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Morphological Characteristics of Three Watersheds of Mahatma Phule Krishi Vidyapeeth Central Campus Rahuri by Remote Sencing and Geographical Information System

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Abstract

Remote Sensing and Geographical Information System (RS-GIS) techniques were used to determine morphological characteristics of Catchment A, B and C catchments of Mahatma Phule Krishi Vidyapeeth Central Campus (west), Rahuri in view of acquiring the accurate data of measurable features of stream network of the drainage basin. Three catchments were identified from Mahatma Phule Krishi Vidtyapeeth Central Campus, Rahuri, Dist.Ahmednagar, Maharashtra based on the drainage pattern and catchment boundary. Thematic maps were prepared and the Cartosat-2DEM of the area were used. Morphological characteristics under areal aspects, linear aspects and relief aspects were determined in ArcGIS 10.2 environment.

Introduction

Remote Sensing technique is a convenient method for morphometric analysis since the satellite images provide synoptic view of a large area which is very useful in picking up drainage network of an area. Multi-spectral satellite data provides a convenient means to analyze drainage and distinct landform characteristics at various scales. The satellite remote sensing has the ability to provide synoptic view of large area and is very useful in analyzing drainage morphometry. Remote sensing techniques using satellite images and aerial photographs are convenient tools for morphometric analysis. Remote sensing and GIS has established as an efficient tool in drainage delineation and updation. Integration of remotely sensed data with GIS is an efficient and widely accepted approach in analyzing morphometric parameters and landform characteristics, Morphometric characteristics of three catchments of MPKV Central Campus (west), Rahuri, Maharashtra for soil and water conservation measures have been analysed by using Remote sensing (RS) and Geographical information System (GIS) techniques.

Methodology

Morphological analysis is the systematic description of watershed's geometry and its stream system to measure the linear aspects of drainage network, areal aspects of watershed and relief aspects of stream network. The drainage map of the study area was used for quantitative morphological analysis of both linear and aerial aspects of the drainage basin. The morphological information pertaining to each of the watershed was obtained

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with reference to its size, shape, slope, relief, stream density, vegetation, and land use and stream network system. Morphometric parameters have been classified into three groups: (a) linear aspect, (b) areal aspect and (c) relief aspect.

Location of the study area

Study area is located in Ahmednagar district, situated on the AhmednagarManmad highway, 35 km from the district place. The neighbouring districts to Ahmednagar district are Solapur (South - East), Osmanabad (South -East), Beed (South -East), Aurangabad (North - East), Nashik (North -West), Thane (North West) and Pune (South –West). Ahmednagar district is the largest district of Maharashtra state in western India. The study area of the research was Mahatma PhuleKrushiVidyapeethcentral campus Rahuri in Ahmednagar district, Maharashtra. The area is located between 19°19 to 19°22′ North latitude and 74° 36′ to 74° 40′ East longitude.

