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Morphometric Analysis of Patapur Micro-Watershed Using Remote Sensing and GIS

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Abstract: *Geomorphological analysis is the systematic description of watershed geometry and its stream system. These parameters directly or indirectly reflect the response of entire watershed based on causative factors that are affecting runoff and sediment loss. To prepare a watershed development plan, morphometric analysis have been studied in the Patapur micro-watershed (541.39 ha), being located at Raichur district of Karnataka. The boundary of the watershed has been digitized from the SOI (Survey of India) toposheet and also DEM and slope maps were prepared with the help of remote sensing and GIS techniques (Arc GIS). Parallelly morphometric parameters such as linear, aerial and relief aspects have been determined to understand the watershed characteristics. In the study area bifurcation ratio (Rb) was varied from 3.° to 2.°, which shows that on undistorted geologic structure and drainage system of moderate peaks and lower order streams. The values of form factor (R_f), shape factor (S_b), circulatory ratio (R_c) and elongation ratios (R_e) were °.°3116, 3.2, °.26 and °.198 respectively which indicates moderately elongated micro-watershed with leading moderate influence on time parameters. The estimated values of relief, relief ratio (R_r) and relative relief (R_R) were found to be 129 m, °.°3°9 and 1.29 km^2 respectively, these indicates the possibly moderate erosion. Over all study suggests that the watershed should be treated with soil and water conservation measures.*

Key words: *Geomorphology, Micro-watershed, Remote sensing and GIS techniques, Soil erosion.*

INTRODUCTION

Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, including shape and dimension of its landforms, physical properties, interrelationship of morphological characteristics and hydrological behavior. The morphometric characteristics at given watershed scale contains important information regarding its formation and development due to all hydrologic and geomorphic processes occur within the watershed and it provides a quantitative description of the drainage system, which is an important aspect of the characters of watersheds.

The morphological characteristics of a basin represent its attributes, which may be employed in synthesizing its hydrological response. Geo-morphological studies of a watershed not only facilitates locating exploitable water potential of aquifers but would be also essential as pre-requisite for selecting proper methods of artificial recharge and to augment ground water recharge sources. GIS and remote sensing techniques have opened up

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wide range of avenues for effective watershed management, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information. The outcome of analysis of linear and areal parameters would be important in determining the effect of catchment characteristics and distribution of stream network of different orders within the catchment area.

MATERIALS AND METHODS

The study was taken up in Patapur micro-watershed having an area of 541.39 ha being located at Patapur village in Manvi taluk of Raichur district in Karnataka (Figure 1). The study area lies between the 16°07′ 35.9° Latitude and 76° 51′ 33.3^2 Longitudes and 16°08¢ 22.3^2 Latitude and 76° 53′ 27.7^2 Longitudes with an average elevation of 447 m above the mean sea

