DETERMINATION OF GEOMORPHOLOGICAL CHARACTERISTICS OF MEGHAL RIVER BASIN USING REMOTE SENSING AND GIS

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ABSTRACT

Meghal is among the river basins of Junagadh district in Saurashtra region of Gujarat state. The soil of this basin is damaged by mismanagement and abuse of nature, reducing its productivity. The study was undertaken in Meghal river basin to determine the geomorphological characteristics of its seven mini-watersheds. The values of linear parameters like bifurcation ratio, drainage frequency, drainage density and the shape parameters like elongation ratio, form factor, circularity ratio, compactness coefficient etc. were estimated using Remote Sensing and GIS software (Geomatica-V10.1). The parameters showed that Meghal is 6^th^ order river basin, which is low in relief, having highly permeable subsoil, comparatively less elongated and has moderate to coarse texture. The study can be useful in implementation of watershed development projects.

KEY WORDS: Geomorphology, GIS. Morphometric analysis, Remote Sensing, Soil erosion, Watershed delineation

INTRODUCTION

Geomorphological characteristics of a river basin play an important role in modeling various hydrological processes, in ungauged catchments with limited data; these parameters can be useful in understanding the hydrological characteristics. Geomorphological analysis is the systematic description of watersheds geometry and line stream channel system to measure the linear aspects of drainage network and areal aspects of drainage basin. Several shape indices or shape parameters are used to characterize river basin geometry.

The conceptual evolution in the geomorphic approach of drainage basins started with the studies conducted by Horton (1932 and 1945), Strahler (1952), Schumm (1956). Later, many researchers have used remote sensing (RS) data and analyzed morphometric properties of the catchment on geographical information system (GIS) platform. Remote sensing and GIS are proved to be efficient tools in drainage delineation and updating (Rudraiah *et al.*, 2008). The morphometric parameters requiring preparation of drainage map, contour map, ordering of the various streams and measurements of catchment area, perimeter, relative relief, relief ratio, length of drainage channels, drainage density, drainage frequency, bifurcation ratio, texture ratio, circulatory ratio and constant channel maintenance helped to understand the nature of the drainage basin (Pankaj and Kumar, 2009). Morphometric analysis coupled with hydrogeological information was used to prepare a generalized scenario for watershed development plans (Subba Rao, 2009).

All the 71 rivers in Saurashtra, the western peninsular region of Gujarat covering an area of about 58,743 square km, are low flowing majorly during rainy season. Meghal falls in the district of Junagadh and encompasses four talukas namely, Maliya, Mendarada, Mangrol and Keshod. Being an agricultural area, the major demand of water is for agriculture. The length of river is about 72 km and slope of basin is 1:1000 to 1:5000. The catchment area is 541 square km with average annual rainfall of 817 mm (Rathod, 2010). The gradually drying up of Meghal River has aggregated, and highlighted water related problems affecting people’s livelihood and has led to a decline and uncertainty in agricultural income. Based on secondary and tertiary drainage pattern of Meghal river basin, the watershed area was sub-divided into 3 sub-watersheds, 7 mini-watersheds and 61 micro-watersheds. Various thematic maps were prepared such as cadastral map, soil map, slope map, drainage map, normalized difference vegetation index (NDVI), soil adjusted vegetation index (SAVI) to know reflectance characteristic of crop (Rathod, 2010).

Geomorphological characters help in understanding the important features of the basin and hence, facilitate the efficient use of the resources. The success of watershed development programme revolves around the conservation of soil and water resources in that watershed and hence, it is imperative to prioritize the watersheds based on conservation and developmental needs. With such inputs, action plans for soil and water conservation can be formulated based on the priority of watershed.

MATERIALS AND METHODS

The study area is Meghal river basin 5G1D2, Dist. Junagadh, Saurashtra region of Gujarat state. It is located between 20° 58' N to 21° 17' N latitude and 70° 13' E to 70° 32' E longitude. The study area falls under Survey of India toposheet number 41K/08 and the IRS LISS III images of 91/57 (Path/Row). It extends up to 541 sq.km of land with total length of river is about 72 km. The climate of area can be classified as sub-tropical and semi-arid. The location map of the study area is shown in Figure 1.

