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IDENTIFICATION AND MAPPING OF GROUNDWATER POTENTIAL ZONE USING ANALYTICAL HIERARCHY PROCESS AND GIS IN LOWER KHARUN BASIN, CHHATTISGARH, INDIA

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ABSTRACT

GIS-remotely sensed data integration has advanced groundwater research. This integration provides a powerful tool for evaluating and prioritizing groundwater supplies. This research uses similar methods to map prospective zones for groundwater availability calculations in the lower Kharun basin. GIS layers were generated for data interpretation, analysis, and satellite picture conversion. The methods created geology, geomorphology, soil, land use, rainfall, lineament, slope, ground water depth, and drainage density layers. The MIF technique, which considers many factors, scores and weights the raster maps of these components to evaluate the data. To find high-potential groundwater locations, a statistical technique is performed on each thematic weighted layer. Four grades, extremely poor, poor, good, and very good, were detected in the groundwater potential zones. The study's groundwater potential zones improve groundwater resource planning and management.

This study examines the Lower Kharun Watershed in central Chhattisgarh. The area's groundwater potential was identified using GIS and AHP (analytical hierarchical process) methods, which yielded accurate results. Potential zones emerge after sorting and weighting layers. The outcome is evaluated using CGWB drill yield data, and a groundwater potential map is created in GIS.

Keywords: AHP, Groundwater Potential Zone, GIS, Remote Sensing, Groundwater, Kharun

INTRODUCTION

Groundwater, which is stored in the crust of the Earth, is considered to be among the most valuable and significant natural resources present on Earth (Meroni et al., 2021;). It is one of the primary sources of water for residential, commercial, industrial, agricultural, and other uses (Ayazi et al., 2010; Manap et al., 2013; Nampak et al., 2014 and Arulbalaji et al., 2019; Melese and Belay, 2021). Other primary sources of water include lakes, rivers, and groundwater (Ayazi et al., 2010; Manap et al., 2013; Hountondji et al., 2020). The ever-increasing demand for water to satisfy human requirements and facilitate development has put a significant strain on this limited supply of freshwater resources. Groundwater is a natural occurrence, and its distribution can be influenced by a wide range of both natural and anthropogenic variables (Arulbalaji et al., 2019; Chaudhari et al.,2021; 2015; Mehta et al.,2018; Mukherjee et al, 1996; Saraf et al, 1998 and Surati et al., 2022). There appears to be a widespread problem with groundwater quality throughout the bulk of India's emerging regions, which are characterized by high population densities and developed economies. Because surface water is not reliably available throughout the year in a nation such as India that is considered to be semiarid for a variety of reasons, residents in such locations rely on groundwater as their primary supply of water to satisfy their requirements (Melese and Belay, 2021).

A computer-based system called a geographic information system (GIS) is used to gather, store, modify, analyze, and present geographic data to address a variety of challenging environmental issues (Cowen, 1988; Jaiswal and Jhariya, 2020; Jaiswal and Jhariya, 2021; Melese and Belay, 2021; Shukla et al., 2021; Verma et al., 2021; Verma et al., 2022). Recently, the use of GIS has been beneficial in identifying prospective groundwater occurrence regions in a cost-efficient way. Groundwater investigation and identifying prospective locations in a given study area are both greatly facilitated by GIS. It has become simpler to supply baseline data for designating groundwater potential zones because of the extensive usage of remote sensing satellite pictures and ground truth data. According to published works, some researchers have used methods such as machine learning and analytical hierarchy process (AHP) with GIS to investigate groundwater potential zones (Jhariya et al., 2016; Saranya and Saravanan., 2020 and Melese and Belay, 2021). The complexity of hydrogeological data is reduced in a number of ways by using remotely sensed data along with GIS technologies (Chaudhari et al., 2022; Halder et al., 2020; Melese and Belay, 2021; Patel et al., 2022 and Shukla et al., 2021).

