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Morphometrical Assessment Using Remote Sensing and GIS Techniques in the Micro Watersheds of Ramganga River Basin, Almora District Uttarakhand India

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ABSTRACT

This chapter deals with the morphometric attributes of the drainage basin included methods of stream orders, bifurcation ratio, stream length ratio, basin configuration, drainage density and stream frequency, slope and relief analysis etc. All these morphometric attributes are examined and explained with reference to the micro study carried out in the middle valley of western Ramganga River in the Kumaun Lesser Himalaya. The impact of the morphological characters on the terrain is reflected by the drainage basin of the area. The relatively gentler slopes are due to more erosion of the bedrock in the fault zone compared to the less deformed bedrock of the surroundings. The drainage of the Ramganga displays as dendritic, sub- parallel, trellis and radial drainage pattern. It is concluded that Remote sensing techniques using satellite images and Geographical information system are convenient tools for morphometric analysis. The satellite remote sensing has the ability to provide synoptic view of large area and is very useful in analyzing drainage morphometry.

Key Words : Morphometry, Remote Sensing, Geographical Information System, Kumaun Himalaya, Ramganga River, Micro-watershed

INTRODUCTION

River flows are related to the topographic and climatic characteristics of a drainage basin which control the amount, time and space distributions of stream flow. The drainage network and basin morphology are the measures of fluvial process operation in the basin The drainage network and basin morphology are the measures of fluvial process operation in the basin. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimension of its landforms (Clarke, 1966). The application of morphometric techniques in geomorphic analysis of drainage basin form has

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provided a sound footing to this discipline. Morphometry affords quantitative information on large scale fluvial landforms, which make up the vast majority of the earth surface (Gardiner, 1971). Miller (1953) stressed on quantitative study of river basin characteristics, particularly shape of basin through circulatory ratio and other related parameters. Morphometric analysis provides quantitative description of the basin geometry to understand initial slope or inequalities in the rock hardness, structural controls, recent diastrophism, geological and geomorphic history of drainage basin (Strahler, 1964). In various studies morphometric data were used to characterize relief (Zavoianu, 1985) and to investigate the influence of the basin geomorphology on hydrological processes at basin scale (Moussa, 2003). A considerable amount of work has been carried out in India also. A few have tested different models derived by Horton, Strahler and others by selection of area in different parts in India. Quantitative description of the basin geometry (morphometric analysis) requires measurements of drainage parameters, gradient of channel network and contributing ground slops of the drainage basin (Nautiyal, 1994). For this, remotely sensed data in conjunction with the data derived from conventional sources provide a tool for delineation of drainage network for analysis of basin geometry (Ravindran, 1995). Nag (1998) carried out morphometric analysis of Chaka sub-basin Purulia district, while Nag and Chakraborty (2003) deciphered the influence of rock types and structures in the development of drainage network in hard rock area. Recently Srinivasa *et al.* (2004) have used remote sensing and geographical information system (GIS) techniques in morphometric analysis of sub-watersheds in Pawagada area of Tumkur district Karnataka. GIS based approach is found to be more appropriate than the conventional methods in evaluation and analysis of drainage morphometry. A morphometric analysis using remote sensing and GIS techniques has been carried out to analyze the influence of rock types and structures in the development of drainage network in semi-arid hard rock areas of Purulia district by Nag and Chakraborty (2003). Chopra *et al.* (2005) has carried out a study for morphometric analysis of two sub-micro-watersheds in Gurdaspur district Punjab using remote sensing and GIS techniques. In spite of mountainous relief, low drainage density values indicate that the area is underlain by impermeable sub-surface material. Malik *et al.* (2011) computed various linear and areal aspects of the Lidder catchment in Kashmir valley using geographical information system. The study has shown that the catchment is in conformity with the Horton's law of stream numbers and law of stream lengths.