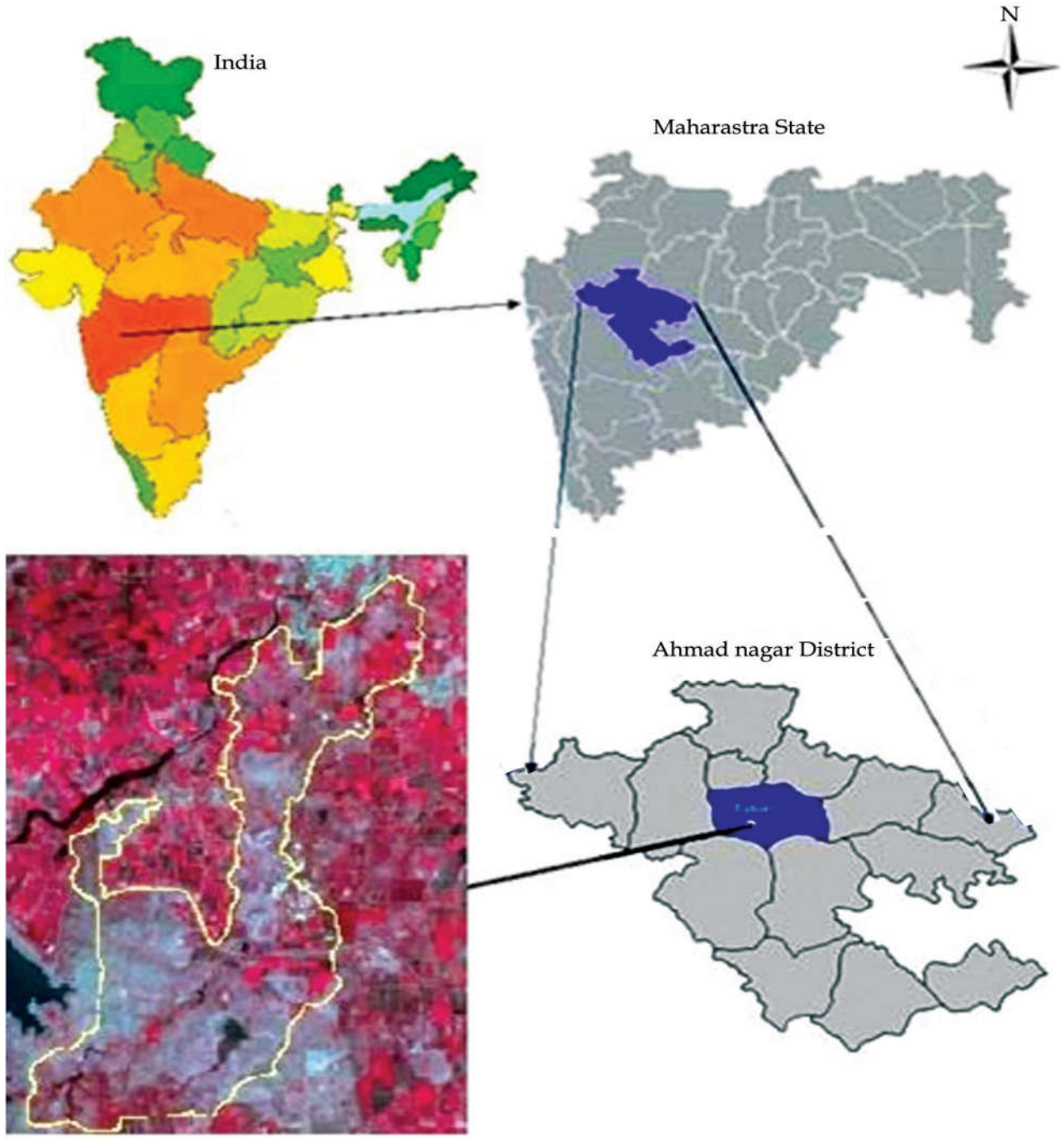

Fig. 1: Location of the study area.

Table : Basic data products used for the study.

Data Collection	Source of Data	Purpose
Cadastral Map	Office of University Engineer, MPKV Rahuri	To Prepare of boundary and base map of study area
Toposheets (47I)	Survey of India	To delineate catchments
Digital Elevation Model (DEM)	Bhuvan website, (NRSC, Hyderabad) (http://bhuvan.nrsc.gov.in)	To prepare slope map, flow direction map, flow accumulation map, contour map and drainage network map of study area

Thematic maps

Thematic maps such as Digital Elevation Model (DEM), land use map, slope map, watershed delineation and meteorological data based rainfall maps are the main inputs for hydrological studies. Cartosat DEM (30 m resolution) data down loaded from (http://bhuvan.nrsc.gov.in) website and processed to derive slope map. Thematic maps were prepared using remote sensing data, DEM data, slope, stream network, etc.

Methodology

Various interpretation techniques and methodologies were adopted to prepare thematic maps for these hydrological studies which include slope map, land use land cover and soil map from the central campus of Mahatma Phule Krishi Vidyapeeth Rahuri, Ahmednagar (M.S.) region.