The data used for the study includes

i. Map of India (Scale 1:15,00,000), Gujarat (Scale 1:37,50,000) and Watershed map of Gujarat (Scale 1:37, 50,000).
ii. Cadastral map of Meghal river basin (Scale 1:4000)
iii. Satellite images of IRS P6 of sensor LISS III digital data

The study was undertaken in Meghal river basin of 54158 ha area. Satellite images of IRS P6 of sensor LISS III (DOP Oct. 14, 2005 and Feb. 1, 2008), AWiFS (DOP Nov. 26, 2007, Dec. 15, 2007, Jan. 18, 2008 and Feb. 25, 2008) were procured from Bhaskaracharya Institute for Space Applications and Geo-informatics, Gandhinagar and for GIS application ArcGIS V9.2 and PCI Geomatica V10.1 software was used. Various thematic maps were prepared such as cadastral map, soil map, slope map, drainage map, watershed maps etc. Based on visual interpretation the demarcation of watershed area was done in Meghal river basin. Based on secondary and tertiary drainage pattern of basin, the watershed area was sub-divided into 3 sub-watersheds, 7 mini-watersheds and 56 micro-watersheds.

Linear aspects of channel system like stream order, stream number, stream length, bifurcation ratio and stream length ratio were calculated based on Horton (1945), Schumm, (1956) and Strahler (1964) considerations.

Area of a basin (A) and perimeter (P) were drawn from topographical maps. The aerial aspects of the drainage basin like drainage density (Dd), stream frequency (Fs), elongation ratio (Re), circularity ratio (Rc) and form factor ratio (Rf) etc. were calculated using thematic maps.

RESULTS AND DISCUSSIONS

The Meghal river basin was divided into seven mini-watersheds with codes *viz*. 5G1D2a1, 5G1D2a2, 5G1D2b1, 5G1D2b2, 5G1D2b3, 5G1D2c1 and 5G1D2c2. The study area is a 6^{th} order drainage basin (Figure 2). The total number of 744 streams were identified of which 597 are 1^{st} order streams, 110 are 2^{nd} order, 25 are 3^{rd} order, 9 in 4^{th} order, 2 in 5^{th} order and 1 in 6^{th} order streams. The Meghal River is a 6^{th} order stream covering an area of 540 km^2. The total length of the 1^{st} order streams is the highest i.e. 388.055 km, and that of 2^{nd} order is 195.086 km, 3^{rd} order is 84.0 km, 4^{th} order is 57.29 km, 5^{th} order is 34.495 km and the lowest 25.287 km is of 6^{th} order. The mean stream length of the basin varies from 0.65 km to 25.287 km which shows inverse trend with the total length of the streams. The Rb ranges between 2.0 to 5.42 which shows that the geologic structures do not distort the drainage pattern. The mean bifurcation ratio value is 3.82 for the study area which indicates that the geological structures are less disturbing the drainage pattern.

Linear parameters of Watershed

As listed in the Table 1, the linear parameters include bifurcation ratio, drainage frequency, length of overland flow, texture ratio and drainage density are linearly proportional to the severity of erosion in the area. This means that as the values of linear parameters increases the degree of erosion in the area increases.

Bifurcation Ratio (Rb)

As described in the earlier section, the mean bifurcation ratios for the mini-watersheds are 3.85, 3.33, 4.55, 3.19, 3.34, 3.85 and 3.92 respectively. Strahler (1957) demonstrated that Rb shows small range of variation for different regions or for different environment dominates. The values range from 3.0 to 5.0 which show that the geologic structures do not distort the drainage pattern.