The mapping of areas with groundwater potential has grown simpler because of the contributions made by remote sensing (RS) and geographic information system (GIS) techniques (Jhariya et al., 2016; Chaudhary and Kumar, 2018; Soro et al., 2020; Gowthaman et al., 2022; Jaiswal et al., 2022). Utilizing remote sensing and geographic information system (RS and GIS) techniques, the current study is being carried out with the goal of determining the potential zones for groundwater. The porosity of a geologically created structure is the primary determinant of both the presence of groundwater and the ways in which it may be used. A region with a more prominent and steep slope will experience a greater volume of runoff, whereas a region with a more prominent and low topography would experience enhanced infiltration (Bagyaraj et al. 2013; Jaiswal et al., 2022; Mangukiya et al., 2022 and Chaudhari et al.,2021). After completing the preparation of thematic layers, the AHP technique was used for matrix preparation, and finally, weighted sum calculation was performed using the normalized weight attained from the matrix. A potential zone map for groundwater was created for the lower Kharun watershed. (Dhiwar et al., 2022; Ganapuram et al., 2009; Murugesan et al., 2013; Suganthi et al., 2013).

DESCRIPTION OF THE STUDY AREA

The longitudinal and latitudinal extent for Lower Kharun lies between 80° 56' 27.6", 82° 22' 22.8"E and 21° 0' 14.4" and 21° 35' 45.6" N, respectively, which primarily covers the majority of the Raipur district and a small part of the Durg and Bemetara districts. A total geographic area of 2541.52 km^2 is covered by the catchment shown in Fig. 1.

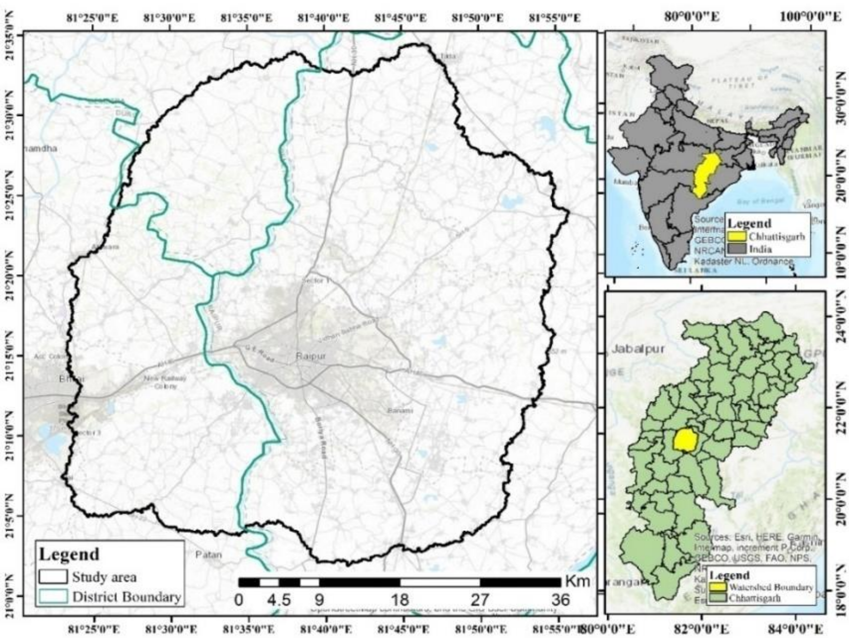

Figure 1: Location of Study Area

Basin comes under the Chhattisgarh's plain area and experiences three distinct seasons: summer (middle of February to middle of June), which are very hot when temperatures reach over 46°C in the hottest month of May, monsoon (middle of June to middle of October) with average annual rainfall in the catchments of approximately 1200 mm, and mild winter (middle of October to middle of February) with the lowest recorded temperature coming in January at 9°C., which contributes together in making the climate a tropical dry to humid one (Kumar, 2014). The southwesterly winds are the driving force behind the monsoon, and the heaviest rains of the season often fall in July and August. The long-term rainfall records for the Kharun Basin show that the five months of June through October account for approximately 90% of the annual precipitation. Droughts occur on a smaller scale every three to four years (Sahu, 2012).