Delineation of watershed

The delineation of watershed was done by using the Survey of Indiatoposheets of 1:50,000 scale with a contour interval of 20 m.The boundary was marked by bisecting the contour lines perpendicularly on the toposheet. The boundary line was drawn where the two streams are going in opposite direction and joining to their higher stream. In delineation process, the base map of topographical sheet is scanned, System GCS (Geographical Coordinate System) and projected to UTM (Universal Transverse Mercator) 43° N zone. In registered and geo-referred to the World Geodetic System WGS 1984 Geographic Coordinate ArcGIS software, the map was registered, geo- referred and digitized for building topology. All the streams present inside the boundary of basin were digitised. Other characteristic features like villages, road networks and water tanks were delineated.

Table : Linear aspects of drainage networks.

Linear parameters	Fomula / Expression
Stream orders (U)	The stream orders were designated as 1st, 2nd, 3rd, and 4th so on.
stream numbers (N_u)	the number of stream segments (N_u) of each stream order (U) of the watershed was counted and recorded
Basin length (L_b)	$L_b = 1.312 \times A^{0.568}$
Average basin width (B)	$B = \frac{A}{L_b}$
Bifurcation ratio (R_b)	$R_b = \frac{N_u}{N_{u+1}}$
Mean stream length (Lu)	$\bar{L}_u = \frac{\sum_{i=1}^{N} L_u}{N_u}$
Stream length ratio (RL)	$R_L = \frac{\bar{L}_u}{\bar{L}_{u-1}}$
Main valley length (Lv)	longest length across the valley from extreme of drainage divide to gauging station.
Main stream length (Lc)	longest segment of each order along the valley of watershed up to gauging station
Rho coefficient (ρ)	$\rho = R_L / R_b$

Table : Areal aspects of drainage networks.

Areal aspects	Formula / Expression
Drainage area (A), ha	portion of the watershed area, contributing the runoff
Form factor (Rf)	$R_f = \frac{A}{L_b^2}$
Drainage density (Dd), km/ sq.km	$D_d = \frac{\sum_{i=1}^{u} L_u \times N_u}{A}$
Stream frequency (F), Nos./sq.km	$F = \sum_{i=1}^{u} \frac{N_u}{A}$
Circularity ratio (Rc)	$C_r = \frac{4\Pi}{P_b^2}$
Elongation ratio (Re)	$E_r = \frac{2R_1}{L_c}$

Table : Relief aspects of drainage networkds.

Relief parameters	Formula / Expression
Stream slope (S), %	S= (H / L) x100
Watershed relief (H), m	elevation difference between basin mouth (discharge point) and the highest point on the basin perimeter
Relative relief (RR)	$R_R = H / P$
Relief ratio (Rr)	$R_r = H / L_b$
Ruggedness number (Rn)	$R_n = H \times D_d$
Geometric number	$GN = (H \times D_d) / S_g$
Time of concentration (Tc), min	$T_c = 0.0195\ L^{0.77} S^{-0.385}$

Base Map

A map representing the outline structure of the study area is known as a base map. It is skeleton structure of an area and represents the shape, size, position and relation of the physical features of an area. The base map is prepared using Survey of Indiatoposheet of 1:50,000 scale.Toposheet was georeferenced and rectified using ArcGIS 10.2 software.Base map consists of various features like road network, settlements, water bodies, and railway line network etc., delineated from the toposheet. The information content of base map is used as a baseline data to finalize the physical features of other thematic maps. Since the toposheets were very old all the features like roads, railways, settlements etc., are updated with the help of rectified and scaled satellite imageries of the study area and ground truth data.

Digital Elevation Model (DEM)

DEM is an important parameter in resource management applications. It is a raster GIS layer representing the area as a regular arrangement of locations (rows and columns) with a value in each cell corresponding to its elevation (Kumar, 2006). The digital elevation model downloaded from website bhuvan.nrsc.gov.in.Using boundary of study area DEM was clipped using Extraction by mask function in Spatial Analyst tool in ArcGIS 10.2. Extracted DEM then subjected to Fills sinks in a surface raster function of Spatial Analyst tool to remove small imperfections in the data.

Generation of thematic maps

Base map

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Drainage map

Drainage map was prepared from Digital Elevation Model, in ArcGIS environment. After preparing the drainage network map, the map was updated using SoIToposheet to know the changes in the study area. Drainage map includes all the streams, tributaries and small stream channels and depicts flow pattern of drainage lines in the study area. The lengths and numbers of all stream orders were obtained from drainage map prepared in ArcGIS 10.2 software using Spatial Analyst tool.

