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RESEARCH ARTICLE

# Integrated Approach of Morphometric and LULC Parameters for Watershed Prioritization in Pachnoi River Basin, North-East India

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## Abstract

**Objective:** This study intends to prioritize the Pachnoi river basin, located in the north eastern part of India, covering an area of 504.54 km$^2$. "Prioritization" indicates the arrangement or sorting of the sub-watersheds within a broad watershed depending upon their risk of environmental problems and accordingly the treatment needed to be executed at high-priority areas. **Methods:** The research adopted an integrated approach combining morphometry and land use/land cover (LULC) parameters. Each morphometric and LULC parameters has been ranked for individual sub-watershed, and thereafter, the averages were determined to generate compound values. Based on compound values determined from the two approaches, rankings have been assigned to each sub-watershed and accordingly, priorities were set. **Findings:** The Pachnoi is a sixth-order watershed with a dendritic drainage pattern and elongated morphology. Depending upon morphometric analysis, SW1, SW2, and SW3 were grouped under high-priority zones, while SW7, SW8, SW9 and SW10 were categorised as high-risk regions based on LULC assessment. Integration of both the approaches has offered significant results, with SW4, SW7, SW8 and SW10 covering an area of 300 km$^2$ (59.46%) within high-risk areas. It implies that these micro-watersheds are more prone to environmental risk factors such as illegal logging, soil erosion, bank erosion, drastic land use change and runoff instability that requires urgent attention. **Novelty:** The novelty lies in adopting an integrated approach using geospatial techniques that would certainly enhance natural resource conservation. The high-risk sub-watersheds facing severe environmental problems necessitates prompt strategy implementation to enhance policymakers and stakeholders in drafting a plan for an integrated watershed management program.

**Keywords:** Pachnoi; Morphometry; LULC; Management; Subwatershed; Prioritization

# 1 Introduction

The imbalanced man-land ratio over time has affected the quality and quantity of natural resources existing over the earth's surface. Environmental deterioration is induced primarily by unprecedented population growth coupled with urbanization and climate change affecting the demand-supply ratio [1]. Remote sensing (RS) and geographic information systems (GIS) are examples of cutting-edge technologies that allow for improved natural resource management and conservation approaches compared to traditional methods [2]. For natural resource management, the watershed forms a fundamental unit. Prioritization within a watershed involves classifying regions considered more convenient and efficient for natural resource management, mitigation and land use planning. The sub-watersheds at high risk to environmental degradation would be allotted a top priority ranking that necessitates urgent conservation measures [3]. Watershed prioritization based studies are carried out as allocation of schemes and funds for development of the entire watershed might be infeasible. Hence, segregating the watershed into micro-watersheds would be more relevant and purposeful in identifying the specific problem encountering by a certain area or sub-watershed and accordingly the problems can be addressed more efficiently for management purpose.

The morphometric analysis involved derivation of the key aspects viz. linear, areal and relief that help in comprehending the neo-tectonic signatures controlling the dynamics of a river basin. For watershed planning and management, quantitative evaluation is a suitable approach to better understand the river basin characteristics. The hydrological structure of a basin is also determined by land use and land cover (LULC) shifts. Understanding the land-use dynamics is significant because of its profound effects on hydrologic processes such as infiltration capacity, runoff and evapotranspiration. The conversion of natural to humanised landscapes has led to the growth of various environmental issues. Excess siltation of stream channels threatens the viability of agriculture in rural watersheds [4].

Research and studies have been attempted on prioritization of sub-watersheds using morphometric and weighted sum approach [5]; morphometric in conjunction with hypsometric, principal component analysis, LULC and machine learning [6,7]; combination of morphometry and LULC parameters in international and national perspectives [8–10].

Watershed prioritization based on integrated approach of morphometry and LULC analysis using geospatial techniques in North-East India for management purpose especially in Brahmaputra valley is limited. Besides, no prior study on this perspective in the study area has been adopted so far. In this light, a study has been undertaken in Pachnoi basin as it is located in a fragile and ecologically sensitive region of North-East India which is frequently prone to environmental degradation such as illegal logging, soil erosion, bank erosion, drastic landuse change and runoff instability. Therefore, , the present research aims to prioritize the study area using the combined effects of morphometric and LULC parameters to recognise the critical sub-watersheds facing high environmental risk. The findings of this research would certainly urge for a clarion call in terms of natural resource management strategy to derive a sustainable integrated watershed by minimizing the environmental risk at grass root level.

## 1.1 Study area

Pachnoi River Basin is situated in a fragile geological set-up of North-East India **(Figure 1 a).** The Pachnoi forms a remarkable northern sub-basin of the Brahmaputra river system as a trunk channel with its tributaries. The basin is situated between the coordinates of 26° 33′ 11′′ N and 27° 04′ 30′′ N, 92° 15′ 21′′ E and 92° 23′ 02′′ E, and covers a total area of 504,58 $km^2$. It falls partly in the West Kameng district of Arunachal Pradesh and partly in three districts: Sonitpur, Udalguri and Darrang of Assam. The river originates from the lower Himalayan range of north-western Arunachal Pradesh. It slopes north-south and finally discharges into the Brahmaputra River beneath Orang National Park in Assam.

On average, the watershed receives an annual rainfall of 1965.5 mm, with maximum rainfall experienced in upper reach amounting to 2988.2 mm. In contrast, the lowest rainfall of roughly 1484.32 mm is witnessed in the central part of the watershed. The average monthly temperature is 26.61°C while the upper reach and central part of the basin experiences about 23.02°C and 28.65°C, respectively. Geologically, the entire basin is mostly dominated by new alluvium of the quaternary age group. It is composed of sand, pebbles, gravel, clay and boulder deposits, making it porous with good drainage. Significant parts of SW7, 8, 9 and 10 occupying the lower reach fall under this geological group. On the other hand, lower Gondwana, Siwalik and old alluvium exist in the upper and central reaches, covering significant sections of SW1 to SW6 indicating less infiltration capacity. Regarding soil texture, loamy skeletal comprises the maximum area of the basin, indicating high permeability with potentiality for groundwater recharge.

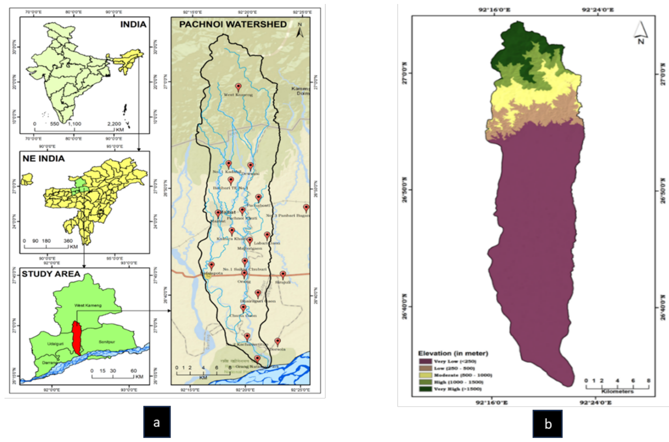



**Fig 1. Map showing (a) location and (b) DEM of the study area**

## 2 Methodology

The ALOS PALSAR DEM of 30 m resolution and Survey of India (SOI) topographical sheets viz. 83A/8, 83B/5, and 83B/6 were used in the GIS environment to delineate the Pachnoi River Basin (Figure 1**b**). The Pachnoi basin was further subdivided into ten sub-watersheds, designated SW1 to SW10. Table 1 represents the standard mathematical formulae used to compute the quantitative variables of morphometric analysis. After determining the morphometric values, ranks have been assigned to individual parameters for each sub-watershed. First rank was given to the sub-watershed with the highest value according to linear and areal aspects, second place to the second highest value, and so on. Table 6 displays the parameters ranked from lowest to highest in terms of area, with the lowest-ranked parameter being given the highest position[3,6].