METHODS AND MATERIALS

To identify prospective groundwater sites within the study watershed, this research gathered and utilized a wide variety of data from a variety of sources to achieve its goal. Shuttle Radar Topography Mission (SRTM) data with a spatial resolution of 30 m elevation were obtained and used in conjunction with the ArcGIS tool to produce a slope and drainage density map. Remote sensing satellite photos and the data that correlate to them have been collected for the goal of building the thematic layers that make up the study watershed. These images will be used to create a model of the watershed. These thematic layers consist of geology, lulc, rainfall, slope, soil, curvature, drainage density, and lineament density. They were produced by utilizing the WMS layer that was taken by Bhuvan. For the rainfall data, IMD data were used, and groundwater level data were obtained from IWRIS. Table 1 contains an inventory of all the information that was consulted.

The multicriteria evaluation method was implemented throughout each of the topic tiers. After superimposing all of the theme layers using the weighted overlay approach, we were able to determine the prospective zones where groundwater exists. A study using a weighted overlay index was carried out so that a rank could be assigned to each parameter of each theme layer.

To determine the weight that should be assigned to each theme layer, the analytical hierarchy process (AHP) method was used. Then, a weighted overlay analysis was performed on these thematic layers, and the final map that was produced was obtained and categorized according to the groundwater potential index that had been calculated. The adopted methodology used for the completion of work is discussed in Fig. 2.

Table 1: Data used

S. No	Data Used	Tile/Pathand Row No./Address	Source
	SOI Toposheet	64G/6, 64G/7, 64G/8, 64G/10, 64G/11, 64G/12, 64G/14, 64G/15, 64G/16	Survey of India Website
1	Landsat-8	LC08_L1TP_142045_20210421_20210421_01_RT	https://earthexplorer.usgs.gov/
2	SRTM 1 Arc-Second 3 Global	n20_e081_1arc_v3	https://earthexplorer.usgs.gov/
3	Geology	Vector data available on website	https://bhukosh.gsi.gov.in/
4	Geomorphology	Vector data available on website	https://bhukosh.gsi.gov.in/
5	Groundwater Level	Field Data	Data collected from field for 2021
6	Lineament	WMS Layer	http://bhuvan-noeda.nrsc.gov.in/gis/thematic/index.php
7	Rainfall	Average Annual Rainfall	India Meteorological Department
8	Soil	Prepared from NBSS Soil Map	NBSSLUP-Nagpur

