicates the number of Sq.km of watershed required to sustain one linear Km of channel. The value obtained is 0.598 sq.km/km.

xxi.Circulatory ratio(Rc): The Circularity Ratio is a similar measure as elongation ratio, originally defined by Miller (1953), as the ratio of the area of the basin to the area of the circle having the same circumference as the basin perimeter. The value of circularity ratio varies from 0 (in line) to 1 (in a circle). Circulatory ratio is influenced by the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin. The circulatory ratio obtained from the analysis is 0.415.

xxii.Length of Overland Flow (Lg): Horton[10] defined length of overland flow as the length of flow path, projected to the horizontal, non channel flow from a point on the drainage divide to a point on the adjacent stream channel. He noted that length of overland flow is one of the most important independent variables affecting both the hydrologic and physiographic development of drainage basins.The length of overland flow for our study area is 0.299 km.

xxiii.Hypsometric Curve

The hypsometric application of a watershed has several topographical and hydrologic applications.As the hypsometric function combines the surface area and the slope value of any elevation point,it can address precise calculation and source identification of sediment derived from the surface runoff in the basin area.

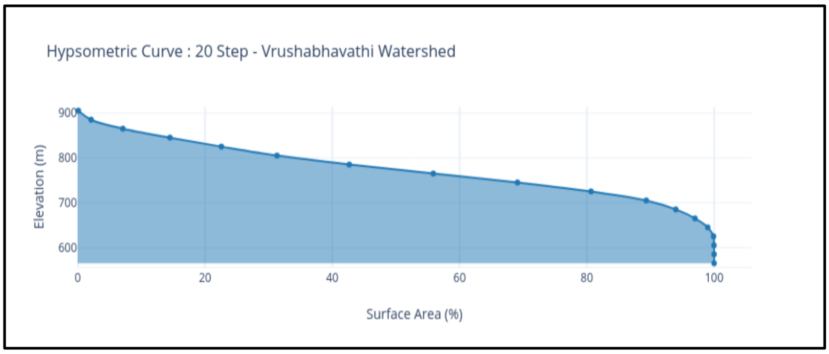


Fig 4.Hypsometric curve of Vrishabhavathi Watershed

This information can help in the runoff control and land use planning effectively from topographic planning.The hypsometric curve for Vrishabhavathi watershed is almost 'S' shaped (see fig.4)with concave upward shaped for higher elevation region, whereas convex upward for the lower elevation region. This indicates the presence of mature and youthful landforms in the watershed area , revealing their mature stage of erosional cycle.

Change Detection Analysis

Change detection analysis is performed using spatial analysis techniques. Change detection[8] is done so as to study the changes in the watershed as a result of urbanisation or decline in the net vegetation index. Two different approaches are used for change detection. The first one is NDVI and the latter one is NDBI.To assist this process , land use land cover map is also prepared using image classification techniques in GIS[2].Land cover data documents show how much of a region is covered by forests, wetlands, impervious surfaces, agriculture, and other land and water types. Water types include wetlands or open water. Land use shows how people use the landscape – whether for development, conservation, or mixed uses. The different types of land cover can be managed or used quite differently.Change detection analysis maps show the net normalized difference in various indexes from 2015 to 2020, thus representing the influence of urbanisation on the watershed.

1. Normalized difference vegetation index [NDVI]

Various activities around watershed areas of Vrishabhavathi river have changed the land cover and vegetation index (NDVI) that exist in the region[31]. The study assessedthe changes in land cover and vegetation density (NDVI) between 2015 and 2020(see fig.5 to fig.8), as well as obtaining the density of vegetation (NDVI) on each of the buffer areas of storm water drain buffer areas of 2015 and 2020 (see fig.5 to fig.8).It can be observed that during the year 2015-16 the NDVI values declined for the entire study area whereas it was concentrated along major reservoirs and highest stream orders in the year 2017-18. The NDVI index started rising in the years 2018-19 and 2019-20 during the following years indicating a paradigm shift in the conservation policies taken by the local governing bodies to save the major green spaces in Bengaluru city. The value stabilises in the year 2019-20 represented by no major increse or decrease in the net NDVI values(see Fig.8).

