

# Morphometric Analysis using Remote Sensing and GIS Techniques in the Bagain River Basin, Bundelkhand Region, India

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## Abstract

**Objectives:** Morphometry is a measurement and mathematical analysis of landforms. The main objective of the study is to calculate the morphometric parameters of the Bagain river basin. **Methods/Statistical Analysis:** Remote Sensing (RS), Geographical Information System (GIS) and Global Positioning System (GPS) proved to be an efficient tool in our modern geographical and geological studies that are been used in the study. Basin morphometry shows numerical analysis or mathematical quantification of different aspects of a drainage basin. In this study Bagain river basin has been selected for morphometric characterization which is a tributary of river Yamuna. The morphometric analysis includes aspects as linear, areal and relief. **Findings:** The region is covered with high altitude Vindhyan hills. There is a large number of drainage systems originated from south and goes to north and downpours in the Yamuna River. The method applied to the river basin gave a recent calculation of the morphometric parameters of the region. **Application/Improvements:** The present study gives an account of information about drainage pattern, stream behaviour and morphometric setting of drainage within the network helping for watershed management.

**Keywords:** Bagain, GIS, Morphometric-Analysis, Remote Sensing, Watershed

## 1. Introduction

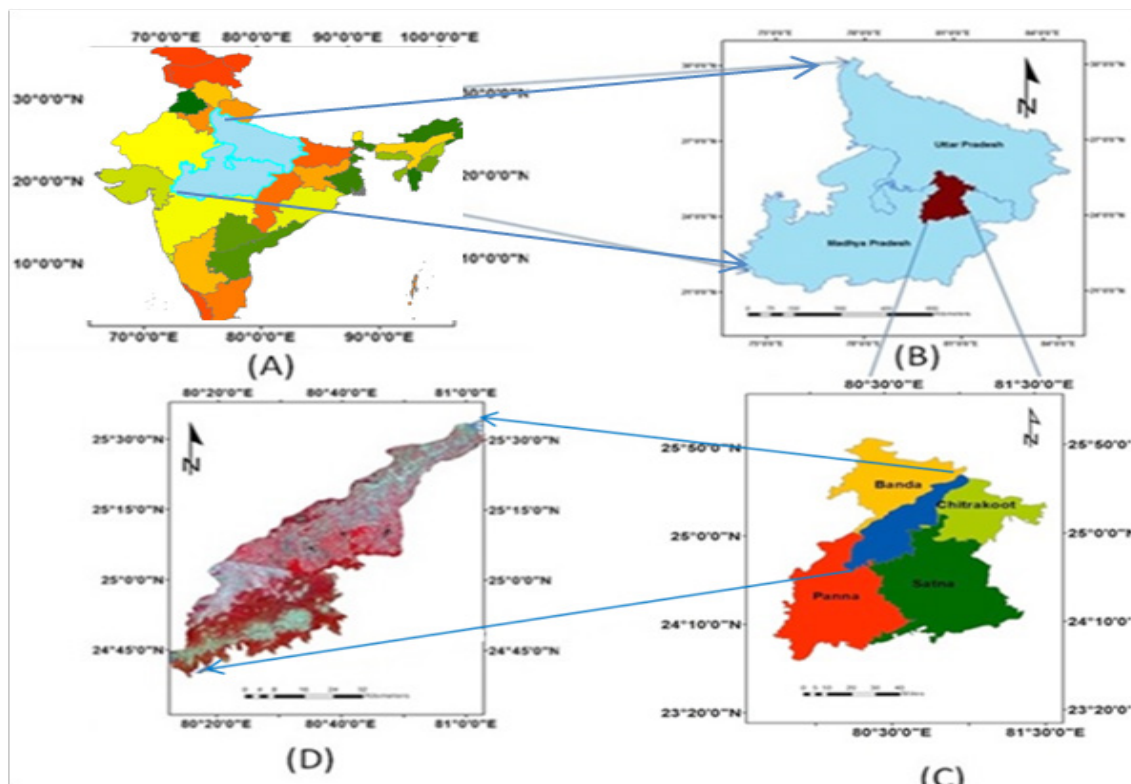
Water demand and growing population have become most important growing issues due to more and more urbanization taking place worldwide. On the other hand, there is increase in demand of water for various uses and decrease in the access of good-quality water due to over-exploited puts an alarming note on heavy water crisis in future. The characteristics assessment using quantitative morphometric analysis of any drainage basin provides good information about the geological characteristics of the rocks exposed and hydrological nature the drainage