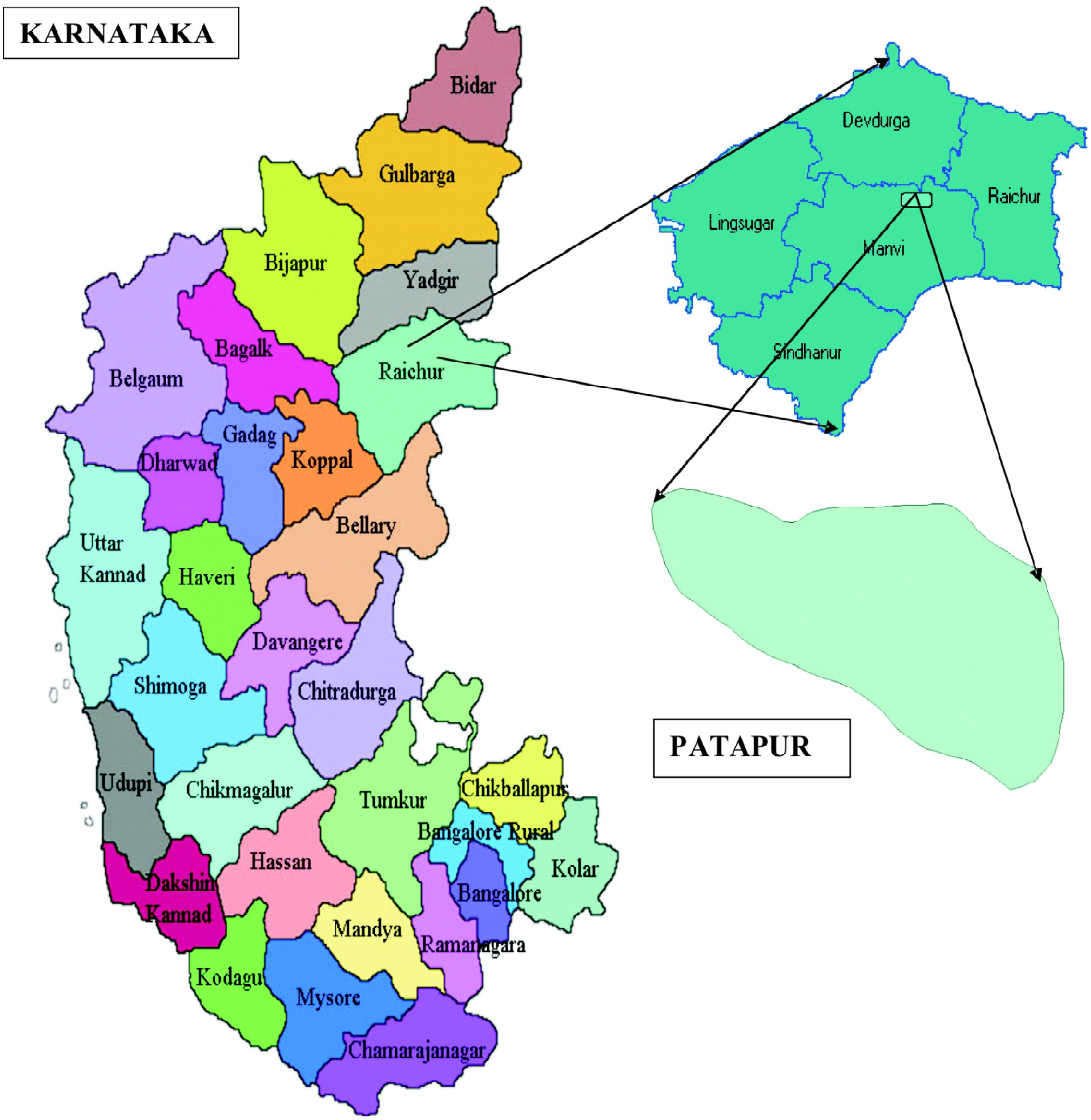

Figure 1: Location map of Patapur micro-watershed in Raichur district.

level (MSL). This watershed is located about 63 km from the Raichur city on Raichur-Lingasugur road.

The study area is falling under the Survey of India toposheet of 56 D/16 (1:50,000). To delineate the watershed boundary and drainage pattern the toposheet was Geo-referenced and digitized. The order was assigned stream by following Strahler, (1964) [1] stream ordering technique and also DEM, and Slope maps were prepared with the help of Remote Sensing and GIS techniques (Arc GIS). Parallelly morphometric parameters such as linear, aerial and relief aspects of the watershed have been determined, which is all about exploring the mathematical relationships between various stream attributes. The methodology is explained as fallows.

Linear Aspects of Channel Systems

Stream order

The term "stream order" is a measure of the position of a stream in the hierarchy of tributaries as explained by Strahler.,1964) [1]. Accordingly, the 1st order streams are those, which have no tributaries. The 2nd order streams are those, which have tributaries of only of 1st order streams. Where two 2nd order streams join, a segment of 3rd order would be formed.

When two 3rd order segments joining 4th order stream would be formed and so on. In case of two different orders meets the highest order would become the order of the new segment.

Basin length (L_b)

It is defined as the maximum length of the basin measured from the outlet.

Average basin width (B)

It is the ratio of basin area to the basin length of the watershed and is expressed as

$$B = \left(\frac{A}{L_b}\right)$$

Where,

A = basin area, km^2

L_b = basin length, km

Bifurcation ratio (R_b)

The term bifurcation ratio (R_b) 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.

$$R_b = \left(\frac{N_u}{N_{u+1}}\right)$$

Where,

N_u = number of stream segments of order 'u' and

N_{u+1} = number of stream segments of next higher order 'u + 1'.

