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Critical Watershed Prioritization through Multi-Criteria Decision-Making Techniques and Geographical Information System Integration for Watershed Management

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Abstract: The Precambrian hard rock topography of the Manbhum-Singhbhum plateau, which is well known for its semi-arid climates prone to drought, is often seen in Purulia district in West Bengal, India. Despite the district's middling groundwater capacity, 17 out of 20 blocks have exorbitant fluoride pollution in the groundwater that negatively impacts the health of local residents. Approximately 13% of the whole area suffers from severe erosion. It is evident that the river Kangsabati and its tributaries are not well fed by rainwater and thereby there is always a dearth of ground water. The aim of this study was to identify and prioritize integral watersheds in the Purulia area using Multi-Criteria Decision Making (MCDM) and Geographic Information Systems (GIS). The evaluation was carried out in the Bandu sub-watershed, which contains five micro watersheds: 2A2B5m, 2A2B5k, 2A2B5h, 2A2B5b, and 2A2B5j. The analysis considered five major factors: lithological properties, land use and land cover, soil erosion, groundwater recharge, and hydrogeomorphology. The weights of these criteria were determined by the Analytical Hierarchy Process (AHP) model, which was then prioritized using the Techniques for Order of Preference by Similarity to the Ideal Solution (TOPSIS) technique. This study emphasized an integrated approach to assess watershed hazards and to establish rational conservation goals. The Central Ground Water Board (CGWB) of India report was referred during data analysis. As a result of this study, the 2A2B5k watershed emerged as the most critical due to its susceptibility across the analyzed parameters. This thorough plan demonstrated the usefulness of identifying watershed threads and prioritizing conservation efforts.

Keywords: Multicriteria Decision-Making techniques; Geographic Information System; Analytical Hierarchy Process; Technique for Order of Preference by Similarity to Ideal Solution; Central Ground Water Board

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1. Introduction

Critical watershed identification is the process of assessing and prioritizing watersheds based on different attributes and traits to ascertain their significance and susceptibility for environmental preservation and natural resource management. Setting watersheds as a top priority helps to improve overall water resource management by facilitating the implementation of artificial recharge zonation and promoting the development of soil and groundwater [1]. In order to map the drainage network and prioritize soil and water conservation efforts in susceptible areas, a methodical scientific technique is utilized to rank sub-watersheds within a basin. Hydrologists claim that as morphometric analysis provides an accurate and quantitative picture of Earth's topography; it garners greater attention in this regard. The quantitative measurement and analysis of the configuration, shape, and dimensions of different landforms on Earth's surface is known as morphometry [2–8]. It also entails a thorough analysis of a basin's drainage infrastructure. This approach involves mathematical tools to offer a watershed analysis method that is both affordable and efficient. Morphometric analysis is a crucial technique in the fields of hydrology and geomorphology and is used in studies of environmental rehabilitation, hydrologic modelling, and the conservation of natural resources [3]. In integrated development planning, watersheds are now considered essential components. Watersheds are becoming more and more important to sustainable development, according to watershed management planners [9]. As a result, modern-day research stresses the importance of a holistic approach, which involves addressing multiple facets of growth. A key component of this holistic approach is to strike a careful balance between development and preservation so that it fits in with the unique social, economic, and environmental needs of the surrounding area. This equilibrium is important because it protects the distinctive characteristics of society and the environment while simultaneously promoting sustainable growth, as acknowledged by researchers and policymakers [10]. These thorough assessments offer crucial information for making well-informed decisions. Investigating these variables gives hydrogeologists the important information they need to develop successful plans for managing watersheds and preserving the environment. Essentially, a thorough examination of these components gives resource management policymakers the information they need to create smart, long-lasting solutions. There is a growing recognition of the critical role that land use/land cover evaluations and quantitative geomorphometric analysis play in the field of watershed management. It has been acknowledged that incorporating these methods into processes for prioritizing watershed protection is essential to improving the management of shared resources [11,12]. Through a deeper knowledge of the complex link between geomorphometric features and patterns of land use and cover, this method helps develop more intelligent and successful conservation plans. By analyzing remote sensing data, basin morphometry, and applied geoscience techniques, numerous researchers have successfully prioritized watersheds, resulting in the production of detailed maps showing potential groundwater recharge areas [13]. The basin of the Tons River in the lower Himalayas has been thoroughly studied by geographers [14]. Their study examined the intricacies at the micro level by using a thorough examination of four important risk factors. These criteria include soil types, lithological traits, land use/land cover patterns, and morphometric features. Recent studies have demonstrated the usefulness of remote sensing as a tool for morphometric analysis. It is now essential to use GIS tools in conjunction with remotely sensed data, such as satellite photos and Digital Elevation Models (DEM) [15]. Many researchers have shown that these technologies make it possible to automatically extract drainage networks [16–22]. To effectively accomplish goals, stakeholders in the governance and administration of watersheds have turned their focus to using multi-criteria decision-making models (MCDM) [23]. There is evidence that policymakers and managers in Indonesia are beginning to understand the significance of using integrated planning techniques across entire river basins [24]. China's small-scale watershed management has been successful in fusing small-scale water resources initiatives with soil conservation efforts [25,26]. The sustainability of irrigation and crop productivity of land and water in India has been negatively impacted by sectoral development and management of watershed resources, such as land and water in their catchment areas. Therefore, shifting from a focused strategy to the development of water resources to a multi-objective approach to the long-term sustainability of river basin environments [27]. Prioritizing critical watersheds uses a multi-objective strategy. There is a discernible study gap in crucial watershed prioritization in the Purulia district of West Bengal, India. No research study has integrated the MCDM models with the priority framework in any Purulia district watershed. Moreover, at the regional level, this cohesion is conspicuously lacking. Hydrologists in Purulia used several approaches to prioritize watersheds. However, these projects have encountered constraints in their scope and distribution. Prioritizing micro-watersheds has been the focus, typically with specific objectives in mind, including lessening soil erosion or improving groundwater recharge. However, a comprehensive, integrated management perspective, which is essential for sustainable watershed management, is absent from this constrained approach. Strictly focusing on individual risk factors ignores the intricate interplay of variables that affect watershed vulnerability. As a result, addressing the essential micro-watersheds' identification calls for an innovative strategy that goes beyond traditional approaches. Adopting a more comprehensive and inclusive strategy for identifying Purulia's critical watersheds will require a fundamental shift. Rather than limiting priorities to a few distinct elements, a comprehensive assessment model should be created. Numerous indicators, such as hydrological dynamics, land use patterns, ecological health, socioeconomic aspects, and projections of climate change, should be included in this model. By combining these components, watershed vulnerabilities may be better understood, which makes resource allocation and prioritization more efficient. It is also essential to take the temporal and spatial dimensions of watershed management into account. A more comprehensive landscape-level perspective is required to understand the interdependence of various hydrological units and their combined influence on regional water resources, as opposed to concentrating only on particular micro-watersheds. A complete and integrated approach must be adopted to handle the complex challenges that the Purulia's watershed management is facing. Through the adoption of a landscape-scale framework and a holistic viewpoint that encompasses various dimensions of vulnerability, it is possible to successfully identify and prioritize critical watersheds, thereby creating the foundation for sustainable management of the region's water resources.

The western region of the Purulia district has been the subject of numerous studies [28], with particular attention paid to morphometric parameters and hydrological processes [29], watershed and soil erosion [30], land degradation [31], forest degradation [32], groundwater [33], water level fluctuation [34], and related studies. The goal of the present study was to prioritize the Bandu sub-watershed's critical watershed by conducting a thorough analysis that considered crucial elements like hydrogeomorphology, lithology, land use and cover, groundwater recharge, and soil erosion. Several MCDM models were used subsequently to analyze the data and extract insightful information for the priority level's final classification. The goals of this study were to: (1) create a thorough database of watershed morphometry; (2) quantitatively evaluate and analyze different risk parameters in the studied area to offer insightful information about potential vulnerabilities and hazards; and (3) create a methodical framework for prioritizing areas for the implementation of conservation programs and projects. The novelty of this study can be expressed as follows in the context of the literature on critical watershed prioritizing studies and highlighting the benefits of the priority framework: (1) the integrated prioritization framework based on MCDM models must be comprehensive to achieve overall watershed success; (2) different micro watersheds have unique characteristics that call for different approaches, which cannot be adequately addressed by using a single, standard method.

2. Study Area

The area of study, the Bandu sub-watershed, resides in the Purulia district in the state of West Bengal, India (Figure 1). The diverse scenery featuring verdant forests, captivating riverscapes, lakes, waterfalls, and hills, along with the rich cultural heritage of the surrounding community, presents a wealth of opportunities for the growth of ecotourism [35]. Out of 20 blocks in the Purulia district, 17 blocks encounter high levels of groundwater adulteration with fluoride [36]. In the semi-arid area, the watershed is distinguished by a subtropical climate. The Bandu River, an ephemeral stream that rises from the northern side of the Ajodhya Hills close to the base of Gorgaburu Peak (620 m above sea level), mostly defines the watershed [37]. Three tributaries from the right and one from the left confluence into the main river Bandu, which covers an area of 215 square kilometers. According to hydrogeology, the study area is part of the Manbhum-Singhbhum plateau's Precambrian hard rock terrain [38]. This area is primarily governed by the existence of several lithological units, the most prominent of which is the Chotanagpur Granite Gneiss (CGG).

Underground water is only found in the Gondwana sediments' worn mantle, saprolitic zones, fractured zones, and Chota Nagpur Geneissic Complex (CNGC) formation. Rainfall is essential for groundwater recharging because the area is semi-arid. Regionally, the region stretches as the peninsular landmass continues eastward [39]. While the plains are made up of meadows, croplands, and barren lands, the hilly terrain is primarily forested. Aquifers and their potentiality are found in the saturated weathering zone 20 m below ground level (mbgl) in the Bandu sub-watershed area, and potential fracture zones are found at 50–60 mbgl, resulting in a sustainable discharge of 2.5 to 2.75 L per second [40]. There are two primary types of villages in the Bandu sub-watershed: those that depend on agriculture and those that depend on wood. While agriculture-based communities only engage in farming, forest-based villages are tucked away in higher plateaus and surrounded by thick forests. Piedmont plains and slopes are home to tropical dry deciduous woods. Five separate micro-watersheds have been created from the Bandu Sub-watershed, each utilizing a different codification scheme based on the Soil and Land Use Survey of India (SLUSI). According to the established classification system, these micro watersheds are designated as 2A2B5m, 2A2B5k, 2A2B5h, 2A2B5b, and 2A2B5J.

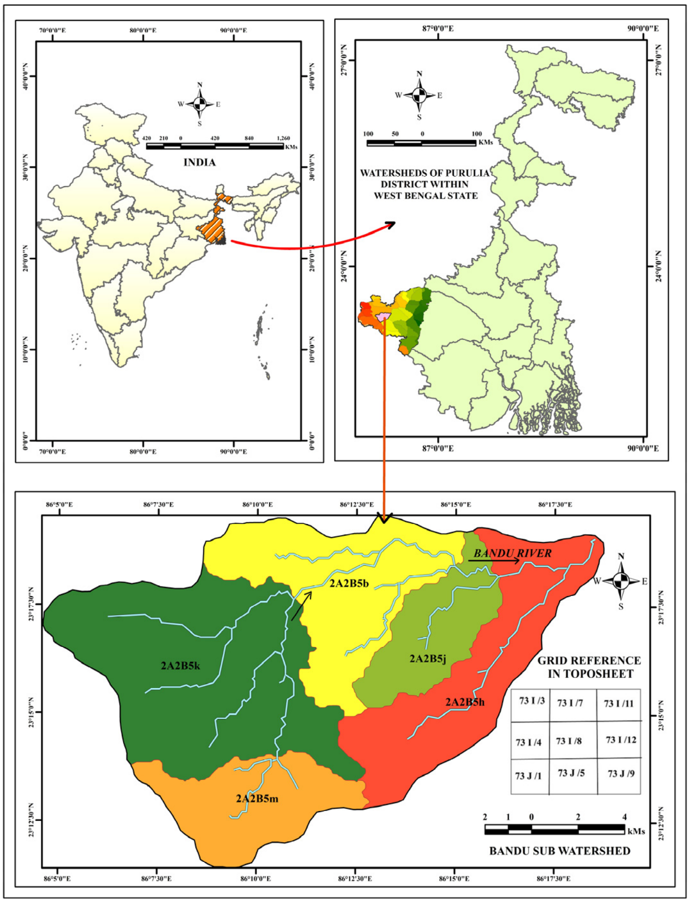


Figure 1. Location map of study map.

3. Materials and Methods

3.1. Data Sets Used

The Bandu sub-watersheds key watershed prioritization map was developed using a variety of datasets.

- The data from the Landsat-9 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) was utilized. This sensor provides an excellent spatial resolution of 30 m over 11 spectral bands. These scenes, which were taken in the dry, pre-monsoon period of early April 2023 under clear atmospheric conditions, were crucial sources of information.