basin. A proper drainage map always provides a reliable index of permeability of the hosting rocks and a better indication of the basin yield.

## 2. Study Area

Bagain river basin is of seventh order system having length of 125.24 km. It covers an area of about 2643.76 km<sup>2</sup> where elevation varies from 509.9 meters to 59.6 meters. It is located between latitude 24°39'4" N and 25°33'52" N, and longitude 80°11'47" E and 81°2'42" E. Bagain river basin (Figure 1) has eight sub basins which

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**Figure 1.** Location Map of Bagain river basin. (A) India, (B) Uttar Pradesh and Madhya Pradesh States of India, (C) Banda, Chitrakoot, Panna, Satna Districts, and (D) Bagain River Basin.

are named as SB1, SB2, SB3, SB4, SB5, SB6, SB7 and SB8, where SB indicates sub basin, to evaluate the spatial variation of morphometric parameters.

### 3. Objective

The authors have calculated morphometric parameters of Bagain river basin to understand the hydrological, geological and geomorphological aspects of the region helping for future watershed prospecting.

### 4. Material and Methodology

The Survey of India topographic maps (1:50,000), LANDSAT 8 Imagery data (15 meters) and ASTER (DEM) digital elevation data were used for the delineation of Bagain river basin. The calculation of drainage analysis of Bagain river basin was based on the methods (Table 1) given by various workers<sup>1-9</sup> and etc. The morphometric variables were categorized into linear, areal and relief aspects.

## 5. Data Analysis and Result

The results of morphometric analysis of BRB and its 8 sub-basins are discussed below-

### 5.1 Drainage Pattern

There present three types of drainage patterns (Figure 2) i.e., dendritic, parallel and trellis. Presence of dendritic drainage pattern shows homogenous and uniform soil type and rocks. Presence of parallel drainage pattern generally indicates area bearing gentle and uniform slope having bed rock of less resistant type. The trellis drainage pattern type is indicative of down-turned folds as synclines forming valleys.

### 5.2 Linear Aspects of Bagain River Basin (BRB)

In this present study, the linear aspects of Bagain River basin consists of parameters like perimeter, stream order, stream number, stream length, stream length ratio and bifurcation ratio.