Stream length

Length of the stream is indicative of the contributing areas of the basin of that order. Generally, cumulative length of streams of a particular order is measured, and the mean length (L_u) of that order stream (u) is obtained by dividing cumulative stream length by the number of segments of that order (Nu). It is expressed as:

$$\overline{L} = \frac{\sum_{i=1}^{N} L_u}{N_u}$$

Where,

L_u = mean length of channel of order u.

N_u = number of stream segment of order u.

Arial aspects

The shape of basin affects stream flow hydrographs and peak flow. The identified parameters including Form factor (R_f), Circularity ratio (R_c), Circularity index (I_c), Compactness co-efficient, Elongation ratio (R_e) and Texture ratio (R_t) were selected to describe the watershed shape as explained by Chow (1962) [2] .

Form factor (R_f)

It is defined as the ratio of area of the basin to the square of the length of basin. (Horton, 1932) [3].

$$R_f = \frac{A}{L_b^2}$$

Where,

A = area of the basin, km^2 and

L_b = length of the basin, km.

Circulatory ratio (R_c)

It is the ratio of circumference of a circle whose area is equal to the area of that of basin to the basin perimeter. Mathematically it is expressed and calculated as follows:

$$R_C = \left(\frac{P_C}{P}\right) = \left(\frac{2\sqrt{pA}}{P}\right)$$

Where,

R_c = circulatory ratio

A = area of the basin, km^2

P = basin perimeter, km. and

P_c = perimeter of the circle having equal area as that of the drainage basin, km.

Circulatory index (I_C)

It is the ratio of the area of the basin to the area of the circle having equal perimeter as that of drainage basin and is expressed as:

$$I_C = \frac{A}{A_c} = \frac{4pA}{P^2}$$

Where,

I_C = Circulatory index,

A = area of the basin, km^2

P = basin perimeter, km and,

A_c = area of the circle having equal perimeter as that of drainage basin, km^2.

Compactness coefficient (C_C)

It is defined as the ratio of the perimeter of the basin to the circumference of a circle whose area is equal to the area of the basin. It is the inverse of circularity ratio and mathematically expressed as:

$$C_C = \frac{P}{2\sqrt{pA}}$$

Where,

C_C = Compactness coefficient,

A = area of the basin, km^2,

P = Basin perimeter, km.

Elongation ratio (R_e)

It is defined as the ratio of diameter of a circle which has same area as the basin to the basin length as explained by Schumm (1954) [4], expressed as

$$R_e = \left(\frac{D_C}{L_b}\right) = \left(\frac{2}{L_b}\right)\sqrt{\frac{A}{p}}$$

Where,

R_e = Elongation ratio

D_c = diameter of the circle having same area as that of the basin, km

L_b = basin length, km,

A = basin area, km^2

Texture ratio (R_t)

It is defined as the number of first order streams per unit perimeter of the drainage basin Horton (1932) [3].

$$R_t = \left(\frac{N_1}{P}\right)$$

Where,

R_t = Texture ratio, No. km^{-1}

N_1 = number of first order streams and

P = basin perimeter, km,

Drainage density (D_d)

It is treated as an important indicator of linear scale of land-form elements in the stream-eroded topography. Horton (1932) [3] defined drainage density (D_d) as the ratio of total length of all stream segments within a specified basin to the basin area.

$$D_d = \left(\frac{L}{A}\right)$$

Where,

D_d = Drainage density, km^{-1}

L = length of all stream segments, km,

A = area of the basin, km^2

Stream frequency (F_u)

Stream frequency is defined as the number of stream segments per unit basin area as explained by Horton (1932) [3] and is given as:

$$F_u = \left(\frac{N}{A}\right)$$

Where,

F_u = stream frequency, No km^{-2}

N = total number of stream segments of all orders,

A = basin area ,km^2

Relief Aspects of Stream Network

Relief aspects of stream network plays an important role in identifying the overall steepness of the drainage basin and is also considered as an indicator for the intensity of erosion processes operating at basins slope.

Watershed relief (H)

Watershed relief (H) is the elevation difference between basin mouth (discharge point) and the highest point on the basin perimeter. Maximum watershed relief is obtained from the available contour maps of the watersheds. It is expressed in meter. In the present study it was calculated by using Digital Elevation Model (DEM) of the study area and taking the elevation difference between the basin discharge point and highest point on the perimeter.

