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Research Article

Geomorphological Studies of Morna River Catchment using Remote Sensing and Geographical Information System

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ABSTRACT

Basin morphometry is a means of numerically analysing or mathematically quantifying different aspects of a drainage basin. In the present study, morphometric analysis of the Morna drainage basin has been carried using earth observation data and geographical information system (GIS) techniques. The morphometric parameters considered for analysis includes the linear, areal and relief aspects of the basin. The Morna basin covers an area of 132.85 sq km and is an 5th order drainage. The mean bifurcation ratio is 4.155 indicating the basin is largely controlled by structure. The basin has high drainage density of 2.81 per km^2 and is elongated in shape. The length of overland flow values of the basin is 0.177. The study has strengthened in understanding the hydrological, geological and geomorphological characteristics of the Morna drainage basin.

Key words: Geomorphology, Remote sensing, GIS

Introduction

Morphometry is defined as the measurement of shape. Morphometric studies in the hydrology were first initiated by the Horton (1945) and Strahler (1957). The morphometric analysis of the watershed or drainage basin and channel network play a vital role for understanding the geohydrological behavior of the watershed. The morphometric parameters of a watershed are reflective of its hydrological response to a considerable extent, and can be helpful in synthesizing its hydrological behavior (Zende and Nagrajan, 2011). A quantitative morphometric characterization of a drainage basin is considered to be the most satisfactory method for the proper planning of watershed management because it enables us to understand the relationship among different aspects of the drainage pattern of the basin.

Traditionally these parameters are obtained from the topographic maps or field surveys. As these are fundamental source for the drainage analysis due to their availability, simplicity and cheapness. However, field mapping is acknowledged as the most accurate way to determine the channel networks, although it is often impractical, especially for the large area and remote watershed situated in the high altitude mountainous region. However, channel networks extraction and watershed delineation from topographic maps require tedious time. And also the extracted mapped data from the topographic maps using traditional method are in non-digital form; thus, require additional work of tediously digitizing the data in order to incorporate with other remote sensing and Geographical Information System (GIS) data (Veenu and Pinnamaneni, 2010).

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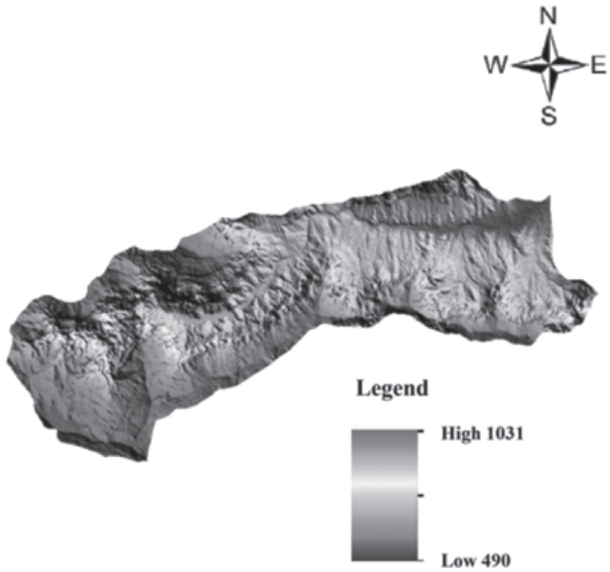

Fig. 1. Digital elevation model of study area

Over the past two decades this information has been increasingly derived from the digital representation of topography, generally called as the DEM (Sreenivasalu and Bhaskar, 2010). In recent years, the automated determination of drainage basin parameter has been shown to be efficient, time saving and ideal application of GIS technology. Hence, the present research has been carried out for morphometric analysis Morna river catchment

Materials and Methods

Data collection and pre-processing

Digital Elevation Model (DEM) was downloaded from SRTM imageries (http://.srtm.csi.cgiar.org). Toposheets of study area were obtained from GIS unit cell, Commissionorate of Agriculture.

Software and System

Arcs-GIS 10.2 were used for data creation, data analysis and output generation.

Watershed delineation

Watershed delineation was performed in ArcGIS 10.2. DEM was used for watershed delineation (Fig. 1). Then, 47 G/15, 47 G/11 and 47 G/16 numbered toposheets were used for validation of watershed delineation.