**Table 1.** Linear, areal and relief aspects calculated for morphometric analysis

| S.No.          | Mophometric Parameters       | Formula                                                                                                                                                                           | Reference    |
|----------------|------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
| Linear Aspect  |                              |                                                                                                                                                                                   |              |
| 1.             | Perimeter (P)                | Length of the drainage basin boundary                                                                                                                                             | ----         |
| 2.             | Basin length(Lb)             | Maximum length of the basin measured parallel to the main drainage line                                                                                                           | <sup>1</sup> |
| 3.             | Stream length (Lu)           | Length of the Major stream                                                                                                                                                        | <sup>2</sup> |
| 4.             | Mean stream length (Lsm)     | Lsm = Lu / Nu ,<br>Lu = Total stream length of order 'u'<br>Nu = Total no. of stream segments of order 'u'                                                                        | <sup>1</sup> |
| 5.             | Bifurcation ratio (Rb)       | Rb = Nu / Nu + 1,<br>Nu = Total no. of stream segments of order 'u'<br>Nu + 1 = Number of segments of the next higher order                                                       | <sup>3</sup> |
| 6.             | Mean bifurcation ratio (Rbm) | Rbm = Average of bifurcation ratios of all orders                                                                                                                                 | <sup>4</sup> |
| 7.             | Stream length ratio (Rl)     | Rl = Lu / Lu - 1 ,<br>Lu = The total stream length of the order 'u'<br>Lu - 1 = The total stream length of its next lower order                                                   | <sup>2</sup> |
| Aerial Aspect  |                              |                                                                                                                                                                                   |              |
| 8.             | Total Area (A)               | Total area of river basin                                                                                                                                                         | ---          |
| 9.             | Drainage density (Dd)        | $Dd = \sum Lu / A$                                                                                                                                                                | <sup>5</sup> |
| 10.            | Stream frequency (Fs)        | $Fs = \sum Nu / A$                                                                                                                                                                | <sup>5</sup> |
| 11.            | Form factor (Rf)             | $Rf = A / Lb^2$                                                                                                                                                                   | <sup>5</sup> |
| 12.            | Circularity ratio (Rc)       | $Rc = 4 \pi A / P^2$                                                                                                                                                              | <sup>6</sup> |
| 13.            | Drainage texture (T)         | $T = Dd \times Fs$                                                                                                                                                                | <sup>2</sup> |
| 14.            | Elongation ratio (Re)        | $Re = 1.128 \sqrt{A} / Lb$                                                                                                                                                        | <sup>3</sup> |
| 15.            | Length of overland flow (Lg) | $Lg = 1/2 Dd$                                                                                                                                                                     | <sup>2</sup> |
| Relief Aspects |                              |                                                                                                                                                                                   |              |
| 16.            | Basin Relief (R)             | $R = H - h$ ,<br>H is maximum elevation and h is minimum elevation within the basin.                                                                                              | <sup>3</sup> |
| 17.            | Dissection Index (DI)        | $DI = R/Ra$                                                                                                                                                                       | <sup>7</sup> |
| 18..           | Relief Ratio (Rr)            | $Rr = R/Lb$                                                                                                                                                                       | <sup>3</sup> |
| 19.            | Ruggedness number (Rn)       | $Rn = R \times Dd$<br>R is the basin relief and Dd is the drainage density                                                                                                        | <sup>8</sup> |
| 20.            | Basin slope (Sb)             | $Sb = \{(M \times N)/A\} \times 100$ ,<br>M is the total length of the contours within the watershed in meters, N is the contour interval in meters and A is the basin area in m2 | <sup>9</sup> |

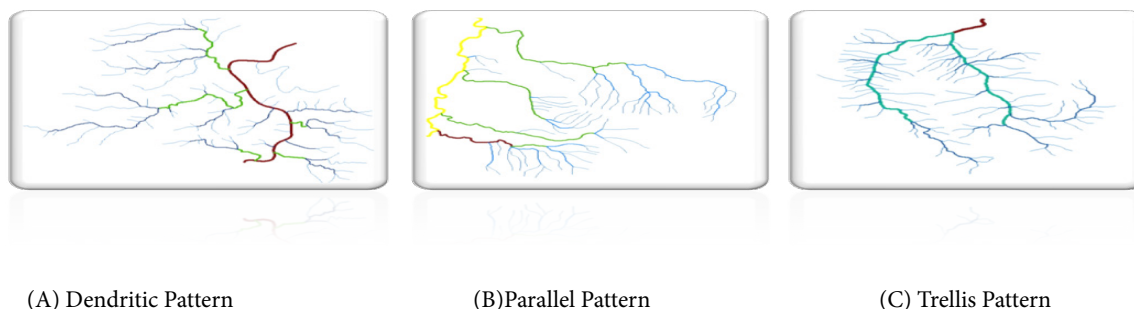


Figure 2. Various drainage Pattern.

### 5.2.1 Perimeter (P)

The P of BRB is 394.78 km and it varies between 56.70 (SB3) and 157.69 km (SB8).

### 5.2.2 Basin Length (Lb)

Lb measures geometrical size and shape of a drainage basin. BRB has a Lb of 125.24 km and that of the sub-basins ranges between 15.87 and 57.59 km.

