Identification of Water Resource Potential Zones of Karu River Basin Using Remote Sensing and Gis Techniques in Purulia District, West Bengal [India]

Shambhu Nath Sing Mura
Assistant Professor of Geography, Vivekananda Mahavidyalaya Burdwan, Purba Bardhaman, West Bengal India.

Abstract:- Remote Sensing and GIS tools broadly help hydrologists to delineate the water resource potential zones for watershed development and management. Water is a valuable natural resource in our daily life. It is used for domestic as well as agricultural purposes. It's amount varies from season to season. It is plenty during the rainy season, but in the dry season, it is scarce. Assessment of the potential zones of water resources is extremely important for protecting water quality and managing surface/groundwater systems. Water resource potential zones are demarcated with the help of Remote Sensing and Geographical Information System (GIS) techniques. In this study, the standard methodology is used to determine the potential of water resources using the integration of RS & GIS techniques. Different parameters that can be considered for identifying water resource potential zones, such as slope, drainage frequency, drainage density, geology, groundwater level, soil, surface water bodies and land use/land cover, are generated using satellite data and a survey of India (SoI) toposheets of scale 1:50000. Suitable ranks are assigned of each category of these parameters. A different thematic map of each parameter is prepared using an ordered weighted averaging technique in Qgis. Finally, a composite map is prepared by assigning all parameters to identify the water resource potential zone. These are classified into five categories: very poor, poor, moderate, good and excellent. This suggested methodology has been applied to achieve the goal of the selected study area in the Purulia district, West Bengal. Water resource potential zones will be useful for the identification of suitable locations for agriculture and domestic use of surface and underground water.

Keywords*: River basin, RS & GIS, Overlay Analysis, Thematic, Potential zones, Water resource*.

1. Introduction

Water resources, both ground and surface, are useful to humans in agriculture, industrial, household, recreational and environmental activities. The main source of water on the Earth's surface is precipitation. After precipitation, rainwater is drained out through surface run-off in the drainage basin. All part of the Earth's surface is under any drainage basin. Some portion of rainwater is stored as underground water. It depends on voids within the geological stratum and bearing formation of the Earth's crust, which act as conduits for transmission and as reservoirs for storing water. Some portion of water is stagnant on the Earth's surface. Surface water bodies, like streams, ponds, etc., can act as recharge zones [1].

Over the years, the growing importance of water based on an increasing population and unscientific exploitation of water is creating a water stress condition. In the present scenario, rainfall is gradually decreasing, uncertain and uneven spatially. This alarming situation is a cost and time-effective technique for proper evaluation of water resources and management planning. Identification of various parameters is important for generating a water resource model of a study area. Karu River basin is a tributary river basin of the Subarnarekha river, which originated in the Ajodhya hill of Purulia district. The terms basin, catchment watershed, etc., are widely used to denote hydrological units [2]. A watershed is a natural hydrological entity that covers a specific area space on the Earth's surface from which the rainfall run-off flows through drains, channels, gullies, streams or rivers at any particular point. The watershed area is a hydrological unit considering various above-mentioned views, and an attempt has been made to locate water resource potential zones for assessment of water availability in the present study area applying Remote Sensing and GIS techniques.

Remote sensing and GIS techniques are widely used in the field of hydrology and water resource development. Satellite remote sensing data is helpful in solving the water resource potential region. Application of remote sensing and geographical information systems can also play a major role in the present day for multi-criteria analysis in resource evaluation and hydro-geomorphological mapping for water resource management. Using remote sensing and GIS techniques, the groundwater potential zone in the tropical river basin of Kerala, India, has been determined [3]. Various information on geology, geomorphology, slope, and land use/land cover has been extracted from sentinel 2B satellite image and Survey of India toposheets. In addition, the GIS platform has been used for the integration of various themes. The generated composite map is further classified according to the spatial variation of the water resource potential. The spatial variations of the potential zones indicate that the water resource occurrence is controlled by geology structures, slopes and landforms. Assessment of the groundwater potential recharge process is an important indicator for the management of water resources and the protection of water quality [4]. Drainage, slope, soil, lithology and geomorphic features of the Karu river basin have been extracted and suggested appropriate methods for water resource potential studies.

2. Objectives

Lorem Karu River is the tributary of the Subarnarekha river basin, which originated in the Ajodhya hills of Purulia district, West Bengal. It is a non-perennial river. This drainage basin receives water from rain in the rainy season, but in summer, it is dried up. During the dry season, people of this drainage basin suffer from water due to lack of water in the river and proper management of water. This area has a subtropical climate characterized by high evaporation and low precipitation. Average annual rainfall varies between 1100 mm and 1500 mm. The relative humidity is high in monsoon season, being 75 to 80 percent. But in the summer, it comes down to 25 to 35 per cent. Keeping in mind, the Author has tried to delineate water resource potential zones in the Karu river basin of Purulia district. The water resource potential map will help in a proper understanding of the sustainable use of water resources in the study area. Geographically, the Karu River basin is extended 23^{0} $07^{/}32.52^{//}$ N to 23^{0} $17^{/}$ $00^{//}$ N latitude and $85^{0}55^{/}7.5^{//}$ E to $86^{0}04^{/}26.6^{//}$ E longitude covering an area of 118 square kilometer and a perimeter of the basin is 70.23 kilometer. The maximum and minimum heights of this basin are 545m and 130m, respectively. After rainfall, water is rapidly washed out from the ground surface due to a steep slope without recharging the ground water. Agriculture activity is the principal source of the economy of the people living in this drainage basin. Both surface and ground waters are used for drinking and irrigation purposes. Potential water resource management is needed for local people for irrigation and domestic purposes. Figure 1 shows the location of the study area.