Stream frequency (Fs)

The stream frequencies of all the mini-watersheds are mentioned in Table 1. Low value of stream frequency of the mini-watershed 5G1D2a1, 5G1D2a2 and 5G1D2c1 i.e. 0.725, 1.059 and 1.369, respectively reveals forest area. High value of drainage frequency in 5G1D2b1, 5G1D2b2, 5G1D2b3 and 5G1D2c2 consecutively given as 2.218, 2.281, 2.593 and 3.678 produces more runoff in comparison to others. Stream frequency (Fs) for the basin exhibits positive correlation with the drainage density value of the area indicating the increase in stream population with respect to increase in drainage density.

Length of overland flow (Lg)

Higher values of length of overland flow indicates lower relief of the area and lower values of length of overland flow indicates higher relief of the area. It is one of the most important independent variables, affects both to the hydrologic and physiographic development of watershed. The small length and depth of overland flow are found in laminar condition. The values of Lg for the mini-watersheds 5G1D2a1, 5G1D2a2, 5G1D2b1, 5G1D2b2, 5G1D2b3 and 5G1D2c1 are 0.682, 0.516, 0.364, 0.274, 0.288, 0.395 and 0.228, respectively.

Texture Ratio (T)

Texture ratio is classified into five class i.e. very coarse (<2), coarse (2-4), moderate (4- 6), fine (6-8) and very fine (>8). The soft or weak rocks unprotected by vegetation produce a fine texture, whereas massive and resistant rocks cause coarse texture. Sparse vegetation of arid climate causes finer textures than those developed on similar rocks in a humid climate. The texture of a rock is commonly dependent upon vegetation type and climate. Texture ratios of the mini-watersheds 5G1D2a1 and 5G1D2a2 are 1.214 and 0.787, which reveal very coarse texture; texture ratio of the mini-watersheds 5G1D2b1, 5G1D2b2, 5G1D2b3 and 5G1D2c1 ranges from 2.06 to 3.46, which reveals to coarse texture; and texture ratio of the mini-watershed 5G1D2c2 is 4.16, which reveals to moderate texture.

Drainage density (Dd)

The watersheds can be grouped into four categories based on Dd as low (below 2.0 km/km^2), moderate (2.0-2.5 km/km^2), high (2.5- 3.0 km/km^2) and very high (above 3.0 km/km^2). Drainage densities of 5G1D2a1, 5G1D2a2, 5G1D2b1, 5G1D2b2, 5G1D2b3 and 5G1D2c1 are given as 0.732, 0.967, 1.371, 1.821, 1.73 and 1.262, respectively, which indicate low drainage density, while in mini-watershed 5G1D2c2, drainage density is 2.19, which indicates moderate drainage density (Table 1). 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. In general, it has been observed over a wide range of geologic and climatic types, that low drainage density is more likely to occur in regions of highly permeable subsoil material under dense vegetative cover, and where relief is low. In contrast, high Dd is favoured in regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief (Nag, 1998).

Shape parameters of watershed

The shape parameters includes elongation ratio, form factor, circularity ratio and compactness coefficient. These parameters are inversely proportional to the severity of soil erosion. As the values of these parameters increases, the priority of the watershed decreases. The variation of these parameters for all the mini-watersheds is given in Table 2 and described as under.

Elongation ratio (Re)

The value of elongation Ratio (Re) generally varies from 0.6 to 1.0 associated with a wide variety of climate and geology and can be grouped into three categories i.e. circular (>0.9), oval (0.9-0.8) and less elongated (< 0.7). Re values of mini-watersheds 5G1D2a1, 5G1D2a2, 5G1D2b1, 5G1D2b2, 5G1D2b3, 5G1D2c1 and 5G1D2C2 are 0.623, 0.531, 0.495, 0.579, 0.665, 0.734 and 0.598, respectively (Table 2), which reveals that the mini-watersheds of the Meghal river basin are less elongated.

Form factor (Rf)

The form factors for all mini-watersheds are given as 0.305, 0.222, 0.192, 0.264, 0.347, 0.423 and 0.281, respectively (Table 2). These observations show that the mini-watersheds are elongated. The elongated watershed with low value of Rf indicates that the basin will have a flatter peak flow for longer duration. Flood flows of such elongated basins are easier to manage than from the circular basin.