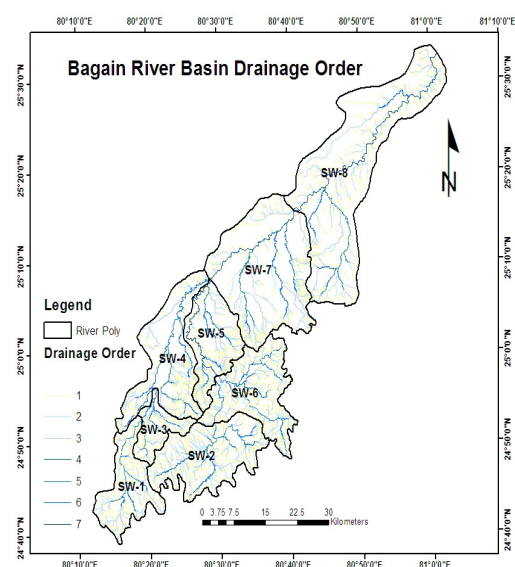


Figure 3. Bagain river basin drainage Order.

### 5.2.3 Length of the Main Stream

This in general denoted by length of the main stream. In the digitisation procedure, the main channel length was digitised using ArcGIS-10.1 software. The analysis showed that the length of the main stream is 174.28 km.

### 5.2.4 Stream Order (Nu)

The first step towards drainage basin analysis is the designation of stream order which shows the relative and hierarchical

relationship between stream segments, their connectivity and the discharge having contributions of the main watershed and its sub-watersheds (Figure 3). In the overall drainage of the basin area pattern of drainage comprises dendritic, parallel and trellis patterns since are constituted of network of various tributaries and its master stream which flows along the general slope direction which in turn are well adhered to the respective geological structures.

### 5.2.5 Stream Number (u)

Horton<sup>2</sup> stated that the numbers of stream segments of each order eventually form an inverse geometric sequence with the order number. The total number of streams in the study area is 5760 as mentioned above.

### 5.2.6 Stream Length (Lu)

The stream network of Bagain River basin was previously categorized into several orders, which were then computed using “Measure” tool of Arc GIS software using Survey of India toposheets as primary data. The stream length according to the law proposed by Horton<sup>2</sup> has been computed. The total length of streams (Lt) in BRB is 4687.58 km

### 5.2.7 Bifurcation Ratio (Rb)

The bifurcation ratio can be defined as a ratio of the number of stream segments of given order to the number of segments of next higher order. Bifurcation ratio is a good index of relief and dissection<sup>3</sup>. Values of *Rb* typically range from the theoretical minimum of 0.73 to 3.15. For the study area mean bifurcation ratio is 2.00 indicates that the geologic structures did not distorted or disturbed the drainage network.

## 5.3 Areal Aspects of Bagain River Basin

The areal aspects generally include various parameters like area, drainage density, drainage texture, stream fre-

quency, form factor, circularity ratio, etc. It is found that size of the basin is inversely related to maximum flood discharge per unit area<sup>10</sup>.

### 5.3.1 Area (A)

The A of BRB is 2643.76 km<sup>2</sup> and it varies between 94.48 (SB3) and 720.26 km<sup>2</sup> (SB8).

### 5.3.2 Drainage Density (Dd)

The drainage density has been found to be an important indicator of the linear scale of landform element in stream which is topographically eroded and is defined as a ratio of the total length of streams of all orders to its drainage area<sup>5</sup>. The low drainage density is often found to be favoured by highly permeable subsoil region bearing dense vegetation cover whose relief is low, whereas high drainage density always favoured in regions having weak or impermeable sub-surface materials, sparse vegetation and high mountain relief (Figure 4).