The study area constitutes an important part of the catchment area of the middle valley of western Ramganga River in Lesser Himalayan terrain which forms a part of Almora district. It lies between 29° 45' N to 29° 53' N latitudes and 79° 15' E to 79° 23' E longitudes. The entire micro-watersheds of the study area of the Western Ramganga is the part of Kumaun Lesser Himalayan belt of gentle and mature topography, which is characterized by Precambrian rocks, covered, with telltale evidences of recent rejuvenation. River Ramganga (w) forms an important drainage system in the Kumaun Himalaya. The present study area comprising seven micro-watersheds of the middle valley of the Western Ramganga River covers an area of 94.8 Km^2. The total drainage system is controlled by lithology and the tectonic features in the area, besides the climatic effects. The Kumaun Lesser Himalaya has a comparatively mature topography with gentle slopes and deeply dissected valleys.

River terraces consisting of uncemented large boulders to pebbles are common geomorphic features, especially at the confluence of two streams or even in the mainstreams (Fig. 1).

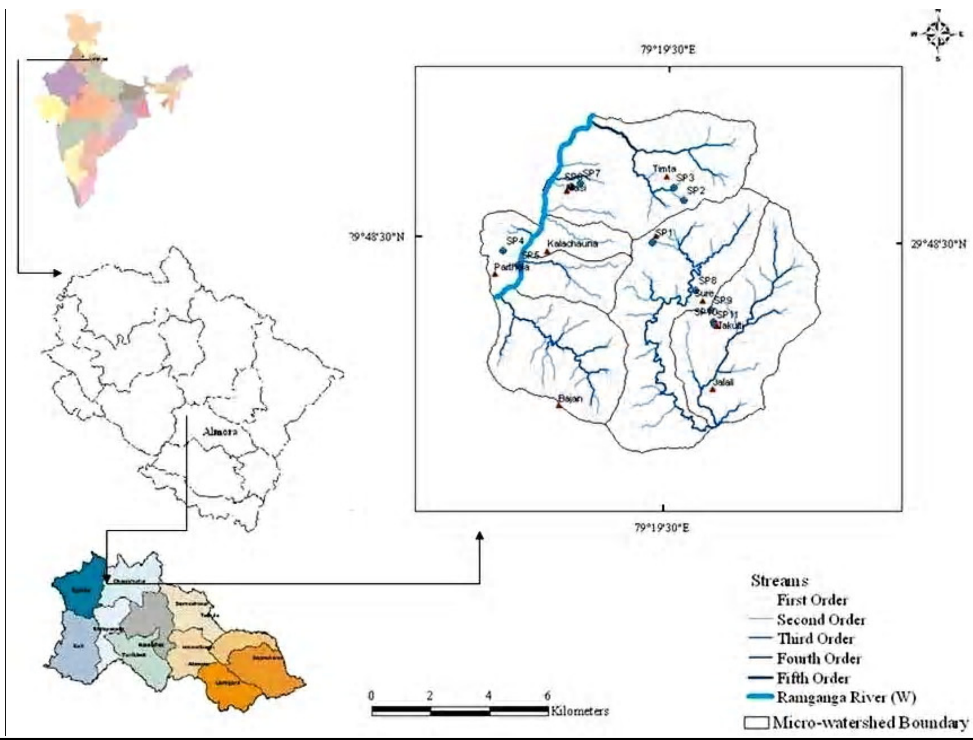

Fig. 1: The location and drainage map of micro-watersheds of Western Ramganga River Basin

The topography has greatly influenced the culture, trade, agriculture and methods of cultivation, irrigation and communication of the hill inhabitants. High relief, fluvial deposits, and interlocking spurs are the important features of the physiography of the Ramganga micro-watersheds. The elevation is high ranging from about 1500 m asl to 3000m asl towards the north, while in the valleys in the south, elevation as low as 300m may be reached. The slope varies from 5° to 40°. Granite and gneisses occupy higher elevations while the biotic garnet schistose rocks, which have provided agricultural land, occupy lower elevations. The study area, situated as it is on the southern slopes of the Himalayas gets most of its rainfall from the monsoon current, which penetrates, through the valleys during June to September (Climate of Uttar Pradesh, 1989). This part of the study area which falls in the Lesser Himalayan zone, enjoys wide fluctuation in climatic conditions due to complex relief and elevation difference. During winter foggy condition prevails in the valley. The winter season prevails November to March months and mean temperature varies from 13.3°C to 6.1°C. Between April and July summer season prevails and mean temperature varies between 29.4° C to 13.9°C. entire hydro-meteorological characteristics of the study area are characterized by the high precipitation generating peak monsoon flows and low precipitation during the dry seasons resulting in low flows. The drainage condition of the study area is naturally excessively drained. The channel bed in the area is rocky or gravelly. The drainage system belongs to an antecedent river *i.e.* the Western Ramganga River.