The compound value method has been adopted after individually ranking each parameter of the 10 sub-watersheds. The composite value is calculated by adding all the ranks for a certain sub-watershed and then dividing that sum by the entire number of morphometric characteristics (20 parameters are considered for this study) represented in Table 4. This process repeats for each sub-watershed until the total compound values are known. The sub-watersheds were classified as low, medium, and high compound values. Sub-watersheds with the highest compound values were assigned the lowest priority, those with the next-lowest values received medium priority, and those with the lowest values received the highest priority[7–9].

Similarly, sub-watersheds are also ranked according to the land use pattern of the study area prepared from Landsat 8 satellite images in the GIS platform using visual interpretation techniques supplemented with a secondary database and field survey. It is important to note that, despite the study area having ten distinct categories of land use/land cover, only three land use classes have been undertaken to further prioritize the sub watersheds. The three land use classes have been considered in comparison to other classes, because mix built up land, fallow land and wasteland have contributed extensively towards drastic change of land use pattern in the study area. Sub-watersheds with the most significant value of mixed built-up land are ranked first, followed by those with progressively decreasing values in the order 2, 3, and so on. After ranking each sub-watershed separately, rankings are summed and divided by the number of land use categories (three LULC classes are used in this research to establish priority); then, compound values are estimated. Sub-watersheds were prioritised by calculating their compound values and classifying them as high, medium, or low. Then, the compound values calculated from morphometry and LULC have been averaged, and the final priority is allotted to the sub-watersheds[3,10,11].

**Table 1. Morphometric parameters with necessary formulae**

| Sl. No. | Morphometric Parameters | | References |
|---|---|---|---|
| **Linear aspects** | | | |
| 1 | Stream order (u) | Hierarchical rank | Strahler (1964) |
| 2 | Stream Length (Lu) | $L_u = L_{u1} + L_{u2 \ldots} + L_{un}$ | Horton (1945) |
| 3 | Stream Length Ratio (Rl) | $R_l = L_u / L_{u-1}$ | Horton (1945) |
| 4 | Stream number (Nu) | $N_u = N_{u1} + N_{u2} + N_{u3} + \ldots N_{un}$ | Strahler (1952) |
| 5 | Bifurcation Ratio (Rb) | $R_b = N_u / N_{u+1}$ | Schumm (1956) |

*Continued on next page*

*Table 1 continued*

| | | | |
|---|---|---|---|
| | | Where, Nu=total number of stream segment of order 'u'; $N_{u+1}$ = stream number of next higher order | |
| 6 | Mean bifurcation ratio (Rbm) | Average of bifurcation ratio of all orders | Strahler (1964) |
| 7 | Mean stream length (Lsm) | $L_{sm}$= $L_u/N_u$ where, $L_u$=stream length and $N_u$= stream number | Horton (1945) |
| 8 | Mean stream length ratio (Rlm) | Average stream length ratio of all orders | Schumn (1956) |
| 9 | Length of overland flow (Lo) | $L_o=1/2D_d$ where Dd=drainage density (km/km$^2$) | Horton (1945) |
| 10 | Constant of channel maintenance (C) | C= $1/D_d$ where Dd=drainage density (km/km$^2$) | Strahler (1964) |
| 11 | Infiltration number (If) | $I_f=F_s$ X $D_d$ where $F_s$= stream frequency and $D_d$= drainage density | |
| 12 | Rho coefficient ($\rho$) | $R_{lm}/R_{bm}$ where $R_{lm}$=mean stream length ratio and $R_{bm}$= mean bifurcation ratio | Horton, 1945 |
| 13 | Drainage intensity (Di) | $D_i=F_s/D_d$ where $F_s$=Stream frequency, Dd=Drainage density | Faniran (1968) |
| **Areal aspects** | | | |
| 14 | Basin length (Lb) | $L_b=1.312$X$A^{0.568}$ | Schumm (1956) |
| 15 | Stream frequency (Fs) | $\Sigma N_u/A$, where $\Sigma N_u$= total number of streams of the basin, A= Area of the basin | Horton (1932) |
| 16 | Drainage density (Dd) | $\Sigma L_u/A$, where $\Sigma L_u$= total stream length of the basin, A= area of the basin | Horton (1945) |
| 17 | Circularity ratio (Rc) | $R_c= 4\pi A/P^2$ where, $\pi$=3.14, A= area of the basin, P= perimeter of the basin | Miller (1953) |
| 18 | Elongation ratio (Re) | $R_e= 2(A/\pi)^{0.5}/L_b$ where, A= area of the basin, $\pi$=3.14, Lb= length of the basin | Schumm (1956) |
| 19 | Texture ratio (Rt) | $R_t=\Sigma N1/P$ where, ΣN1=total number of streams of first order, P=perimeter of the basin | Horton (1945) |
| 20 | Form factor (Ff) | $F_f = A/L_b^2$ where A= area of the basin and $L_b$ = length of the basin | Horton (1932) |
| 21 | Compactness Coefficient (Cc) | $C_c= 0.2821P/A^{0.5}$ where, P=perimeter of the basin and A=area of the basin | Horton (1945) |
| 22 | Drainage texture (Dt) | $D_t=N_u/P$ where Nu= stream number and P= perimeter of the basin | Horton (1945) |
| 23 | Lemniscate ratio (K) | $K= L_b^2/4A$ where, $L_b$= length of the basin, A= area of the basin | Chorley (1957) |
| 24 | Shape index (Sb) | $1/F_f$ where $F_f$ = form factor | Horton (1932) |

*Continued on next page*

*Table 1 continued*

| | | | |
|---|---|---|---|
| **Relief aspects** | | | |
| 25 | Basin relief (Bh) | $B_h$= H-h, where H= highest elevation and h= lowest elevation | Strahler (1952) |
| 26 | Relief ratio (Rh) | $R_h$= $B_h/L_b$ where, Bh= basin relief and $L_b$= basin length | Schumm (1956) |
| 27 | Relative relief (Rhp) | $R_r$ = H X 100/P where H= highest elevation and P= perimeter of the basin | Melton (1957) |

# 3 Results and Discussion

## 3.1 Morphometric parameters

In order to prioritise sub-watersheds for management and sustainable development of natural resources, it is a prerequisite to evaluate morphometric parameters for an insight into the dynamics of watershed characteristics[12–14]. The morphometric assessment incorporates three aspects, viz. linear, areal and relief, which are vividly described below.

**Linear Aspects**

**Stream order (u)**

Stream ordering was first proposed by R.E. Horton in 1945 and developed by Strahler in 1957. A second-order stream is generated at the confluence of two first-order streams or unbranched finger-tip tributaries. At the crossroads, two second-order streams combine to form a third-order stream, and so on. The basin's underlying physiographic and structural regulation causes stream order differentiation. Figure 2**(a)** represents Pachnoi as a sixth-order basin exhibiting a dendritic drainage pattern. The sub-watersheds with different stream orders are represented in Table 2.

**Stream Number ($N_u$)**

A watershed's total number of streams includes waterways from every stream order. Horton's (1932) law of stream number establishes a geometric sequence in which the stream number decreases as the stream order increases. The steep terrain in the northern half of the Pachnoi watershed is home to the highest concentration of lower-order stream segments, and finger-tip tributaries. It has been observed that as the order of the streams increases, the number of streams decreases in all sub-watersheds. The Pachnoi watershed has 757 total streams, including 593 first-order streams and 124 second-order streams. Table 2 indicates the stream numbers from different stream orders.

**Stream length ($L_u$)**

The distance travelled by those streams in a watershed is calculated by adding up the lengths of all the different stream segments. According to Horton's law of stream length (1945), the sum of the stream lengths decreases for a given sequence. This parameter is indicative of understanding the runoff characteristics. Shorter stream length represents steeper gradients, while longer stream lengths are characteristics of gentler slope areas. 726.15 kilometres of streams throughout the watershed have been recorded, with most shorter streams falling into the first order. However, discrepancies are marked in a few sub-watersheds, as total stream length does not decrease with increasing stream order.