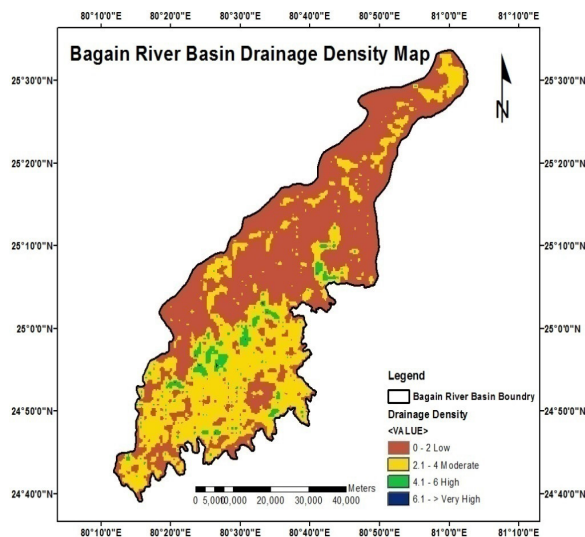


Figure 4. Drainage Density Map.

### 5.3.3 Drainage Texture (T)

Drainage texture has been categorised as:

- less than 2 shows very coarse,
- value between 2 and 4 shows coarse,
- value between 4 and 6 shows moderate,
- value between 6 and 8 shows fine and
- rest greater than 8 shows very fine drainage texture<sup>11</sup>.

In the present study the drainage texture value of Bagain river basin stands at 14.59, it indicates that the pattern of texture of Bagain River basin is very fine drainage texture.

### 5.3.4 Stream Frequency (Fs)

The value of stream frequency of Bagain river basin found to be 2.18. Thus, the stream frequency falls under moderate frequency class in the study area (Figure 5). The stream frequency found in the study area shows a positive correlation with its calculated drainage density, indicating an increase in the stream population with the increase in drainage density.

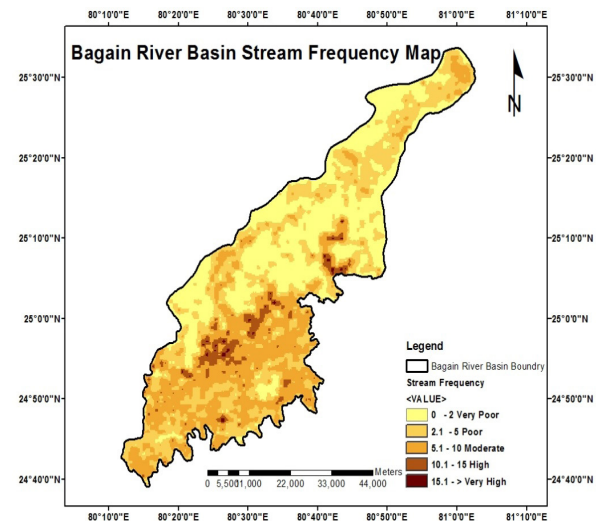


Figure 5. Stream Frequency Map.

### 5.3.5 Form Factor (Rf)

The value of form factor of Bagain River basin is 0.80 indicating the lower value of form factor which represents an elongated shape.

### 5.3.6 Length of Overland Flow (Lg)

In this study, the computed value of length of overland flow is 0.28 which shows low surface runoff of the study area.

## 5.4 Relief Aspects of Bagain River Basin

### 5.4.1 Basin relief (R)

The R of Bagain river basin is 420 m and of the sub-basins ranges between 300 and 270 m Table 2 which indicates the mountainous physiography.

### 5.4.2 Dissection Index (DI)

Dissection Index implies degree of dissection or vertical erosion. It explains the development of landscape in any

physiographic region<sup>12</sup>. The value of 'DI' vary between '0' (shows the complete absence of vertical erosion and prevalence of flat surface) and '1' (vertical cliffs/escarpment on land or at seashore). Higher 'DI' value implies larger terrain's undulation and hence instability. Higher 'DI' value results in enhanced erosion leading to large amounts of sediment debris. 'DI' value of the study area is 0.62, which indicates the basin is a moderately dissected (Figure 6).