Geology of the study area:

Himalaya, the Lesser Himalaya in particular, poses a great challenge to the earth-scientists to unravel mysteries of its tectonics, stratigraphy and its hidden mineral wealth. The Kumaun Lesser Himalaya is demarcated by two major thrust planes. In the south the young sedimentary Siwalik realm is served from it by the Karol and Nahan Thrusts commonly called the Main Boundary Thrust (MBT) and in the north the Main Central Thrust (MCT) delimits the northern boundary of the extremely cataclastically deformed and retrogressively transformed assemblage of medium-grade metamorphics and Precambrian granites of the Lesser Himalaya Munsiari (=Jutogh) Formation against the Precambrian high-grade metamorphics of the Great Himalaya (Valdiya, 1980). Geologically, micro-watersheds are located in the Almora Crystallines of Almora-Dudatoli Nappe between Chaukhutia and Bhikiyasain. Main tectonic features of this area is a synclinal axis between North Almora Thrust (NAT) and South Almora Thrust (SAT), running from west to east direction in the upper portion of the study area

Methods of Investigation:

Morphometry is a very sensitive and delicate tool and when it is overcrowded with unnecessary and excessive mathematical formula and equations, the results become confused and so the intuitive power of the researcher is lost, but when the useful and easier techniques, which are within the reach of geographers, are applied, morphometry certainly renders good results.

The present attempt endeavors to study morphological attributes taking the micro-watersheds from the middle valley of Western Ramganga in Kumaun Lesser Himalayan region as a study unit. The area covered by the present investigations forms a part of Almora district of Uttarakhand and is included within topographic sheet 53 O/5 of the Survey of India. It is bounded by latitudes 29° 45' N and by 29° 51' N and longitudes 79° 15' E and 79° 23' E. Drainage basin map of the study area has been prepared from digital data of IRS both LISS –III and PAN data. Satellite imageries had been geo-referenced and merged using image processing software ERDAS IMAGIN. The morphometric parameters were computed using the formula of various scholars presented in Table 1. For digitization, computation and output generation Arc GIS Software were used.

Basin Delineation:

In this study part of the middle valley of Western Ramganga River has been divided into 7 micro-watersheds named Kanoli Micro-watershed,Gagas Micro-watershed, Jalali Micro-watershed, Chausar Micro-watershed, Dhanar Micro-watershed, Barjui-Sudhari Micro-watershed, Lamabagar Micro-watershed.

Morphometric Analysis :

The morphometric analysis of a drainage basin and its stream channel system can be better achieved through the measurements of linear aspects of the drainage networks, area aspects of the drainage basins and relief aspects of channel networks and contributing ground slopes. The morphomertical parameters that are discussed in this paper are broadly grouped under the three following categories.

(i) Relief aspect of the micro-watersheds

(ii) Linear aspect of the channels system

(iii) Areal aspect of the micro-watersheds

Relief Aspect:

Relief aspect includes the analysis of terrain characteristics through hypsometric curves, clinographic curve, percentage hypsometric curves and profiles, which assist in dealing with different aspects of landform characteristics of a drainage basin or of any geomorphic unit. Fluvial (basin) morphometry includes the consideration of linear, areal and relief aspects of a fluvially evolved drainage basin

Average Slope:

The term 'slope' in its broadest sense means an element of earth's solid surface, including both terrestrial and submarine surfaces; it is, therefore, simply an element of the interface between the lithosphere and either hydrosphere or atmosphere (Strahler, 1956). The slope is related to the history of streams flowing at its base. Slope is, by far, the most important morphological attribute, which helps to discern the surface configuration of a drainage basin. There is also a close relationship between slope conditions and morphometric attributes of terrain *viz*., absolute relief, relative relief, dissection index, drainage density and drainage frequency (Table 1).