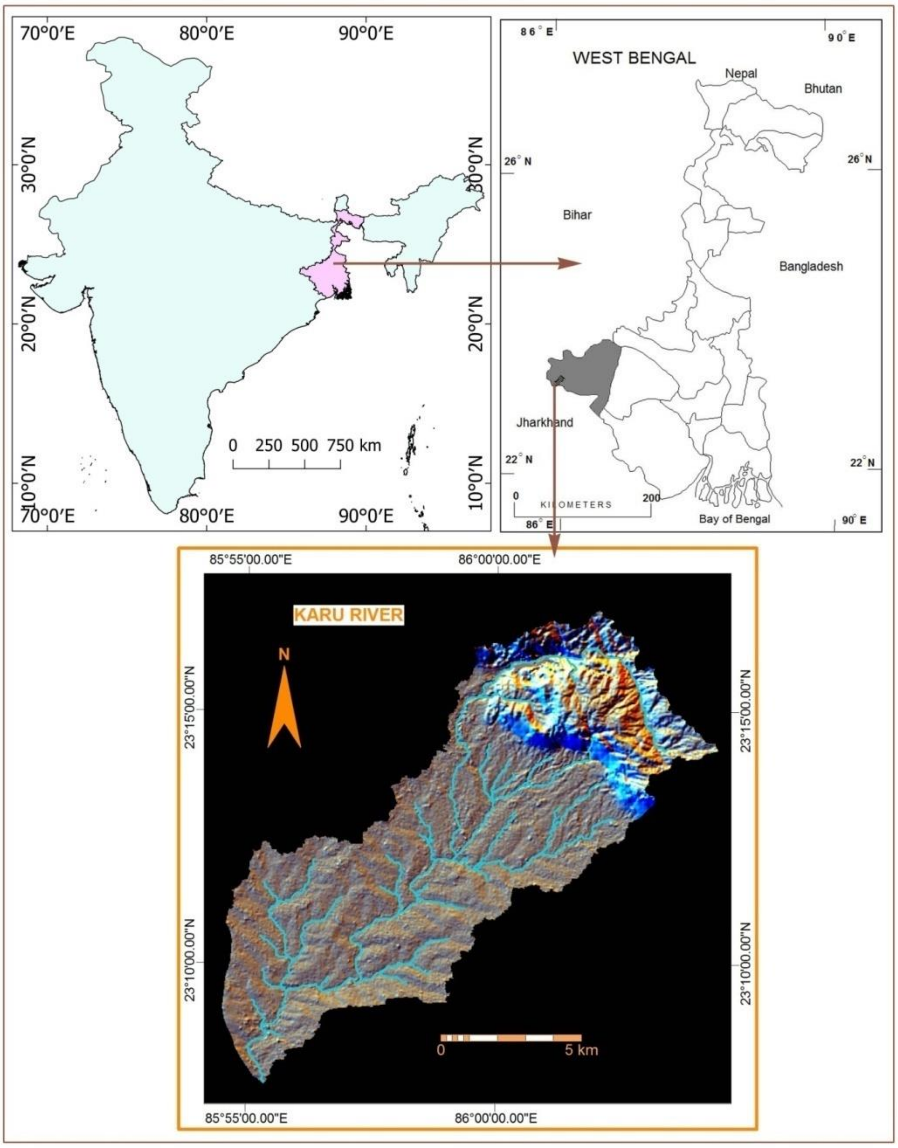

Fig.1 Location map of the study area

3. Materials/Data used

Various data have been used to fulfil the objective of the present study. In this study, sentinel data has been used to identify the different geomorphic features. Survey of India topographical maps of a scale 1:50000 (No. 73E/15, 73E/16, 73I/3 and 73I/4) also have been used. SRTM data (Cartosat-I) has been used to identify the elevation of the study area. A geological map from the Geological Survey of India (GoI) and groundwater level data from the Central Ground Water Board (GoI) have been used for the identification and delineation of water resource potential zones in the Karu River basin.

4. Methodology

The proposed methodology of the study comprises the preparation of a base map, land use/land cover and geological maps, digitizing and image processing techniques by using GIS software and interpretation of outputs. Survey of India (SoI) toposhhets on a scale of 1:50000 have been used to demarcate the river basin, and further, the basin area has been divided into one square kilometer grids (Figure 2). Different parameters related to water resources, such as average slope, drainage frequency and drainage density, have been extracted from each grid and categorized into several classes and assigned weight to each class. The soil map of the study area is categorized on the basis of water content, and weight has been assigned correspondingly. In this way, other parameters are used to determine the water resource potential, like land use/land cover, geology of rocks, groundwater and surface water bodies. Elevation data has been extracted from Cartosat-I, and it is used to prepare slope and drainage maps. This methodology is widely used for preparing water resource potential maps for small to medium size drainage basins.

All the above themes are processed and analyzed, and weight is given to evaluate suitable water potential zones. In the present study, average slope drainage density & frequency, soil, groundwater, surface water bodies, geology and land use/ land cover, etc., are considered to identify water resource potential in the Karu River basin. All these thematic layers are weighted sum raster overlay analysis using Qgis 2.18 and MapInfo 10.0. Figure 3 shows the methodology of the proposed study through a diagrammatic way.