**Stream length ratio ($R_l$)**

Mean stream lengths of successive orders are compared to determine the stream length ratio. Sub-watershed stream length ratios vary from 0.09 to 181.5, putting this watershed in the late juvenile geomorphic stage. However, specific differences have been seen in SW2, SW4, SW6, SW7 and SW8, which may be explained by slope, geological structure, topography, hydrological features, etc., which instantly affect stream flow.

**Bifurcation Ratio ($R_b$)**

The bifurcation ratio equals the number of streams of order $N_u$ divided by the number of streams of order $N_{u+1}$ [15]. The geological and structural features of the basin subsurface are the bifurcation ratio's primary drivers. According to Strahler (1957), the average Rb value in a mature drainage basin is between 2 and 5. A high Rb value indicates a low and drawn-out peak flow, while a low Rb value indicates a high and sudden peak flow. High infiltration capacity and excellent groundwater potentiality are provided by the watershed's high mean bifurcation ratio of 1.50 to 6.17 across all sub-watersheds (Table 3).

**Length of Overland Flow ($L_o$)**

A significant element in a watershed's physiographic and hydrologic evolution is its length of overland flow. The distance water travels on the ground before entering identifiable stream channels varies with slope and land usage. Higher $L_o$ values indicate low relief with poor infiltration and runoff, while low $L_o$ values represent high relief with good infiltration capacity and runoff. The $L_o$ values range from 0.20 to 1.65, wherein SW2 and 10 hold the highest and lowest values, respectively.

**RHO coefficient ($\rho$)**

RHO coefficient is called the bifurcation ratio and is connected to the number of drainage systems and the physiographic evolution of basins. It is defined as the ratio of the length of a stream to the bifurcation ratio. This data may be used to gauge the basin's water storage capacity. Findings show that SW10 has the most significant rho coefficient while SW3 has the lowest.

**Constant of channel maintenance (C)**

Constant of channel maintenance has the same square-per-unit measuring technique as drainage density and is the reverse of it. Schumm (1956) defines it as the basin area necessary to support one metre of stream bed. In this study, SW10 holds a maximum value of 2.43, and SW2 holds a minimum value of 0.30, respectively.

**Infiltration number ($I_f$)**

The potential for infiltration into a basin can be estimated by multiplying the drainage density by the stream frequency. According to the study, $I_f$ value ranges from 15.47 to 0.03, wherein the highest value is attributed to SW2 and the lowest value to SW10.

**Drainage intensity ($D_i$)**

The rate at which streams drain is measured in terms of drainage intensity. The basin's low drainage density, roughness, and intensity ratings make it especially vulnerable to soil erosion. The present study reveals that SW1 holds the highest $D_i$ value of 1.53, indicating a higher risk of soil erosion, while SW7 holds the lowest value of 0.15.

**Areal Aspects**

**Form factor ($F_f$)**

The form factor is the ratio of basin area to the square of basin length. This variable, whose value is between 0 and 1, identifies the basin's form and the level of flow activities. The basin shape is directly or indirectly influenced by various determinants viz., length of trunk channel, basin size, topography, gradient, geology, lithological characteristics, etc. A low $R_f$ value implies elongation of the basin with lower peak flow in a more extended period, while a high $R_f$ indicates a circular-shaped basin having high peak flow in a shorter time interval. The form factors of the sub-watersheds range from 0.09 to 0.26, with the lowest value found in SW6 and the highest in SW7 (Table 3).

**Circularity Ratio ($R_c$)**

The circularity ratio is defined as the ratio of the circumference of a circle with the same diameter as the watershed to the watershed's total area. The values range between 0 and 1, with smaller numbers indicating an elongated form and larger numbers, denoting a more circular one. Table 4 represents the $R_c$ values that vary from 0.19 (SW7) to 0.36 (SW9) with maximum sub-watersheds of elongation shape determining less runoff and high permeable geologic formations.

**Elongation Ratio ($R_e$)**

The elongation ratio is a valuable measure of basin size and form. The diameter of a circle that is proportional to the basin area can be used to calculate the maximum length of the basin". It shows that higher elevations have a faster infiltration rate, resulting in less surface runoff. In contrast, high $R_e$ implies a low and gentle topography with less permeability rate, thus, increasing the chances of flood occurrences. Low relief, high infiltration, and low runoff concentration are all indicated by the range of Re values between SW7 and SW6.

**Stream Frequency ($F_s$)**

The number of streams per square kilometre is used to calculate the frequency of streams. Simply dividing the total number of streams by the basin's area will provide the stream frequency value. Table 3 reflects the $F_s$ values that vary from a minimum of 0.08 km/km$^2$ to 4.69 km/km$^2$, wherein SW2 and SW10 occupy the highest and lowest Fs, respectively. Higher $F_s$ represent steep slopes, sparse vegetative cover, and greater permeability, leading to reasonable infiltration rate and runoff conditions.

**Drainage density ($D_d$)**

Landscape dissection and runoff potential are significantly influenced by drainage density, among other factors. It is the total area of the watershed divided by the total number of individual streams, regardless of their order in time. The watershed's Dd varies from 0.41 in SW10 to 3.30 in SW2 (Table 3). Low $D_d$ values are experienced in regions with gentle slopes, luxuriant vegetative cover, and high permeability, inducing a high infiltration rate. On the other hand, the higher the $D_d$, the higher the elevation with steep slopes with low sub-surface permeable characteristics, resulting in overland flow.

**Drainage Texture ($D_t$)**

A fluvial dissected landscape's channel spacing illustrates drainage texture. Stream frequency, drainage density, length of overland flow, and consistent channel maintenance are all essential aspects to consider when assessing drainage texture. SW1 (5.44), and SW10 (0.13), had the greatest and lowest values, respectively. According to the data, the drainage texture of the watershed is coarsest in SW7, SW8, and SW10, and mild from SW1 to SW6 (Table 3). This suggests a high infiltration rate in certain sub-watersheds due to resistive permeable underlying material, abundant flora, and flat topography.

**Texture Ratio ($R_t$)**

The texture ratio measures the relationship between first-order streams and basin perimeter. Lithological structure, infiltration capability, and terrain slope are at the top of the list of variables affecting the texture ratio. SW1 has the highest texture ratio, and SW10 has the lowest, ranging from 0.07 to 4.23 (Table 3). This indicates the presence of very course to course texture that intensifies the infiltration rate accompanied by the flat gradient in the watershed.

**Compactness Coefficient ($C_c$)**

The watershed's shape can be viewed through the compactness coefficient, which is the ratio of the watershed's perimeter to the circumference of its equivalent circular area. The intricate connection between the actual hydrologic basin and the circular basin of the same area is shown in the value of $C_c$. Conversely, smaller numbers show a reduced possibility for erosion, while higher values show more considerable potential for erosion. The greatest Cc value is recorded in SW3, followed by SW5 and SW6, while the lowest $C_c$ value of 0.08. (Table 3). Lower values signify less erosion susceptibility, while sub-watersheds bearing higher values are more prone to erosion.

**Lemniscate ratio (K)**

The slope of the basin can be calculated using the value derived from the lemniscate ratio, and is obtained by dividing four times the basin's area by the square of the basin's length. The research found that SW6 had the best total ranking with a value of 0.97, while SW7 had the worst with a value of 2.87 (Table 3).

**Shape index ($S_b$)**

Being a dimensionless entity, the shape index can be defined as the reciprocal of the form factor. It has an immediate impact on the processes of erosion and sediment transport. In this study, SW 7 holds the highest $S_b$ value of 11.11, whereas SW6 occupies the lowest value of 3.36 (Table 3).