Slope analysis has revealed that the area of the micro-watersheds of middle Ramganga basin is characterized by five distinct categories of slopes *viz.;* Gentle slope, moderate slope, moderately steep slope, steep slope and very steep slope.

Gentle slope in the area characterizing the lower valley slopes and flood plains in the NWW to SW part of the middle Ramganga river basin. It is associated with the lower to upper middle valley of the river Ramganga, lower to middle valley of Chausar gadhera and upper valley slopes of the Kanoli, Gagas and Jalali micro-watersheds. Moderately steep slope is associated with rounded hills with broad crests, low elevation spurs, intermediate parts of hills and outer margins of uplands. Steep slopes are found towards middle to upper valley of Barjui-Sudhari and Dhanar gadhera, towards upstream areas of the Chausar gadhera , lower to middle reaches of Kanoli gadhera, first and second order streams of Jalali gadhera and upper, middle and lower reaches of Gagas gadhera in the study area. Higher altitude, folded structure, local disturbances along with the colluvial-Fluvial processes are the determinant factors in the development of higher degree of slopes as 35° and above in the rugged hilly tract and junction of water-divides of the micro-watersheds.

Relief Ratio (Rh):

When basin relief H is divided by the horizontal distance on which it is measured, there results a dimensionless relief ratio (Rh). The elevation difference between the highest and

Table 1 : Formula adopted for computation of morphometric parameters

Morphometric Parameter	Symbol /Formula/Description	Definition	Reference
Relief Ratio	Rh =H/ Lb H = Basin Relief Lb = Basin Length	Basin Relief / distance between the highest point and outlet in the basin	Schumm (1956)
Drainage Density (Dd)	Dd = Lu / A Dd = Drainage Density Lu = Total stream length of all order A = Area of the basin	Total stream length of all order/ Area of the basin	Horton (1945)
Stream /Drainage Frequency (Fu)	Fu = Nu / A Fu = Stream Frequency Nu = Total no of streams of all order A= Area of the basin (km^2)	Number of stream segments per unit basin area	Horton (1945)
Texture Ratio (T)	T = Nu / P T = Texture Ratio Nu = Total no of streams of all order P = Basin Perimeter		Horton (1945)
Circulatory Ratio (Rc)	Rc = $4\pi A / P^2$ Rc = Circulatory Ratio π = Pi value i.e. 3.14 A = Area of the basin (km^2) P= Square of the Perimeter (km^2)	Basin area / Area of circle having circumference equal to the basin perimeter	Miller (1953)
Elongation Ratio (Re)	Re = $(2 \sqrt{A / \pi}) / Lb$ Re = Elongation Ratio Lb=Length of the basin(km) A = Area of the basin (km^2)	Diameter of a circle having the same area as the basin /Basin length	Schumm(1956)
Farm Factor (Rf)	Rf = A/Lb2 Rf = Farm Factor A = Area of the basin (km^2) Lb2= Square of the basin length	Ratio of the Basin area to the square of the length of the basin	Horton (1932)
Stream Length Lu	Length of the stream		Horton (1945)
Length of Main Stream L	Length measured along the longest water course from the outlet point to upper limit to the basin boundary		Horton (1945)
Mean Stream Length Lsm	Lu / Nu Lsm-,Mean stream length Lu- Total stream length of order u Nu- Total number of stream segments of order u		Strahler (1964)
Bifurcation Ratio	Rb= Nu / Nu +1 Rb- Bifurcation Ratio Nu- Total number of stream segments of order u Nu +1-Number of stream segments of next higher order	Ratio of number of streams of lower order/ number of streams of the next higher order	Horton (1932)

lowest points on the valley floor of a sub-watershed is its total relief, whereas the ratio of maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line is relief ratio (Rh) (Schumm, 1956). In the present study Rh ranges from 0.09 in Gagas micro-watershed to 0.27 in Lamabagar micro-watershed. It is noted that the ratios of 3 micro-basins vary from 0.09-0.13 the area of micro-watershed is composed of resistant rocks and all the three gadheras *i.e*. Chausar, Gagas and Jalali flows through granitic rocks with local occurrence of gneiss, chlorite-schist and quartzite. Relief ratio in these three micro-basins decreased as basin length and size increased. Relief ratio in these three micro-basins decreased as basin length and size increased. High relief ratios are found in areas of comparatively weak rocks such as Dhanar (0.20), Barjui-Sudhari (0.26) and Lamabagar (0.27).