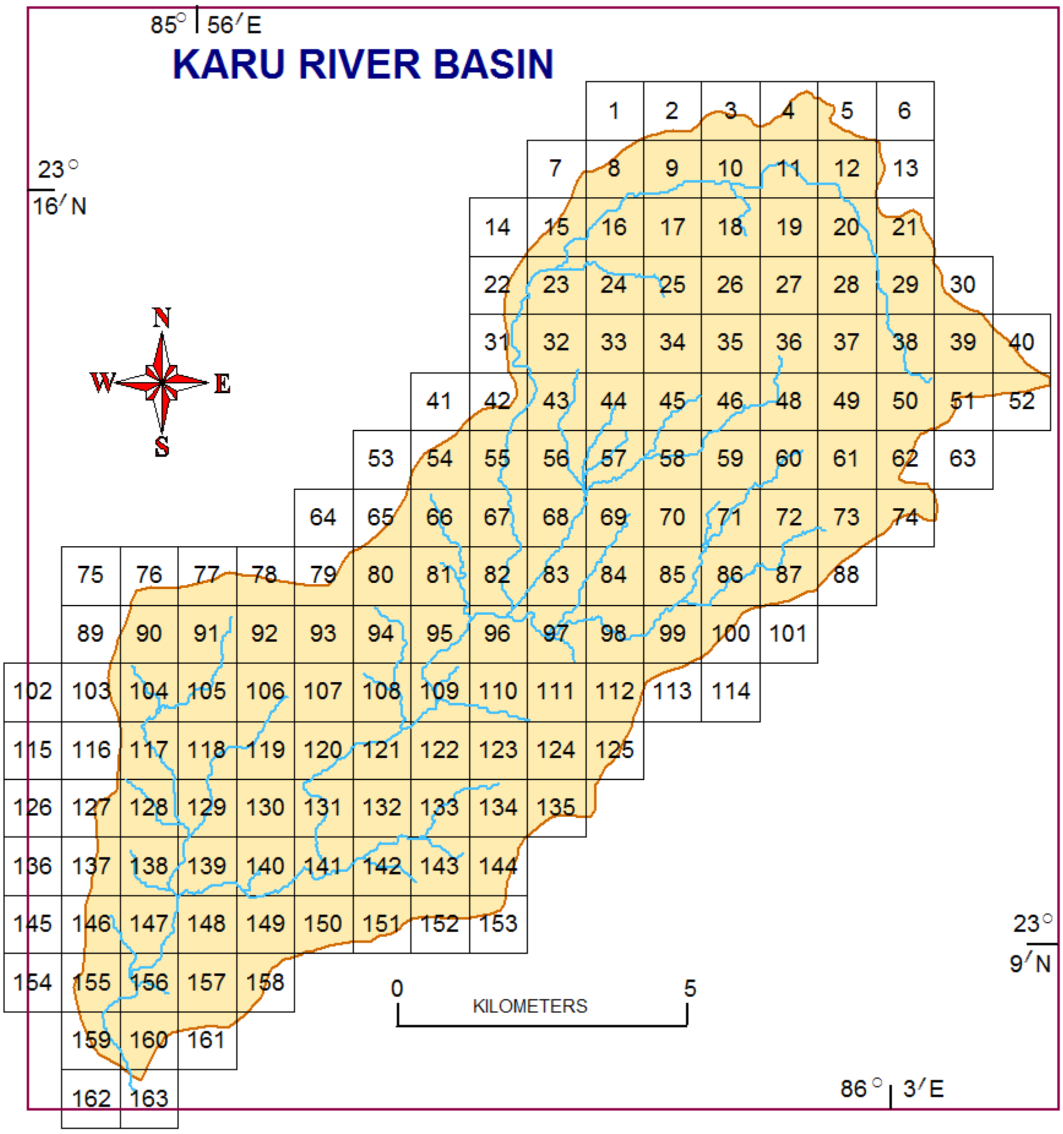

Fig. 2 Grid layout of the study area

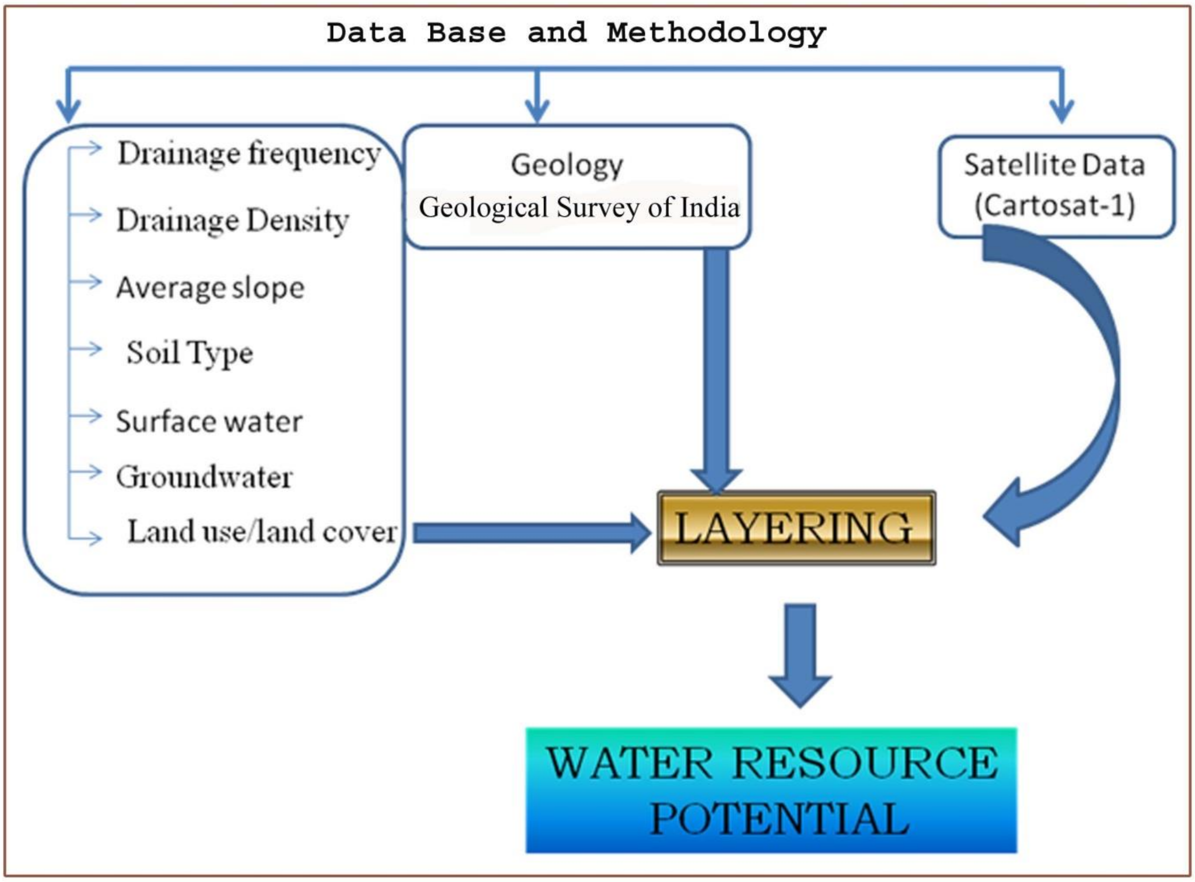

Fig. 3 Data base & methodology

5. Result and Discussion

a. Drainage frequency

The drainage pattern in an area is an important parameter for the availability of water resources. It is controlled by regional structure, geomorphology, lithology, etc. So, it is an important aspect of water resource availability in the study area. Satellite data and GIS have been used to generate data on the spatial deviations in drainage characteristics, thus providing insight into hydrologic conditions necessary for developing watershed management strategies [5]. The drainage pattern of the basin is dendritic type, and generally, streams flow from the northeast to the southwest direction. Dendritic drainage network type indicates homogeneity in texture and lack of structural control and helps in understanding various terrain parameters such as the nature of bedrock, infiltration capacity, etc. [6]. Drainage frequency has been extracted from each grid (per square kilometer) for the preparation of a drainage frequency map. It has been categorized into high (>2 stream/sq. km), medium (1 to 2 stream/sq.km.) and low (<1 stream/sq.km.) drainage frequency zones (Figure 4). The high drainage frequency zone covers 29.40 per cent of the study area. The medium drainage frequency zone covers 22.29 per cent of the area, and 48.31 per cent of the area lies under the low drainage frequency zone. Table 1 shows the different drainage frequency zones and their weight on the basis of the water availability of the selected area.

Table 1
Drainage frequency zones and weight assignment

Sl. No.	Drainage frequency (stream number /sq.km.)	Water resource prospects	Area covered in sq. km.	Area covered in %	Weight
1	Above 2	High	34.69	29.4	3
2	1 to 2	Medium	26.3	22.29	2
3	Below 1	Low	57.01	48.31	1

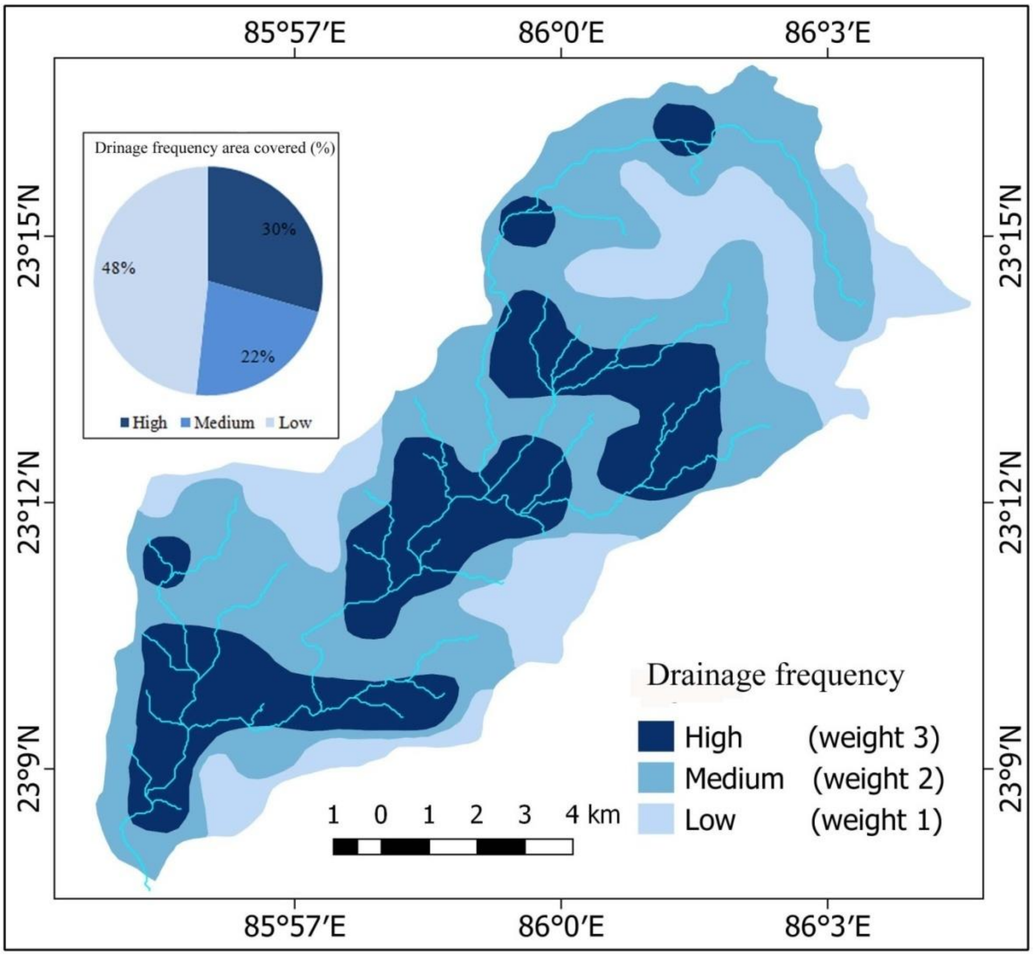

Fig. 4 Weight assignment on the basis of water prosperity of drainage frequency zones
Source: Srtm, 2023 & Author's compilation

b. Drainage density

According to Strahler [7], drainage density is shown by Dd=L/A , Where L is stream length, and A is unit area. Figure 5 and Table 2 shows the different drainage density zones and weight of the study area. It is classified into high (>2 km./sq. km.), medium (1 to 2 km/sq. km.) and low (<1 km./sq. km.) drainage density zones and assigns weight on the basis of drainage density of the study area. The high drainage density zone covers an area of 5.71 per cent of the study area. Medium drainage density zone covers 39.40 per cent of the area, and 54.89 per cent of the area lies under low drainage density zone. The low drainage density zone shows a poorly drained basin with a slow hydrological response from the watershed; making it highly susceptible to flooding, gully erosion, etc. [8]. High drainage density zone shows a quick hydrological response to rainfall events. Besides, a high drainage density zone is characterized by impermeable subsoil material, sparse vegetation and high mountain relief [9].