- Four 1:50,000 scale Survey of India (SOI) topographic sheets (73E/14, 73E/15, 73E/16, and 73I/3) were used to chart the Bandu sub-watershed in detail. These maps functioned as ground truth references in addition to helping with the geometric correction of satellite photos. With a root mean square error (RMSE) of 0.40 to 0.50 pixels, the map image-to-map registration demonstrated exceptional accuracy, while the image-to-image registration obtained an astounding 0.10 to 0.14.
- The Digital Elevation Model (DEM) data from the Shuttle Radar Topography Mission (SRTM) was used for accurate morphometric analysis. SRTM's 30 m of spatial resolution and advanced computational capabilities, when combined with its C-band interferometric radar setup [41,42] allowed for quick determination of morphometric parameters. Additionally, vector data encompassing Lithology and hydrogeomorphology at a scale of 1:250,000 were sourced from the Geological Survey of India's official website, Bhukosh [41]. Table 1 provides data sources used in the study.

Table 1. Data products used in the study.

Data	Purpose	Resolution/Scale	Year	Source
Landsat-9	LULC	30 mt	Early April, 2023	(http://earthexplorer.usgs.gov/, accessed on 17 March 2024) [42]
SRTM-DEM	Drainage morphometry	30 mt	Early April 2023	(http://earthexplorer.usgs.gov/, accessed on 17 March 2024) [42]
Toposheet	Delineation of watershed	1:250,000	1961	Survey of India (SOI), Kolkata [43]
Lithology	Lithological units	1:250,000	2023	(https://bhukosh.gsi.gov.in/Bhukosh/Public, accessed on 17 March 2024) [44]
Geomorphology	Geomorphic divisions	1:250,000	2020	(https://bhukosh.gsi.gov.in/Bhukosh/Public, accessed on 17 March 2024) [44]

3.2. Methodology Used

3.2.1. The Methodology for Morphometric Analysis

Linear, areal, and relief parameters are crucial metrics in morphometric analysis that are used to measure the properties of drainage networks and landforms within a watershed [45–47]. Relief factors explore the steepness and ruggedness of the terrain, whereas linear parameters concentrate on the characteristics of the stream and areal parameters offer a more comprehensive picture of the size and structure of the watershed [48–50]. When taken as a whole, these measurements enable scientists to learn a great deal about the complex dynamics of watersheds. Table 2 provides an explanation of the methods used in the computation of these indexes.

Table 2. Methods adopted for computation of Geomorphometric units.

Geomorphometric Units	Formula	References
	Linear parameters	
Stream order (U)	Hierarchical rank	[8]
Stream number (N_u)	$N_{u1} + N_{u2} \ldots + N_{un}$	[47]
Stream length (L_u)	$L_{u1} + L_{u2} \ldots + L_{un}$	[47]
Mean stream Length (L_{sm})	Average of stream length of all orders	[47]
Stream Length Ratio (L_{ur})	L_u/L_{u-1} L_u = total stream length of 'U' order, L_{u-1} = the total stream length of next lower order	[47]
Mean Stream Length Ratio (R_{lsm})	Average of stream length ratios of all orders	[51]
Bifurcation Ratio (R_b)	N_u/N_{u+1} N_u = total number of streams of 'U', N_{u+1} = number of streams of next higher order	[51]
Mean bifurcation Ratio (R_{bm})	average of bifurcation ratios of all orders	[8]

Table 2. *Cont.*

Geomorphometric Units	Formula	References
	Areal Parameters	
Basin area (A)	Analysis in GIS environment	
Basin perimeter (p)	Analysis in GIS environment	
Basin length (Lb)	Distance between outlet and farthest point on basin boundary	
Relative perimeter	A/P	
Mean basin width	A/Lb	
Drainage density (Dd)	L_u/A	[47]
Stream Frequency (Fs)	N_u/A	[51]
Drainage texture (Dt)	N_u/P	[51]
Drainage Intensity (Di)	Fs/Dd	[52]
Elongation Ratio (Re)	$1.128(A)^{0.5}/L_{ar}$	[51]
Infiltration Number (If)	$Dd \times Fs$	[52]
Circularity Ratio (Rc)	$4\pi A/P^2$	[53]
Form factor (Rf)	A/Lar^2	[47]
Length of overland flow (Lg)	$1/(2 \times Dd)$	[51]
Constant of channel maintenance (c)	1/Dd	[51]
Compactness coefficient (Cc)	$0.2821 \times P/(A)^{0.5}$	[54]
Shape factor (Ru)	${L_{ar}}^2/A$	[53]
Fineness ratio (Rfn)	L_{ar}/p	[55]
Texture ratio (Rt)	N_{u1}/P $N_{u1} =$ stream number of 1st order	[56]
	Relief Parameters	
Maximum elevation of the area (Me)	Extracted from DEM	
Minimum elevation of the area (Mm)	Extracted from DEM	
Basin relief (H)	Me − Mm	[47]
Relief ratio (Rh)	H/Lar	[47]
Ruggedness number (Rn)	$(H \times Dd)/1000$	[51]
Melton Ruggedness number (MRn)	$H/(A)^{0.5}$	[57]
Relative relief (Rr)	H/P	[58]
Dissection Index	H/M	[57]

3.2.2. The Methodology for Quantifying Various Risk Parameters

A comprehensive strategy was used in the crucial watershed prioritizing process, considering important factors that are necessary for efficient watershed management, such as soil erosion, groundwater recharge, lithological risk, hydro geomorphology, and land use and cover (LULC). After carefully examining each of these critical parameters, ratings were given to distinct micro watersheds by their unique attributes. Areas requiring immediate attention were indicated by a rank of 1, where 1 represents the highest priority. A compound mean value was obtained by taking the mean of all ranks for each parameter within each micro watershed [59]. The most urgent intervention was suggested by a low compound mean value, whereas generally stable watershed conditions were indicated by a high value, indicating a lower priority [60,61].

1. Soil erosion risk:

Communities, agriculture, and the environment are all seriously threatened by soil erosion. They have a direct impact on erosion processes, so certain geomorphometric units, including bifurcation ratio, drainage density, stream frequency, and drainage texture, were carefully selected to measure crucial areas prone to soil erosion [11,62,63]. Additionally, the inverse link between geomorphometric units such as compactness coefficient, form factor, circularity ratio, and elongation ratio with erosion was investigated [64,65], allowing for a thorough identification of places within the watershed that are vulnerable [66]. The units that directly contribute to erosion were given the highest priority with the highest value, while those that have an inverse effect were given the highest priority with the lowest value by using the method of ranking and prioritization. It was also underlined that the study area's weathering pattern, which is wholly governed by geochemistry, determines the risk of soil erosion. The region has a high saturation zone of silica that is resistant to erosion and weathering. Conversely, most of the minerals are feldspathic and micaceous, which are very susceptible to erosion and chemical weathering, altering the morphology of the land.

2. Groundwater Recharge Potential:

During periods of intense rainfall, surface water runoff can be minimized via effective recharge of groundwater. This is especially important in watersheds that are prone to erosion. Recharge zones might be prioritized to reduce the likelihood of surface runoff. A variety of carefully selected geomorphometric techniques were used to quantify key locations for groundwater recharge. The highest priority with the highest value was given to geomorphometric units having a direct and significant impact on groundwater recharge, including shape factor, compactness coefficient, length of overland flow, and constant of channel maintenance [47,67,68]. Conversely, because of their inversely proportional relationship with groundwater recharge, units like stream frequency, drainage density, drainage texture, form factor, elongation ratio, relief ratio, ruggedness index, circularity ratio, and basin relief were given the highest priority with the lowest value [46,68,69]. This ensured a precise identification of key zones that are essential for the sustainable management of water resources.

3. Hydro geomorphological risk:

Understanding the natural flow of water within a watershed is aided by hydrogeomorphology. By examining hydrogeomorphological features—including rivers, valley fills, pediments, denudational hills, residual hills, and lateritic upland—researchers can determine how water flows through the landscape. The study found that the landscape is shaped by certain elements such as rivers, ponds, residual hills, dissected hills, and valleys, peneplain surfaces, valley fills, pediments, and denudational hills. Certain aspects were carefully evaluated to calculate the hydrogeomorphological risk associated with important watersheds. Features exhibiting possible groundwater vulnerability, such as dissected hills, Inselbergs, and residual hills [39,70,71], were given top priority based on the feature's highest area percentage, indicating a pressing need for conservation activities. Conversely, areas with lower risk, such as valley fills, point bars, and pediments [72–75], were given the highest priority with the lowest area percentage, which made it possible to strategically allocate resources and implement interventions with the watershed's degree of hydro geomorphological vulnerability.

4. Lithological risk:

The hydrological behavior, soil fertility, and susceptibility to erosion of a watershed are significantly influenced by the types and composition of rocks and soil included within it. Watershed managers can learn a great deal about locations that are vulnerable to erosion and water contamination, among other issues, by analyzing lithological data. A variety of lithological units were identified to estimate lithological risk within the study area, with granite gneiss appearing as the major unit. Other noteworthy units were quartz vein, amphibolite, mica schist, biotite gneiss, granulite, pegmatite, silica vein, calc gneiss, and meta ultrabasite. Mica schist, and biotite gneiss were given the highest priority with the lowest area percentage because they have moderate to high permeability. These rocks frequently include natural fissures, and mica is a common mineral present in both biotite gneiss and mica schist. Rain and surface water can seep into the earth through these rocks. Conversely, the highest priority with the highest value was given to pegmatite, granulite, granite gneiss, amphibolite, and hornblende. The permeability of these rock types is frequently moderate to low. Rocks like amphibolite and meta ultrabasite typically have little space for storing water because of their density and compactness.

5. Land Use and Land Cover:

Watershed managers can locate deforested areas, agricultural stretches, marshes, and natural habitats within the watershed by looking at land use and land cover (LULC) patterns. The general health of ecosystems and water supplies is specifically impacted by each form of land use. Water quality is threatened by deforested areas because they are prone to erosion. With the use of classified satellite photos showing the land use and land cover (LULC) of sub-watersheds, watershed prioritization was carefully carried out. Priorities were assigned by the proportion of land occupied by various use land-use groups. Considering their extensive covering, the highest attention was given to agricultural fallow areas, plantations, cultivated fields, shrub regions, settlements, lateritic uplands, and barren lands. These places were considered essential because of their direct influence on human activity and changes to ecology [12,76]. Conversely, the water bodies, river courses, and forests received the highest priority, despite having the lowest area proportion, recognizing their critical significance in preserving the natural habitats and ecological balance within the watershed.

3.2.3. Methodology to Develop Watershed Prioritization Approach Considering Various Risk Parameters

Following the quantification of the risk characteristics, the Order of Preference by Similarity to the Ideal Solution (TOPSIS) method was linked with an Analytical Hierarchy Process (AHP)-based weighted approach to prioritize the sub-watershed [77]. Using the AHP technique, which was presented by Harker (1987), the assignment of weights to various risk parameters was calculated by combining field expertise, study of the literature from credible journals, and expert opinion on the relevant subject [78]. The Euclidean variance between the negative and positive ideal solutions for decision-making alternatives was then evaluated using the TOPSIS approach [79]. Considering both the positive and negative ideal solutions allowed for the determination of the alternatives' proximity coefficient to the ideal solution, enabling a comprehensive assessment of their relative effectiveness and shortcomings. The order of importance was determined by how close the problem was to the perfect solution.

1. AHP methodology

The AHP technique places a strong emphasis on creating judgment matrices [80,81]. Using Saaty's 1–9 scale, this stage permits the thematic layers to be assigned weights based on their relative relevance. The fundamental steps to determine the weights and consistency of the indicators are outlined below:

Step 1. Setting up the judgment matrices (p) by utilizing Equation (1) to create the pairwise comparison matrix.

$$\mathrm{P} = \begin{bmatrix} \mathrm{P11} & \mathrm{P12} & \ldots & \mathrm{P1n} \\ \mathrm{P21} & \mathrm{P22} & \ldots & \mathrm{P2n} \\ \vdots & \ddots & \ddots & \vdots \\ \mathrm{P1n} & \mathrm{P2n} & \ldots & \mathrm{Pnn} \end{bmatrix} \quad (1)$$

where P_{nn} denotes the element that corresponds to while P_n shows the nth indicator element.

Step 2. Using Equation (2), the Normalized Weights were ascertained.

$$\mathrm{Wn} = \left(\mathrm{GMn} / \sum_{n=1}^{Nf} \mathrm{GMn}\right) \quad (2)$$

where GMn stands for arithmetic means for the nth row in the pair-wise matrix and Wn stands for normalized weights.

Additionally, Equation (3) was used to calculate the GM of the *i*th row in the judgment matrices.

$$\mathrm{GMn} = \sqrt[\mathrm{Nf}]{\mathrm{P1n} \ldots \mathrm{PnNf}} \quad (3)$$

Step 3. Using Equation (4), a consistency ratio (CR) was calculated to validate the consistency of the judgments. The most crucial requirement is that the CR value must be 0.10 or below to be approved.