**Relief Aspect**

**Basin Relief ($B_h$)**

The relief of a basin is one of the most crucial elements in determining the denudational characteristics that ultimately influence the geomorphic processes of a basin. The key metric for determining its size is the vertical distance between a basin's highest and lowest points. The highest and lowest basin relief are 2775 metres and 74 metres, respectively (Table 4). It determines the inclination of the basin, which affects soil erodibility. The basin relief in the upper reach reflects a steep gradient with less infiltration and high runoff. On the contrary, in the central and southern parts, gentle slopes with flat terrain induce less runoff and high infiltration. (Table 3).

**Relief ratio ($R_h$)**

The relief ratio of a basin can be calculated by dividing the vertical distance between the highest and lowest points of the basin by the length of the principal drainage line. According to Schumm (1956), slope steepness is a gauge of how much a basin's slope is being worn away by wind and water. The northern half of the watershed has a steep gradient and high relief, while the middle and lower portions have a moderate slope and flat terrain, giving a relief ratio of 0.21 to 0.05. Table 3 shows that SW3 has the highest value of 0.21 m, and SW7 has the lowest value of 0.04 m.

**Relative relief ($R_{hp}$)**

The relative relief can be computed by having the highest elevation of each sub-watershed and its parameter. The present study indicates SW3 with the highest value and SW8 with the lowest value (Table 3).

**Ruggedness ratio ($R_n$)**

Strahler (1958) defines the ruggedness ratio as the outcome of drainage density and basin relief, which denotes the surface's unevenness. The highest $R_n$ value has been found at SW3, while the lowest $R_n$ value is at SW10 (Table 3).

**Table 2. Computation of a few linear attributes: stream number, length and length ratio**

| Sub-Watersheds | Stream Order (u) | 1st order | 2nd order | 3rd order | 4th order | 5th order | 6th order | Total |
|---|---|---|---|---|---|---|---|---|
| SW1 | Stream No. (Nu) | 277 | 62 | 14 | 2 | 1 | | 356 |
| | Stream Length (Lu) (Km) | 142.62 | 41.61 | 16.77 | 12.93 | 17.41 | | 231.34 |
| | Stream Length Ratio ($R_1$) (Km) | | 0.29 | 0.4 | 0.77 | 1.34 | | 2.8 |
| SW2 | Stream No. (Nu) | 110 | 20 | 2 | 1 | | | 133 |
| | Stream Length (Lu) (Km) | 60.05 | 19.9 | 4.94 | 8.7 | | | 93.59 |
| | Stream Length Ratio ($R_1$) (Km) | | 0.33 | 0.24 | 1.76 | | | 2.33 |
| SW3 | Stream No. (Nu) | 28 | 3 | 1 | | | | 32 |
| | Stream Length (Lu) (Km) | 15.3 | 5.63 | 4.64 | | | | 25.57 |
| | Stream Length Ratio ($R_1$) (Km) | | 0.36 | 0.82 | | | | 1.18 |
| SW4 | Stream No. (Nu) | 40 | 9 | 2 | 2 | 1 | | 54 |
| | Stream Length (Lu) (Km) | 24.69 | 12.17 | 2.79 | 14.53 | 1.34 | | 55.52 |

*Continued on next page*

*Table 2 continued*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Stream Length Ratio ($R_l$) (Km) | | 0.49 | 0.22 | 5.2 | 0.09 | | 6 |
| SW5 | Stream No. (Nu) | 72 | 13 | 3 | 1 | | | 89 |
| | Stream Length (Lu) (Km) | 38.12 | 13.32 | 9.71 | 8.59 | | | 69.74 |
| | Stream Length Ratio ($R_l$) (Km) | | 0.34 | 0.72 | 0.88 | | | 1.94 |
| SW6 | Stream No. (Nu) | 41 | 8 | 2 | 1 | | | 52 |
| | Stream Length (Lu) (Km) | 18.94 | 5.91 | 6.89 | 2.2 | | | 33.94 |
| | Stream Length Ratio ($R_l$) (Km) | | 0.31 | 1.16 | 0.31 | | | 1.78 |
| SW7 | Stream No. (Nu) | 7 | 3 | 1 | | 1 | | 12 |
| | Stream Length (Lu) (Km) | 7.97 | 11.61 | 8.85 | | 45.36 | | 73.79 |
| | Stream Length Ratio ($R_l$) (Km) | | 1.45 | 0.76 | | 5.12 | | 7.33 |
| SW8 | Stream No. (Nu) | 5 | 1 | | 2 | | | 8 |
| | Stream Length (Lu) (Km) | 11.54 | 4.2 | | 6 | | | 21.74 |
| | Stream Length Ratio ($R_l$) (Km) | | 0.1 | | 1.42 | | | 18.51 |
| SW9 | Stream No. (Nu) | 8 | 3 | | | | 1 | 12 |
| | Stream Length (Lu) (Km) | 18.81 | 6.67 | | | | 20.92 | 46.4 |
| | Stream Length Ratio ($R_l$) (Km) | | 0.35 | | | | 3.13 | 3.48 |
| SW10 | Stream No. (Nu) | 5 | 2 | 1 | | | 1 | 9 |
| | Stream Length (Lu) (Km) | 4.21 | 6.28 | 5.45 | | | 32.28 | 48.22 |
| | Stream Length Ratio ($R_l$) (Km) | | 1.49 | 0.86 | | | 5.92 | 8.27 |

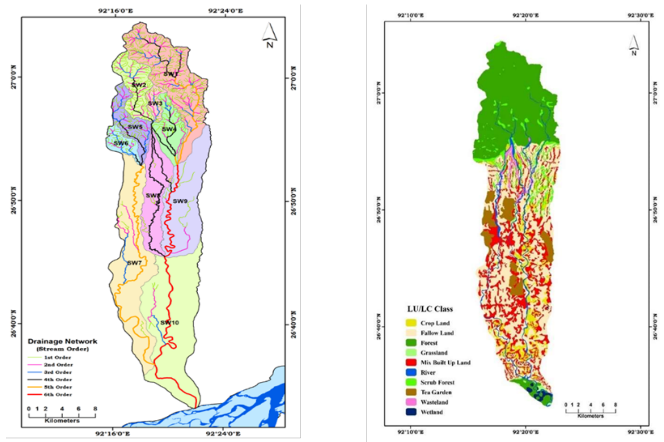
**Table 3. Sub watershed wise morphometric result and associated ranking**