Table 2
Drainage density zones and assignment of weight

Sl. No.	Drainage density (stream length in km./sq.km.)	Water resource prospects	Area covered in sq. km.	Area covered in %	Weight
1	Above 2	High	6.74	5.71	3
2	1 to 2	Medium	46.49	39.4	2
3	Below 1	Low	64.77	54.89	1

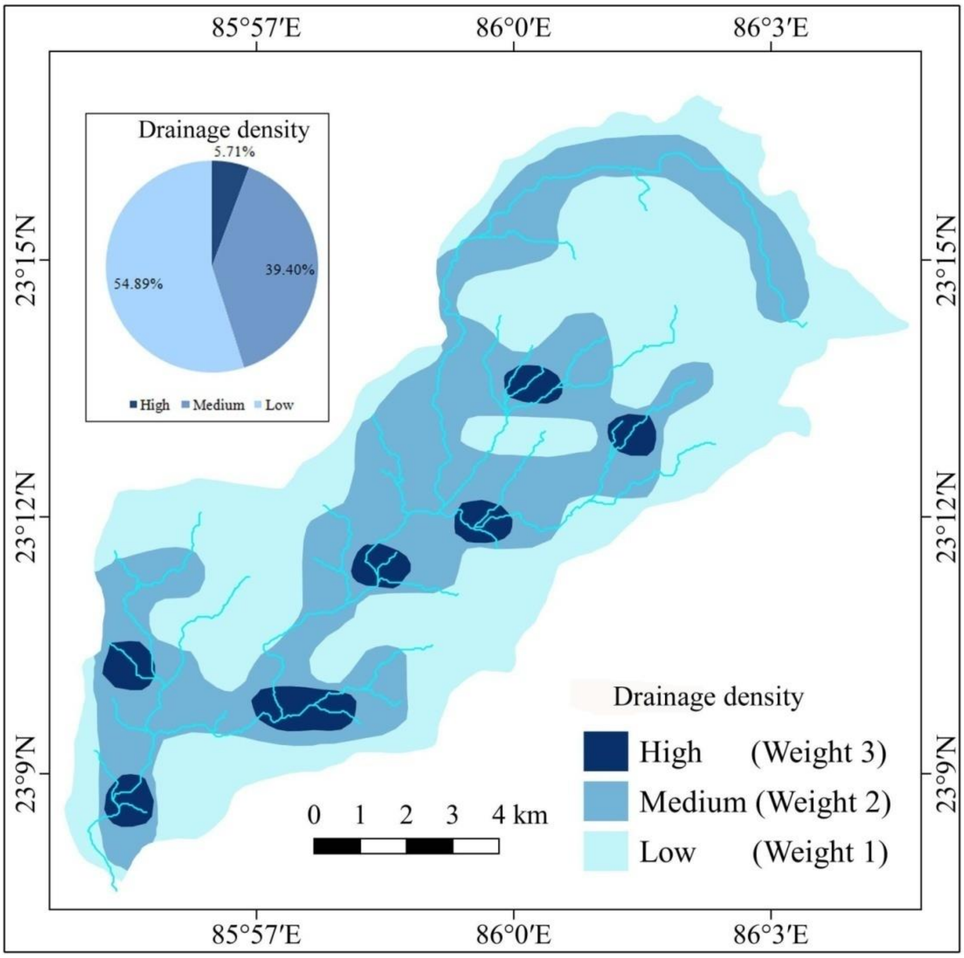

Fig 5 Drainage density zones and assignment of weight on the basis of water prosperity
Source: Srtm, 2023 & Author's compilation

c. Average slope

The term 'slope' means an element of Earth's terrestrial and submarine surfaces; it is, therefore, simply an element of the interface between the lithosphere and atmosphere [10]. According to Wentworth 1930 [11], the average slope is calculated by using the formula: θ=(N x i)/K, where N is the number of contour crossing per kilometer, i is the contour interval, and K is constant (636.6 for the kilometer grid). The average slope of the basin has been classified into high (>40 degrees), moderate (20-40 degrees) and low (<20 degrees) slope zones and has assigned weight to each zone on the basis of water availability. It is an important parameter for the availability of surface as well as sub-surface water. The slope controls the surface run-off and infiltration, which affects the water resource availability. The high average slope zone covers an area of 28.99 per cent of the study area and assigned weight. 28.83 per cent of the area is under a moderate average slope zone, and it has been assigned weight. 42.18 per cent of the area lies under a low average slope zone (Below 200). Figure 6 and Table 3 depict the average slope and assigned weight of the study area.

Table 3

Average slope zones and assigned weight

Sl. No.	Slope	Water resource prospects	Area covered in sq. km.	Area covered in %	Weight
1	Below 20^0	High	49.77	42.18	3
2	20^0 to 40^0	Moderate	34.02	28.83	2
3	Above 40^0	Low	34.21	28.99	1

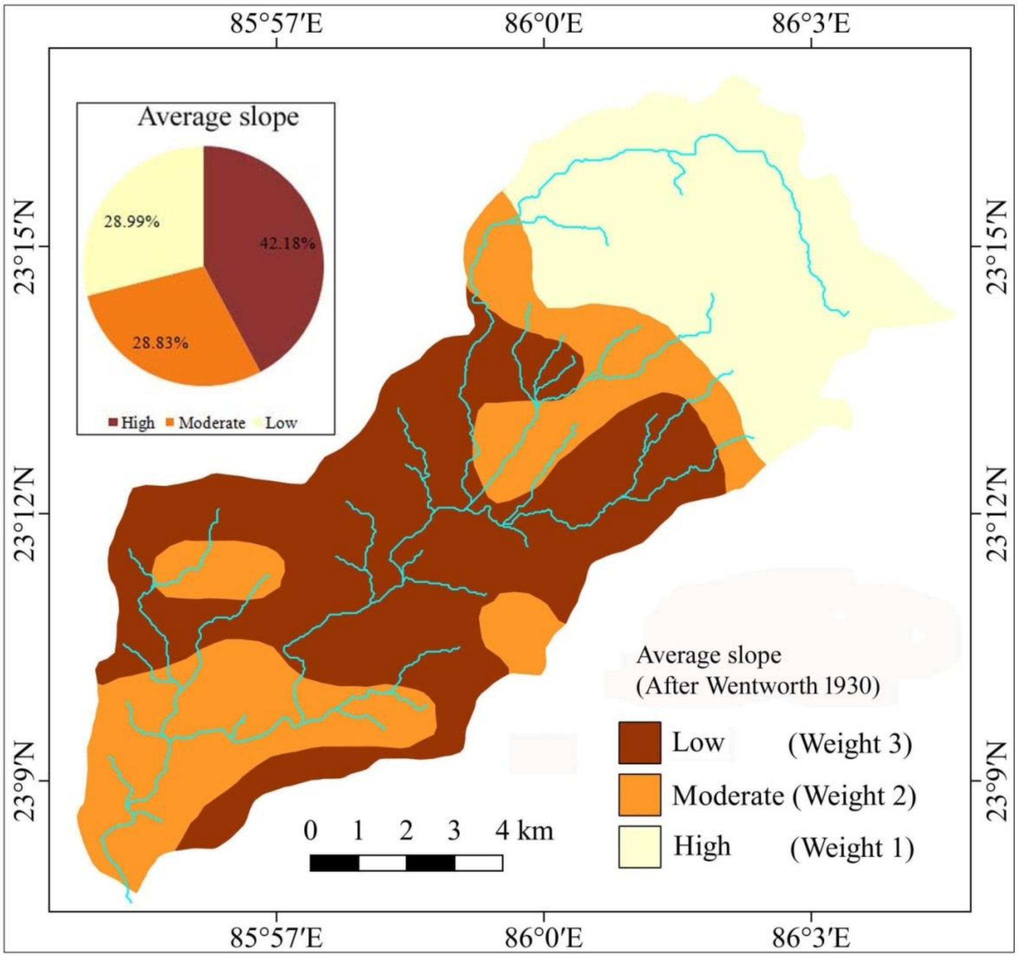

Fig 6 Average slope map zones & weight of assignment

Source: Toposheet no. 73E/15, E/16 I/3, I4 (1973) & Author's compilation

d. Soil

Water retention is mainly dependent on the particle size of the soil. The chance of water holding capacity is higher in the finer soil due to the cohesive nature of the soil. The pore space in the soil shows the voids between soil particles and is occupied by air or water. The quantity and size of the pore spaces are determined by the soil textures, bulk density and structures [12]. Water percolation through the soil depends on the soil texture, which in turn recharges the groundwater. The soil of the basin is classified into gravelly loam loam, fine loam, fine texture and fine loamy coarse loamy, and each category has been assigned weight on the basis of water holding capacity. Figure 7 and Table 4 show the soil characteristics and weight of the study area. Gravelly loam loam soil covers 3.80 per cent of the study area. 21.87 per cent of the area lies under fine loam soil. Fine texture and fine loamy coarse loamy soil cover 55.57 and 18.75 per cent of the area of the basin, respectively.