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \quad (4)$$

where RI stands for the random inconsistency index and CI stands for the consistency index. Table 3 displays the RI scale.

Table 3. Random Inconsistency Index (RI) based on Saaty, (1984, 2008).

n	1	2	3	4	5	6	7	8	9	10	11	12	13
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.53	1.56

Source: Adopted from Saaty [80,81].

Step 4. Equation (5) was used to construct the Consistency Index (CI).

$$CI = \left(\frac{\lambda max \ - \ Nf}{Nf \ - 1} \right) \tag{5}$$

In this case, Equation (6) was utilized to calculate λmax, the judgement matrix's Eigen value.

$$\lambda max = \sum\nolimits_{n-1}^{Nf} \frac{(PW)n}{NfWn} \tag{6}$$

where the weight vector (column) is denoted by W.

2. TOPSIS methodology

This approach is based on the fundamental idea that the best course of action should differ significantly from the worst course of action and should approximate the most favorable solution [82]. The optimal answer is given the first rank, whereas the poorest option is close to a rank of zero [83,84]. For the preferred alternative, a higher coefficient of closeness is generally preferable. The following explanation can be given for this method of ranking options:

Step 1. Equation (7) was utilized in the construction of the normalized decision matrix.

$$R = (r_{ij})_{m \times n} = \begin{array}{c} \\ L_1 \\ L_2 \\ \vdots \\ L_m \end{array} \begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} X_{11} & X_{12}\ldots & X_{1n} \\ X_{21} & X_{22}\ldots & X_{2n} \\ \vdots & \vdots & \vdots \\ X_{m1} & X_{m2}\ldots & X_{mn} \end{bmatrix} \end{array} \tag{7}$$

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a^2 ij}}$$

where m stands for the number of micro watersheds, j for the alternative index, and i for the criterion index (i = 1,. . .,m). For the purpose of prioritization, the micro watersheds were designated as L_1, L_2,. . .,L_m and the criterion as C_1, C_2,. . .,C_n. In relation to alternative j, the matrix members indicated the values of criterion i.

Step 2. Equation (8) was utilized to ascertain the Weighted Normalized Decision Matrix.

$$V_{ij} = \ R_{ij} \times \ W_j \tag{8}$$

where V_{ij} stands for the weighted normalized matrix's elements, R_{ij} for the normalized matrix's elements, and W_j for the weight related to criteria j and AHP was used to determine these weights.

Step 3. Equations (9) and (10) were used to identify the positive (C_J^+) and negative (C_J^-) ideal solutions.

$$\left(C_J^+\right) = \underset{1 \le i \le m}{min}\{V_{ij}\} \tag{9}$$

$$\left(C_J^-\right) = \underset{1 \le i \le m}{min}\{V_{ij}\} \tag{10}$$

Step 4. Using Equations (11) and (12) to calculate the differences between each alternative and the positive and negative ideal solutions.

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_i^+ - v_{ij}\right)^2},\ i = 1, 2, \ldots, m \tag{11}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_i^- - v_{ij}\right)^2},\ i = 1, 2, \ldots, m \tag{12}$$

Step 5. Using Equation (13) to get the relative proximity to the ideal solution (Cl_+^i)

$$\left(Cl_+^i\right) = \frac{S_i^-}{S_i^+ + S_i^-} \tag{13}$$

4. Analysis and Results

4.1. Estimation of Morphometric Parameters

Comprehensive data on the linear, areal, and relief parameters of the five micro watersheds was provided by this study and is shown in Table 4. The Bandu River is notable for being classified as a third-order stream. The average bifurcation ratio in the Bandu sub-watershed is 15.4, indicating a range of high to moderate surface runoff and steep to mild ground slopes. The 2A2B5m micro watershed shows the lowest total number of streams, covering 12.5% of the whole area, while the 2A2B5k sub watershed has the highest total number of stream orders, covering 75 square kilometers, or 35% of the total area. The infiltration number varied significantly throughout the examined watershed, ranging from 0.20 (2A2B5h) to 1.81 (2A2B5j). To be more precise, micro watershed 2A2B5k has the most first-order streams, while micro watershed 2A2B5m has the fewest, showing different patterns of drainage. The study area's drainage density revealed an impermeable surface in 2A2B5, with high relief (616 m) and scant vegetation [47]. The micro watershed 2A2B5m displays the lowest form factor value ($\leq$0.36), indicating a longer duration of a flatter peak flow [56]. The drainage network is in the youthful to mature stage of development, according to the circularity ratios, which vary from 0.31 to 0.49 across all micro watersheds [53]. In the study area, the stream frequency values ranged from 0.52 to 1.85, indicating moderate to high surface runoff [56,69]. It is interesting to note that, indicating different levels of terrain ruggedness, micro watershed 2A2B5m showed the highest ruggedness. number and micro watershed 2A2B5b is the lowest. Furthermore, the study area's relief ratio values, which varied from 17.42 to 69.83, showed the presence of high relief features and steep slopes. The elongation ratios were found to range from 0.33 to 1.26, where 2A2B5m showed the lowest ratio and 2A2B5h the highest. Within the study area, the dissection index varied between 0.50 and 0.62. The sub-watershed 2A2B5b is noteworthy for having the highest recorded constant of channel maintenance. Different geomorphometric units were mapped using ArcGIS 10.8 software (Figures 2 and 3).

Table 4. Linear, aerial, and relief aspects of morphometric parameters.

Geomorphometric Units	2A2B5k	2A2B5b	2A2B5j	2A2B5h	2A2B5m
Total no. of stream order	54	33	41	23	15
Number of stream order 1	50	31	39	22	13
Number of stream order 2	2	2	2	1	1
Number of stream order 3	2	0	0	0	1
Length of stream order 1 in mt.	35,769.50	14,315.60	17,938.00	14,599.50	13,086.50
Length of stream order 2 in mt.	13,547.20	2246.41	3630.78	2469.55	7256.89
Length of stream order 3 in mt.	1274.57	0	0	0	455.61
Total length of streams in mt.	50,591.42	16,562.0	21,568.81	17,069.1	20,799.09

Table 4. *Cont.*

Geomorphometric Units	2A2B5k	2A2B5b	2A2B5j	2A2B5h	2A2B5m
Stream length ratio	13.27	6.37	4.94	5.91	17.73
Bifurcation ratio	13	15.50	19.50	22	7
Area in square-km	75.85	43.47	22.09	43.68	27.31
Perimeter in km	44.83	38.42	23.94	41.82	26.92
Fineness ratio	0.29	0.16	0.20	0.14	0.65
Form factor	0.43	1.07	0.90	1.24	0.08
Shape Factor Ratio	2.32	0.93	1.10	0.80	11.51
Drainage Texture	1.20	0.85	1.71	0.54	0.55
Compactness Coefficient	1.45	1.64	1.44	1.79	1.48
Circularity ratio	0.48	0.37	0.49	0.31	0.47
Elongation ratio	0.74	1.16	1.07	1.26	0.33
Drainage density in km/km^2	0.66	0.38	0.97	0.39	1.85
Stream frequency	0.71	0.75	1.85	0.52	0.54
Constant of channel maintenance	1.49	2.62	1.02	2.55	0.53
Infiltration Number	0.47	0.28	1.81	0.20	1.01
Drainage Intensity	1.06	1.9	1.90	1.34	0.29
Average Length of Overland Flow (km)	0.74	1.31	0.51	1.27	0.26
Total Basin Relief (H) m	336	342	345	372	309
Relief Ratio	25.32	53.66	69.83	62.92	17.42
Relative Relief Ratio	7.49	8.90	14.41	8.89	11.47
Ruggedness Number	0.22	0.13	0.33	0.14	0.57
Height of Basin outlet (m)	270	240	233	219	307
Maximum Height of basin (m)	606	582	578	591	616
Dissection index	0.55	0.58	0.59	0.62	0.50

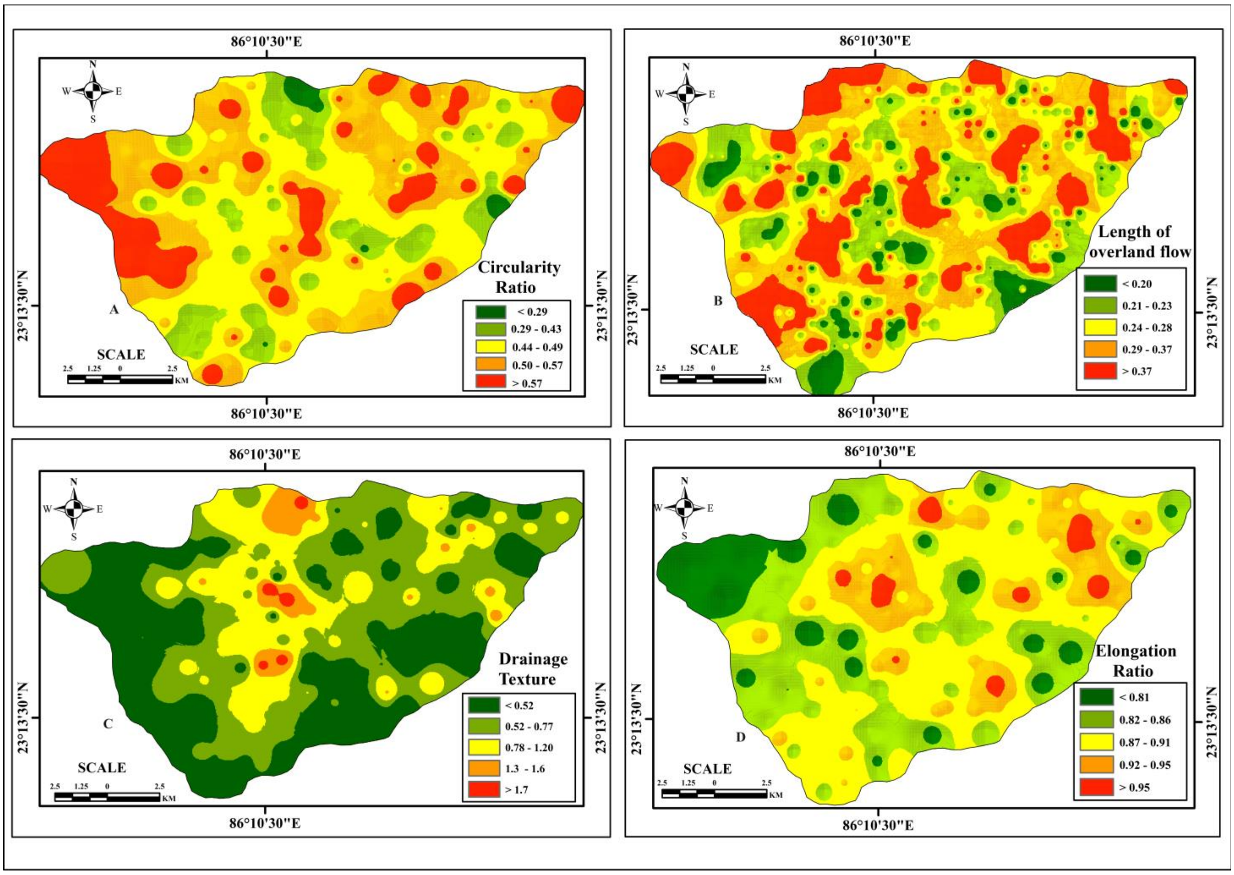


Figure 2. Maps of Geomorphometric units: (**A**) circularity ratio, (**B**) length of overland flow, (**C**) drainage texture, (**D**) elongation ratio.