Contour map

The contour map of MPKV central campus west region was developed using Digital Elevation Model (DEM) in ArcGIS 10.2 Software. Raster surface function in 3D Analyst tool used to generate contour map.

Slope map

Slope is the most important terrain characteristic which plays a vital role in morphology, runoff processes, soil erosion, infiltration and land use/ land cover (Jhaet al., 2007; Yehet al., 2008). It is very important for understanding the spatial distribution, development and management of both land and water resources and major controlling factor in the development and formation of different landforms. The slope map was prepared for the study area from the DEM.

Results

Generation of thematic maps

Using ArcGIS 10.2 version, various thematic maps were generated such as base map, drainage map, contour map, digital elevation model, slope map, flow accumulation map, as a spatial database.

Base map

The base map is represented by villages, roads,

streets, canal, Places, etc. The base map was prepared using SoItoposheet and ground truth data in ArcGIS10.2 software.

The digital elevation model downloaded from website bhuvan.nrsc.gov.in. The DEM was reclassified into two classes namely high (570 m) and low (510 m) and used to precisely delineate the physiographic features.

Contour map

Contour map was prepared from Digital Elevation Model of study area with 5 m contour interval. The corresponding contour intervals were recorded in the attribute table. The total length of contours was 184.74 km.

Slope map

The slope map was derived using the DEM for the study area. The slope map was classified into six classes according to IMSD guidelines

Drainage map

Drainage map was prepared by using Digital Elevation Model of study area. The drainage pattern observed in the study area was dendritic. The highest stream order is 3rd order. The total length of streams draining to respective outlet points of the catchments was found out using ArcGIS software.

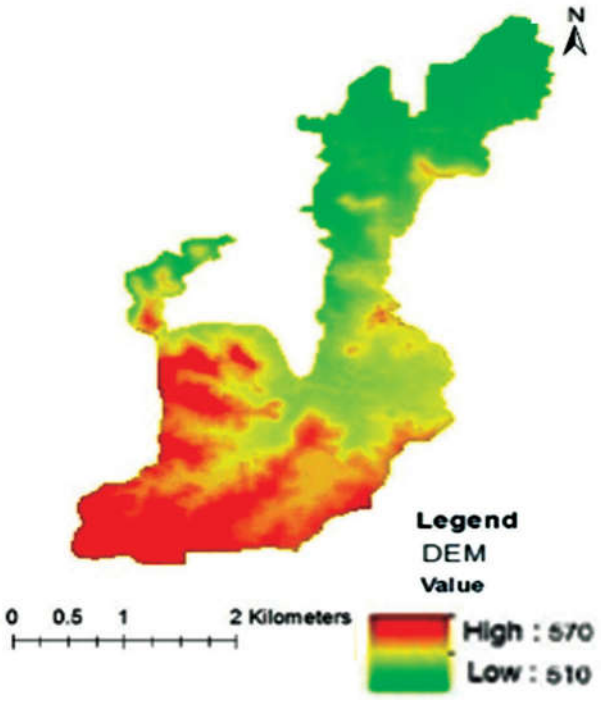

Fig. DEM of MPKV Central Campus (West).

Fig. Contour Map of MPKV Central Campus (West).

Table 1: Stream order and its mean stream lengths of Watershed A,B and C under MPKV central campus Rahuri.

Parameters	Stream order (U)			Total
	I	II	III	
Catchment-A				
No. of streams	51	9	1	61
Stream length, km	14.116	9.327	2.373	26.609
Mean stream length, km	0.276	1.036	2.374	4.479
Catchment-B				
No. of streams	3	1	-	4
Stream length, km	0.826	0.309	-	1135
Mean stream length, km	0.275	0.309	-	0.584
Catchment-C				
No. of streams	5	2	1	8
Stream length, km	2.050	1.095	0.110	3.255
Mean stream length, km	0.410	0.547	0.110	1.067

Table 2: Areal aspects of Watershed A,B and C under MPKV central campus Rahuri.