Circularity ratio (Rc)

The Circularity ratio (Rc) value equal to 1.0 indicates the watershed as complete circle. The value of Circularity ratio (Rc) of all the mini-watersheds are 0.291, 0.571, 0.227, 0.24, 0.273, 0.282 and 0.229, respectively, which indicate strongly elongated and highly permeable homogenous geologic materials. This indicates that the mini-watersheds are elongated in shape with low discharge of runoff and highly permeable subsoil condition. The high value of circularity ratio indicates the late maturity stage of topography. This anomaly may due to diversity of slope, relief and structural conditions prevailing in the watershed.

Compactness coefficient (Cc)

The compactness coefficients (Table 2) values are 1.441, 1.467, 1.708, 1.59, 1.352, 1.356 and 1.516, respectively, for all the mini-watersheds. Compactness coefficient is used to express the relationship of a hydrologic basin with that of a circular basin having the same area as the hydrologic basin. A circular basin is the most hazardous from a drainage stand point because it will yield the shortest time of concentration before peak flow occurs in the basin.

CONCLUSION

Meghal is a 6^{th} order drainage basin. The variation in order and size of the mini watersheds is largely due to physiographic and structural conditions of the region. Bifurcation ratio ranges from 3.0 to 5.0 with mean value of 3.82. It indicates that geological structures do not disturb the drainage pattern. Due to presence of forest, three of the mini-watersheds have low stream frequency, while the remaining produce more runoff. Length of overland flow varies from 0.682 to 0.228, which depicts the relief of area. Texture ratio with variation of 0.78 to 4.16 reveals moderate to coarse texture of soil in the basin. Drainage density from 0.73 to 2.19 of the basin is likely to occur due to highly permeable subsoil in the region of low relief. The Meghal river basin can be considered comparatively less elongated by the values of elongation ratio from 0.49-0.73. Low values of form factor ranging from 0.19 to 0.42 gives an idea of longer duration peak flows. Presence of highly permeable homogeneous geologic material is specified by the values of circularity ratio from 0.22 to 0.57. It can be concluded that, remote sensing and GIS can be very useful tools for determination of geomorphological characteristics. Such type of studies will supplement the soil conservation and watershed development projects.

ACKNOWLEDGEMENTS

The author highly acknowledges the support rendered by Bhaskaracharya Institute for Space Application and Geo- Informatics (BISAG), Gandhinagar for data procurements.

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Table 1: Linear parameters of watershed

Mini-Watershed	Bifurcation Ratio (Rb)	Stream Frequency (Fs)	Length of Overland Flow (Lg)	Texture Ratio (T)	Drainage Density (Dd)
5G1D2a1	3.85	0.725	0.6826	1.2140	0.7325
5G1D2a2	3.33	1.059	0.5169	0.7877	0.9672
5G1D2b1	4.55	2.218	0.3646	2.0672	1.3712
5G1D2b2	3.19	2.281	0.2745	3.0000	1.8217
5G1D2b3	3.34	2.593	0.2889	3.4648	1.7306
5G1D2c1	3.85	1.369	0.3959	2.4390	1.2629
5G1D2c2	3.92	3.678	0.2280	4.1614	2.1926

Table 2: Shape parameters of watershed

Mini- Watershed	Elongation Ratio (Re)	Form Factor (Rf)	Circulatory Ratio (Rc)	Compactness Coefficient (Cc)
5G1D2a1	0.6237	0.3057	0.291	1.4411
5G1D2a2	0.5316	0.2220	0.571	1.4671
5G1D2b1	0.4955	0.1929	0.227	1.7088
5G1D2b2	0.5798	0.2641	0.240	1.5900
5G1D2b3	0.6655	0.3479	0.273	1.3526
5G1D2c1	0.7344	0.4237	0.282	1.3561
5G1D2c2	0.5982	0.2812	0.229	1.5167