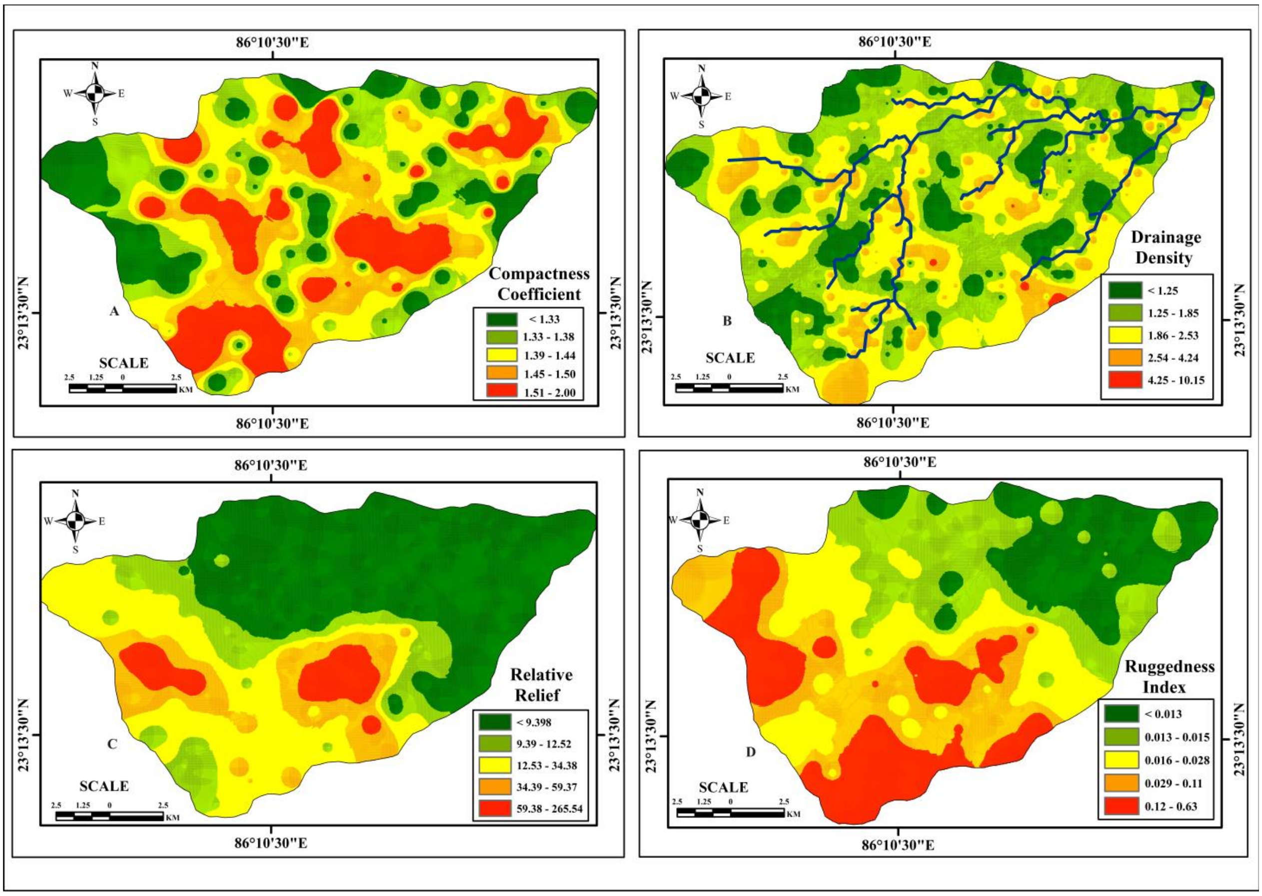


Figure 3. Maps of geomorphometric units, (**A**) compactness coefficient, (**B**) drainage density, (**C**) relative relief, (**D**) raggedness index.

4.2. Compound Scores of Individual Micro Watersheds and Prioritization

As Tables 5–9 (Supplementary Tables S1–S8) shows, the Bandu sub watershed of the study area's micro watersheds underwent a thorough ranking and prioritization procedure. As a result of this prioritization process, which was based on compound scores, the micro watersheds were divided into three different priority categories. Although 2A2B5k obtained the lowest priority concerning land use land cover, it was given the greatest priority in this study because of its higher sensitivity to erosion, ground water deficiencies, and large lithological risk. Conversely, due to ground water shortages and the substantial ecological effects of land use and land cover, 2A2B5b was given top attention. In terms of lithological risk, erosion, and hydro-geomorphological influence, it received minimal priority. A different watershed, 2A2B5j, received top priority because of its significant hydrological, land use, land cover, and increased erosion. It prioritizes lithological risk at a medium level and ground water surplus at a lower level. In contrast, 2A2B5h received the lowest priority for erosion and the greatest priority for lithological risk, a medium priority for hydrogeomorphology, ground water recharge, and land use/cover. In addition, 2A2B5m received a medium priority in terms of lithological risk, ground water recharge, and erosion. This was because of the reduced significance of hydrogeomorphology and land use/cover. Figures 4 and 5 exhibit a thematic map of land use, land cover, lithology, and hydrogeomorphology that illustrates the relative importance of each micro watershed with respect to particular risk parameters.

Table 5. Micro watershed wise soil erosion risk prioritization based on compound scores (CS).

Micro Watersheds	Br	Dd	Sf	Dt	Lof	Tsl	CCm	Ff	Cr	Er	CS	Priority
2A2B5k	4	3	3	2	3	1	1	2	4	2	2.5	high
2A2B5b	3	5	2	3	1	5	4	4	2	4	3.3	moderate
2A2B5j	2	2	1	1	4	2	2	3	5	3	2.5	high
2A2B5h	1	4	5	5	2	4	3	5	1	5	3.5	low
2A2B5m	5	1	4	4	5	3	2	1	3	1	2.9	high

Br: bifurcation ratio, Dd: drainage density, Sf: stream frequency, Dt: drainage texture, Lof: length of overland flow, Tsl: total stream length, CCm: constant of channel maintenance, Ff: form factor, Cr: circularity ratio, Er: elongation ratio.

Table 6. Micro watershed wise ground water recharge risk prioritization based on compound scores (CS).

Micro Watersheds	Lof	CC	Sf	CCm	Dd	Dt	Br	Ff	Er	Cr	Rr	CS	Priority
2A2B5k	3	3	3	3	3	4	2	2	2	4	2	2.77	high
2A2B5b	1	2	2	1	1	3	3	4	4	2	3	2.31	high
2A2B5j	4	4	1	4	4	5	4	3	3	5	5	3.85	low
2A2B5h	2	1	5	2	2	1	5	5	5	1	4	3.08	moderate
2A2B5m	5	5	4	5	5	2	1	1	1	3	1	3	moderate

Lof: length of overland flow, CC: compactness coefficient, Sf: stream frequency, CCm: constant of channel maintenance, Dd: drainage density, Dt: drainage texture, Br: bifurcation ratio, Ff: form factor, Cr: Circularity ratio, Er: elongation ratio, Rr: relief ratio.

Table 7. Micro watershed wise hydro geomorphological risk prioritization based on compound scores (CS).

Micro Watersheds	I	Pt	Pn	Pb	Rh	MDh	Vf	W	P	R	HDh	CS	Priority
2A2B5k	2	4	1	1	2	2	2	1	-	-	-	1.87	high
2A2B5b	-	2	4	4	-	3	3	4	-	-	-	3.17	low
2A2B5j	-	1	2	2	3	4	1	2	1	1	-	1.78	high
2A2B5h	-	3	3	3	4	5	4	3	2	2	2	3	moderate
2A2B5m	1	5	5	5	1	1	5	5	3	3	1	3.18	low

I: inselberg, Pt: pediment, Pn: pediplain, Pb: point bar, Rh: residual hill, MDh: moderately dissected hills, Vf: valley fills, W: waterbody, P: pond, R: river, HDh: highly dissected hills.

Table 8. Micro watershed wise lithological risk prioritization based on compound scores (CS).

Micro Watersheds	BG	GG	HS, A, MU	P	MS	CG, G	Gss	CS	Priority
2A2B5k	2	1	1	2	-	-	-	1.5	high
2A2B5b	-	3	5	-	3	-	-	3.67	low
2A2B5j	-	5	4	1	1	2	-	2.6	moderate
2A2B5h	-	2	3	-	2	1	1	1.8	high
2A2B5m	1	4	2	-	-	-	-	2.33	moderate

BG: biotite gneiss, GG: granite gneiss, HS: hornblende schist, A: amphibolite, MU: meta ultrabasite, P: pegmatite, MS: mica schist, CG: calc gneiss, G: granulite, Gss: graphite silimate schist.

Table 9. Micro watershed wise land use land cover prioritization based on compound scores (CS).

Micro Watersheds	Ag	S	W	Lu	Sh	Pl	AgF	R	Df	Bl	CS	Priority
2A2B5k	4	5	3	2	4	4	4	2	4	2	3.4	low
2A2B5b	1	1	1	5	3	2	1	4	1	5	2.4	high
2A2B5j	2	2	4	3	2	3	2	3	2	1	2.4	high
2A2B5h	3	3	5	4	1	1	3	5	3	4	3.2	moderate
2A2B5m	5	4	2	1	5	5	5	1	5	3	3.6	low

Ag: agricultural land, S: settlement, W: waterbody, Lu: lateritic upland, Sh: shrubs, Pl: plantation, AgF: agricultural fallow, R: river, Df: dense forest, Bl: barren land.

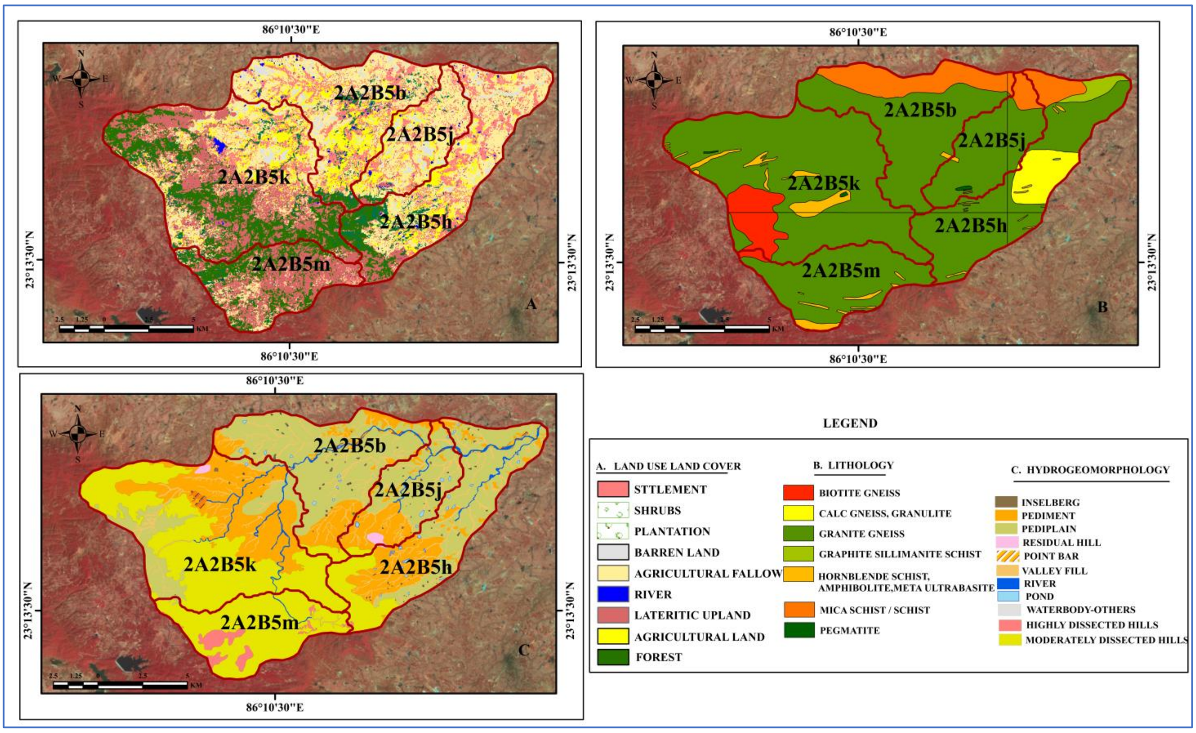


Figure 4. Maps of watershed prioritization conditioning parameters.

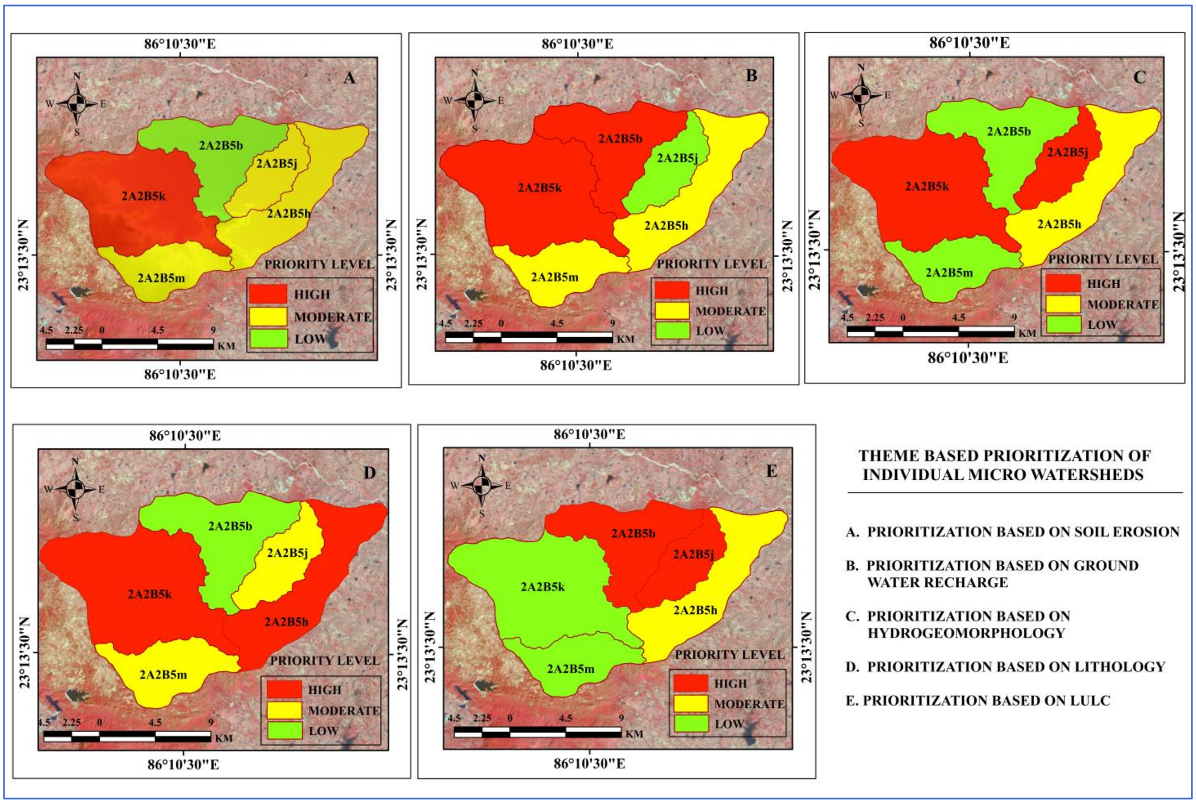


Figure 5. Risk based/theme-based prioritization of micro watersheds.