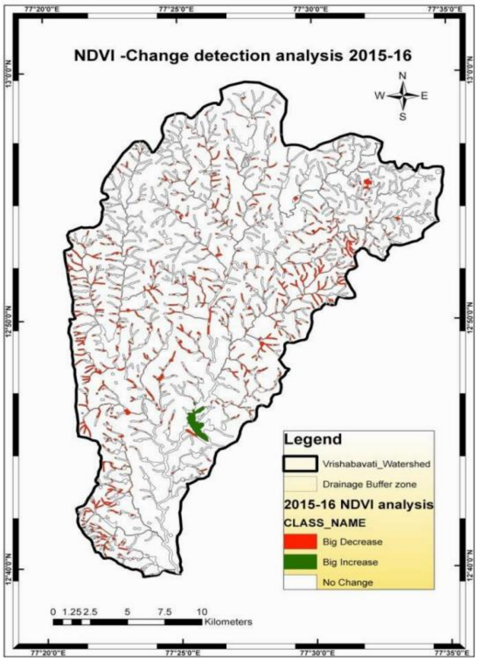


fig.5

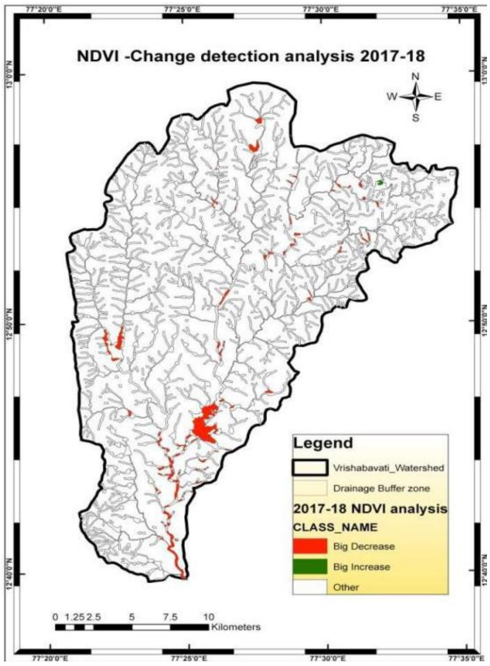


fig.6

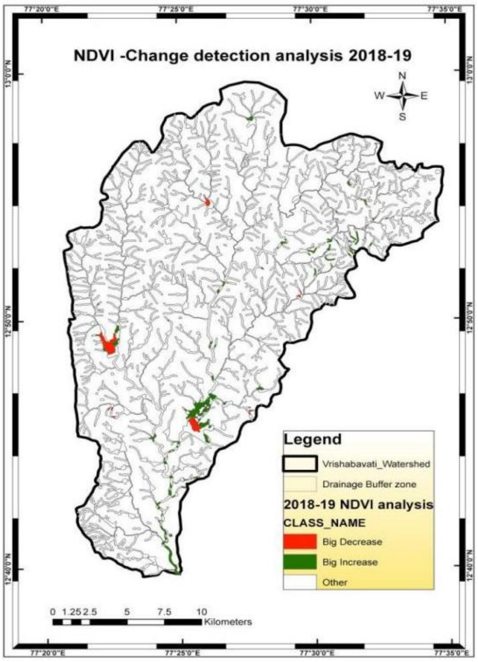


fig.7

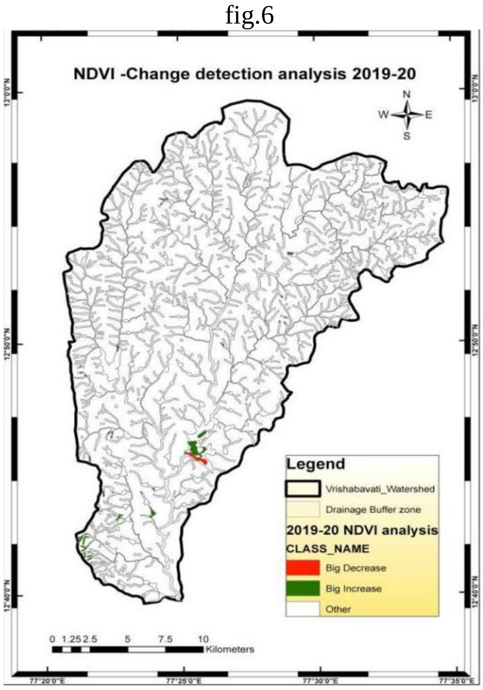


fig.8

`

2. Normalized Difference Built Up Index (NDBI)

This index highlights urban areas where there is typically a higher reflectance in the shortwave-infrared (SWIR) region, compared to the near-infrared (NIR) region. Applications include watershed runoff predictions and land-use planning[5][8]. Built Up = NDBI - NDVI. It is easily identified that the higher value in the range indicates the Built-up area whereas a very low or negative value indicates the barren land or forest area[24].This index highlights urban areas where there is typically a higher reflectance in the shortwave-infrared (SWIR) region, compared to the near-infrared (NIR) region (as shown in fig.9 to fig.12).The data is used to cross-validate the net equalized NDBI values in the watershed observed during the years 2015-16 , 2017-18,2018-19 and 2019-20. These four term observation indicates that the builtup index has grown by nearly 22% from the first term and then peaked to nearly 39% (indicated by big increase in 2018-19) and then declines in the key reservoir area (Fig 12, spotted area with green and red). Also a big decrease along the stream order buffer zones indicate that the initiatives of local government to curb the illegal occupation of storm water drainage and natural streams have been a great success.