Linear Aspect :

The linear aspects deals with the hierarchical orders of streams, numbers and lengths of stream segments and various relationships among them and related morphometric laws e.g. law of stream numbers and stream lengths etc.

Stream Order:

The first step in basin morphometry is designation of stream orders, following a system introduced in U.S.A. by Horton (1945), and later slightly modified by Strahler (1952). The stream order is a measure of the position of a stream in the hierarchy of the tributaries. Out of the seven micro-watersheds Kanoli is of fifth order, whereas the Jalali, Gagas and Chausar are of fourth order and Dhanar and Lamabagar of third order, only Barjui Sudhari micro-watershed is having second order. it is noticed that the maximum frequency is in case of first order streams. It is also observed that there is a decrease in stream frequency as the stream order increases.

Stream Length:

The total stream lengths of various orders of the Western Ramganga micro-watersheds have been measured. Stream length is the total length of streams in a particular order. Generally, the total length of stream segments decrease with stream order. There are positive relationship found between the total stream length and order in the study area. The maximum length of stream segment is recorded in fifth order stream *i.e.* Kanoli while as minimum in second order stream Barjui Sudhari. Thus the total stream lengths of different orders of the basin tend to decrease proportionately with increasing order over homogeneous topographic conditions and controls.

Stream Length Ratio:

Stream length ratio is the ratio of the mean length of one order to the next lower order of the stream segments. According to Horton (1945), the length ratio is the ratio of the mean length of streams of one order to that of the next lower order stream segments, which tends to be constant throughout the successive orders of a watershed. The stream length ratio between the streams of different orders of the study area shows a change in each basin. This change might be attributed to variation in slope and topography, indicating the late youth stage of geomorphic development in the streams of the study area (Singh and Singh, 1997; Vittala *et al.,* 2005). The mean value of stream length ratio ranges between 1.2 and 6.0 in micro-watersheds.

Mean Stream Length:

It states that the lengths of the stream segments of the successive stream orders approximate to direct geometric sequence (Sparks, 1974). The mean stream length (Lu) has been calculated by dividing the total stream length of order u by the number of streams segments Nu of that order. It is seen, that Lsm values exhibit variation from 0.46 to 14.20 in the study area.

Bifurcation Ratio:

Horton (1932) defined bifurcation ratio as the relationship between the number of stream segments of a given order (Nu) to the number of stream segments of the next higher order. Generally the term bifurcation ratio (Rb) is used to express the ratio of the number of streams of any given order to the number of streams in the next higher order. Thus, the ratio between the number of stream and successive order is the bifurcation ratio and this is simply a measure of the amount of branching of the drainage lines. The bifurcation ratios of seven micro-basins have been calculated following to Hortonian rules. Mean bifurcation ratio of all the seven micro basins range between 2.7 (Lamabagar) to 10 (Barjui-Sudhari). High values of the ratio indicate lower degree of drainage integration and vice-versa.

Areal Aspect:

the areal aspects includes the analysis of basin perimeters, basin shape (both geometrical and topological), basin area and related morphometric laws viz., law of basin area and law of allometric growth ;stream frequency ,drainage density and drainage texture etc.

Drainage Density:

Density of drainage network was investigated by Neumann in the early 20th century (1900) and was defined by Horton (1932). Analysis of drainage density was first introduced by Horton (1932) as the ratio of the total channel segments lengths (cumulated for all orders) within a basin to the basin area. Horton's drainage density is a measure of channel spacing. It is the ratio of total channel lengths of all orders to the drainage area and has the dimension of the inverse channel length. The higher the number is the closer together are the channels.

In the study area the drainage density value is ranging between 2.07-3.78 Km/Km^2. The variations in drainage density may be attributed to the changes in the subsurface lithological characteristics of the area. The high values of drainage density indicate weak rocks and consistent of impermeable subsurface material and sparse vegetation cover with mountainous relief.