4.3. Final Prioritization Based on AHP-TOPSIS Model

The weights allocated to each criterion were determined by creating a pairwise comparison matrix of the criteria using the AHP approach [85,86]. As shown in Table 10, the most important criteria were hydrogeomorphology, land use and cover, soil erosion, and groundwater recharge, and all of them received the highest weights. Lithology, conversely, was deemed to be the least important criterion. For the pairwise comparisons, Saaty's scale, which ranges from 1 to 9, was used to indicate the relative weight of each criterion. Equation (4) was used to calculate the consistency ratio (CR) value of 0.00422 (Supplementary Table S9), which denotes the acceptability of the subjective judgment values [82]. This proved uniformity among all pairwise comparison matrices, confirming the validity of the assessment procedure. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method was used to determine the final prioritizing to accomplish the suggested objectives, as shown in Table 11 (Supplementary Tables S10 and S11). After the TOPSIS methodology was applied, the micro watersheds 2A2B5k were found to be the best options based on how close they were to the ideal solution (Figure 6).

Table 10. The criteria relative weights W_j.

Criteria	Soil Erosion	Ground Water Recharge	LULC	Hydro Geomorphology	Lithology	Geometric Mean	Relative Weights
Soil Erosion	1	1.28	1.28	1.8	3	1.54	0.29
Ground Water Recharge	0.77	1	1	1.4	2.33	1.20	0.22
LULC	0.77	1	1	1.4	2.33	1.20	0.22
Hydro Geomorphology	0.55	0.71	0.71	1	1.66	0.86	0.16
Lithology	0.33	0.42	0.42	0.6	1	0.51	0.09

Table 11. The ranking of alternatives.

Micro Watersheds	S_i^+	S_i^-	Cl_+^i	Final Rank	Final Prioritization
2A2B5k	0.0184	0.0030	0.1382	1	high
2A2B5b	0.0078	0.0174	0.6902	5	low
2A2B5j	0.0120	0.0107	0.4698	3	moderate
2A2B5h	0.0138	0.0097	0.4126	2	moderate
2A2B5m	0.0110	0.0098	0.4713	4	moderate

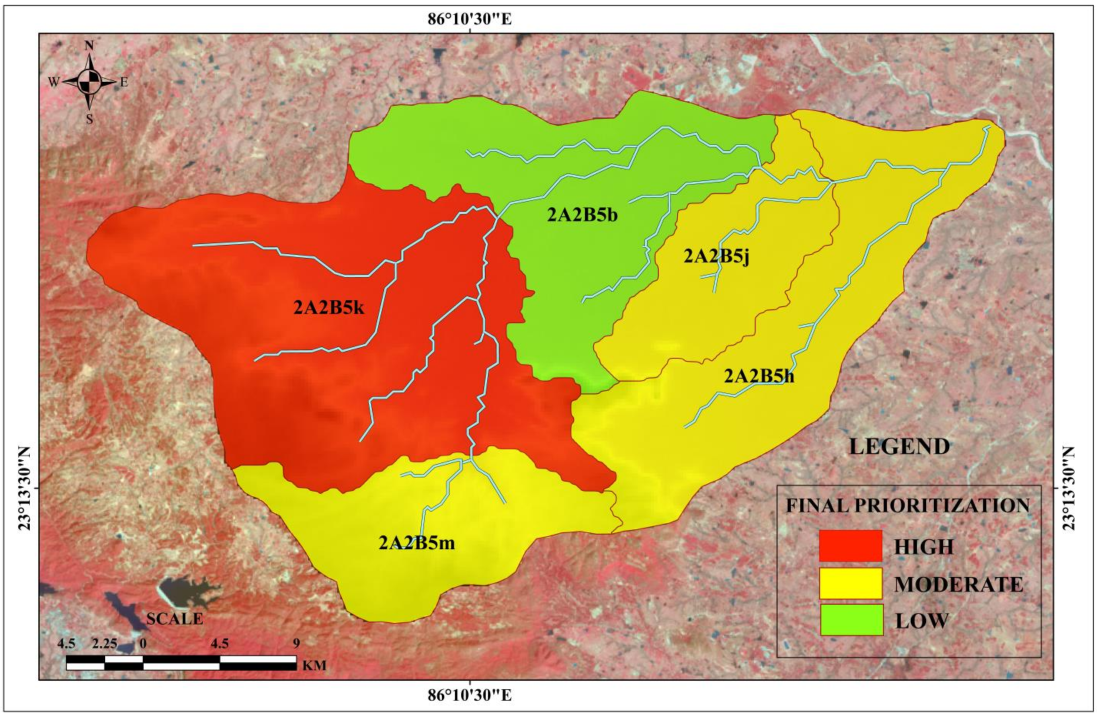


Figure 6. Final map of watershed prioritization.

5. Model Validation

5.1. Interpreting Geological Data with Reference to Field

To establish the lithological control on Groundwater potentiality, the foliated nature of the rocks was taken into consideration (foliation planes are made up of micaceous minerals, which are flaky and generate weak zones in rocks for water percolation). The gneissic rocks present in the area recorded alternate banding of Quartzo-feldspathic mass (less foliated) and micaceous (biotite enriched) band, which were more foliated. Therefore, the permeable character of the rock is potential enough to hold the water. However, mica schists are highly foliated and are prone to weathering and erosion and mostly occur in the valley regions with legible occurrences of rock outcrops. Therefore, even if there is water, it is most likely to occur in ponds and dug wells in the low contoured region. Other metamorphites, like granulites are almost devoid of foliation planes and completely unsuitable to hold ground water and these areas cannot be treated under watersheds.

5.1.1. Angular Unconformity Exposure

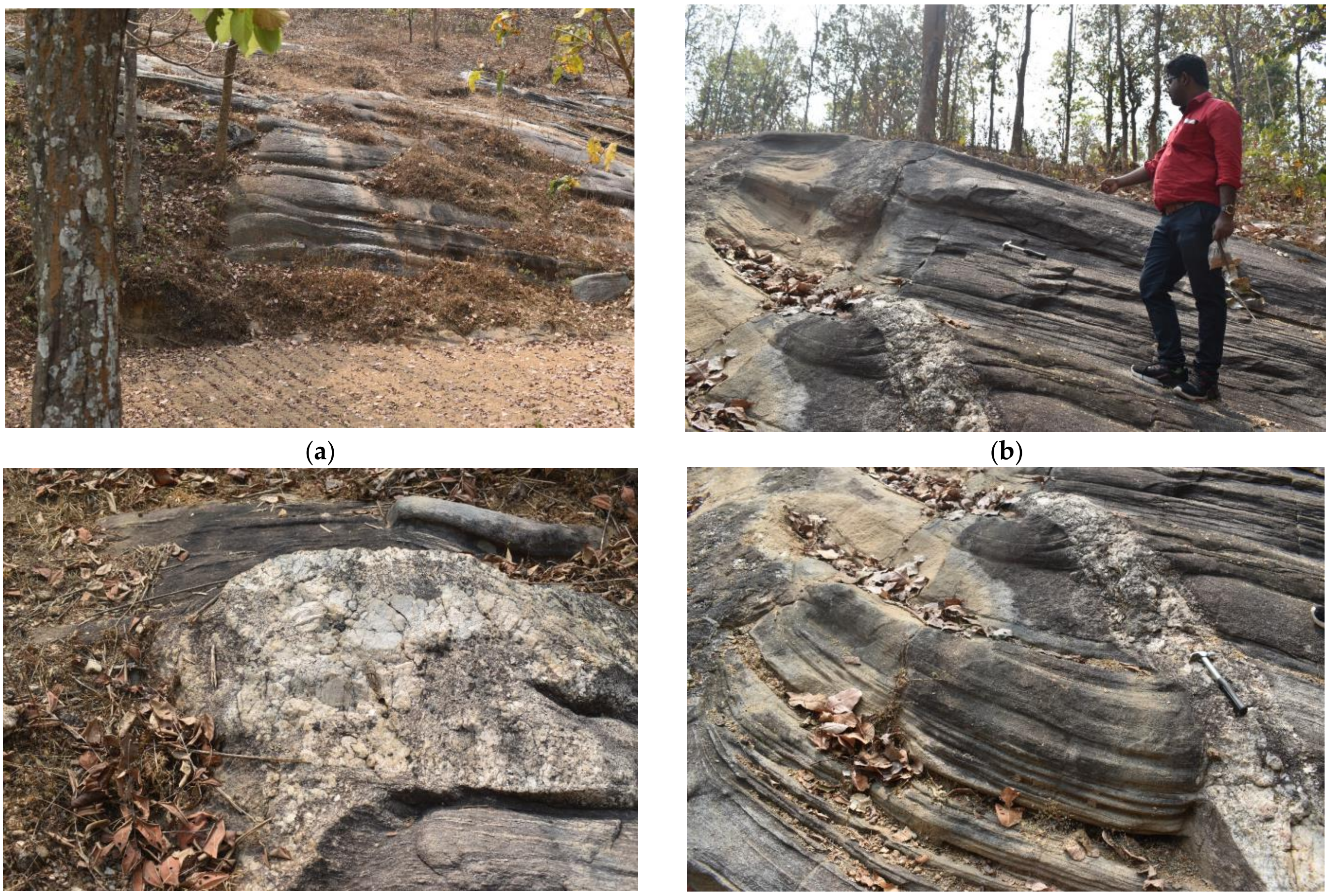
In Ayodhya hill, (latitude 23°14′26.39″, longitude 86°9′56″) a typical outcrop of angular unconformity was identified (Figure 7), indicating a significant interruption in the geological deposition and subsequent erosion before the younger rocks were deposited. The contact between the older and younger rocks exhibits a noticeable angle or discordance. Here, the older rock granitic gneiss complex with horizontal bedding surface whereas younger rock is folded, features of reclined fold is observed within phyllitic rock, where foliation plane is almost vertical, and the strike direction is north-east to south-west. These geological features were observed in 2A2B5k micro watershed, provide valuable insights into the history of the region, including tectonic events, deformation processes, and the relationship between different rock units.

(**a**) (**b**) (**c**) (**d**)

Figure 7. (**a**) Angular unconformity is observed; (**b**) hammer also acts as a scale; (**c**) fold pattern is developed in gneissic rock; (**d**) foliation plane present in phyllites.

5.1.2. East-West Aligned Granitic Gneiss Mass

Huge exposure of east–west trending of granitic gneiss body with an extension of around 500 m in length and around 20 m in width was observed (Figure 8) in 2A2B5k micro watershed (latitude 23°12′52″, longitude 86°8′52″) with the outcrop records three different features: (a) usual gneissic character, which is a high-grade metamorphic rock formed from the recrystallization of granite or other igneous rocks (gneissic rocks typically exhibit banded or foliated texture due to the alignment of mineral grains during metamorphism); (b) enrichment of biotite in significant amounts resulting in the formation of biotite gneiss, which is a dark-colored mica mineral (the presence of biotite gives the rock a banded appearance with altering light and dark layers); (c) differential weathering forming ribbed character of the exposure. Apart from this a separate event of cross-cutting silica vein intrusion in the formation of lentoid structure.