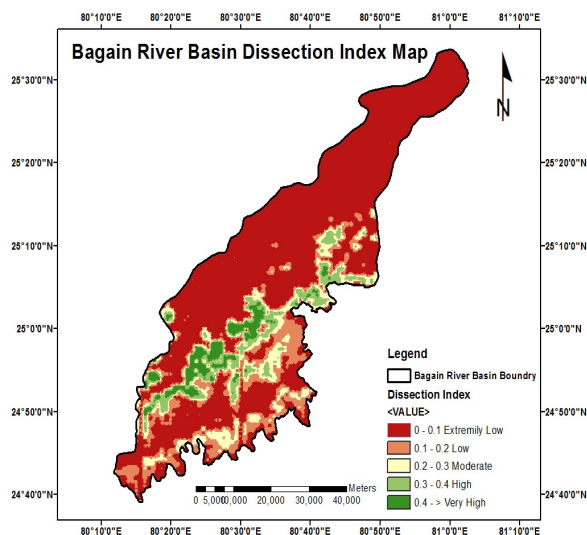


Figure 6. Dissection Index Map.

#### 5.4.3 Relief Ratio (Rr)

The Rr of Bagain River Basin is 0.034, while the values of the sub-basins are shown in Table 2. SB1 has the lowest Rr Value is 0.010 whereas SB2, SB3, SB4, SB5, SB6, SB7 and SB8 have higher Rr values ( $Rr > 0.083$ ), indicating steep terrain configuration.

#### 5.4.4 Ruggedness Number (Rn)

The Rn of BRB is 0.74 and that of the sub-basins ranges between 0.34 and 0.80 in Table 2. The ruggedness number of the sub-basins indicates higher soil erosion susceptibility.

#### 5.4.5 Basin Slope (Sb)

Slope analysis is a significant parameter. It is generally controlled by the region's climate morphogenic processes. The Sb of BRB is 41.02% while that of the sub-basins ranges from 36.16 to 54.13 in Table 2, revealing moderate to highly sloppy characteristic of the terrain bearing mountainous river basins (Figure 7 and 8).

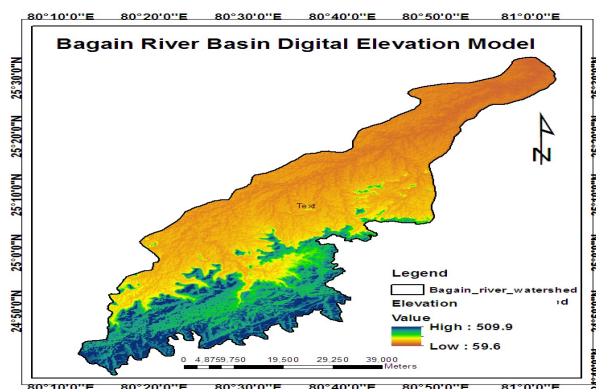


Figure 7. Digital Elevation Map.

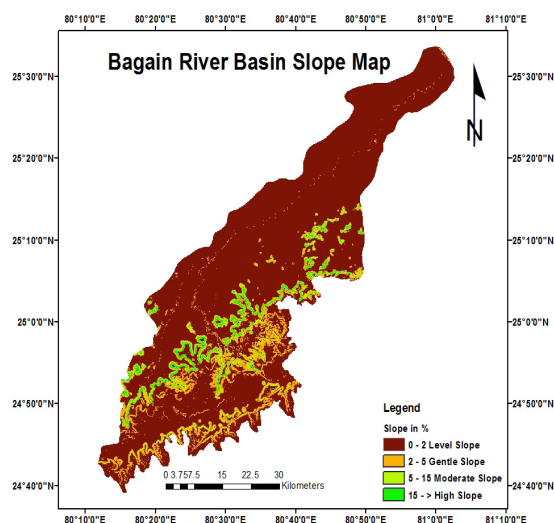


Figure 8. Slope Map.