| Parameters | SW1 | SW2 | SW3 | SW4 | SW5 | SW6 | SW7 | SW8 | SW9 | SW10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean bifurcation ratio | 4.47 (3) | 5.83 (2) | 6.17 (1) | 2.99 (6) | 4.29 (4) | 3.71 (5) | 2.11 (8) | 2.75 (7) | 1.89 (9) | 1.50 (10) |
| Mean stream length ratio | 0.70 (7) | 0.77 (5) | 0.59 (10) | 1.50 (4) | 0.64 (8) | 0.59 (9) | 2.44 (2) | 0.76 (6) | 1.74 (3) | 2.75 (1) |
| Stream frequency | 4.45 (2) | 4.69 (1) | 4.00 (4) | 2.21 (6) | 3.66 (5) | 4.32 (3) | 0.12 (9) | 0.19 (7) | 0.17 (8) | 0.08 (10) |
| Drainage density | 2.89 (3) | 3.30 (2) | 3.19 (1) | 2.27 (6) | 2.87 (4) | 2.82 (5) | 0.76 (8) | 1.11 (7) | 0.67 (9) | 0.41 (10) |
| Drainage texture | 5.44 (1) | 3.58 (2) | 1.70 (6) | 1.75 (5) | 2.34 (4) | 2.47 (3) | 0.15 (9) | 0.17 (8) | 0.24 (7) | 0.13 (10) |
| Length of overland flow | 1.44 (3) | 1.65 (1) | 1.60 (2) | 1.14 (6) | 1.43 (4) | 1.41 (5) | 0.38 (8) | 0.56 (7) | 0.34 (9) | 0.20 (10) |
| RHO coefficient | 0.15 (6) | 0.13 (9) | 0.09 (10) | 0.50 (4) | 0.14 (8) | 0.15 (7) | 1.15 (2) | 0.27 (5) | 0.92 (3) | 1.83 (1) |
| Drainage intensity | 1.53 (1) | 1.42 (3) | 1.25 (5) | 0.97 (6) | 1.27 (4) | 1.53 (2) | 0.15 (10) | 0.17 (9) | 0.25 (7) | 0.19 (8) |
| Infiltration number | 12.86 (2) | 15.47 (1) | 12.76 (3) | 5.01 (6) | 10.5 (5) | 12.18 (4) | 0.09 (9) | 0.21 (7) | 0.11 (8) | 0.03 (10) |
| Constant of channel maintenance | 0.34 (7) | 0.30 (10) | 0.31 (9) | 0.44 (5) | 0.34 (8) | 0.35 (6) | 1.31 (3) | 0.90 (4) | 1.49 (2) | 2.43 (1) |
| Ruggedness number | 3.03 (5) | 3.69 (2) | 3.79 (1) | 2.58 (6) | 3.18 (4) | 3.66 (3) | 1.03 (8) | 1.38 (7) | 0.85 (9) | 0.66 (10) |
| Circulatory ratio | 0.23 (3) | 0.26 (5) | 0.28 (6) | 0.32 (7) | 0.21 (2) | 0.34 (9) | 0.19 (1) | 0.24 (4) | 0.36 (10) | 0.33 (8) |
| Elongation ratio | 0.46 (5) | 0.54 (8) | 0.55 (9) | 0.50 (7) | 0.44 (3) | 0.57 (10) | 0.33 (1) | 0.37 (2) | 0.45 (4) | 0.47 (6) |
| Form factor | 0.17 (5) | 0.23 (8) | 0.24 (9) | 0.20 (7) | 0.15 (3) | 0.26 (10) | 0.09 (1) | 0.11 (2) | 0.17 (4) | 0.18 (6) |
| Lemniscate ratio | 1.48 (6) | 1.07 (3) | 1.02 (2) | 1.26 (4) | 1.64 (8) | 0.97 (1) | 2.87 (10) | 2.21 (9) | 1.50 (7) | 1.40 (5) |
| Shape index | 5.88 (7) | 4.34 (3) | 4.16 (2) | 5.0 (4) | 6.66 (8) | 3.84 (1) | 11.11 (10) | 9.09 (9) | 5.88 (6) | 5.55 (5) |
| Compactness coefficient | 0.11 (4) | 0.18 (7) | 0.33 (10) | 0.17 (6) | 0.22 (9) | 0.24 (8) | 0.11 (3) | 0.15 (5) | 0.10 (2) | 0.08 (1) |
| Basin relief | 1.05 (10) | 1.12 (8) | 1.19 (6) | 1.14 (7) | 1.11 (9) | 1.30 (3) | 1.36 (2) | 1.25 (5) | 1.28 (4) | 1.62 (1) |
| Relief ratio | 0.05 (9) | 0.10 (4) | 0.21 (1) | 0.10 (3) | 0.09 (5) | 0.19 (2) | 0.04 (10) | 0.06 (8) | 0.06 (7) | 0.06 (6) |
| Relative relief | 4.42 (3) | 6.68 (2) | 8.70 (1) | 4.09 (4) | 4.08 (5) | 3.01 (6) | 0.23 (8) | 0.05 (10) | 0.78 (7) | 0.17 (9) |

**Note:** Figures within parentheses indicate ranks

## 3.2 Prioritization of Sub-Watersheds using Morphometric Parameters

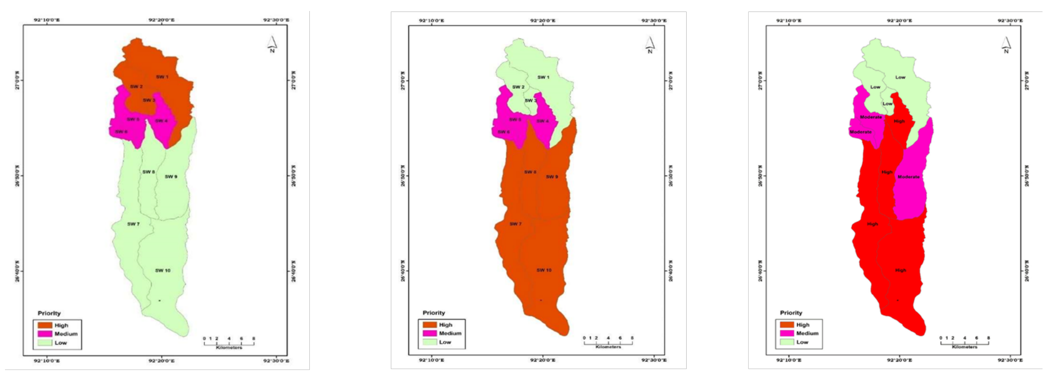
Prioritization has been followed to determine and address the most critical sub-watersheds with the implementation of conservation strategies.[16,17]. This method has been used to investigate the sub-watersheds vulnerability to various conditions, including runoff, peak flow, soil erosion, etc[18]. Amongst the morphometric parameters, 20 parameters have been considered depending upon their effectiveness rate on the factors as mentioned earlier.




a b

**Fig 2. Map showing (a) Strahler's stream ordering and (b) LULC of study area**

However, sub-watersheds with the highest values for areal parameters have been ranked lowest, suggesting a possible indirect relationship between these two factors [3,18–20]. After assigning ranks to all the parameters individually for each sub-watershed, the ranks have been added and then divided by the 20 parameters to find the compound values (Table 4). Compound values range from 4.3 to 6.4 (Table 6), which are arranged in three priority-based categories viz. low (<5.0), medium (5.0 to 5.7) and high (>5.7). The lowest compound value sub-watershed is rated first, followed by the next lowest, and so on. The sub-watershed identified with the highest compound value, on the other hand, has been given the lowest priority. According to this technique, it has been observed that SW1, SW2 and SW3 fall under the high-priority category, followed by SW 4, SW5 and SW6 under medium priority and SW7, SW8, SW9 and SW10 have received low priority (Figure 3 **a**).




a b c

**Fig 3. Map showing prioritization based on (a) morphometry (b) LULC (c) Integrated approach of morphometry and LULC**

**Table 4. Calculation of compound parameters and prioritization of sub-watershed**

| Parameters | SW1 | SW2 | SW3 | SW4 | SW5 | SW6 | SW7 | SW8 | SW9 | SW10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean bifurcation ratio | 3 | 2 | 1 | 6 | 4 | 5 | 8 | 7 | 9 | 10 |
| Mean stream length ratio | 7 | 5 | 10 | 4 | 8 | 9 | 2 | 6 | 3 | 1 |
| Stream frequency | 2 | 1 | 4 | 6 | 5 | 3 | 9 | 7 | 8 | 10 |
| Drainage density | 3 | 2 | 1 | 6 | 4 | 5 | 8 | 7 | 9 | 10 |
| Drainage texture | 1 | 2 | 6 | 5 | 4 | 3 | 9 | 8 | 7 | 10 |
| Length of overland flow | 3 | 1 | 2 | 6 | 4 | 5 | 8 | 7 | 9 | 10 |