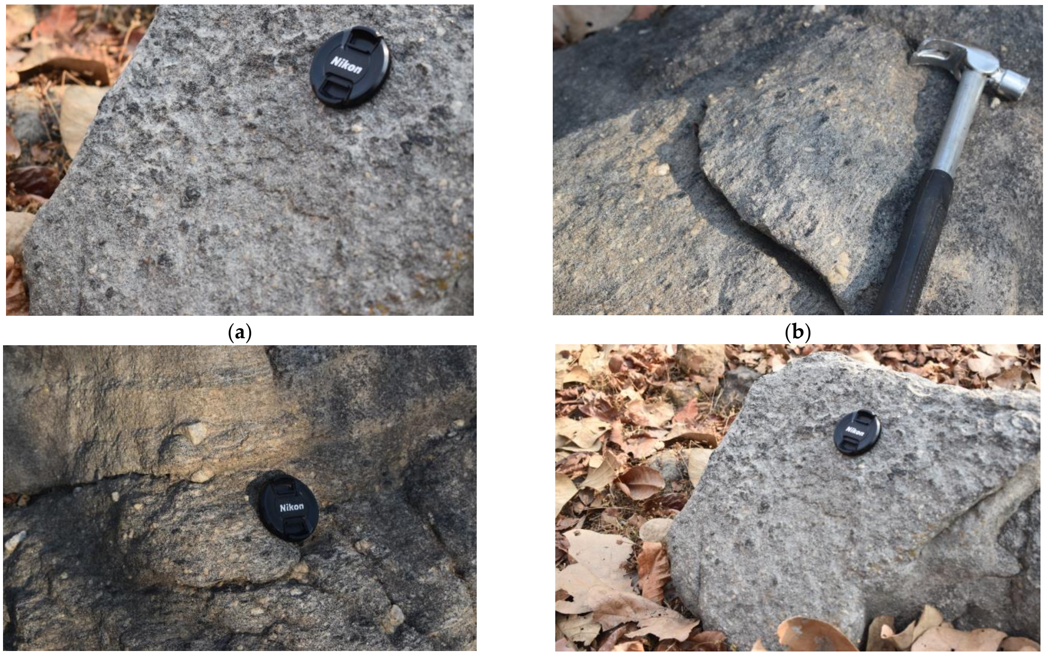


(**a**) (**b**) (**c**) (**d**)

Figure 8. (**a**) East–west trading granitic gneiss is observed; (**b**) a large-scale silica lense is produced; (**c**) a separate event of cross cutting silica vein within the gneissic body; (**d**) hammer also acts as a scale.

5.1.3. Isolated Ledge of Gneissic Rock

An isolated outcrop of gneissic rock (latitude 23°13′46″, longitude 86°6′53″) was found (Figure 9) in 2A2B5K micro watershed with evidence of injection of metamorphic fluid which had resulted in the production of high-grade metamorphic mineral like staurolite, being arranged in the form of mineral lineation. High-grade metamorphism involves significant heat and pressure, leading to the formation of minerals with specific stability and characteristics. Evidence of metasomatic fluid invasion with earlier dissolved minerals is documented.



(**a**) (**b**) (**c**) (**d**)

Figure 9. (**a**–**d**) Isolated outcrop of gneissic rock is observed and hammer acts as a scale.

5.1.4. Large Scale Silicification Accompanied by Brecciation

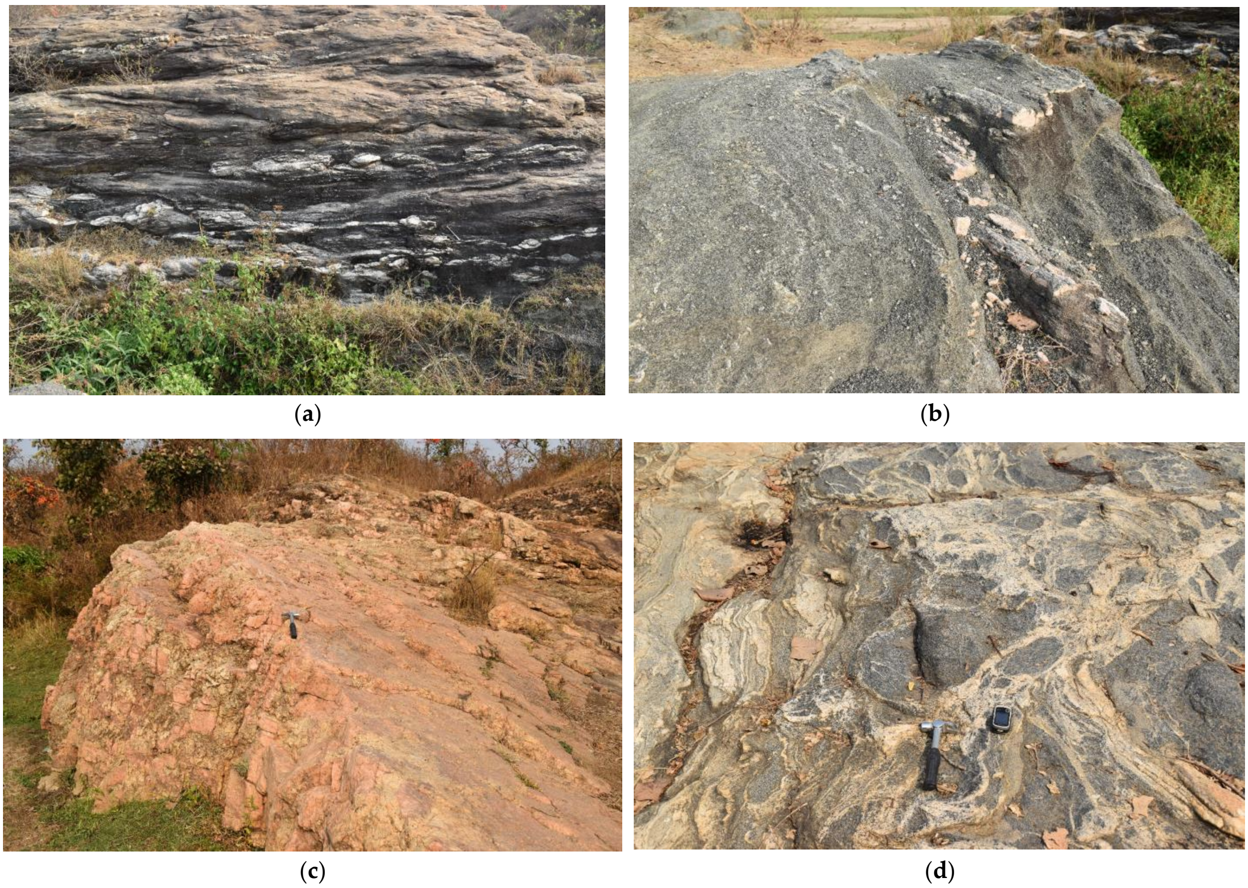
In the 2A2B5m micro watershed, an east–west trending granite bodies (latitude 23°14′22″, longitude 86°6′51″) are continuously exposed. To proceed further north, evidence of migmatisation was again documented, but here the production of melanosome is typically identified (Figure 10). Another important feature noticed was the presence of large-scale silicification along with brecciation, following the same east–west trend, suggesting dissected bands of tectonic lineaments. In the context of groundwater, silicification can affect the permeability of rocks, while the brecciation process can enhance groundwater circulation by providing pathways for water to move through the fractured rock, affecting the groundwater's flow and storage characteristics. In summary, silicification can reduce permeability, while brecciation can increase it by creating fractures. Both processes play significant roles in shaping the movement and storage of groundwater in geological formations.

(**a**) (**b**)

Figure 10. (**a**) The production of Leucosome during Migmatisation; (**b**) presence of large scale silicification along with brecciation.

5.1.5. Principal Rock Types and Lithological Imprints

In the Bandu Nala section (latitude 23°18′5.23″, longitude 86°11′48″), within the 2A2B5b micro watershed, four conspicuous geological observations are made (Figure 11). These are (a) the existence of granitic gneiss; (b) the existence of amphibolite rock, which is a metamorphic rock composed primarily of amphibolite minerals, which are typically dark-colored and can include minerals like hornblende, and actinolite; (c) the existence of north west–south east trending quartz-feldspathic rock bands, which are occasionally rich in orthoclase feldspar along with muscovite giving it a pegmatite look (pegmatites are coarse-grained igneous rocks with large crystals); and (d) the most important aspect of these areas is the presence of Migmatite within the quartz–feldspathic rock bands. The lenses of amphibolite exist as paleosomes, indicating an older geological zone, and the quartz feldspar bands are termed as neosomes, suggesting the newly formed unit within the migmatite. In such a setting, the quartz and feldspathic bands could create pathways for water to infiltrate into the ground. Quartz is generally impermeable, while feldspar-rich bands may have more permeable zones, this heterogeneity in permeability can influence the movement of water. It is interesting to note that the veins of quartz–feldspathic rock bands are passing through the amphibolite are depicting anastomosing pattern. Anastomosing refers to a branching or interconnected pattern, often observed in geological features such as veins or river channels. When quartz and feldspar rich material passes through amphibolite, it can contribute to the creation of fractures and porosity within the rock, this enhanced porosity allows increased water infiltration and storage, potentiality facilitating ground water recharge.



(**a**) (**b**) (**c**) (**d**)

Figure 11. (**a**) The existence of Granitic Gneiss; (**b**) the existence of Amphibolite rock; (**c**) the existence of north west–south east trending Quartz-Feldspathic rock bands; (**d**) anastomosing pattern is typically identified within the migmatites, look for the black area, which is melanosome. The light colored part is Leucosome, Neosome not evident in the photo.

5.2. Interpreting a Report of CGWB

A report titled "Aquifer Mapping and Management of Ground Water Resources" was published by the Central Ground Water Board (CGWB), which is part of the Government of India's Ministry of Jal Shakti. Understanding ground water nature, aquifer geometry, dispositions, characteristics, and resource management are the goals of the National Aquifer Mapping and Management Program (NAQUIM), which was started by CGWB in the XIIth plan [40]. The study presents chemical parameter ranges based on three observation wells, four exploration wells, and four National Health Services (NHS) for Arsha block, an administrative division within the Purulia Sadar subdivision of the Purulia district. It is evident from the data that there are higher than allowed levels of fluoride in "Sirkabad village" and "Jhunjka village". It was found that the fluoride concentration in both locations was 1.62 mg/L, which is more than the allowable limit. Jhunjka village is in 2A2B5h, and Sirkabad village is in 2A2B5K micro watershed. High fluoride levels are an indicator of the susceptibility of the study area.

6. Discussion

Figure 6 shows the study area's final prioritized map, which shows several micro watersheds and their relative priorities. The watersheds were categorized into three separate priority zones according to how close they were to the optimal solution (Cl^i_+).

1. High priority

It was determined that the 2A2B5k watershed faces shortages in groundwater supplies and is extremely vulnerable to severe erosion. The watershed has a variety of topographical differences and elevation patterns. Vegetation loss has resulted from altered water flow patterns caused by unstable lithology, tourism pressure, soil-water conservation-related initiatives, and anthropogenic activities. In the watershed, there is evidence of a transition from natural woods to cultivated areas, with dry river channels turning into degraded areas and forest sections turning into agricultural land. Likewise, immediate action is needed to conserve soil erosion to stop topsoil loss in the area under study.

2. Medium priority

The 2A2B5j, 2A2B5h, and 2A2B5m watersheds were categorized as medium priority due to very mild land degradation and anthropogenic activities. Moderate lithological hazards, moderate groundwater recharge, and moderate soil erosion are all present in these watersheds. The pediplain topography of these watersheds is characterized by moderate to low dissected residual hills; the region is primarily made up of grasslands with a few villages. Water bodies have been moderately impacted by human activity, and denudation processes are moderately active and have a moderate capacity for infiltration. Moreover, a low bifurcation ratio divides bedrock with moderate permeability.

3. Low priority

The 2A2B5b watershed was classified as a micro watershed with rolling plains and extremely low gradients under the low priority category. The watershed shows excess groundwater recharge and minimal susceptibility to erosion. In this watershed, the topsoil is protected from surface runoff and raindrop damage by vegetative cover, crop residue, and efficient management techniques. A change toward sustainable land use practices was demonstrated by the conversion of barren fields into grazing areas. This change benefits the region's agricultural livelihoods and encourages environmental rehabilitation.