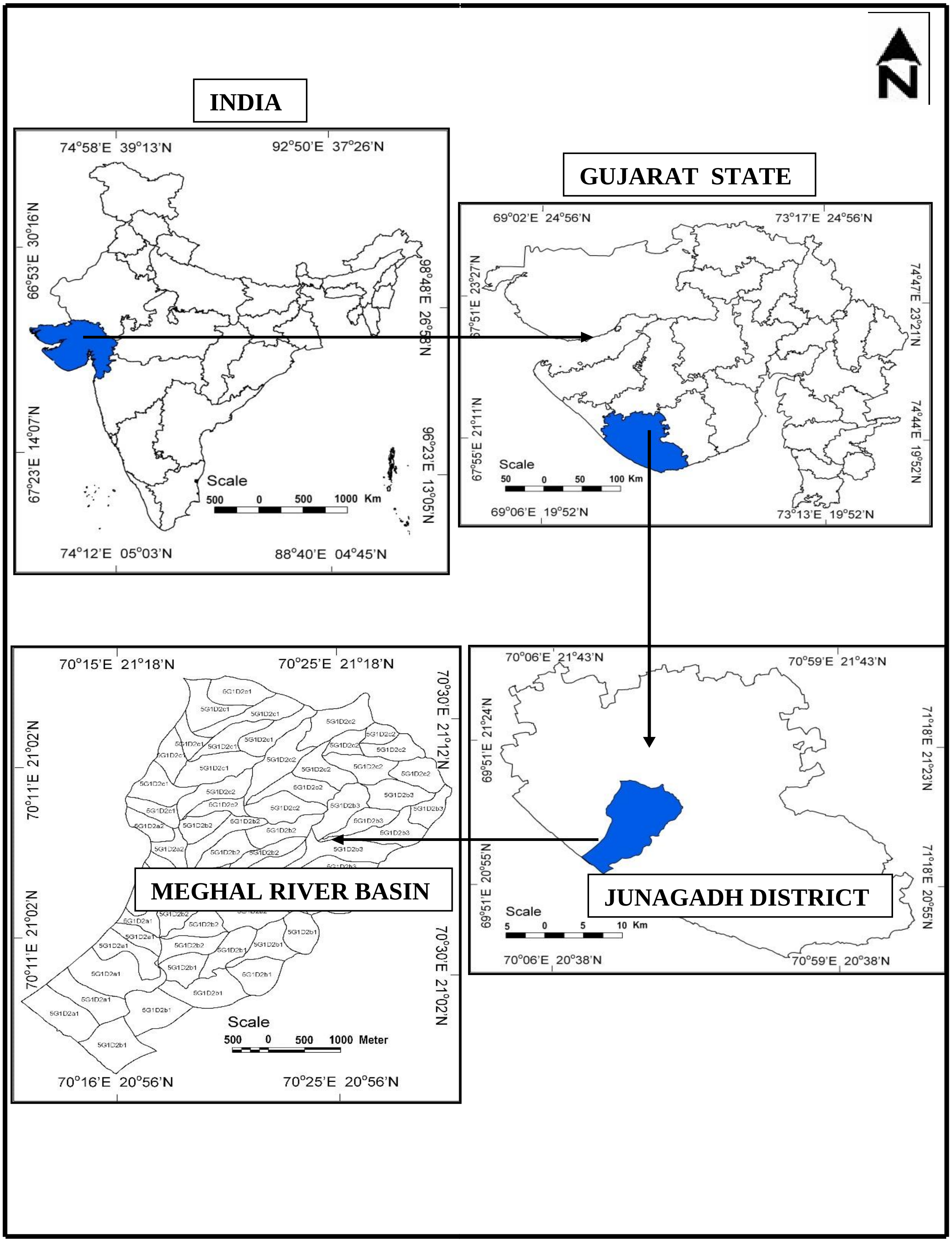

Fig. 1: Location map of study area (Meghal River Basin)