Relative relief (R_R)

Melton (1957) [5] defined relative relief, R_R as the ratio of the maximum watershed relief to the perimeter length. It is computed using following expression.

$$R_R = \frac{H}{L_P}$$

Where,

R_R = Relative relief

H = Watershed relief, km,

L_p = Length of perimeter,

Relief ratio (R_r)

Schumm (1954) [4] defined the relief ratio (R_r) as the ratio of maximum watershed relief divided by the maximum watershed length. It is computed using following expression.

$$R_r = \left(\frac{H}{L_b}\right)$$

Where,

R_r =Relief ratio

H = Watershed relief, km.

L_b = Basin length, km

Ruggedness number (R_N)

The product of relief (H) and drainage density (D_d) is called ruggedness number.

$$R_N = H \times D_d$$

Where,

R_N = Ruggedness number

H = Watershed relief, km.

D_d = Drainage density, km/km^2

Geometric Number

The geometric number is a ratio of ruggedness number to the slope of ground surface. Slope of the ground surface was calculated by taking the elevations difference between basin mouth and highest point on the basin perimeter where the stream order touches the basin perimeter divided by length of the highest stream reach. The estimated value of the slope of ground surface is 1.3°9 percent.

$$\text{Geometric number} = H \times D_d / S_g$$

Where,

H = Watershed relief, km,

S_g = Slope of ground surface, km km^{-1}

Time of concentration (T_c)

It is the time required to move the surface runoff from remotest point of the watershed to its outlet. It is mathematically expressed as:

$$T_c = °.°195L^{°.77} S^{-°.385}$$

Where,

L = Length of stream reach, m.

S = Average slope of the stream reach. (1.3°9 percent).

The spatial analyst tool of Arc GIS was used to derive the Digital Elevation Model (Figure 2) and slope map (Figure 3) from SRTM. The derived slope map for the micro watershed was reclassified using reclass tool of Arc GIS to slope ranging between 1-66 percent.