7. Conclusions

The inhabitants of Purulia District in West Bengal, India, face a vicious cycle of environmental difficulties as a result of the intricate interactions between deforestation, water depletion, and land degradation [87,88]. An integrative approach to study is necessary because of the varying risks associated with each of these resources and the way of long run impact in which they are interconnected. Regarding land, water, and forest resources, compliance with the Sustainable Development Goals of the United Nations by 2030 is essential [89]. When evaluating groundwater recharge deficits and soil erosion, geomorphometric units are crucial. Because of its high sensitivity, the 2A2B5k watershed in the study area is prioritized for soil erosion risk, requiring extensive soil erosion control measures. The 2A2B5b watershed has the lowest priority, whereas the 2A2B5m, 2A2B5j, and 2A2B5h watersheds are of medium priority. The study area, which is well-known for its tourism appeal, is severely contaminated with fluoride, which has been worsened by monoculture agriculture practices. This emphasizes how important it is to identify locations that are susceptible to different environmental problems. Some ancient ways are still used in remote villages to fulfill their daily water demands. Ensuring water supply for irrigation and livestock watering demands requires the implementation of water harvesting facilities, such as farm ponds or storage tanks. The conversion of Ayodhya Hill into a dedicated vegetable growing center has the potential to revolutionize agricultural methods in the area. Additionally, for efficient runoff control and in situ moisture conservation, field bunding or land leveling techniques are essential. In order to address these complex challenges, specific management and development plans for each micro watershed are needed, with a focus on community involvement and stakeholder engagement in the implementation of sustainable solutions. To address environmental challenges in the Bandu watershed and promote sustainable growth while protecting the environment, a comprehensive plan for managing the watershed that integrates soil, water, and forest resource management is necessary. Future work could consider a comprehensive range of stakeholders in the decision-making process to enhance the utility and practical implications of this study.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16083467/s1, Table S1: Quantification of the risk of soil erosion, Table S2: Quantification of the Ground Water Recharge risk, Table S3: Quantification of the Hydro Geomorphological risk, Table S4: Percentage of the total area of the Hydro Geomorphological risk, Table S5: Quantification of the Lithological risk, Table S6: Percentage of the total area of the Lithological risk, Table S7: Quantification of the Land Use Land Cover risk, Table S8: percentage of the total area of the Land use Land Cover risk, Table S9: Assessing the consistency ratio (CR) for the various thematic risk parameters, Table S10: The Normalized Matrix, Table S11: The weighted Normalized Matrix.

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References

1. Tiwari, R.N.; Kushwaha, V.K. Watershed Prioritization Based on Morphometric Parameters and PCA Technique: A Case Study of Deonar River Sub Basin, Sidhi Area, Madhya Pradesh, India. *J. Geol. Soc. India* **2021**, *97*, 396–404. [CrossRef]
2. Agarwal, C.S. Study of Drainage Pattern through Aerial Data in Naugarh Area of Varanasi District, U.P. *J. Indian Soc. Remote Sens.* **1998**, *26*, 169–175. [CrossRef]
3. Choudhari, P.P.; Nigam, G.; Singh, S.; Thakur, S. Morphometric Based Prioritization of Watershed for Groundwater Potential of Mula River Basin, Maharashtra, India. *Geol. Ecol. Landsc.* **2018**, *2*, 1–12. [CrossRef]
4. Clarke, J.J. *Morphometry from Maps, Essays in Geomorphology*; Elsevier Publishing Company: New York, NY, USA, 1966; pp. 235–274, References—Scientific Research Publishing. Available online: https://www.scirp.org/(S(351jmbntvnsjt1aadkposzje))/reference/ReferencesPapers.aspx?ReferenceID=1152655 (accessed on 30 October 2023).
5. Singh, S.; Sing, M.C. Morphometric Analysis of Kanhar River Basin. *Natl. Geogr. J. India* **1997**, *43*, 31–43, References—Scientific Research Publishing. Available online: https://www.scirp.org/(S(lz5mqp453edsnp55rrgjct55.))/reference/referencespapers.aspx?referenceid=2029747 (accessed on 30 October 2023).
6. Pal, B.; Samanta, S.; Pal, D. Morphometric and Hydrological Analysis and Mapping for Watut Watershed Using Remote Sensing and GIS Techniques. *Int. J. Adv. Eng. Technol.* **2012**, *2*, 357–368.
7. Singh, R.; Bhatt, C.M.; Vajja, H.P. Morphological study of a watershed using remote sensing and GIS techniques. *Hydrol. J.* **2003**, *26*, 55–66.
8. Strahler, A.N. Quantitative Geomorphology of Drainage Basin and Channel Networks. In *Handbook of Applied Hydrology*; McGraw Hill: New York, NY, USA, 1964.
9. Wang, G.; Mang, S.; Cai, H.; Liu, S.; Zhang, Z.; Wang, L.; Innes, J.L. Integrated Watershed Management: Evolution, Development and Emerging Trends. *J. For. Res.* **2016**, *27*, 967–994. [CrossRef]
10. Heathcote, I.W. *Integrated Watershed Management: Principles and Practice*; John Wiley & Sons: Hoboken, NJ, USA, 1998.
11. Javed, A.; Khanday, M.Y.; Ahmed, R. Prioritization of Sub-Watersheds Based on Morphometric and Land Use Analysis Using Remote Sensing and GIS Techniques. *J. Indian Soc. Remote Sens.* **2009**, *37*, 261–274. [CrossRef]
12. Puno, G.R.; Puno, R.C.C. Watershed Conservation Prioritization Using Geomorphometric and Land Use-Land Cover Parameters. *Global J. Environ. Sci. Manag.* **2019**, *5*, 279–294. [CrossRef]
13. Roy, S.; Sahu, A.S. Effectiveness of Basin Morphometry, Remote Sensing, and Applied Geosciences on Groundwater Recharge Potential Mapping: A Comparative Study within a Small Watershed. *Front. Earth Sci.* **2016**, *10*, 274–291. [CrossRef]
14. Chauhan, P.; Chauniyal, D.; Singh, N.; Tiwari, R. Quantitative Geo-Morphometric and Land Cover-Based Micro-Watershed Prioritization in the Tons River Basin of the Lesser Himalaya. *Environ. Earth Sci.* **2016**, *75*, 498. [CrossRef]
15. Pandey, A.; Chowdary, V.; Mal, B. Identification of Critical Erosion Prone Areas in the Small Agricultural Watershed Using USLE, GIS and Remote Sensing. *Water Resour. Manag.* **2007**, *21*, 729–746. [CrossRef]
16. Bertalan-Balazs, B.; Bíró, T.; Dyke, G.; Singh, S.; Szabo, S. Extracting Water-Related Features Using Reflectance Data and Principal Component Analysis of Landsat Images. *Hydrol. Sci. J.* **2018**, *63*, 269–284. [CrossRef]
17. Colombo, R.; Vogt, J.V.; Soille, P.; Paracchini, M.L.; De Jager, A. Deriving River Networks and Catchments at the European Scale from Medium Resolution Digital Elevation Data. *Catena* **2007**, *70*, 296–305. [CrossRef]
18. Magesh, N.S.; Jitheshlal, K.V.; Chandrasekar, N.; Jini, K.V. Geographical Information System-Based Morphometric Analysis of Bharathapuzha River Basin, Kerala, India. *Appl. Water Sci.* **2013**, *3*, 467–477. [CrossRef]
19. Narsimlu, B.; Gosain, A.; Chahar, B.; Singh, S.; Srivastava, P. SWAT Model Calibration and Uncertainty Analysis for Streamflow Prediction in the Kunwari River Basin, India, Using Sequential Uncertainty Fitting. *Environ. Process* **2015**, *2*, 79–95. [CrossRef]
20. Palanisamy, A.; Padmalal, D. Sub-Watershed Prioritization Based on Drainage Morphometric Analysis: A Case Study of Cauvery River Basin in South India. *J. Geol. Soc. India* **2020**, *95*, 25–35. [CrossRef]
21. Paudel, D.; Thakur, J.K.; Singh, S.; Srivastava, P. Soil Characterization Based on Land Cover Heterogeneity over a Tropical Landscape: An Integrated Approach Using Earth Observation Data-Sets. *Geocarto Int.* **2014**, *30*, 1–24. [CrossRef]
22. Rai, P.; Mishra, V.; Mohan, K. A Study of Morphometric Evaluation of the Son Basin, India Using Geospatial Approach. *Remote Sens. Appl. Soc. Environ.* **2017**, *7*, 9–20. [CrossRef]
23. Brooks, K.; Ffolliott, P.; Magner, J. *Hydrology and the Management of Watersheds*, 4th ed.; John Wiley & Sons: Hoboken, NJ, USA, 2012; pp. 1–533. [CrossRef]
24. Fulazzaky, M.A. Challenges of Integrated Water Resources Management in Indonesia. *Water* **2014**, *6*, 2000–2020. [CrossRef]
25. He, C.; Harden, C.P.; Liu, Y. Comparison of Water Resources Management between China and the United States. *Geogr. Sustain.* **2020**, *1*, 98–108. [CrossRef]
26. Zhang, X.; Shao, M.; Li, S.; Peng, K. A Review of Soil and Water Conservation in China. *J. Geogr. Sci.* **2004**, *14*, 259–274. [CrossRef]
27. Joshi, P.; Shiferaw, B.; Wani, S.; Bouma, J.; Scott, C. Watershed Development in India: Synthesis of Past Experiences and Needs for Future Research. *Indian J. Agric. Econ.* **2004**, *59*, 303–320.
28. Mondal, B.K.; Das, R.; Das, R. Watershed Prioritization Based on Morphometric Analysis Using Geospatial Technique in the Upper Kasai Sub-Watershed of Purulia District, West Bengal (India). In *Fluvial Systems in the Anthropocene: Process, Response and Modelling*; Islam, A., Das, P., Ghosh, S., Mukhopadhyay, A., Das Gupta, A., Kumar Singh, A., Eds.; Springer International Publishing: Cham, Switzerland, 2022; pp. 193–226. [CrossRef]

29. Dolui, G.; Das, K.; Das Chatterjee, N.; Bhattacharya, R. Multi-Criteria-Based Morphometric Prioritization for Soil Erosion Susceptibility and Denudation Rate Assessment of Purulia District, India. In *Drainage Basin Dynamics: An Introduction to Morphology, Landscape and Modelling*; Springer: Berlin/Heidelberg, Germany, 2022; pp. 477–502. [CrossRef]
30. Saha, A. GIS Based Soil Erosion Estimation Using Rusle Model: A Case Study of Upper Kangsabati Watershed, West Bengal, India. *Int. J. Environ. Sci. Nat. Resour.* **2018**, *13*, 001–008. [CrossRef]
31. Saini, K.M.; Deb, T.K.; Mitra, P.P.; Ghatol, S.G.; Sen, A.K.; Saha, N.C.; Das, S.N. Assessment of Degraded Lands of Puruliya District, West Bengal Using Remotely Sensed Data. *J. Indian Soc. Remote Sens.* **1999**, *27*, 23–30. [CrossRef]
32. Manna, M.; Mondal, B. The Emerging Issue of Forest Degradation in Purulia District. *West Bengal Geoinform. Sustain. Environ. Manag.* **2017**, *1*, 137–156.
33. Mondal, S. Remote Sensing and GIS Based Ground Water Potential Mapping of Kangshabati Irrigation Command Area, West Bengal. *J. Geograp Natur. Disast* **2012**, *01*, 1–8. [CrossRef]
34. Patel, P.; Gupta, D. Mapping Groundwater Level Fluctuation and Utilisation in Puruliya District, West Bengal. In *Geostatistics and Geospatial Technologies for Groundwater Resources in India*; Springer: Berlin/Heidelberg, Germany, 2021.
35. Dolui, S.; Chakraborty, S. *Selection of Preferable Eco-Tourism Destinations Using Analytical Hierarchy Process in Purulia District, West Bengal (India)*; Research Square: Durham, CA, USA, 2022. [CrossRef]
36. Bera, B.; Bhattacharjee, S.; Chamling, M.; Ghosh, A.; Sengupta, N.; Ghosh, S. Fluoride Dynamics in Precambrian Hard Rock Terrain of North Singhbhum Craton and Effect of Fluorosis on Human Health and Society. In *Groundwater and Society: Applications of Geospatial Technology*; Shit, P.K., Bhunia, G.S., Adhikary, P.P., Dash, C.J., Eds.; Springer International Publishing: Cham, Swirerland, 2021; pp. 319–348. [CrossRef]
37. Roy, A. Viability of Rainwater Harvesting in Drought Prone Areas of West. Bengal: An Empirical Study on Bandu River Basin in Purulia District. *Int. J. Soc. Sci. Humanit. Invent.* **2014**, *1*, 155–164.
38. Kundu, A.; Nag, S. Assessment of Groundwater Quality in Kashipur Block, Purulia District, West Bengal. *Appl. Water Sci.* **2018**, *8*, 33. [CrossRef]
39. Nag, S. Application of Lineament Density and Hydrogeomorphology to Delineate Groundwater Potential Zones of Baghmundi Block in Purulia District, West Bengal. *J. Indian Soc. Remote Sens.* **2005**, *33*, 521–529. [CrossRef]
40. Choudhury, A.; Ezung, Z.; Barua, M. *NAQUIM Report of Purulia District West Bengal*; ReseachGate: Berlin, Germany, 2023.
41. Bhuyan, M.J.; Deka, N. Delineation of Groundwater Potential Zones at Micro-Spatial Units of Nagaon District in Assam, India, Using GIS-Based MCDA and AHP Techniques. *Environ. Sci. Pollut. Res.* **2022**, *29*, 1–22. [CrossRef] [PubMed]
42. Dolui, G.; Das, N.; Guchhait, S.; Roy, S. *Multi-Criteria Decision-Making Approach Using Remote Sensing and GIS for Assessment of Groundwater Resources*; Springer: Berlin/Heidelberg, Germany, 2021; pp. 59–79. [CrossRef]
43. Modak, S.; Das, D. *A Study on Groundwater Level Fluctuation in Water Scare Region of Upper Catchment Area of Kumari River Basin in Purulia District, West Bengal*; ReseachGate: Berlin, Germany, 2018; pp. 18–25.
44. Haokip, P.; Khan, M.; Choudhari, P.P.; Cimusa Kulimushi, L.; Qaraev, I. Identification of Erosion-Prone Areas Using Morphometric Parameters, Land Use Land Cover and Multi-Criteria Decision-Making Method: Geo-Informatics Approach. *Environ. Dev. Sustain.* **2022**, *24*, 527–557. [CrossRef]
45. Ansari, Z.R.; Rao, L.A.K.; Yusuf, A. GIS Based Morphometric Analysis of Yamuna Drainage Network in Parts of Fatehabad Area of Agra District, Uttar Pradesh. *J. Geol. Soc. India* **2012**, *79*, 505–514. [CrossRef]
46. Biswas, S.; Sudhakar, S.; Desai, V. Prioritisation of Subwatersheds Based on Morphometric Analysis of Drainage Basin: A Remote Sensing and GIS Approach. *J. Indian Soc. Remote Sens.* **1999**, *27*, 155–166. [CrossRef]
47. Horton, R.E. Erosional Development of Streams and Their Drainage Basins; Hydrophysical Approach to Quantitative Morphology. *Geol. Soc. Am. Bull.* **1945**, *56*, 275–370. [CrossRef]
48. Avinash, K.; Deepika, B.; Jayappa, K.S. Basin Geomorphology and Drainage Morphometry Parameters Used as Indicators for Groundwater Prospect: Insight from Geographical Information System (GIS) Technique. *J. Earth Sci.* **2014**, *25*, 1018–1032. [CrossRef]
49. Pakhmode, V.; Kulkarni, H.; Deolankar, S.B. Hydrological-Drainage Analysis in Watershed-Programme Planning: A Case from the Deccan Basalt, India. *Hydrogeol. J.* **2003**, *11*, 595–604. [CrossRef]
50. Vittala, S.S.; Govindaiah, S.; Gowda, H.H. Prioritization of Sub-Watersheds for Sustainable Development and Management of Natural Resources: An Integrated Approach Using Remote Sensing, GIS and Socio-Economic Data. *Curr. Sci.* **2008**, *95*, 345–354.
51. Schumm, S.A. Evolution of Drainage Systems and Slopes in Badlands at Perth Amboy, New Jersey. *Geol. Soc. Am. Bull.* **1956**, *67*, 597–646. [CrossRef]
52. Faniran, A. The Index of Drainage Intensity: A Provisional New Drainage Factor. *Aust. J. Sci.* **1968**, *31*, 326–330.
53. Miller, V.C. *A quantitative geomorphic study of drainage basin characteristics in the clinch mountain area Virginia and Tennessee*; Columbia Univ: New York, NY, USA, 1953.
54. Gravelius, H. *Morphometry of Drainage Bassins*; Elsevier: Amsterdam, The Netherlands, 1914; References—Scientific Research Publishing. Available online: https://www.scirp.org/(S(lz5mqp453edsnp55rrgjct55.))/reference/referencespapers.aspx?referenceid=2852054 (accessed on 31 October 2023).
55. Pingale, S.M.; Chandra, H.; Sharma, H.; Mishra, S.S. Morphometric Analysis of Maun Watershed in Tehri-Garhwal District of Uttarakhand Using GIS. *Int. J. Geomat. Geosci.* **2012**, *3*, 373–387.
56. Horton, R.E. Drainage-Basin Characteristics. *Trans. Am. Geophys. Union* **1932**, *13*, 350–361.