## 6. Discussion

The watershed have moderate slope as shown by dendritic drainage pattern that generally implies the presence of massive crystalline hard rock in the terrain<sup>12</sup>. The bifurcation ratios calculated are good indicators of structurally controlled development of drainage pattern in the region. The values of drainage density and drainage texture (intermediate type) indicate that impermeable rocks are underlying the surface soil of the area. The study also reveals that DEM could be useful in studying the topography within GIS environment. Geomorphological study is solely based on the systematic study of present day landforms which can be related to their origin, nature, development, geologic changes features and their relationship with other underlying structures. The technology has been effectively and economically used in

**Table 2.** Morphometric parameters of Bagain River Basin( BRB) and its sub-watersheds

| Parameter      | SB1    | SB2    | SB3    | SB4    | SB5    | SB6    | SB7    | SB8    | BRB     |
|----------------|--------|--------|--------|--------|--------|--------|--------|--------|---------|
| Linear Aspects |        |        |        |        |        |        |        |        |         |
| P              | 85.85  | 109.90 | 56.70  | 114.85 | 75.39  | 105.91 | 104.70 | 157.69 | 394.78  |
| MSL            | 22.52  | 27.2   | 20.96  | 51.62  | 45.24  | 33.28  | 45.16  | 69.6   | 174.28  |
| (LB)           | 26.33  | 29.65  | 15.87  | 38.92  | 27.41  | 25.62  | 32.49  | 57.59  | 125.24  |
| Nu_1           | 419    | 643    | 256    | 530    | 557    | 746    | 545    | 613    | 4309    |
| Nu_2           | 105    | 170    | 65     | 157    | 134    | 186    | 145    | 163    | 1125    |
| Nu_3           | 21     | 48     | 15     | 31     | 25     | 48     | 33     | 36     | 258     |
| Nu_4           | 5      | 11     | 3      | 6      | 4      | 9      | 5      | 7      | 51      |
| Nu_5           | 1      | 3      | 1      | 1      | 1      | 3      | 1      | 1      | 13      |
| Nu_6           | 0      | 1      | 0      | 1      | 0      | 2      | 0      | 0      | 3       |
| Nu_7           | 0      | 0      | 0      | 0      | 1      | 0      | 1      | 1      | 1       |
| St             | 551    | 876    | 340    | 726    | 722    | 994    | 730    | 821    | 5760    |
| Lu_1           | 232.12 | 393.65 | 164.79 | 293.80 | 270.93 | 416.23 | 325.90 | 463.03 | 2540.02 |
| Lu_2           | 85.65  | 180.93 | 44.91  | 102.24 | 93.45  | 152.68 | 163.62 | 209.23 | 1033.55 |
| Lu_3           | 51.18  | 82.08  | 19.95  | 70.34  | 51.36  | 73.76  | 85.30  | 78.87  | 513.39  |
| Lu_4           | 24.96  | 51.27  | 17.49  | 44.39  | 37.12  | 44.14  | 52.78  | 46.96  | 321.18  |
| Lu_5           | 22.52  | 22.78  | 2.30   | 20.20  | 6.50   | 26.13  | 22.13  | 29.34  | 159.26  |
| Lu_6           | 0.00   | 16.12  | 0.00   | 26.87  | 0.00   | 23.70  | 0.00   | 0.00   | 50.58   |
| Lu_7           | 0.00   | 0.00   | 0.00   | 0.00   | 69.60  | 0.00   | 65.67  | 69.60  | 69.60   |
| LT             | 416.43 | 746.83 | 249.43 | 557.84 | 528.96 | 736.65 | 715.40 | 897.03 | 4687.58 |
| RB_1/2         | 2.71   | 2.17   | 3.67   | 2.87   | 2.89   | 2.72   | 1.99   | 2.21   | 2.46    |
| RB_2/3         | 1.67   | 2.20   | 2.25   | 1.45   | 1.82   | 2.06   | 1.92   | 2.65   | 2.01    |
| RB_3/4         | 2.05   | 1.60   | 1.14   | 1.58   | 1.38   | 1.67   | 1.62   | 1.68   | 1.60    |
| RB_4/5         | 1.10   | 2.25   | 7.60   | 2.19   | 5.71   | 1.68   | 2.38   | 1.60   | 2.02    |
| RB_5/6         | 0.00   | 1.41   | 0.00   | 0.75   | 0.00   | 1.10   | 0.00   | 0.00   | 3.15    |
| RB_6/7         | 0.00   | 0.00   | 0.00   | 0.00   | 0.00   | 0.00   | 0.00   | 0.00   | 0.73    |
| RB             | 1.26   | 1.61   | 2.44   | 1.47   | 1.97   | 1.54   | 1.32   | 1.36   | 2.00    |
| RL-2/1         | 0.37   | 0.46   | 0.27   | 1.18   | 0.34   | 0.37   | 0.50   | 0.45   | 0.41    |
| RL-3/2         | 0.60   | 0.45   | 0.44   | 0.69   | 0.55   | 0.48   | 0.52   | 0.38   | 0.50    |
| RL-4/3         | 0.49   | 0.62   | 0.88   | 0.63   | 0.72   | 0.60   | 0.62   | 0.60   | 0.63    |
| RL-5/4         | 0.90   | 0.44   | 0.13   | 0.46   | 0.18   | 0.59   | 0.42   | 0.62   | 0.50    |
| RL-6/5         | 0.00   | 0.71   | 0.00   | 1.33   | 0.00   | 0.91   | 0.00   | 0.00   | 0.32    |
| RL-7/6         | 0.00   | 0.00   | 0.00   | 0.00   | 0.00   | 0.00   | 0.00   | 0.00   | 1.38    |
| RL             | 0.39   | 0.45   | 0.29   | 0.72   | 0.30   | 0.49   | 0.34   | 0.34   | 0.62    |
| Areal aspects  |        |        |        |        |        |        |        |        |         |
| A              | 187.01 | 305.15 | 94.48  | 310.27 | 212.71 | 278    | 535.86 | 720.26 | 2643.76 |
| Dd             | 2.23   | 2.45   | 2.64   | 1.80   | 2.49   | 2.65   | 1.34   | 1.25   | 1.77    |
| T              | 6.42   | 7.97   | 6.00   | 6.32   | 9.58   | 9.39   | 6.97   | 5.21   | 14.59   |
| Fs             | 2.95   | 2.87   | 3.60   | 2.34   | 3.39   | 3.58   | 1.36   | 1.14   | 2.18    |