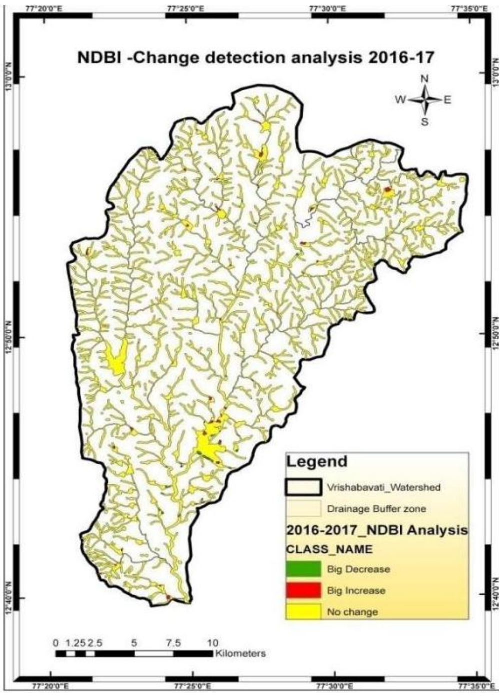


fig.9

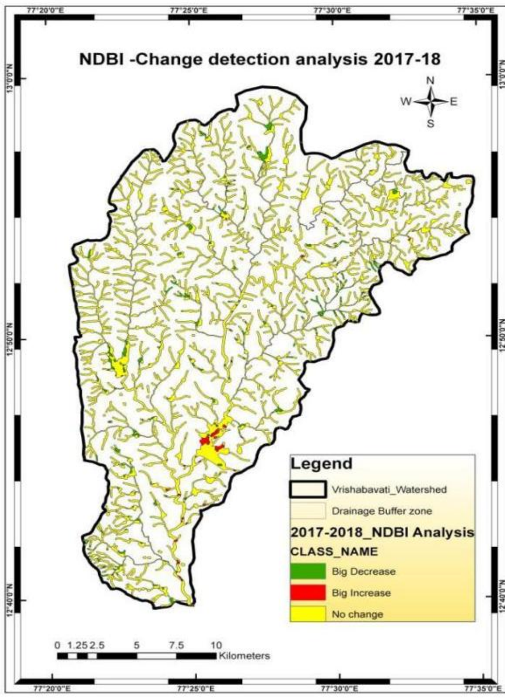


fig.10

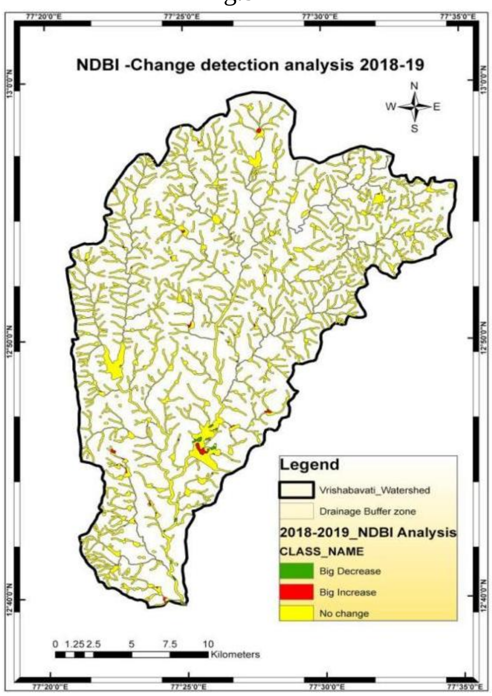


fig.11

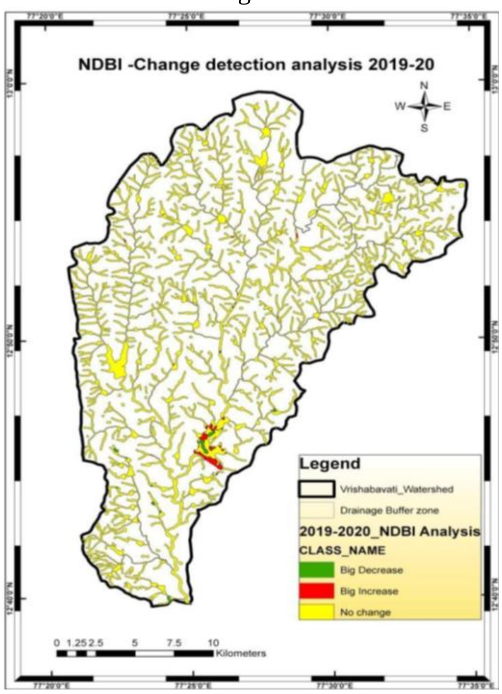


fig.12

VI. Discussion

Vrishabhavathi watershed and its sub-watersheds of third and fourth order have been found with dendritic pattern drainage basin. These sub basins are mainly dominated by lower order streams. The morphometric analysis is carried by the measurement of linear, aerial and relief aspects of basins. Slope in the watershed indicates moderate to least runoff and negligible soil loss condition.Hypsometric analysis proves the same. The maximum stream order frequency is observed in case of first-order streams and then for second order.

Hence, it is concluded that there is a decrease in stream frequency as the stream order increases and viceversa. Thecalculations of basic parameters, derived parameters and shape parameters, indicate there is no geological or structural control over the land. From the derived parameters the watershed falls in the region of low resistance, highly permeable subsoil and overburden materials with less runoff conditions and high overland flow indicating longer flow path and thus, gentler slopes.Texture ratio (T) indicates that the sub-watersheds falls under very coarse to coarse drainage texture, wherein the entire watershed belongs to relative to course and permeable subsoil. The shape parameters implies sub-circular to less elongated basin with high infiltration capacity.The relief aspects points that the basin is in mature to older stages of geomorphological evolution.The pressure of urbanisation was experienced both in the lower and higher order streams and across major reservoirs. This scenario has increased from 2015 to 2020 as indicated by the change detection analysis with a neutral NDVI values towards the recent years and a major decrease in the NDBI values throughout the buffer zone. This is a better sign of river rejuvenation and vegetative health in the Vrishabhavathi watershed area.

VII. Conclusion