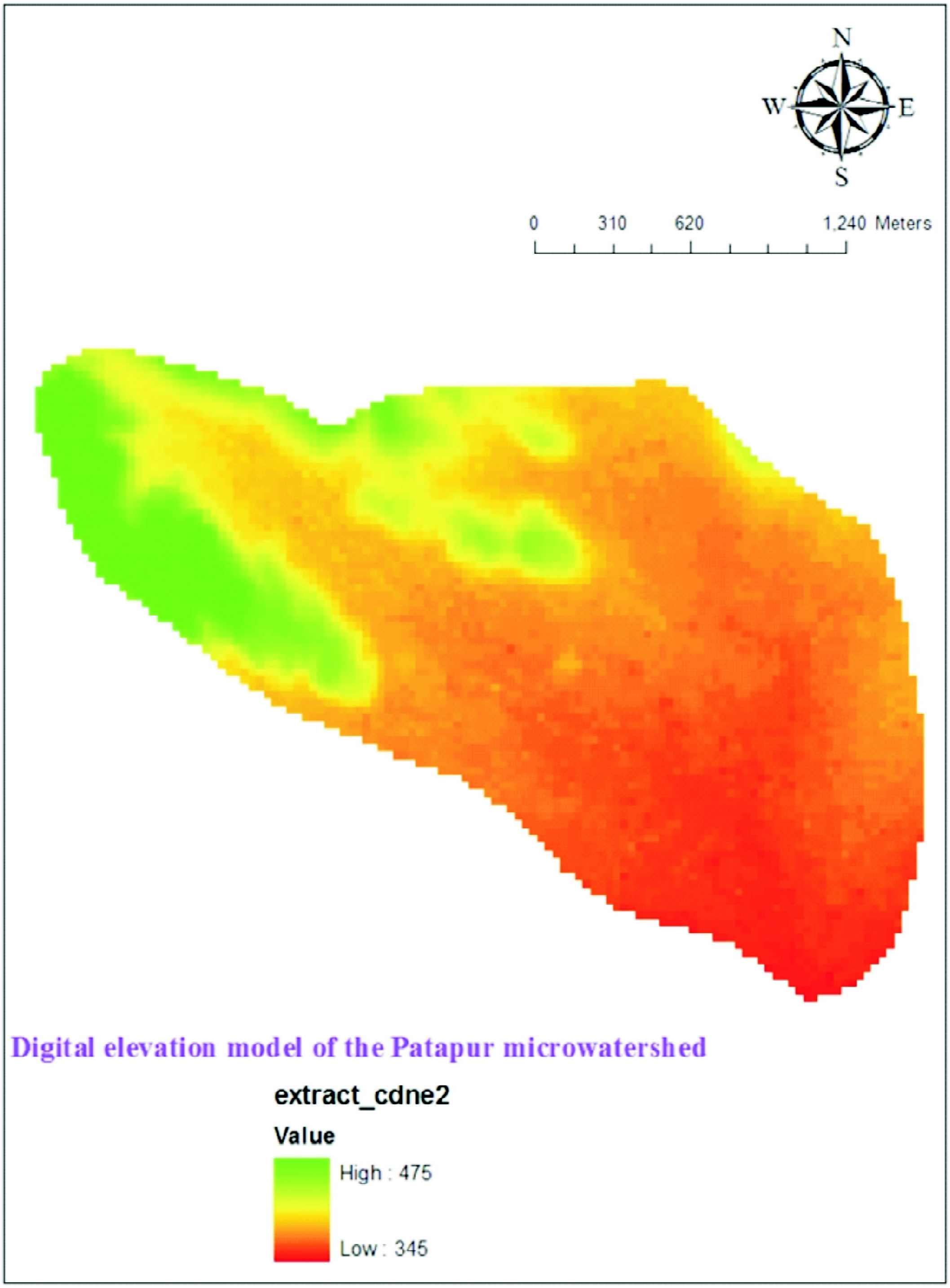

Figure 2: Digital elevation model of the Patapur micro-watershed.