Table 4
Soil texture characteristics and weight assignment

Sl. No.	Soil type	Water resource prospects	Area covered in sq. km.	Area covered in %	Weight
1	Fine texture	High	65.57	55.57	4
2	Fine loamy coarse loamy	Medium	22.12	18.75	3
3	Fine loam	Low	25.81	21.87	2
4	Gravelly loam loam	Very low	4.5	3.81	1

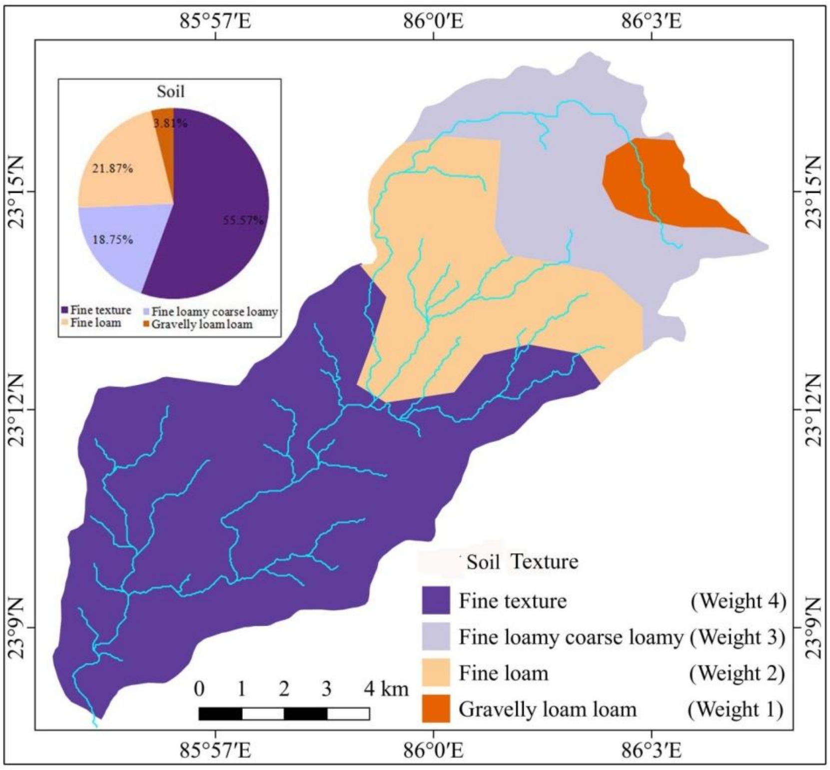

Fig 7 Soil map zones according to water prosperity & weight assignment
Source: NBSS & Regional Centre, Kolkata and Author's compilation

e. Surface water

Surface waters have been essential not only to humans but to all life forms on Earth ever since life began. Plants and animals grow and congregate around waterways simply because water is essential to life. It might seem that river happens to run through many cities in the world, but it is not that the rivers go through the city but rather that the city was built and grew around the river [13]. Most surface water comes from rainfall, and it is run-off from the surrounding catchment area. Of course, not all water ends up in rivers; some evaporates, some is used by vegetation, and part of it soaks into the ground for recharging our groundwater systems, some of which can seep back into the river beds. Surface water includes any form of water on the Earth's surface, like water in streams, rivers, lakes, wetlands, reservoirs and creeks. It is the indicator of water availability on the Earth's surface. On this basis, the area under surface water (per square kilometer grid) has been categorized and has been assigned a weight for each category (Figure 8 & Table 5). The high surface water zone (above 0.060 sq. km.) covers 9.84 per cent area. Medium (0.030 to 0.060 sq. km./sq. km.) and low (Below 0.030 sq. km. / sq. km.) surface water zones cover 28.87 per cent and 69.29 per cent area of the study area respectively.

Table 5

Zones of surface water bodies and assigned weight

Sl. No.	Surface water in sq. km./sq. km.	Water resource prospects	Area covered in sq. km.	Area covered in %	Weight
1	Above 0.060	High	11.61	9.84	3
2	0.030 to 0.060	Moderate	24.63	20.87	2
3	Below 0.030	Low	81.76	69.29	1

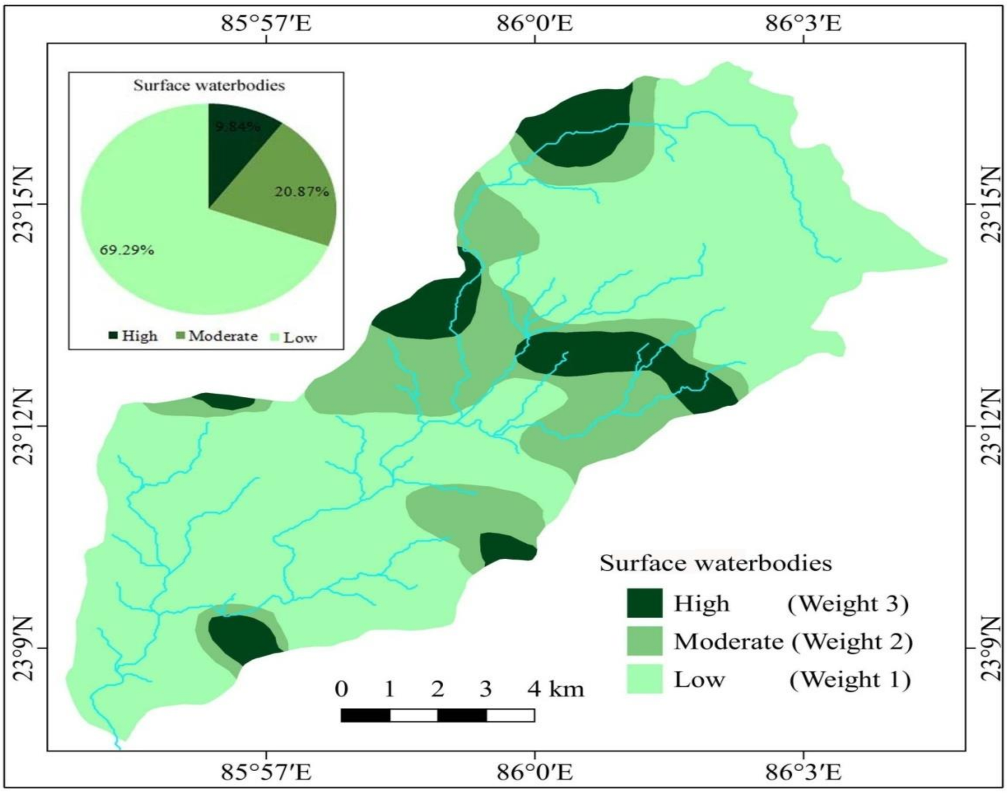

Fig. 8 Surface waterbodies zones and assignment of weight

Source: Google Earth, 2019 & Author's compilation

f. Groundwater

The groundwater level is an upper-level surface of underground water in which the soils and rocks are permanently saturated with water [14]. Various kinds of ecosystems depend on groundwater: aquatic (wetlands, rivers, and lakes receiving groundwater), terrestrial (with phreatophyte vegetation, either shallow-rooted in alluvial settings or deep-rooted in arid zones) and even subterranean (in limestone formations with karstic caverns). Accordingly, groundwater is an essential part of any ecosystem-based adaptation measure, green infrastructure or a nature-based solution [15]. Here, the groundwater level is measured from the mean sea level. In the study area, 32.57 per cent of the area lies below 275 meters from the mean sea level. 275 to 300 meters groundwater level from the mean sea level covers an area of 30.36 per cent, and 37.07 per cent of the area is below 300 meters height from the mean sea level (Figure 9). According to the height of groundwater levels from mean sea level, weight has been assigned to each zone to understand the variability of groundwater resources of the study area. Table 6 depicts the groundwater level category and assigned weight of the study area.