Slope map

The slope map of the study area was developed from the Digital Elevation Model (DEM) acquired from SRTM DEM imageries (http://srtm.csi.cgiar.org) (Fig. 2).

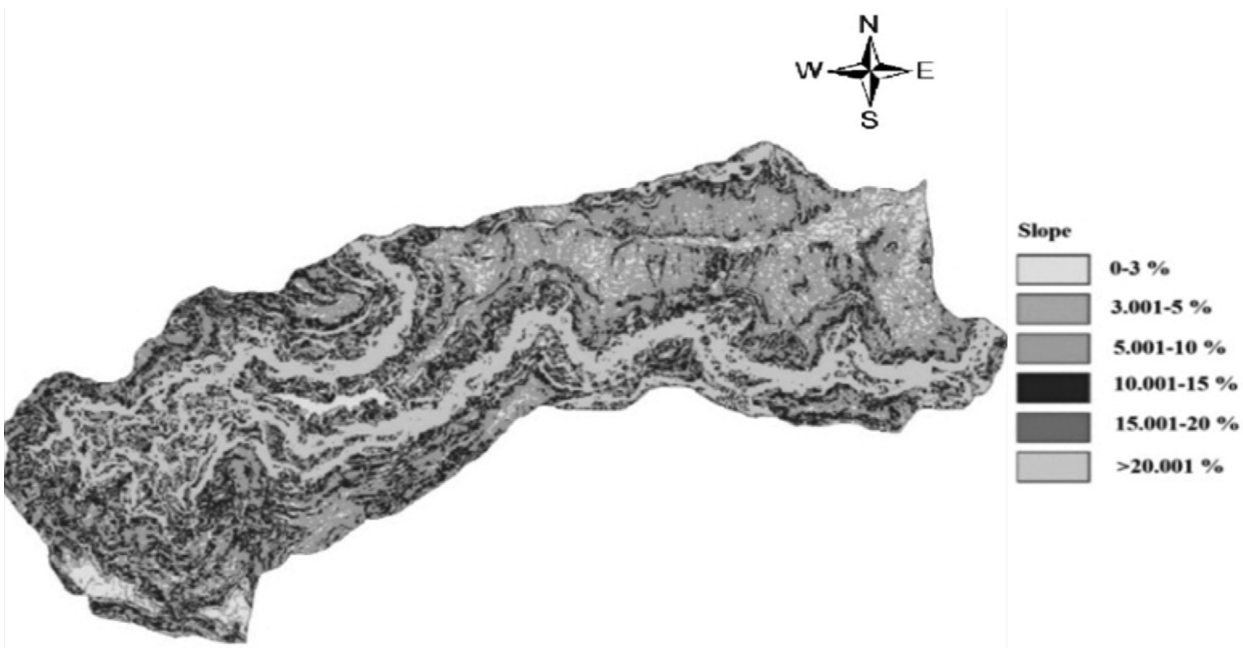

Fig. 2. Slope map of study area

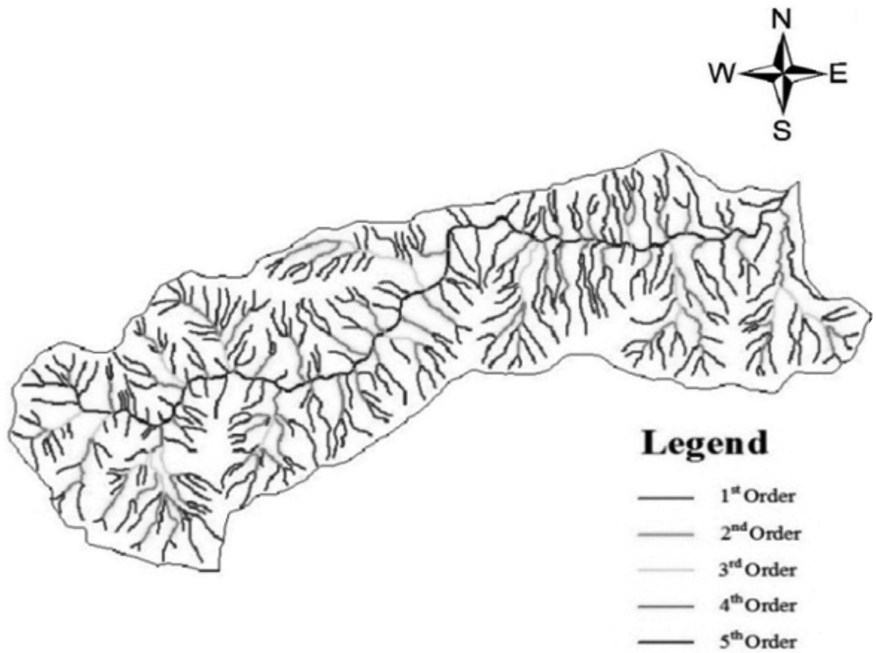

Fig. 3. Drainage map of study area

Stream order Map

Stream order map of the study area was extracted using the DEM (Fig. 3). SOI toposheets of the study were used for validation of stream order map prepared using DEM. The Strahler's stream ordering system was adopted for stream ordering (Singh and Singh, 1997).

Results and Discussion

Linear Aspects of Drainage Networks

Stream order: It has been found that the study area is a 5th order drainage basin. Total 398 numbers of streams were identified out of which 296 were of 1st order, 79 of 2nd order, 18 of 3rd order, 4 of 4th order and 1 of 5th order stream. Higher stream order of watershed indicated the greater discharge and higher velocity of the stream flow.

Stream number: The numbers of the stream segments were decreasing as the stream orders were increasing. The higher number of streams in lower order led to lesser permeability and infiltration. It was observed that maximum frequency was in case of first order streams. It was noticed that there was decrease in stream frequency as the stream order increases (Waikar and Nilawar, 2014).

Stream length: Streams of relatively smaller lengths are characteristics of areas with larger slopes and finer textures. Longer lengths of streams are generally indicative of flatter gradients. The total length of stream segments in the Morna catchment was maximum in the first order streams and decreases as the stream order increased. This brought out inference that the basin was subjected to erosion, also that some areas of the basin could be characterized by variation in lithology and topography (Singh and Singh, 1997)