57. Melton, M.A. *An Analysis of the Relations among Elements of Climate, Surface Properties, and Geomorphology*; Columbia Univ: New York, NY, USA, 1957.
58. Smith, G.-H. The Relative Relief of Ohio. *Geogr. Rev.* **1935**, *25*, 272–284. [CrossRef]
59. Hembram, T.K.; Saha, S. Prioritization of Sub-Watersheds for Soil Erosion Based on Morphometric Attributes Using Fuzzy AHP and Compound Factor in Jainti River Basin, Jharkhand, Eastern India. *Environ. Dev. Sustain.* **2020**, *22*, 1241–1268. [CrossRef]
60. Balasubramanian, A.; Duraisamy, K.; Thirumalaisamy, S.; Krishnaraj, S.; Yatheendradasan, R.K. Prioritization of Subwatersheds Based on Quantitative Morphometric Analysis in Lower Bhavani Basin, Tamil Nadu, India Using DEM and GIS Techniques. *Arab. J. Geosci.* **2017**, *10*, 1–18. [CrossRef]
61. Patel, D.; Dholakia, M.; Nandhakumar, N.; Srivastava, P. Water Harvesting Structure Positioning by Using Geo-Visualization Concept and Prioritization of Mini-Watersheds Through Morphometric Analysis in the Lower Tapi Basin. *J. Indian Soc. Remote Sens.* **2012**, *40*, 299–312. [CrossRef]
62. Khare, D.; Mondal, A.; Mishra, P.; Kundu, S.; Meena, P. Morphometric Analysis for Prioritization Using Remote Sensing and GIS Techniques in a Hilly Catchment in the State of Uttarakhand, India. *Indian J. Sci. Technol.* **2014**, *7*, 1650–1662. [CrossRef]
63. Langbein, W.B. *Topographic Characteristics of Drainage Basins*; US Geological Survey Water-Supply Paper, 968-C; USGPO: Washington, DC, USA, 1947; pp. 125–157.
64. Chandrashekar, H.; Lokesh, K.V.; Sameena, M.; Roopa, J.; Ranganna, G. GIS –Based Morphometric Analysis of Two Reservoir Catchments of Arkavati River, Ramanagaram District, Karnataka. *Aquat. Procedia* **2015**, *4*, 1345–1353. [CrossRef]
65. Rama, V.A. Drainage Basin Analysis for Characterization of 3rd Order Watersheds Using Geographic Information System (GIS) and ASTER Data. *J. Geomat.* **2014**, *8*, 200–210.
66. Kottagoda, S.D.; Abeysingha, N. Morphometric Analysis of Watersheds in Kelani River Basin for Soil and Water Conservation. *J. Natl. Sci. Found. Sri Lanka* **2017**, *3*, 273–285. [CrossRef]
67. Avinash, K.; Jayappa, K.S.; Deepika, B. Prioritization of Sub-Basins Based on Geomorphology and Morphometricanalysis Using Remote Sensing and Geographic Information System (GIS) Techniques. *Geocarto Int.* **2011**, *26*, 1–24. [CrossRef]
68. Rao, N.; Chakradhar, G.; Srinivas, V. Identification of Groundwater Potential Zones Using Remote Sensing Techniques in and Around Guntur Town, Andhra Pradesh, India. *J. Indian Soc. Remote Sens.* **2001**, *29*, 69–78. [CrossRef]
69. Smith, K.G. Stand Grading Texture Erosional Topography. *Am. J. Sci.* **1950**, *248*, 655–668. [CrossRef]
70. Acharya, T.; Nag, S. Study of Groundwater Prospects of the Crystalline Rocks in Purulia District, West Bengal, India Using Remote Sensing Data. *Earth Resour.* **2013**, *1*, 54–59. [CrossRef]
71. Nag, S. Delineation of Groundwater Potential Zones in Hard Rock Terrain in Kashipur Block, Purulia District, West Bengal, Using Geospatial Techniques. *Int. J. Waste Resour.* **2016**, *6*, 1000201. [CrossRef]
72. Das, S. Delineation of Groundwater Potential Zone in Hard Rock Terrain in Gangajalghati Block, Bankura District, India Using Remote Sensing and GIS Techniques. *Model. Earth Syst. Environ.* **2017**, *3*, 1589–1599. [CrossRef]
73. Ghosh, A.; Adhikary, P.P.; Bera, B.; Bhunia, G.; Shit, P. Assessment of Groundwater Potential Zone Using MCDA and AHP Techniques: Case Study from a Tropical River Basin of India. *Appl. Water Sci.* **2022**, *12*, 1–22. [CrossRef]
74. Jasrotia, A.; Bhagat, B.; Taloor, A.; Kumar, R. Remote Sensing and GIS Approach for Delineation of Groundwater Potential and Groundwater Quality Zones of Western Doon Valley, Uttarakhand, India. *J. Indian Soc. Remote Sens.* **2013**, *41*, 365–377. [CrossRef]
75. Sikdar, P.; Chakraborty, S.; Adhya, E.; Paul, P. Land Use/Land Cover Changes and Groundwater Potential Zoning in and around Raniganj Coal Mining Area, Bardhaman District, West Bengal—A GIS and Remote Sensing Approach. *J. Spat. Hydrol.* **2004**, *4*, 1–24.
76. Goyo, S.L.; Puno, G. Usage of Land Use/Land Cover and Anthropogenic Parameters in Prioritizing Conservation in Sub Watersheds of Upper Pulangi River. *East Asian J. Multidiscip. Res.* **2023**, *2*, 2081–2098. [CrossRef]
77. Diwakar, A.; Singh, S.; Pramanik, M.; Chaudhary, S.; Negi, M. Soil Erodibility Mapping Using Watershed Prioritization and Morphometric Parameters in Conjunction with WSA, SPR and AHP-TOPSIS Models in Mandakini Basin, India. *Int. J. River Basin Manag.* **2022**, 1–67. [CrossRef]
78. Harker, P.; Vargas, L. The Theory of Ratio Scale Estimation: Saaty's Analytic Hierarchy Process. *Manag. Sci.* **1987**, *33*, 1383–1403. [CrossRef]
79. Hwang, C.-L.; Yoon, K. Methods for Multiple Attribute Decision Making. In *Multiple Attribute Decision Making: Methods and Applications A State-of-the-Art Survey*; Hwang, C.-L., Yoon, K., Eds.; Lecture Notes in Economics and Mathematical Systems; Springer: Berlin/Heidelberg, Germany, 1981; pp. 58–191. [CrossRef]
80. Saaty, T.L. The Analytic Hierarchy Process: Decision Making in Complex Environments. In *Quantitative Assessment in Arms Control: Mathematical Modeling and Simulation in the Analysis of Arms Control Problems*; Avenhaus, R., Huber, R.K., Eds.; Springer: Boston, MA, USA, 1984; pp. 285–308. [CrossRef]
81. Saaty, T.L. Decision Making with the Analytic Hierarchy Process. *IJSSCI* **2008**, *1*, 83. [CrossRef]
82. Berdie, A.D.; Osaci, M.; Muscalagiu, I.; Barz, C. A Combined Approach of AHP and TOPSIS Methods Applied in the Field of Integrated Software Systems. *IOP Conf. Ser. Mater. Sci. Eng.* **2017**, *200*, 012041. [CrossRef]
83. Huang, I.B.; Keisler, J.; Linkov, I. Multi-Criteria Decision Analysis in Environmental Sciences: Ten Years of Applications and Trends. *Sci. Total Environ.* **2011**, *409*, 3578–3594. [CrossRef]
84. Jadidi, O.; Firouzi, F.; Bagliery, E. TOPSIS Method for Supplier Selection Problem. *World Acad. Sci. Eng. Technol.* **2010**, *47*, 956–958.

85. Hudait, M.; Patel, P.P. Site Suitability Assessment for Traditional Betel Vine Cultivation and Crop Acreage Expansion in Tamluk Subdivision of Eastern India Using. AHP-Based Multi-Criteria Decision Making Approach. *Comput. Electron. Agric.* **2022**, *200*, 107220. [CrossRef]
86. Silva López, J.O.; Salas López, R.; Rojas Briceño, N.B.; Gómez Fernández, D.; Terrones Murga, R.E.; Iliquín Trigoso, D.; Barboza Castillo, E.; Oliva Cruz, M.; Barrena Gurbillón, M.Á. Analytic Hierarchy Process (AHP) for a Landfill Site Selection in Chachapoyas and Huancas (NW Peru): Modeling in a GIS-RS Environment. *Adv. Civ. Eng.* **2022**, *2022*, e9733322. [CrossRef]
87. Mahato, N. Environment and Migration, Purulia, West Bengal. *Policies Pract.* **2010**, *32*. Available online: https://www.researchgate.net/publication/315799602_Environment_and_Migration_Purulia_West_Bengal (accessed on 17 March 2024).
88. Roy, A. Deforestation in social context: A case study of Purulia district in West Bengal, India introduction. *Res. World–J. Arts Sci. Commer.* **2014**, *5*, 114–120.
89. Weiland, S.; Hickmann, T.; Lederer, M.; Marquardt, J.; Schwindenhammer, S. The 2030 Agenda for Sustainable Development: Transformative Change through Sustainable Development Goals? *Politics Gov.* **2021**, *9*, 90–95. [CrossRef]