Table 6

Zones of groundwater level and weight assignment

Sl. No.	Groundwater level from mean sea level	Water resource prospects	Area covered in sq. km.	Area covered in %	Weight
1	Above 300m	High	43.74	37.07	3
2	275m to 300m	Medium	35.83	30.36	2
3	Below 275m	Low	38.43	32.57	1

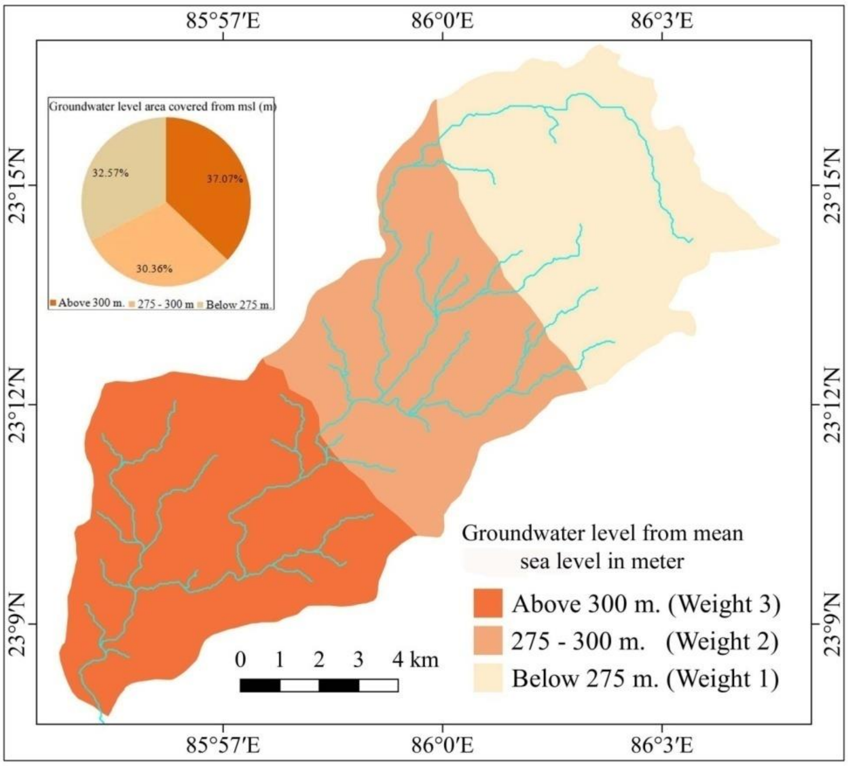

Fig. 9 Groundwater level zones & assignment of weight

Source: CGWB, Govt. of India & Author's compilation

g. Geology

Geology is an important controlling factor for infiltration of surface water into the sub-surface. It is the lithological characteristics of the rock that prove to be the most crucial factor in deciding the infiltration of surface water to the sub-surface levels. Different rocks are seen in the study area, such as Alluvium, Granite Gneiss, Mica-schist and Amphibolites. Alluvium covers 26.62 per cent of the study area. Granite Gneiss covers 57.91 per cent, and Mica schist covers 10.36 per cent area of the study area. 5.11 percent area lies under amphibolites. On the basis of groundwater rechargeability, weights have been assigned to each rock group. Figure 10 and Table 7 show the different rock groups and their water resource potentiality.

Table 7

Geological rocks and weight assignment

Sl. No.	Rocks type	Water resource prospects	Area covered in sq. km.	Area covered in %	Weight
1	Alluvium	High	31.41	26.62	3
2	Granite gneiss	Medium	68.34	57.91	2
3	Mica-schist	Low	12.22	10.36	1
4	Amphibolite	Very low	6.03	5.11	1

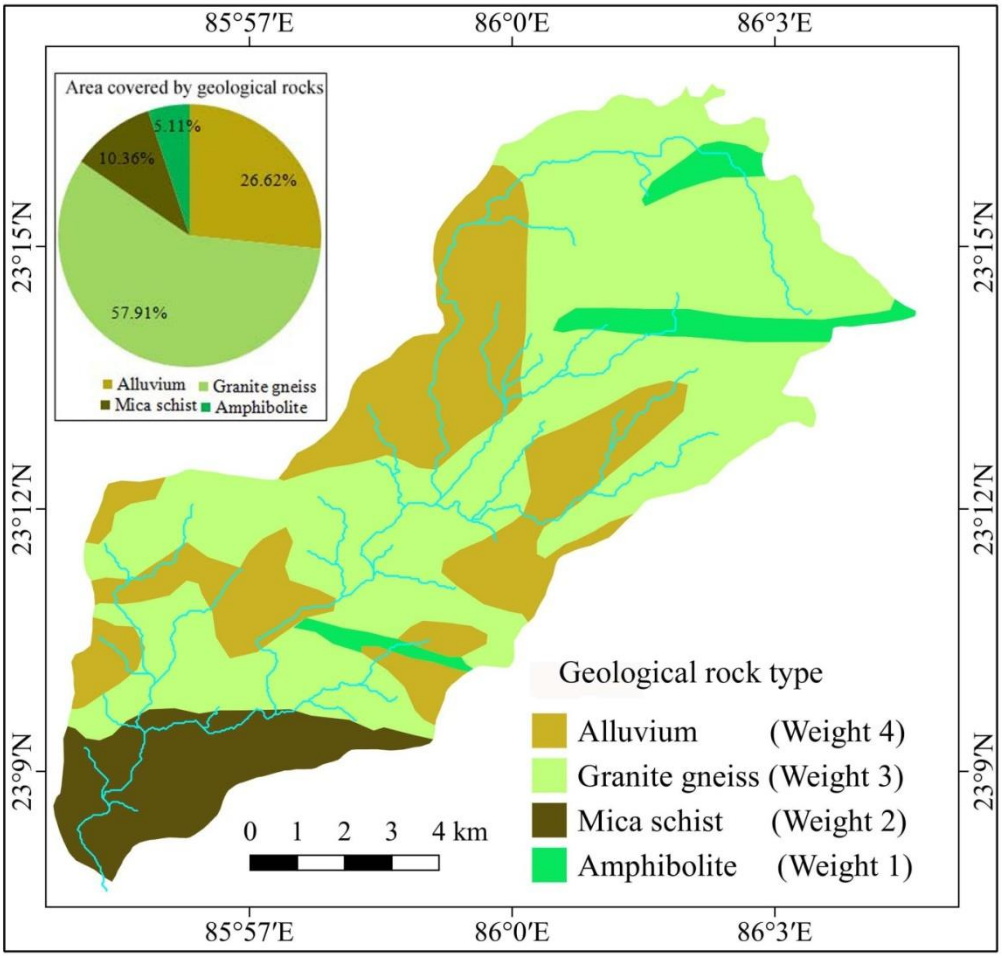

Fig. 10 Geological rock characteristics & assignment of weight according to water prosperity

Source: SoI, Govt. of India & Author's compilation

h. Land use/land cover

Land use/ land cover is one of the important parameters for water resource availability on the Earth's surface. It includes agricultural land, vegetation cover, surface water bodies (stream, lake, pond, wetland, khal, etc.), current fallow land, and bare soil/rock and built-up. Land use/land cover plays a significant role in the development of water resources, and it controls hydrogeological processes such as infiltration, evaporation and surface run-off. Infiltration of surface water will be high, and discharge of water will be less in the forest areas. Land use land cover change can also modify the underlying mechanisms of transferring rainfall to water yield by altering the ecosystem's hydrological characteristics such as infiltration, evapotranspiration and groundwater recharge capacity [16]. Figure 11 and Table 8 show the land use/land cover category and weight of the study area, whereas 41.98 per cent is agricultural land and 32.55 per cent of the area is under vegetation cover. Surface water covers 5.21 per cent area of the study area. 20.26 per cent of the area lies under settlement/other built-up/bare rock/soil. On the basis of water retention capacity, weights have been assigned to each land use/land cover category. Land use land cover variation reflects the hydrological services of different land ecosystems.