*Continued on next page*

*Table 4 continued*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| RHO coefficient | 6 | 9 | 10 | 4 | 8 | 7 | 2 | 5 | 3 | 1 |
| Drainage intensity | 1 | 3 | 5 | 6 | 4 | 2 | 10 | 9 | 7 | 8 |
| Infiltration number | 2 | 1 | 3 | 6 | 5 | 4 | 9 | 7 | 8 | 10 |
| Constant of channel maintenance | 7 | 10 | 9 | 5 | 8 | 6 | 3 | 4 | 2 | 1 |
| Ruggedness number | 5 | 2 | 1 | 6 | 4 | 3 | 8 | 7 | 9 | 10 |
| Circulatory ratio | 3 | 5 | 6 | 7 | 2 | 9 | 1 | 4 | 10 | 8 |
| Elongation ratio | 5 | 8 | 9 | 7 | 3 | 10 | 1 | 2 | 4 | 6 |
| Form factor | 5 | 8 | 9 | 7 | 3 | 10 | 1 | 2 | 4 | 6 |
| Lemniscate ratio | 6 | 3 | 2 | 4 | 8 | 1 | 10 | 9 | 7 | 5 |
| Shape index | 7 | 3 | 2 | 4 | 8 | 1 | 10 | 9 | 6 | 5 |
| Compactness coefficient | 4 | 7 | 10 | 6 | 9 | 8 | 3 | 5 | 2 | 1 |
| Basin relief | 10 | 8 | 6 | 7 | 9 | 3 | 2 | 5 | 4 | 1 |
| Relief ratio | 9 | 4 | 1 | 3 | 5 | 2 | 10 | 8 | 7 | 6 |
| Relative relief | 3 | 2 | 1 | 4 | 5 | 6 | 8 | 10 | 7 | 9 |
| Sum of rankings (x) | 92 | 86 | 98 | 109 | 110 | 102 | 122 | 128 | 125 | 128 |
| Total parameters (y) | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| Compound parameter (x/y) | 4.6 | 4.3 | 4.9 | 5.45 | 5.5 | 5.1 | 6.1 | 6.4 | 6.25 | 6.4 |
| Ranking | 2 | 1 | 3 | 5 | 6 | 4 | 7 | 9 | 8 | 10 |
| Final priority | High | High | High | Medium | Medium | Medium | Low | Low | Low | Low |

## 3.3 LULC Assessment

The LULC map of the study area has been prepared following the visual interpretation technique in the GIS platform. Cropland, fallow land, mixed built-up, forest, wasteland, scrub forest, wetland, grassland, tea garden, and river were the ten land use categories pertaining to the study region. Figure 2 **(b)** illustrates the LULC map prepared for 2022, indicating that fallow land dominates covering an area of 162.43 $km^2$ (32.18 %).

The LULC distributional pattern reflected a distinctive characteristic of the region (Table 5**).** The hilly terrain has been extensively occupied by dense forest landscape, including a part of the Rowta and Chariduar reserve forests, which were previously free from human interference but over time evidences from LULC status revealed human encroachment to these forest areas leading to illegal logging, soil erosion and runoff instability. Moreover, based on the suitability of easy accessibility, bestowed with various favourable geographical factors, the central and lower part of the basin that falls within the jurisdiction of Assam is densely populated practising intensive agriculture. The field survey revealed that, paddy cultivation is the primary activity among the rural communities. During the off season cropping period, the occupants prefer to practice alternative sources such as large and small tea cultivation, Self-Help Groups (SHGs) and quarrying activities. Lack of adequate facilities, low productivity and income from agricultural activities have compelled the rural communities to choose other options. Among the horticultural crops, the most commonly grown is Arecanut (Betel Nut) which has been witnessed from field inquiry. Based on the population statistics, it has been established that owing to population blooming, particularly during the last decade, the category of mix-built-up, fallow land and waste land have experienced a drastic change resulting in acute pressure on natural resources. Thus, the wasteland and fallow land are required to be rejuvenated by adopting effective strategies. Amongst the LULC categories indicated, the present research has employed only three land use groups that have experienced rapid transformation, such as mixed built-up land, fallow land, and wasteland, which have been considered further for prioritising of the sub-watersheds based on environmental and social considerations.

For LULC-based sub-watershed prioritization, the following land use categories have been undertaken.

**Mix Built-up land**

The mix-built-up land category represents a combination of residential, commercial, industrial, transportation, and some degree of household woodlands alongside artificial, impermeable surfaces and cleared land. Compared to the sub-watersheds located in upper reach of the basin, the ones in the plain landscape attract high population growth encompassing various development activities. Amongst the sub-watersheds, SW7 has the highest share of mix-built-up land, accounting 26.72 %, followed by SW 10 (25 %), SW8 (23.66 %) and SW9 (20.80 %), respectively. It's a common consensus that the absence of this category is observed in SW2 and SW3 (upper section of the study area), while SW7 has witnessed the highest share (29.73%), followed by SW10 (27.26%) and SW8 (14.28%) due to the population growth (central and lower parts of the study area).

**Fallow Land**

Fallow land forms a part of agricultural land that is being left uncultivated or unplanted. The satellite imagery of multispectral bands selected to prepare the LULC map of the study area belongs to post harvesting period wherein the land category reflects the non-use of land for cultivation. As mentioned earlier, during this period (post-harvesting), the occupants earn their livelihood by practising alternative activities along with winter paddy cultivated in some corners of the region. Among all the sub-watersheds, SW7 has the highest share of fallow land (49.86 %), followed by SW10 (48.20 %), SW9 (33.12 %) and SW8 (21.41%), respectively (Table 7).

**Wastelands**

Wastelands signify the unused area of land that has become barren or unproductive. The study region possesses a vast area under the wasteland category that requires to be brought under use by applying certain strategies for its treatment. Wastelands of the study area are mostly distributed along the river sides, parts of Rowta and Chariduar reserve forest and the foothill regions. SW8 has the highest share of wasteland (3.07%), followed by SW5 and SW4, represented in Table 7.

**Table 5. 5.Sub watershed wise LULC Pattern**

| LULC Categories | SW1 | SW 2 | SW 3 | SW 4 | SW5 | SW6 | SW7 | SW8 | SW 9 | SW10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Area in $Km^2$ | | | | | | | | | |
| Crop Land | 0.23 | 0 | 0 | 0.28 | 0.42 | 0.6 | 6.2 | 1.83 | 1.83 | 16.08 |
| Fallow Land | 3.56 | 0 | 0 | 6.55 | 1.16 | 1.44 | 50.55 | 21.41 | 33.12 | 48.2 |
| Forest | 71.46 | 26.78 | 7.23 | 11.68 | 19.39 | 6.85 | 0 | 0.04 | 0.53 | 6.84 |
| Mix Built Up Land | 0.54 | 0 | 0 | 1.06 | 0.31 | 0.22 | 29.73 | 14.28 | 11.31 | 27.26 |
| River | 1.73 | 0.44 | 0.26 | 1.5 | 0.57 | 0.34 | 4.83 | 2.9 | 2.14 | 4.69 |
| Scrub Forest | 3.9 | 1.1 | 0.41 | 2.62 | 1.93 | 2.47 | 0.61 | 1.64 | 5.57 | 0 |
| Wasteland | 0.09 | 0 | 0 | 0.79 | 0.81 | 0.36 | 0.12 | 3.07 | 0.32 | 0.26 |
| Tea Garden | 0 | 0 | 0 | 0 | 0 | 0 | 10.86 | 4.99 | 3.54 | 5.82 |
| Wetland | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0 | 0.02 | 2.6 |
| Grassland | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 1.35 |

## 3.4 Prioritization of sub-watersheds using LULC parameters

The sub-watersheds with the most significant proportion of each land use type—mixed built-up land, fallow land, and wastelands were given priority when grading. Because these three categories are of prime concern for environmental degradation and also for agricultural sustainability in an area where agriculture remains the main source of livelihood. Expansion of mixed built-up land always exerts pressure on the man-land ratio, reducing productivity and finally pushing people to change their occupations[(15,21,22)]. Similarly, a higher percentage of fallow land influences people to choose other alternatives; hence, their interest decreases towards crop cultivation during the main cropping season. Further, it would be appreciated if the fallow and wastelands could be cultivated, especially during cropping season, by adopting scientific inputs. As such, ranks have been assigned chronologically in all three land use categories. Sub-watersheds with the highest percentage of area under land use categories, viz. fallow land, mixed built-up land and wasteland, have been ranked highest (Table 6). The sub-watersheds with the lowest compound parameters have been ranked as highest for other watersheds. Finally, three priority categories, high, medium, and low have been selected based on the value of the compound parameter and the ranks granted (Figure 3 **b**). Compound values with (<4) have been classified as high priority, between (4-6) as medium, and (>6) as low priority. Sub watersheds SW7, SW8, SW9, and SW10 have the highest priority, followed by SW4, SW5, and SW6 with medium, and SW1, SW2, and SW3 with the lowest priority depicted in Figure 3 **(b)**.