Areal aspects	Catchments		
	A	B	C
Drainage area (A), ha	842.2	66.77	162.5
Form factor (R_f)	0.43	0.61	0.54
Drainage density (D_d), km km^{-2}	3.15	1.69	2.00
Stream frequency (F), Nos.km^{-2}	7.36	5.99	4.92
Circularity ratio (R_c)	0.53	0.63	0.70
Elongation ratio (R_e)	0.74	0.88	0.83
Compactness coefficient (C_c)	1.37	1.26	1.19
Ellipticity index (E_i)	1.80	1.28	1.44
Texture ratio (R_t)	3.60	0.81	0.92
Constant of channel maintenance (C), km^2 km^{-1}	0.31	0.59	0.5
Length of overland flow (Lg), km	0.15	0.29	0.25
Drainage texture (Dt)	4.37	1.09	1.48

Table 3: Bifurcation ratio and stream length ratio of Watershed A,B and C under MPKV central campus Rahuri.

Catchments	Bifurcation ratio (Rb)	Stream length ratio (RL)	Rho Coefficient
Catchment-A	2.77	2.12	0.76
Catchment-B	3	1.12	0.37
Catchment-C	2.15	0.71	0.33

Table 4: Relief aspects of Watershed A,B and C under MPKV central campus Rahuri.

Relief parameters	Catchments		
	A	B	C
Stream slope (S), %	0.84	2.20	1.16
Watershed relief (H), m	37	23	20
Relative relief (R_R)	2.61	6.28	3.71
Relief ratio (R_r)	0.008	22.05	0.011
Ruggedness number (R_n)	0.12	0.039	0.040
Geometric number	13.90	1.77	3.46
Time of concentration (Tc), min	84.92	15.99	30.51

After analysis it was found that the watershed is of 3rd order type and drainage pattern is dendrite which indicates the homogeneity in texture and lack of structural control (Mittal, 2002). The maximum length and basin width of watershed was found to be 4.40 and 1.91 km for catchment -A, 1.04 and 0.64 km catchment -B, 1.72 and 0.94 km for catchment –C. The values of stream lengths for 1st, 2nd and 3rd order streams were found to be 14.116, 9.327, 2.373, km for catchment -A, 0.826, 0.309 for catchment-B, 2.050, 1.095, 0.110 for catchment-C. It revealed that the total length of stream segments is maximum in first order streams and decreases as the stream order increases.

The mean stream lengths of 1st, 2ndand 3rd order streams were 0.276, 1.036, and 2.374 km for catchment-A, 0.275, 0.309 for catchment-B, 0.410, 0.547, 0.110 for catchment-C which indicates the mean length of the stream of the particular order increases with the increase in the order of stream and decreases at last order which means the mean length of a stream of a given order is greater than that of immediate lower order but less than that of the next higher order (Horton, 1945). This confirms the property of the stream order, number and their corresponding length.

Horton (1945) stated that the mean watershed area of successive orders tends to form a geometric series and the watershed area increases with the increase in stream order. Area of a higher order stream includes the total area covered by all streams of lower order. Areal aspects of drainage network include measurement of areal elements such as drainage area, form factor, drainage density, drainage texture, stream frequency, circularity ratio, elongation ratio, compactness co-efficient, ellipticity index, texture ratio, constant of channel maintenance and length of overland flow in a systematic way. High value of density indicates well developed network and torrential runoff likely to cause violent flood, while a low value signifies a less developed network and a modest runoff which is explained by high permeability of the terrain.

The value of drainage texture (km-1) depends upon a number of natural factors such as climate, rainfall, vegetation, lithology, soil type, infiltration capacity, relief and stage of development (Smith, 1950). Smith (1950) classified drainage density into five different classes of drainage texture, i.e. less than 2, indicates very coarse, between 2 and 4 is coarse, between 4 and 6 is moderate, between 6 and 8 is fine and greater than 8 represents very fine drainage texture. Only catchment-A falls in moderate drainage texture category and others in very coarse drainage texture category.

With low value of ruggedness number, it is evident that watershed is having gentle slope. All the factors under liner, areal and relief aspects pertaining to Watershed A, B and C are depicted in the above tables.

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