By this research, we conclude on the basis of morphometric and change detection analysis carried over the Vrishabhavathi river basin that the Vrishabhavathi morphology is severely affected by the rapid urbanization in recent decades. Runoff pattern has not changed majorly; only some changes in peak times in several months have occurred. Drainage network is entirely affected, streams of various orders are disappearing, vegetation and green cover is reduced as we observed in the analysis. From this study it can be concluded that remote sensing techniques and GIS tools proved to be a competent tool in morphometric analysis and change detection analysis for the spatio-temporal analysis of urban influence, climate, vegetation, geomorphological and hydrological evolution of the Vrishabhavathi river basin area. This analysis work can be used for decision making in self governance to improve living standards of people in the Vrishabhavathi watershed area or river basin by implementing appropriate plans for land use and watershed management.

References

[1]. Agrawal, C. S., “Study of Drainage Pattern through aerial data in Navgrah area of Varanasi district”, U.P., Jour. Indian Society of Remote Sensing, pp.169- 175., (1998).

[2]. Bhatta, B. 2009. Analysis of urban growth pattern using remote sensing and GIS: a case study of Kolkata, India. International Journal of Remote Sensing, 30: 4733– 4746.

[3]. Chorley, R.J., Schumm, S.A., Sugden D.E., “Geomorphology”. Methuen, London, (1984).

[4]. Clarke J.I., “Morphometry from Maps. Essays in geomorphology”, Elsevier publication. Co., New York, pp 235–274., (1996).

[5]. Congalton, R. (1991). A review of assessing the accuracy of classifications of remotely sensed data. Remote Sensing of Environment, 37: 35–46.

[6]. Eze, B. E., J, E., “Morphometric Parameters of the Calabar River Basin: Implication for Hydrologic Processes”, Jour. of Geogr and Geology , vol. 2, No. 1, September (2010).

[7]. Gottschalk, L.C., “Reservoir sedimentation in handbook of applied hydrology”. McGraw Hill Book Company, New York (Section 7-1), 1964.

[8]. Guindon, B., Zhang, Y. and Dillabaugh, C. (2004). Landsat urban mapping based on a combined spectral–spatial methodology. Remote Sensing of Environment, 92: 218– 232.

[9]. Hack, J. T., Studies of longitudinal stream profiles in Virginia and Maryland: U. S. geological survey professional paper, 294-B, pp 45-97,(1957).

[10]. Horton, R.E., “Erosional development of streams and their drainage basins; hydrophysical approach to quantitative mor- phology”, Bull Geol Soc Am 56:275– 370, (1945).

[11]. Horton,R.E., “Drainage basin characteristics”, Trans. Amer. Geophys. Union.,13, pp 350-361, 1932.