Bifurcation ratio (R_b): Bifurcation ratio (R_b) of watershed varied from 3.74 to 4.5. Mean bifurcation ratio was 4.157. The bifurcation ratio depends upon the geological and lithological development of the drainage basin. The Rb values of study area (Table 1) indicated that there was a uniform increase in Rb values from the first order streams to the fourth order streams. However, a decrease in the Rb values was noticeable from the fourth order streams to fifth order stream. These differences are depending upon the geological and lithological development of the

Table 1

Stream order (u)	No of streams (N_u)	Stream length (km)	Mean stream length (km)	Mean stream srea (km^2)	Bifurcation ratio (R_b)	Stream length ratio (R_l)	Stream area ratio (R_a)
1	296	263.13	0.808	4.8	-		-
2	79	63.28	0.797	9.3	3.740	3.74	1.93
3	18	22.14	1.245	81.34	4.380	2.845	8.74
4	4	5.570	1.643	89.34	4.500	3.974	1.09
5	1	24.25	24.25	132.85	4.000	0.229	1.48
				Average	4.155	2.69	3.310

drainage basin. The higher Rb values in the study area indicated that the basin was largely controlled by structures (Strahler, 1957).

Mean stream length: Mean stream lengths of first order, second order, third order, fourth order and fifth order stream were 0.953 km, 0.808 km, 1.245 km, 1.643 km and 24.252 km, respectively. Total length of stream decreases with increase in order of stream. This might be due to the geomorphologic, lithological and structural control and contrast.

Stream length ratio (R_l): Stream length ratio (R_l) of II/I order was 3.74, III/II order was 2.845, IV/III order was 3.974,V/IV order was 0.229. These variations in ratio in the study area were due to variations in slope and topography. Among all the Horton's ratio, the stream length ratio had the maximum effect on the peak of GIUH peak. Higher values of R_l would make the condition favourable for flooding in the downstream region. The R_l values does not depend upon the size of the river basin but it is characterised by basin shape.

Stream area ratio (R_{a-}): Stream area ratio (R_{a-}) of II/I order was 1.93, III/II order was 8.74, IV/III order was 1.09, V/IV order was 1.48. Average of stream area ratio for Morna catchment is 3.310, which is considered as low. At low values of the stream area ratio ($R_a < 6$), the peak discharge of the hydrograph decreased but at higher values of the area ratio ($R_a > 6$), the peak discharge of the hydrograph increased, with increase in area ratio.