|                       |       |       |       |       |       |       |       |       |       |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Rf                    | 0.27  | 0.35  | 0.38  | 0.20  | 0.28  | 0.42  | 0.51  | 0.22  | 0.80  |
| Lg                    | 0.22  | 0.20  | 0.19  | 0.28  | 0.20  | 0.19  | 0.37  | 0.40  | 0.28  |
| <b>Relief aspects</b> |       |       |       |       |       |       |       |       |       |
| R(Mtr)                | 270   | 300   | 300   | 300   | 300   | 300   | 270   | 270   | 420   |
| Rr                    | 0.010 | 0.010 | 0.019 | 0.077 | 0.011 | 0.012 | 0.083 | 0.052 | 0.034 |
| DI                    | -     | -     | -     | -     | -     | -     | -     | -     | 0.62  |
| Rn                    | 0.73  | 0.74  | 0.79  | 0.54  | 0.75  | 0.80  | 0.36  | 0.34  | 0.74  |
| Sb                    | 7.42  | 6.05  | 9.10  | 6.94  | 5.74  | 9.14  | 4.95  | 3.59  | 5.96  |

analysis and inventory for basin area development and management<sup>13-20</sup>.

## 7. Conclusion

The groundwater occurrence in the study area are mostly restricted in the recent alluviums, top weathered parts of the hard crystalline rocks having lower relief and in the fissures and fractures as secondary porosities in the hard crystalline rocks. For sustainable development groundwater exploitation should be done from the above mentioned water bearing zones. The investigation done can be used for Bagain river basin area management in terms of watershed management and protecting the natural environment.

## 8. Acknowledgments

Authors are thankful to V.C., MGCGV for providing Remote Sensing and GIS Lab, Chitrakoot and Head, Department of Geology, BHU for providing the lab facility for the present study.

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