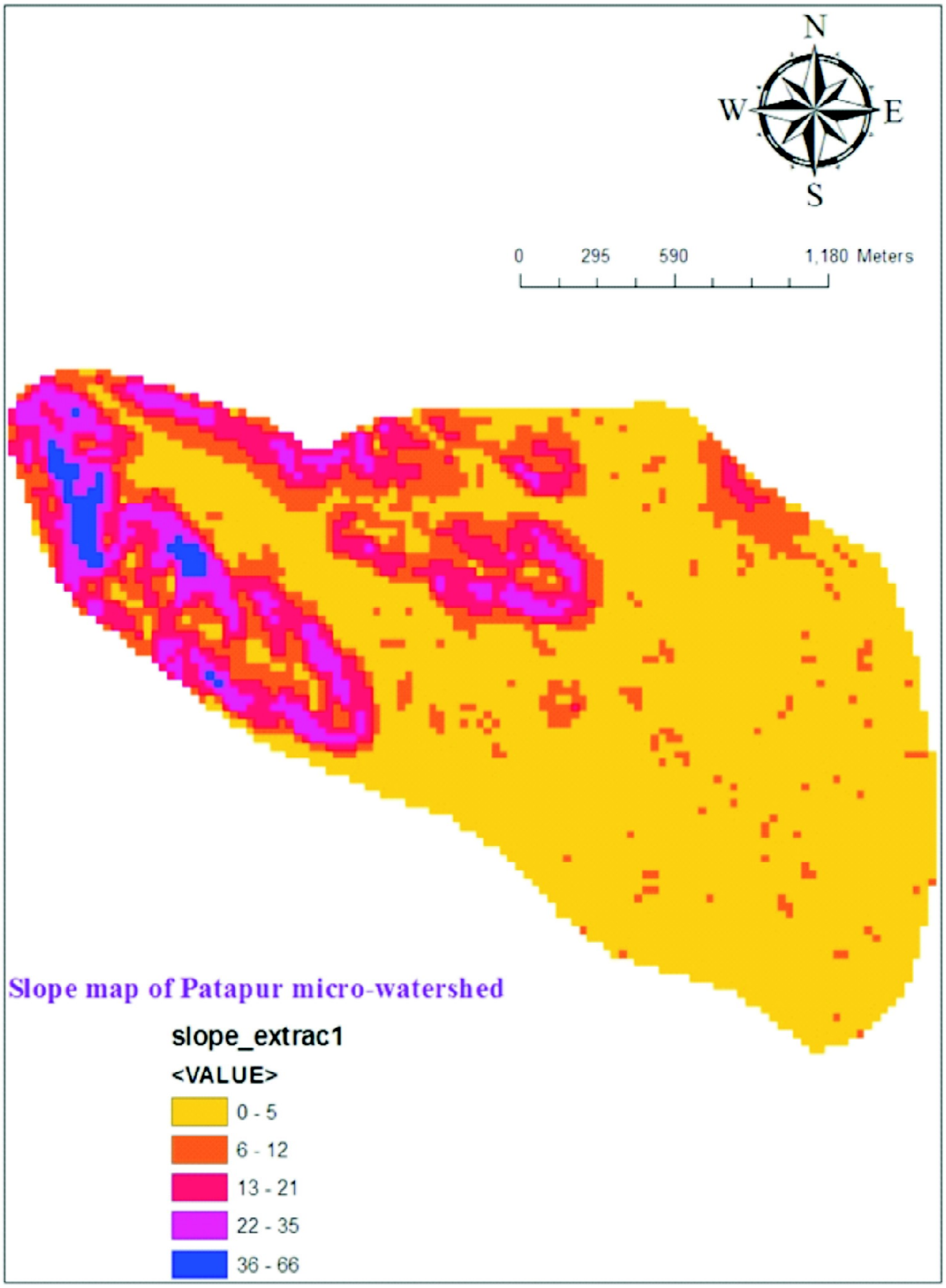

Figure 3: Slope map of the Patapur micro-watershed.

RESULTS AND DISCUSSION

The geomorphological analysis and measurements were made from the digitized drainage pattern of the Patapur micro-watershed. Watershed boundary and digitized drainage pattern are shown in Figure 4.

Linear Aspects of Drainage Network

Length of basin was about 4167.7° m and average basin width was 1299 m. The watershed was of 3rd order type and drainage pattern was dendrite. The numbers of stream of 1st, 2nd and 3rd orders were 9, 2 and 1 respectively (Table 1). In any drainage basin, relative stream orders not only indicate the size and scale of watershed but also afford approximate index of the amount of stream flow which could be produced by a particular network. It has also noticed that there was a decrease in stream frequency as the stream order increases. The present micro-watershed found to be developed in direct