Table 8
Land use/land cover category and assigned weight

Sl. No.	Land use/land cover type	Water resource prospects	Area covered in sq. km.	Area covered in %	Weight
1	Vegetation	Very High	38.41	32.55	5
2	Waterbodies	High	6.15	5.21	4
3	Agricultural land	Medium	49.53	41.98	3
4	Settlement	Low	1.51	1.34	2
5	Bare rock/soil	Very low	22.4	18.92	1

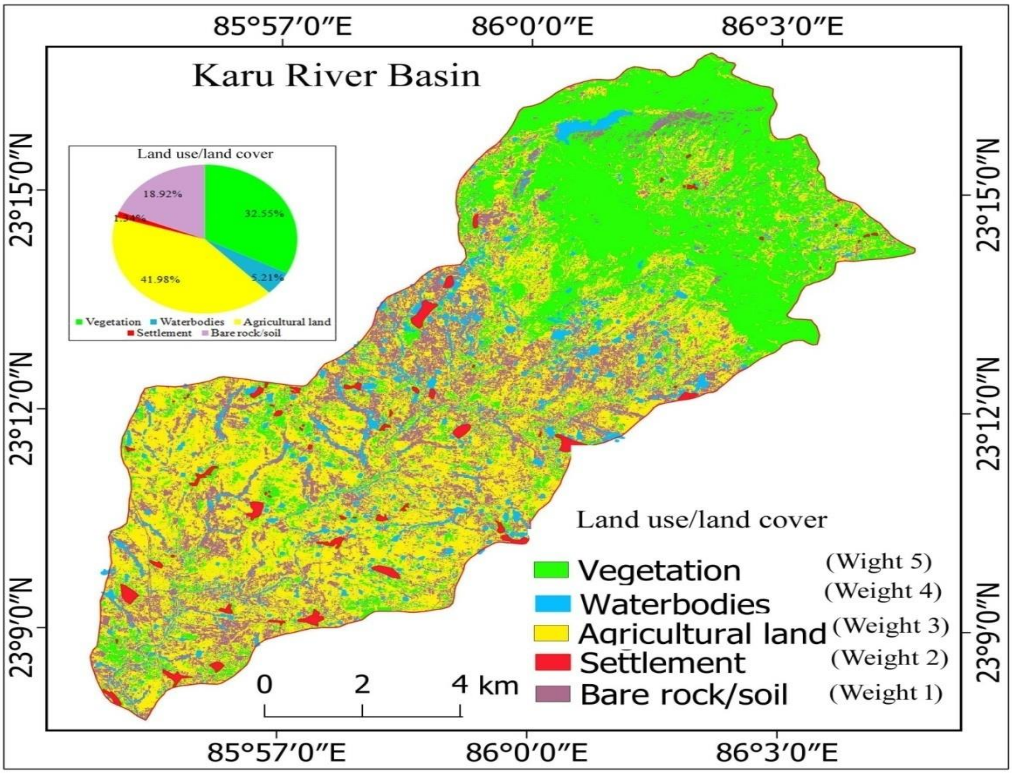

Fig. 11 Weight assignment of land use/land covers zone according to water prosperity

Source: Sentinel 2B, 2019 & Author's compilation

6. Assignment of weight

The surface water potential zones are obtained by overlaying all the thematic maps in terms of the weighted overlay method using a geospatial tool in Qgis 2.18. Thematic map weight is assigned according to the influence of water resources on each thematic map [17].

All the thematic maps are converted from vector to raster format by the weighted overlay method. Surface water, geology and land use/land cover were assigned higher weight, whereas slope and groundwater level were assigned lower weight. Assigned weights to the different thematic maps and individual weights are given for the sub-variable. GIS has been analyzed carefully, and weights are given to the sub-variable [18].

The highest weight is assigned to the feature with the highest water potentiality, and the lowest weight is given to the lowest potential features. The drainage frequency, such as higher drainage frequency, is given the highest weight and lower weight is assigned for lower drainage frequency. Higher drainage density is given the highest weight, and lower weight is assigned to lower drainage density. As far as slope, higher weights are assigned for lower (Gentle) slope and lower weight value is assigned to higher (Steep) slope. In land use/land cover, a higher weight value is assigned to surface water bodies and agricultural land and a lower weight value is assigned to vegetation, built-up and barren land. All the assigned weighted value of the different thematic map is tabulated in Table 9.

Table 9

Assigned weight for different parameters of water resource potential zone

Sl. No.	Parameter	Classes	Water Prosperity	Score	Maps Weight
1	Drainage frequency (No. of stream per sq. km.)	Above 2	High	3	12
		1 to 2	Medium	2	
		Below 1	Low	1	
2	Drainage density (Stream length per sq. km.)	Above 2	High	3	12
		1 to 2	Medium	2	
		Below 1	Low	1	
3	Average slope (Degree)	Below 20	High	3	10
		20 to 40	Medium	2	
		Above 40	low	1	
4	Soil	Fine texture	High	3	13
		Fine loamy, coarse loamy	Medium	2	
		Gravelly loam loam	Low	1	
		Fine loam	Very low	1	
5	Surface water (Sq. km. per sq. km.)	Above 0.060	High	3	15
		0.030 to 0.060	Medium	2	
		Below 0.030	Low	1	
6	Groundwater level (Meter from mean sea level)	Above 300	High	3	11
		275 to 300	Medium	2	
		Below 275	Low	1	
7	Geology	Alluvium	High	3	14
		Granite gneiss	Medium	2	
		Mica schist	Low	1	

		Amphibolite	Very low	1	
8	Land use/land cover	Water bodies	High	3	13
		Agricultural land	Medium	2	
		Vegetation	Low	1	
		Built-up	Very low	1	

7. Conclusion

Geographical information systems and remote sensing techniques are powerful methods for determining the water resource potentiality in the Karu River basin of Purulia district, West Bengal. This basin reveals that the integration of eight thematic maps, such as drainage frequency, drainage density, average slope, soil, surface water bodies, groundwater level, geology and land use/land cover, gives first-hand information to local authorities and planners about the area suitable for water resource exploration. The given study area is classified into excellent, very good, good, poor and very poor water potential zones, which have been indicated in Figure 12. As per Table 9 and table 10, the study area reveals that the area has low drainage frequency (below 1 stream per sq. km.), low drainage density (below 1 km stream length per sq. km.), high slope (above 400), fine loamy coarse loamy and gravelly loam loam soil, low surface water bodies (below 0.030 sq. km. per sq. km.), below 275 meter groundwater level from mean sea level, the area under granite gneiss and amphibolites, and area covered with vegetation and bare rock/soil is observed as very poor water potential zone, and it covers an area of 27.53 per cent of the study area. Poor water potential zone in the study area is seen that the area of medium drainage frequency (1 to 2 streams per sq. km.), medium drainage density (1 to 2 streams length per sq. km), moderate slope (200 to 400), fine loam and fine texture soil, the area under below 0.060 sq. km. surface water bodies per sq. km., area of 275 meter to 300 meter groundwater level from mean sea level, the area under alluvium and granite gneiss rock and area covered with vegetation and bare rock/soil is observed as poor water potential water zone and it covers an area of 16.87 per cent of the study area. The area has medium drainage frequency (1 to 2 streams per sq. km.), medium drainage density (1 to 2 streams length per sq. km.), moderate slope (200 to 400), fine loam and fine texture soil, low surface water bodies (below 0.030 sq. km per sq. km), above 275 meter groundwater level from mean sea level, granite gneiss rock and area covered with agricultural land and scatter vegetation is observed as good water potential zone, and it covers an area of 25.27 per cent of the study area. A very good water potential zone is seen in the area where medium drainage frequency (1 to 2 streams per sq. km.), medium drainage density (1 to 2 km. stream length per sq. km.), moderate slope (200 to 400), fine texture and fine loam soil, the area under below 0.060 sq. km. surface water bodies per sq. km., area of above 275 meter groundwater level from mean sea level, area of alluvium soil and area covered with agricultural land is observed as very good water potential zone and it covers an area of 23.85 per cent of the study area. Excellent water potential zone reveals that the area of high drainage frequency (above 3 streams per sq. km.), area of high drainage density (above 3 km. length per sq. km.), below 200 slope area, area of fine texture and fine loam soil, above 0.030 sq. km. surface water bodies per sq. km., the area under above 300-meter groundwater level from mean sea level, area under granite gneiss rock and area covered with agricultural land and water bodies is observed as excellent water potential zone and it covers an area of 6.48 per cent of the study area. Water resource potential information will help the local people or planners in the effective identification of suitable locations for the extraction of water. The present methodology of this paper will be used fully by the researcher as a guideline for further research.