[12]. Letsinger, Sally & Balberg, Allison & Hanna, Elias & Hiatt, Erin. “Geohydrology: Watershed Hydrology’’. 10.1016/B978-0-12-409548-9.12389-9,(2020).

[13]. Mahadevaswamy, G., Nagaraju, D., Siddalinga Murthy, S., Lakshmamma MSL., Nagesh, P.C., Rao, K., “Morphometric analysis of Nanjangud taluk, Mysore District, Karnataka, India, using GIS Techniques”, Int Journal Of Geomatics and Geosci, vol.1, No. 4, 2011.

[14]. Magesh, N.S., Jitheshlal, K.V., Chandrasekar, N., Jini, K.V., “GIS based morphometric evaluation of Chimmini and Mupily watersheds, parts of Western Ghats”, Thrissur District, Kerala, India. Earth Sci Inform, vol:.5(2), pp.111–121., (2012).

[15]. Melton, M.A., An Analysis of the relations among elements of climate, Surface properties and geomorphology, Project NR 389042, Tech. Rep. 11, Columbia University,(1957).

[16]. Montgomery, D.R., DIETRICH, W.E., “Where do channels begin?” In:-“Drainage basin morphometry for identifying zones for artificial recharge: A case study from Gagas River Basin”, India, 2011.

[17]. Muller, J.E., “An introduction to the hydraulic and topographic sinuosity indexes”, Ann Assoc Am Geogr 58:371–385, (1968).

[18]. Nag, S.K., Chakraborty, S., “Influence of rock types and structures in the development of drainage network in hard rock areas”, Journ. Of Indian Soc. Rein. Ser., vol.31(1), pp. 25-35.,(2003).

[19]. Nautiyal, M., D., “Morphometric analysis of a drainage basin, district Dehradun, U. P”. Jour. Indian Soc. Remote Sensing, 22(4): pp. 251-261., (1994).

[20]. Obi Reddy, G.E., Maji, A.K., Gajbhiye, K.S., “GIS for morphometric analysis of drainage basins”, GIS india, 11(4): 9, (2002).

[21]. Perez-Pena JV, Azanon JM, Azor A (2009) CalHypso: an ArcGIS extension to calculate hypsometric curves and their statistical moments. Applications to drainage basin analysis in SE Spain. Comput Geosci 35(6):1214–1223.

[22]. Pike RJ, Wilson SE (1971) Elevation-relief ratio, hypsometric integral and geomorphic area—altitude analysis. Geol Soc Am Bull 82:1079–1084

[23]. Praveen, K.R., Kshitij, M., Sameer, M., Aariz, A., Varun, N.M., "A GIS based approach in drainage morphometric analysis of Kanhar River Basin", Applied water science, Springer Open, (2014).
[24]. Ramachandra, T.V., Bharath, H.A. and Barik, B., Urbanisation Pattern of Incipient Mega Region in India, TEMA. Journal of Land Use, Mobility and Environment, (2014), 7(1), 83-100.
[25]. Rudraiah M, Govindaiah S, Srinivas VS Morphometry using remote sensing and GIS techniques in the sub-basins of Kagna river basin, Gulbarga district, Karnataka, India. J Indian Soc Remote Sens, (2008) 36:351–360
[26]. Sapkale, J.B., "Alluvium excavation from Tarali channel: A study of the impact of human intervention on channel morphology", unpublished Ph.D. thesis, doctoral diss., University of Pune, (2008).
[27]. Sapkale, J.B., "Cross Sectional and Morphological Changes after a Flood in Bhogawati Channel of Kolhapur, Maharashtra", Indian Geographical Quest, vol. 02, pp. 68-78., (2013).
[28]. Schumm, S.A., "Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey", Geol Soc Am Bull 67:597–646,(1956).
[29]. S.Singh, M.C., "Morphometric analysis of kanhar river basin, National Geographic", Jour. Of India. 43(1): pp. 31-43., 1997.
[30]. Smith, K. G., "Standards for grading textures of erosional topography", Am. Jour. Sci., 248: pp. 655- 688, 1950.
[31]. Strahler, A.N., "Quantitative geomorphology of drainage basins and channel networks", In: (Chow, V.T., ed.) Handbook of applied hydrology. McGrawHill, New York, pp. 439–476., (1964).
[32]. Strahler, A.N., "Quantitative analysis of watershed geomorphology", Trans Am Geophys Union 38:913– 920, (1957).

Bipin Anand, et. al. "Morphometric Analysis and Change Detection Analysis of Vrishabhavathi River basin using Remote sensing and GIS." *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 17(6), 2020, pp. 45-55.