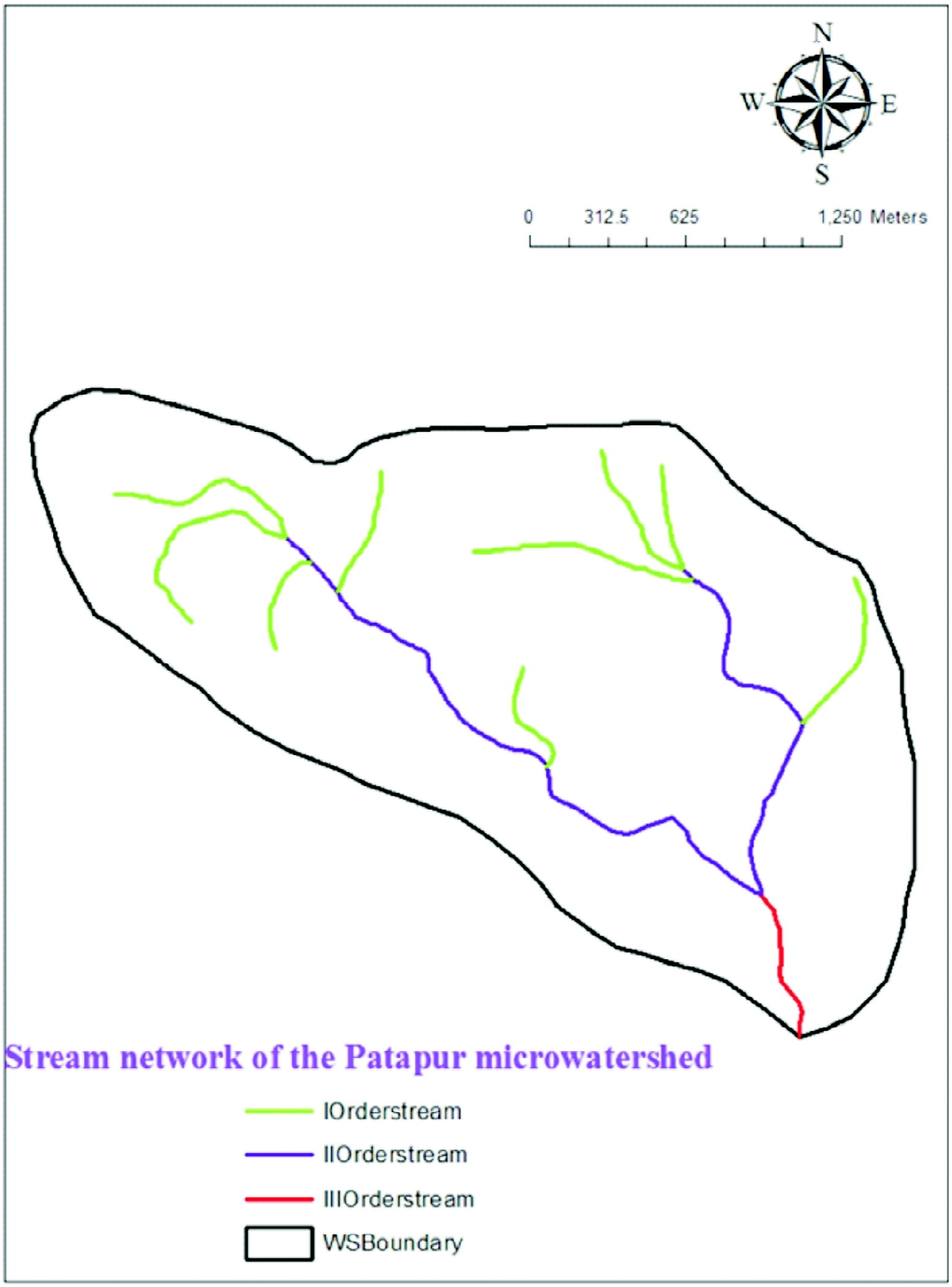

Figure 4: Drainage pattern of the Patapur micro-watershed.

sequence of its size or drainage line. These results are in agreement with the earlier findings by Sethupathi *et al.*, (2°11) [6].

The length of a stream is a measure of the hydrological characteristics of the underlying rock surface and the degree of drainage. Wherever the formation was permeable, only a small number of relatively longer streams are formed in a well drained watershed, a large number of streams of smaller length are developed where the formations were less permeable. The total stream lengths in 1st, 2nd and 3rd orders were 587°.84 m, 4262.279 m and 635.148 m (Table 1), respectively. Imran *et al.* (2°11) [7] reported that higher the order, longer the length of streams was noticed in nature. Horton's law of stream lengths supports the theory that geometrical similarity is preserved generally in watershed with increase in order. These results were in agreement with the earlier findings by Horton (1945) [8]. In the selected study area bifurcation ratio (R_b) varies from 3.° to 2.° and the mean bifurcation of the entire basin was 3.25 which shows that on undistorted geologic structure and existence of drainage system on of moderate peaks and lower order streams are approximately 3.25 times more than subsequent higher order.

Table 1
Linear aspects of drainage network

Sl. No.	*Stream order*	*Number of stream order*	*Bifurcation Ratio (R_b)*	*Stream length (L_u)*	*Average stream length*
1.	1	9	4.5	587°.48 m	652.28 m
2.	2	2	2	4262.28 m	2131.14 m
3.	3	1	3.25	635.15 m	635.15 m

Arial Aspects of Watershed

Under this aspect, the study revealed the relation between area, watershed shape which affects stream flow hydrographs and peak flow and they effectively defined the degree of relative elongation or compactness. In other words they have helped to configure the extent of irregularity of drainage area from circular shape. The calculated values of farm factor, shape factor circulatory ratio and elongation ratios were R_f = °.°31, S_b = 3.2, R_c = °.26 and R_e = °.198 (Table 2). From all these values it was observed that Patapur micro-watershed indicated moderately elongated micro-watershed with leading moderate influence on time parameters and low discharge of runoff with permeable subsoil condition.

Relief Aspects of Channel Network

The estimated value of relief was 129 m, based on which relief ratio (R_r) and relative relief (R_R) were found to be °.°3°9 and 1.29 km^2 respectively (Table 3). This is an indication of possibly moderate erosion and reflects that the watershed be treated with soil and water conservation measures. In addition to these properties ruggedness number and geometric number (°.255 and °.1948) implied that area was moderately prone to soil erosion and geologically have intrinsic structural complexity in association with relief and drainage density. These