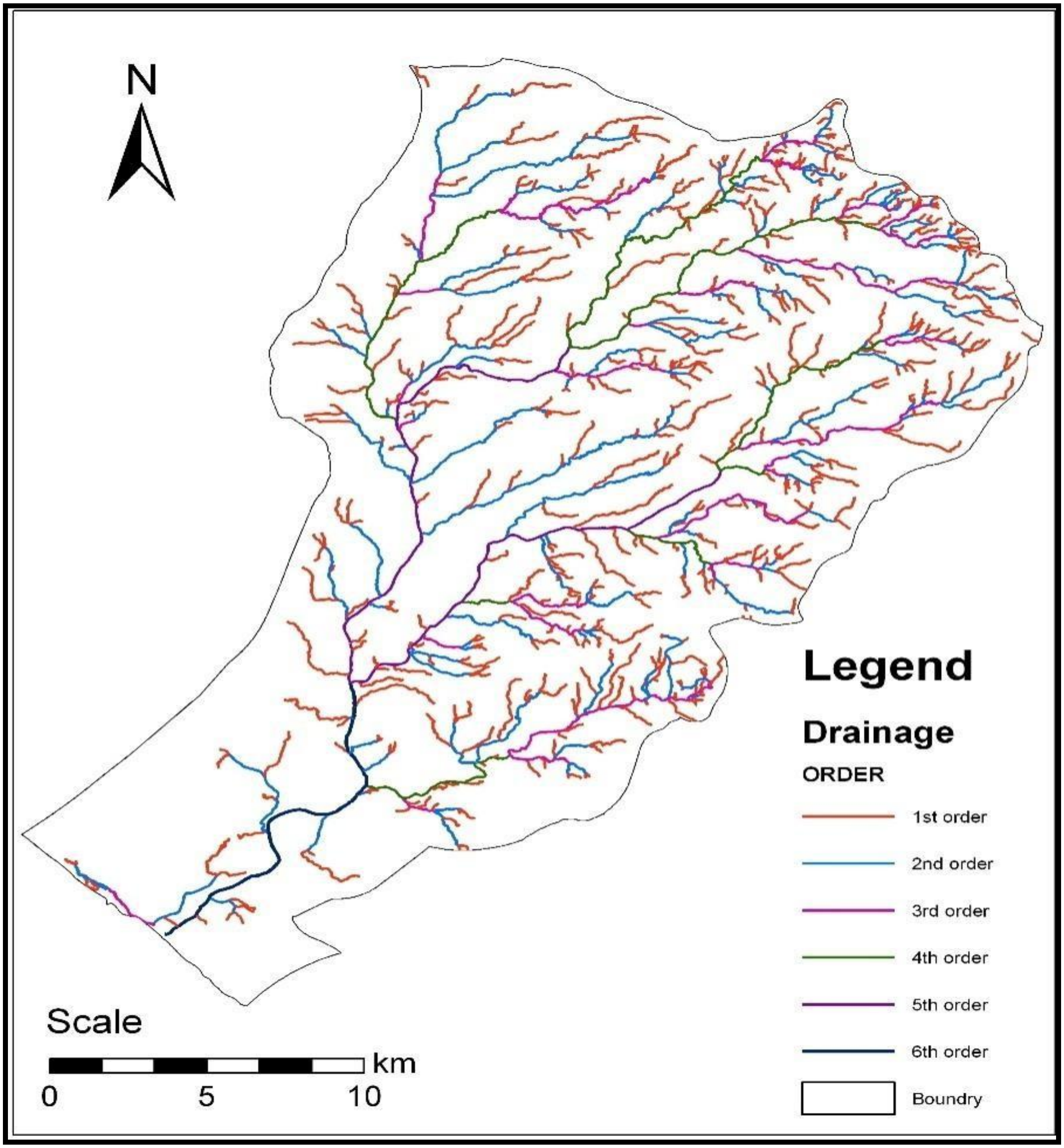

Fig. 2: Drainage map of Meghal River Basin

[MS received : March 27 , 2019] *[MS accepted :March 30, 2019]*