## 3.5 Integration of morphometric parameters and LULC ranking

Prioritization of sub-watersheds based only on morphometry or LULC without combining the two methods would have been vague in drawing valid results and arriving at better decisions for the management of the natural resources Subsequently, after ranking and calculating the compound parameter values for each sub-watershed based on both morphometry as well as LULC, priorities have been ascertained to different sub-watersheds. Apart from this, various studies and research have highlighted the beneficial effect of integrating or combining the two methods to identify the most vulnerable sub-watershed. Accordingly, planning and strategies have been initiated to safeguard from excess degradation, particularly soil loss or erosion[(8)]. Similarly, the present study, therefore, has accomplished the task of providing the final priority by considering the compound factor values generated from morphometry and LULC[(3,18)]. After finding the averages from these compound values, the integrated ranking has been assigned to each sub-watershed. The final priority ranking indicated SW7 and SW8 with the same compound values and in such circumstances, the most influencing factor affecting the sub-watersheds has been investigated. It has been observed

**Table 6. Ranking of sub-watersheds based on three LULC categories**

| LULC Categories | SW1 | SW2 | SW3 | SW4 | SW5 | SW6 | SW7 | SW8 | SW9 | SW10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Area ($km^2$ ) under LULC categories and ranking of sub-watersheds (only ranks are added) | | | | | | | | | |
| Fallow Land | 0 (8) | 0 (9) | 0 (10) | 6.55 (5) | 1.16 (7) | 1.44 (6) | 50.55 (1) | 21.41 (4) | 33.12 (3) | 48.2 (2) |
| Mix Built Up Land | 0.22 (8) | 0 (9) | 0 (10) | 1.06 (5) | 0.31 (7) | 0.54 (6) | 29.73 (1) | 14.28 (3) | 11.31 (4) | 27.26 (2) |
| Wasteland | 0.09 (8) | 0 (9) | 0 (10) | 0.79 (3) | 0.81 (2) | 0.36 (4) | 0.12 (7) | 3.07 (1) | 0.32 (5) | 0.26 (6) |
| Sum of ranking (X) | 24 | 27 | 30 | 13 | 16 | 14 | 9 | 8 | 12 | 10 |
| Total Number of Parameters (Y) | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Compound Parameter (X/Y) | 8 | 9 | 10 | 4.3 | 5.3 | 5.3 | 3 | 2.7 | 4 | 3.3 |
| Final Ranking | 8 | 9 | 10 | 5 | 6 | 7 | 2 | 1 | 4 | 3 |
| Priority | Low | Low | Low | Medium | Medium | Medium | High | High | High | High |

that SW7 comprises the maximum area under fallow land, which is more susceptible to soil erosion. That is why a high priority is assigned to SW7, followed by SW8 and SW10 respectively. Based on the integrated ranking shown in table 7, SW4, SW7, SW8 and SW10 have been grouped under high priority which require urgent implementation of constructive strategies to protect the resources from further depletion. The priority results of the sub-watersheds using the integrated approach have provided satisfactory results as these sub-watershed units have been suffering from soil erosion when witnessed through extensive field surveys. Figure 3 **(c)** illustrates the final ranking of sub-watersheds into three categories viz. low, moderate and high.

**Table 7. Final priority computed from integrated approach of morphometry and LULC**

| SW | Morphometric | LULC | Compound value | Integrated ranking | Final Priority |
|---|---|---|---|---|---|
| 1 | 4.6 | 8 | 6.3 | 8 | Low |
| 2 | 4.3 | 9 | 6.65 | 9 | Low |
| 3 | 4.9 | 10 | 7.45 | 10 | Low |
| 4 | 5.45 | 4.3 | 4.87 | 4 | High |
| 5 | 5.5 | 5.3 | 5.4 | 7 | Moderate |
| 6 | 5.1 | 5.3 | 5.2 | 6 | Moderate |
| 7 | 6.1 | 3 | 4.55 | 1 | High |
| 8 | 6.4 | 2.7 | 4.55 | 2 | High |
| 9 | 6.25 | 4 | 5.12 | 5 | Moderate |
| 10 | 6.4 | 3.3 | 4.85 | 3 | High |

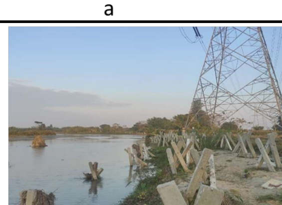
## 3.6 Erosion and mitigation strategies

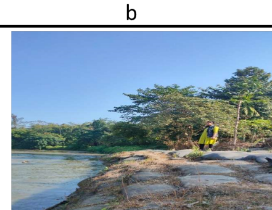
Analysis of morphometric and LULC characteristics have been considered as the best feasible approaches to identify the probable risk areas from physical and human perspectives. Scientific risk assessment of the vulnerable areas in the watershed provides a base to minimize the consequences through constructive measures. Sub-watershed prioritization using morphometric parameters illustrates that SW1, SW2 and SW3 are at high risk owing to the highest priority from the viewpoint of runoff instability, unstable peak flow, soil erosion etc. One of the advantages of these three sub-watersheds is the abundance of evenly distributed forest cover. Therefore, the probability of soil erosion risk is less prominent in those three sub-watersheds. However, the problems of runoff instability and unstable peak flow can be balanced with channelized stream flow using scientific methods and techniques.

a

b







due to declining production in conjunction with other factors etc. are commonly observed. This leads to many environmental as well as societal concerns nowadays as it induces other issues like lowering the ground water table, interruption in surface runoff flow, loss of biodiversity, wetland encroachment, loss of occupation etc., which have been increasing at an alarming pace. During field survey, few glimpses of severe erosion have been witnessed shown in figure 4a and 4b where villages such as Fata Simalugaon, Saikia Chuburi, Dhupguri, Biskhuti, Deva Pukhuri and Rowmari of Pachnoi basin have been affected annually. To prevent excess erosion, the locals have adopted weak structural measures lacking scientific base depicted in Figure 4**c** and **d** that requires to be replaced with effective management strategies.

## 4 Conclusion

This research implies the application of geospatial technology as part of a more comprehensive and integrated strategy to prioritize 10 sub-watersheds in the Pachnoi river basin. Evaluation of morphometric parameters and LULC analysis has been carried out to assess the hydrogeomorphology and land utilization pattern of the basin so that formulation of conservation policies based on up-to-date database could be initiated in the risk-prone areas. The basin has a sixth-order structure, with mass streams mainly of the first and second orders (94.71%). The drainage pattern is less structurally controlled for the bulk of the smaller watersheds, as measured by the mean bifurcation ratio. Positive correlations between stream frequency and drainage density induce porous subsurface and a coarse drainage texture contributing to substantial runoff in this watershed. The natural land use has been converted into humanised landscape leading to rapid soil loss, erosion and runoff rates. Morphometric based prioritization has categorised SW1, SW2, and SW3 facing high risk while SW7, SW8, SW9, and SW10 were deemed to be of high priority based on LULC parameters. Combining these two methods (morphometry and LULC analysis) indicated SW4, SW7, SW8 and SW10 have been treated as common sub-watersheds categorised under high priority covering an area of 300 $km^2$. These sub-watersheds require immediate implementation of constructive strategies and measures so that the study region could be protected from extreme environmental crisis. Looking at the adverse effect annually, no scientific based strategies have been enforced. Therefore, the results of such a study using remote sensing and GIS technology can be used as a jumping-off point for decision-makers, watershed managers, and planners to preserve existing resources by adopting comprehensive policies and mitigation measures.