Table 2
Arial aspects of Patapur micro-watershed

Sl. No.	*Arial aspects*	*Permissible Values*
1.	Area	541.39 ha
2.	Perimeter	1°°°°.32 m
3.	Farm factor (R_f)	°.°31
4.	Circulatory ratio (R_{c-})	°.26
5.	Circulatory index (I_c)	°.°68
6.	Compactness Co-efficient (C_c)	°.°32
7.	Elongation ratio (R_e)	°.198
8.	Texture ratio (R_t)	°.9
9.	Drainage density (D_d)	1.98 km km^{-2}
1°.	Stream frequency (F)	°.°24 No. ha^{-1}
11.	Shape factor (S_b)	3.2°
12.	Length of overland flow	°.252 m

Table 3
Relief aspects of stream network

Sl. No.	*Relief aspects of stream network*	*Permissible Values*
1.	Relief (H)	°.129 km
2.	Relative relief (R_R)	1.29 km^2
3.	Relief ratio (R_r)	°.°3°9
4.	Ruggedness number (R_N)	°.26
5.	Geometric number	°.1948
6.	Time of concentration (T_c)	1°.9857 min

results are in agreement with the earlier findings by Subramanyan (1974) [9].

Slope map (Figure 3) provides information regarding the distribution of various slope classes that helps in understanding the runoff characteristics and drainage pattern of the area. In the micro-watershed area the North-West comprised strong sloping lands and towards East it was very gentle sloping to nearly level. This was evident from the aspect of slope that the drainage pattern in the watershed was also in that direction with the outlet at °-5, 6-12, 13-21, 22-35, 36-66.

Most of the area of the watershed falls under the category of °-5 percent (329722°.54 m^2) followed by lower pediment area (83944.45 m^2) the class of 6-12 percent .Upper pediment area (18°9621.13 m^2) in the class of 13-21 percent. The hillocks and mounts occupy an area of (178395.5 m^2) in the slope class of 22-35 percent and 36-66 percent (44718.38 m^2).

CONCLUSION

In the Patapur micro-watershed, bifurcation ratio (R_b) varies from 3.° to 2.° and the mean bifurcation of the entire basin was 3.25 which shows that on undistorted geologic structure and existence of drainage system on of moderate peaks and lower order streams were approximately 3.25 times more than subsequent higher order. The calculated values of farm factor, shape factor, circulatory ratio and elongation ratios were R_f = °.°31, S_b = 3.2, R_c = °.26 and R_e = °.198, from all these values it was observed that Patapur micro-watershed indicated moderately elongated micro-watershed with leading moderate influence on time parameters. The estimated value of relief, relief ratio (R_r) and relative relief (R_R) were found to be 129 m, °.°3°9 and 1.29 km^2 respectively, these indicates the possibly moderate erosion. Over all study suggests that the watershed should be treated with soil and water conservation measures.

References

Strahler, A.N., (1964), Quantitative geomorphology of drainage basin and Channel networks. *Handb. Appl. hydrology*, McGraw Hill, New York, section 4-11.

Chow, V.T., (1962), Quantitative Geomorphology, *Handb. Appl .Hydrology*, Mc-Graw Hill Book Company.

Horton, R.E., (1932), Drainage Basin Characteristics, Trans. *Am. Geophysiacal Union*., 3: 35°-361.

Schumm, S.A., (1954), The relation of Drainage Basin Relief to Sediment Loss, *Int. Asso. Scie. Hydrology* ., 36: 216-219.

Melton, M.A., (1957), An analysis of the relations among elements of climate, surface properties and geomorphology. Department of Geology., Columbia Uni, Technical Report, 11, pp. 389.

Sethupathi, A.S., Lakshmi, N.C., Vasanthamohan, V. and Mohan, S.P., (2°11), Prioritization of mini watersheds based on morphometric analysis using RS and GIS techniques in a draught prone Bargur Mathur sub watersheds, Ponnaiyar River basin. *Int. J. Geomatics and Geosciences.,* 2(2): 4°3-414.

Imran. M, M., Sultan, B.M. and Nissar, A.K., (2°11), Watershed based drainage morphometric analysis of lidder catchment in Kashmir valley using geographical inf ormation system. *Recent Res. in Sci. and Tech.,* 3(4): 118-126.

Horton, R.E., (1945), Erosional development of streams and their drainage basins: Hydrophysical approach to quantitative morphology. *Geo. Soc. Am. Bulletin*., 56: 275-37°.

Subramanyan, V., (1974), A quantitative analysis of two drainage basins around Sagar, University of Saugor, Sagar, Madhya Pradesh., 4°(1): 76-99.