TABLE 10

WATER RESOURCE POTENTIAL CATEGORIES

Sl. No.	Water resource potential zone	Area covered (sq. km)	Area covered (%)
1	Very Poor	32.49	27.53
2	Poor	19.91	16.87

3	Good	29.82	25.27
4	Very Good	28.14	23.85
5	Excellent	7.64	6.48

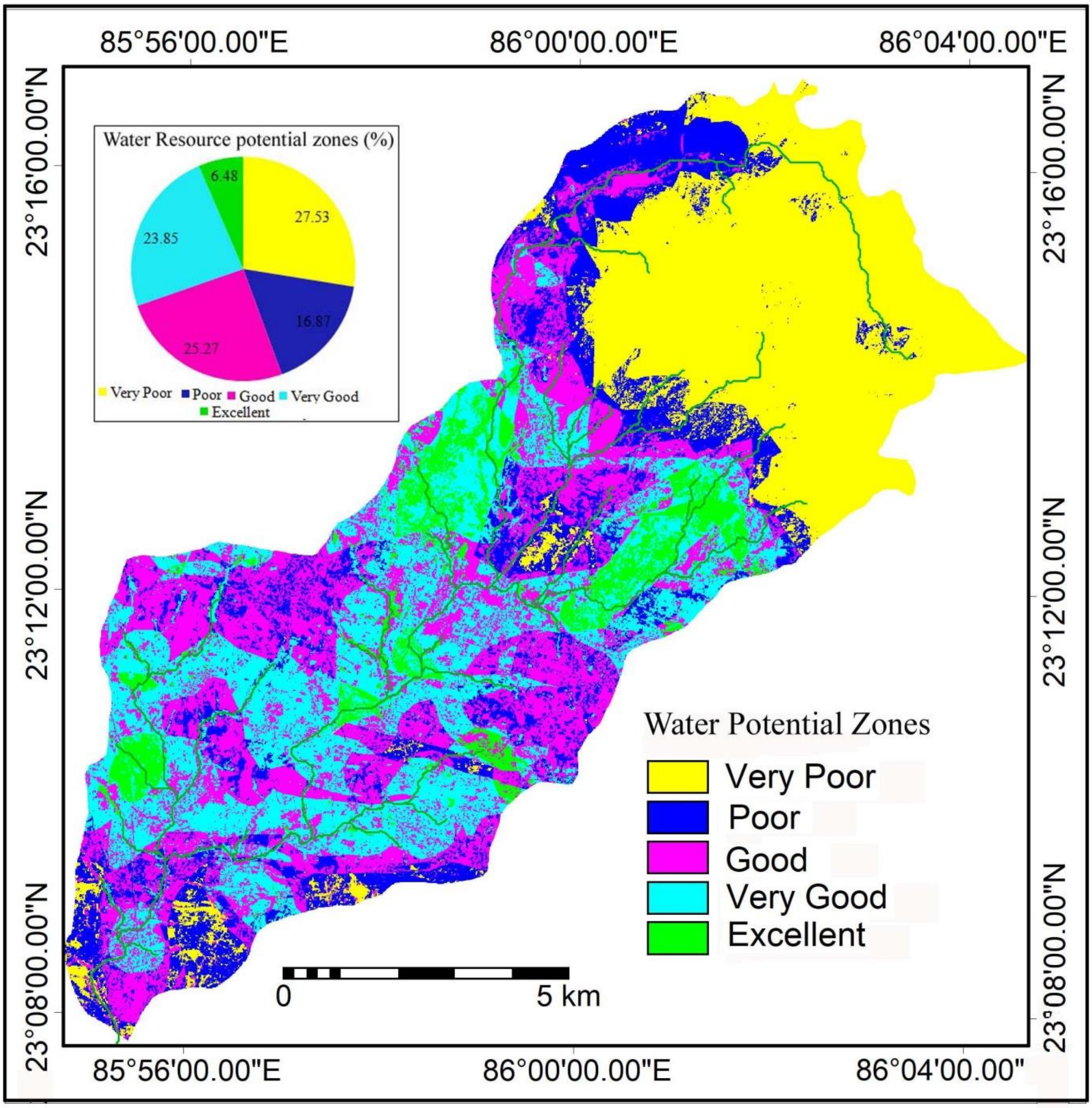

Fig. 12 Water resource potential Zones Map of Karu River Basin

Acknowledgement

The author expresses his gratefulness to Dr. A. Gope, Associate Professor in Geography, Vivekananda Mahavidyalaya, Burdwan, West Bengal, India, for constant valuable guidance, encouragement and support for completing research work.

Reference

[1] B. Murugesan, R. Thirunavukkarasu, and G. Balasubramanian. “Application of Remote Sensing and GIS Analysis for Groundwater Potential Zone in Kodaikanal Taluka, South India.” Earth Science 7.1 (2012): 65-75.

[2] A. K. Bhattacharya, and P. K. Srivastava. “Delineation of Groundwater Targeting in a Hard Rock Terrain using Fracture Pattern Modeling, Niva River Basin, Andhra Pradesh.” Hydrology Journal 8.5 (2000): 494-502.

[3] K. R. Preeja, S. Joseph, J. Thomas, and H. Vijith. “Identification of Groundwater Potential Zones of a Tropical River Basin using Remote Sensing and GIS Techniques, Kerala, India.” J Indian Soc 39.1 (2011): 83-94.

[4] H. Yeh, C. H. Lee, K. C. Hsu, and P. H. Chang. “GIS for Assessment of the Groundwater Recharge Potential Zone.” Environ Geol, 58 (2008): 185-195.

[5] A. K. Das, and S. Mukherjee. “Drainage Morphometry using Satellite Data and GIS in Raigad District, Maharastra, India.” J Geol Soc 65 (2005): 577-586.

[6] P. Singh, A. Gupta, M. Singh. “Hydrology Inferences from Watershed Analysis for Water Resource Management using Remote Sensing and GIS Techniques.” EJRS, Elsevier 17 (2014): 111-121.

[7] A. N. Strahler. “Quantitative Slope Analysis.” Geological Society of America Bulletin 67.5 (1956): 571-596.

[8] I. A. Abboud, and R. A. Nofal. “Morphometric Analysis of Wadi Khumal Basin, Western Coast of Saudi Arabia, using Remote Sensing and GIS Techniques.” Journal of African Earth Sciences 126 (2017): 58-74.

[9] D. N. Vinutha, and M. R. Janardhana. “Morphometry of the Payaswini Watershed, Coorg District, Karnataka, India, using Remote Sensing and GIS Techniques.” International Journal of Innovative Research in Science, Engineering and Technology 3.5 (2014): 516-524.

[10] A. N. Strahler. “Quantitative Slope Analysis.” Geological Society of America Bulletin 67.5 (1956): 571-596.

[11] I. S. Evans. “General Geomorphometry, Derivatives of Altitude and Descriptive Statistics (1st ed.).” (R. J. Chorley, Ed.) London: Routledge (1972).

[12] F. Thomas, D. Franzen, and L. Cihacek. “Soil, Water and Plant Characteristics Important to Irrigation.” North Dakota: North Dakota State University (1996).

[13] Department of Environment and Natural Resources. Yaman: Northern Teritory Government of Australia (1992).

[14] A. Augustyan, P. Baueq, and B. Duignam. “Encyclopedia Britannica.” (1970).

[15] “Groundwater Overview Making the Invisible Visible.” International Groundwater Assessment Centre (IGRAC). UNESCO. (2018).

[16] R. Defries, and N. K. Eshleman. “Land-use Change and Hydrologic Processes: A Major Focus for the Future.” Hydrological Processes 18.18 (2004): 2183-2186 (CrossRef).

[17] J. Krishnamurthy, K. N. Venkatesa, V. Jayaraman, and M. Manivel. “Approach to Demarcate Groundwater Potential Zones through Remote Sensing and Geographic Information System.” International Journal of Remote Sensing 17.10 (1996): 1867-1884.

[18] L. C. King. “The Study of Worlds Plain Lands: A New Approach in Geomorphology.” Quarterly Journal of Geological Society of London 106 (1950): 101-103.