## References

1) Arefin R, Mohir MMI, Alam J. Watershed prioritization for soil and water conservation aspect using GIS and remote sensing: PCA-based approach at northern elevated tract Bangladesh. *Applied Water Science*. 2020;10(4):1–19. Available from: https://doi.org/10.1007/s13201-020-1176-5.
2) Dhaloiya A, Hooda RS, Kumar D, Malik A, Kumar A. Geoinformatics-based assessment of gross irrigation requirement of different crops grown in the south-western region of Haryana, India. *Current Directions in Water Scarcity Research*. 2022;7:299–316. Available from: https://doi.org/10.1016/B978-0-323-91910-4.00018-2.
3) Das B, Singh S, Jain SK, Thakur PK. Prioritization of Sub-Basins of Gomti River for Soil and Water Conservation Through Morphometric and LULC Analysis Using Remote Sensing and GIS. *Journal of the Indian Society of Remote Sensing*. 2021;49(10):2503–2522. Available from: https://doi.org/10.1007/s12524-021-01410-w.
4) Belay T, Mengistu DA. Impacts of land use/land cover and climate changes on soil erosion in Muga watershed, Upper Blue Nile basin (Abay), Ethiopia. *Ecological Processes*. 2021;10(1):1–23. Available from: https://doi.org/10.1186/s13717-021-00339-9.
5) Godif G, Manjunatha BR. Prioritizing sub-watersheds for soil and water conservation via morphometric analysis and the weighted sum approach: A case study of the Geba river basin in Tigray, Ethiopia. *Heliyon*. 2022;8(12):e12261–e12261. Available from: https://doi.org/10.1016/j.heliyon.2022.e12261.
6) Shekar PR, Mathew A, S AP, Gopi VP. Sub-watershed prioritization using morphometric analysis, principal component analysis, hypsometric analysis, land use/land cover analysis, and machine learning approaches in the Peddavagu River Basin, India. *Journal of Water and Climate Change*. 2023;14(7):2055–2084. Available from: https://doi.org/10.2166/wcc.2023.221.
7) Kumar A, Singh S, Pramanik M, Chaudhary S, Maurya AK, Kumar M. Watershed prioritization for soil erosion mapping in the Lesser Himalayan Indian basin using PCA and WSA methods in conjunction with morphometric parameters and GIS-based approach. *Environment, Development and Sustainability*. 2022;24(3):3723–3761. Available from: https://doi.org/10.1007/s10668-021-01586-8.
8) Bagwan WA, Gavali RS. An Integrated Approach for the Prioritization of Subwatersheds in the Urmodi River Catchment (India) for Soil Conservation using Morphometric and Land Use Land Cover (LULC) factors. *Journal of Sedimentary Environments*. 2021;6(1):39–56. Available from: https://doi.org/10.1007/s43217-020-00041-4.
9) Bhattacharya RK, Chatterjee ND, Das K. Multi-criteria-based sub-basin prioritization and its risk assessment of erosion susceptibility in Kansai–Kumari catchment area, India. *Applied Water Science*. 2019;9(4):1–30. Available from: https://doi.org/10.1007/s13201-019-0954-4.
10) Setiawan O, Nandini R. Sub-watershed prioritization inferred from geomorphometric and landuse/landcover datasets in Sari Watershed, Sumbawa Island, Indonesia. In: 3rd International Conference on Environmental Geography and Geography Education, 12 September 2020, East Java, Indonesia;vol. 747 of IOP Conference Series: Earth and Environmental Science. IOP Publishing. 2021;p. 012004–012004. Available from: https://iopscience.iop.org/article/10.1088/1755-1315/747/1/012004.
11) Ojha S, Puri L, Bist SP, Bastola AP, Acharya B. Watershed prioritization of Kailali district through morphometric parameters and landuse/landcover datasets using GIS. *Heliyon*. 2023;9(6):1–14. Available from: https://doi.org/10.1016/j.heliyon.2023.e16489.
12) Arulbalaji P, Padmalal D. Sub-watershed Prioritization Based on Drainage Morphometric Analysis: A Case Study of Cauvery River Basin in South India. *Journal of the Geological Society of India*. 2020;95(1):25–35. Available from: https://doi.org/10.1007/s12594-020-1383-6.

13) Kanhaiya S, Singh S, Singh CK, Srivastava VK, Patra A. Geomorphic evolution of the Dongar River Basin, Son Valley, Central India. *Geology, Ecology, and Landscapes*. 2019;3(4):269–281. Available from: https://doi.org/10.1080/24749508.2018.1558019.
14) Benzougagh B, Meshram SG, Dridri A, Boudad L, Baamar B, Sadkaoui D, et al. Identification of critical watershed at risk of soil erosion using morphometric and geographic information system analysis. *Applied Water Science*. 2022;12(1):1–20. Available from: https://doi.org/10.1007/s13201-021-01532-z.
15) Samal DR, Gedam S. Assessing the impacts of land use and land cover change on water resources in the Upper Bhima river basin, India. *Environmental Challenges*. 2021;5:1–13. Available from: https://doi.org/10.1016/j.envc.2021.100251.
16) Barman BK, Rao CUB, Rao KS, Patel A, Kushwaha K, Singh SK. Geomorphic Analysis, Morphometric-based Prioritization and Tectonic Implications in Chite Lui River, Northeast India. *Journal of the Geological Society of India*. 2021;97(4):385–395. Available from: https://doi.org/10.1007/s12594-021-1696-0.
17) Bogale AG, Adem AA, Mekuria W, Steenhuis TS. Application of geomorphometric characteristics to prioritize watersheds for soil and water conservation practices in the Lake Tana Basin, Ethiopia. *Geocarto International*. 2023;38(1):1–21. Available from: https://doi.org/10.1080/10106049.2023.2184502.
18) Krishnan A, Ramasamy J. Morphometric assessment and prioritization of the South India Moyar river basin sub-watersheds using a geo-computational approach. *Geology, Ecology, and Landscapes*. 2022;p. 1–11. Available from: https://doi.org/10.1080/24749508.2022.2109819.
19) Tukura NG, Akalu MM, Hussein M, Befekadu A. Morphometric analysis and sub-watershed prioritization of Welmal watershed, Ganale-Dawa River Basin, Ethiopia: implications for sediment erosion. *Journal of Sedimentary Environments*. 2021;6(1):121–130. Available from: https://doi.org/10.1007/s43217-020-00039-y.
20) Priya K. Sub-Watershed Prioritization of Kariangote River in Kerala Based on Drainage Morphometry and Geomorphology – A Remote Sensing and GIS Approach. *Indian Journal Of Science And Technology*. 2023;16(13):978–988. Available from: https://doi.org/10.17485/IJST/v16i13.2057.
21) Waiyasusri K, Chotpantarat S. Watershed Prioritization of Kaeng Lawa Sub-Watershed, Khon Kaen Province Using the Morphometric and Land-Use Analysis: A Case Study of Heavy Flooding Caused by Tropical Storm Podul. *Water*. 2020;12(6):1–23. Available from: https://doi.org/10.3390/w12061570.
22) Munoth P, Goyal R. Impacts of land use land cover change on runoff and sediment yield of Upper Tapi River Sub-Basin, India. *International Journal of River Basin Management*. 2020;18(2):177–189. Available from: https://doi.org/10.1080/15715124.2019.1613413.