Areal Aspects of Drainage Networks

Form factor: The form factor value of Morna river catchment was 0.25 (Table 2). The lower value of form factor represented was an elongated shape of watershed. An elongated basin with low form factor indicated that the basin had flatter peak for longer duration. Flood flows in such elongated basins are easier to manage than of the

Table 2

Sr. No.	Morphometric parameter	Symbol	Value
1	Area (km^2)	A	132.85124
2	Perimeter (km)	P	62.51081
3	Basin length (km)	L_b	71.6
4	Form factor	R_F	0.254
5	Circularity ratio	R_C	0.426
6	Elongation ratio	R_L	0.54
7	Drainage density (km km^{-2})	D_d	2.81
8	Drainage texture (km^{-1})	T	5.71
9	Constant of channel maintenance (km^2 km^{-1})	C	0.355

circular basin because the whole volume of discharge doesn't get accumulated at same time at outlet like circular basin.

Circulatory ratio: The circulatory ratio of Morna river catchment was 0.426. As circulatory ratio is between 0.4-0.5, it indicated that it is elongated in shape (Waikar and Nilawar, 2014). In present case, value of circulatory ratio indicated, that basin was elongated in shape and were characterised by the high to moderate relief and the drainage system were structurally controlled. It also indicated that basin had low discharge of runoff.

Elongation ratio: Values of elongation ratio ranging between 0.1 and 0.6 indicate roundity and low degree of integration within a basin. Values between 0.6 and 1.0 assume pear-shaped characteristics of a well integrated drainage basin. The varying shapes of watershed can be classified with the help of the index of elongation ratio, i.e. circular (0.9-0.10), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and more elongated (less than 0.5). The elongation ratio of Morna river catchment was 0.54. This indicate that catchment was of elongated shape. It indicated that watershed was having flatter peak flow for longer duration.

Drainage density: The drainage density indicates the closeness of spacing of channels, for the whole basin. The drainage density of Morna river catchment was 2.81 km km^{-2}. The high drainage density was due to the regions of weak or impermeable surface materials, sparse vegetation, and mountainous relief. Also high drainage density leads to fine drainage texture, and indicates that catchment area is more prone to flooding.

Constant of channel maintenance: The constant of channel maintenance indicates the number of km^2 of basin surface required to develop and sustain a channel of length 1 km long. The constant of channel maintenance was found 0.355 km km^2 for Morna river catchment. It indicated that magnitude of surface area of watershed needed to sustain unit length of stream segment.

Drainage texture: The drainage density and drainage frequency have been collectively defined as drainage texture. Smith (1950) has classified drainage texture into five different textures i.e., very coarse (< 2), coarse (2 to 5), fine (5 to 8) and very fine (> 8). The drainage texture of the watershed was 5.71 per km. Drainage texture shows the relative spacing of the drainage line. The drainage texture of Morna catchment was less than 8, and therefore, it showed fine drainage texture.

Relief aspects of drainage network

Relief: Total relief for Morna river catchment was 505 m (Table 3). This indicated moderate relief and steep slope in the Morna river catchment. High value of relief led the low infiltration and high runoff from the catchment.

Table 3

Sr. No.	Parameter	Value
1.	Slope (%)	0-25
2.	Relief (m)	505
3.	Relief ratio	0.027
4.	Relative relief	0.807
5.	Ruggedness number	1.414
6.	Length of overland flow (km^2 km^{-1})	0.177

Relief ratio: The relief ratio was 0.027 for the Morna river catchment. This value of relief ratio indicated the presence of hilly region in the catchment.

Relative relief: Relative relief for the Morna river catchment was 0.807 which was considered low. Low relative relief indicated the peak discharge rates were likely to be low and low erosion from the catchment.

Ruggedness number: This number represented that if drainage density was increased and keeping relief as constant, the average horizontal distance from drainage divide to the adjacent channel was reduced. On the other hand if relief is increased by keeping drainage density constant, the elevation difference between the drainage divide and adjacent channel goes on increasing. In the present study, ruggedness number was 1.414.

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