Drainage Frequency:

The total number of stream segments of all orders per unit area is known as stream frequency (Horton, 1932). Horton's stream frequency is the number of stream segments of all order per unit of drainage area, having the dimension of L^{-2}. Drainage frequency gives an idea of the distributional pattern of river with its tributary per square Kilometer. It is generally observed that high frequency is recorded towards that source of river where many affluent carry water to the consequent of the river network. The drainage frequency has been calculated for all the seven micro-basins. Very high value of drainage frequency (Df) is noticed in Chausar (6.28) micro-basin of fourth order In the Barjui-Sudhari micro-basin drainage frequency is low (2.92), which correspond to the rocky, hilly terrain of the micro-basin with sparse vegetation and impermeable sub-surface strata.

Drainage Texture:

Drainage texture refers to the relative spacing of drainage lines regardless of occupancy by perennial streams. It is the total number of stream segment of all orders per perimeter of that area (Horton, 1945). The drainage texture is one of the important criteria for which it may be easy to find the nature of topography where it is highly dissected or not (Pradhan, 1980). In the middle valley of Western Ramganga river the texture ratio depends upon the development of the first order streams on different lithologies. In the study area the values of the drainage texture ratio varies from 1.1 to 6. The highest texture ratio among micro-basins is observed in the Chaucer micro-watershed, where texture ratio more than 6 indicates high annual rainfall and moist soils. Whereas Barjui-Sudhari has only 1.1 texture ratio. Strahler (1964) explains that the areas of lower drainage density have coarse drainage texture and those with higher density with fine texture.

Farm Factor:

Form factor is defined as the ratio of the area of the basin to the square of the length of the basin (Horton, 1932). The value of farm factor would always be greater than 0.78 for a perfectly circular basin. Smaller the value of farm factor more elongated will be the basin. In the study area it is noted that form factor values vary from 0.33 to 0.68. The values of form factor in Jalali (0.33), Barjui-Sudhari (0.34), Gagas (0.35) and Dhanar (0.38) indicate that they are elongated in shape and Chausar (0.48) indicate the sub-circular shape of the basin.

Elongation Ratio:

It is the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. A circular basin is more efficient in run-off discharge than an elongated basin (Singh, 1997). The value of elongation ratio (Re) varies from 0 (in highly elongated shape) to unity *i.e.* 1 (in circular shape) associated with a wide verity of climate and geology. The elongation ratio value of the micro-watersheds vary from 0.64 to 0.93. Elongation ratio provides meaningful index for classifying micro-basins into varying shapes such as circular (>0.9), less elongated (0.7-0.8) and elongated (< 0.7) on the basis of which discharge runoff can be best understood.

Circulatory Ratio:

It is ratio of the area of the basin to the area of circle having the same circumference as the perimeter of the basin (Miller, 1953). In other words, it is the relationship between the area of the basin and the area of the circle of the same perimeter of the given basin. In the study area circulatory ratios for all the micro-watersheds are ranging between 0.41 and 0.75. Among the fourth order basins (Chausar, Gagas and Jalali), the Chausar gadhera has a high circulatory ratio of 0.75 followed by Kanoli gadhera (0.67) which is a fifth order basin.

Gagas gadhera shows low circulatory ratio of 0.41. Three micro-basins are moderately circular with circulatory ratio ranging from 0.58 for Jalali to 0.55 for Dhanar and 0.49 for Barjui-Sudhari.

Conclusion:

Ramganga river basin is bounded by the water divide which demarcates it from Kosi river basin in the south and Alaknanda in the north. Ramganga river itself with many small streams and rivulets form the drainage network of the study area, the Ramganga basin which is irregular and uneven is drained upto sixth order stream with many ephemeral and seasonal drainage lines. The study area comprising sub-parallel, sub-dendritic and trellis drainage pattern with intermediate drainage texture Network of first and second order streams joining together have given rise to dendritic to sub-dendritic drainage pattern. Third and fourth order streams have given rise to sub-dendritic to sub-parallel drainage pattern. Fifth order stream has carved out tight 'V' shaped narrow valley in the study area.

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