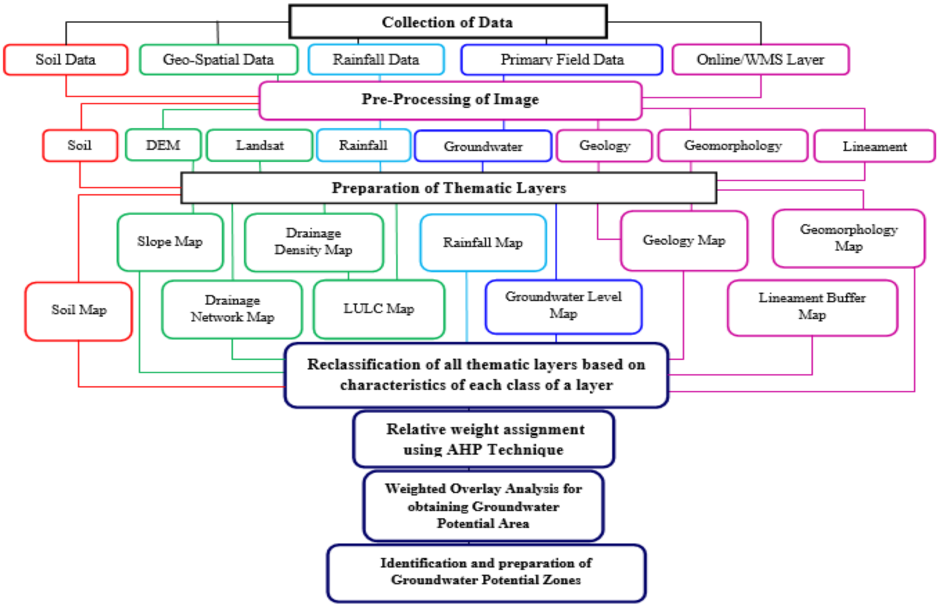

Figure 2: Workflow for the present study

AHP process used for weightage assignment

The AHP approach was first introduced by Saaty in 1980 and was used to standardize weights based on experience and expert choice. It is said that this normalization process will lessen the bias in the way the weights are given to the thematic layers. Then, these weights are checked to ensure that they are all the same, as shown by (Saaty, 1980; Malczewski, 1999). The AHP is a definitive way to make decisions that take into account an overview of the real-world data based on relative parameters. All the factors with their relative importance were created with parameters along with their relative priorities (Indhulekha and Jhariya, 2020; Sarvanan et al., 2021). The data are gathered, identified, and weighed to determine how important they are so that they can be used to make decisions. The decisions are made by putting the comparison matrix in a way that each shows an influence over the other and vice versa. The matrix for comparing the parameters was created by arranging the influencing factors in rows and columns in the same order and then evaluating each one on a scale from 1 to 9 based on how much it affected the decision (Saaty and Sodenkamp, 2008). The relative impact of the classes within each component on the groundwater potential is considered when comparing them.

Steps involved in AHP

The process begins with the selection of all of the parameters that will eventually be used for decision making. In the following steps, each of these parameters will be maintained on the same scale to facilitate comparisons. On a scale that ranges from 1 to 9, Saaty (1980) assigned a point value to indicate how significant each component was. A score of 1 indicates that both criteria are of equal value, whereas a score of 9 indicates that the more important criterion is of utmost significance (Table 2). In the second phase, which consists of finding the average weights of each factor by making use of the data obtained from the preceding step, the normalized matrix is utilized. This phase determines the average weights of each factor. The consistency index (CI) of the Eigen matrix is calculated in the third phase. This index is specified in equation 1, and its calculation is based on the highest or principal index value of the matrix in addition to the matrix's order (Sarvanan et al., 2021; Ying et al., 2007):

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{1}$$

where *CI* is the consistency index, λmax is the eigen value and '*n*' represents the number of factors considered for the criteria.

Table 2: 1-9 scale for Relative Importance given by Satty (1980)

S No.	Details of Relative Importance
1	With Equal importance
2	Slightly Important
3	Moderately Important
4	More than Moderately Important
5	Strong Importance
6	Stronger Importance
7	Very Strongly importance
8	Very, very strong importance
9	Extremely Importance

As per the literature, the consistency matrix will be considered correct only if the consistency ratio (CR) is less than 10%, which will be calculated using Eq. (2) given below (Indhulekha and Jhariya., 2020; Sarvanan et al., 2021):

$$CR = \frac{CI}{RI} \tag{2}$$

where *RI* is the random index (Table 3) defined by the number of considered factors '*n*'.

Table 3: Random index for different matrix sizes

Size of Matrix (*n*)	1	2	3	4	5	6	7	8	9	10
Random Index (*RI*)	0	0	0.58	0.89	1.12	1.24	1.32	1.41	1.45	1.49

Overall, 9 factors were taken that were considered to have an influence on the groundwater potential (GWP), which were used to establish the comparison matrix given in Table 4, priority vector and normalized vector (Table 5), which was calculated after preparing the 1x9 matrix, and taking the λ_{max} average value of 9.69 from them, which was calculated using the following equation:

$$\lambda_{max} = \frac{9.91 + 9.89 + 9.67 + 9.61 + 9.69 + 9.62 + 9.55 + 9.45 + 9.33}{9} \tag{3}$$

Table 4: Matrix used for comparison of nine influencing factors

	Geology	Soil	Rainfall	Water level	Geomorphology	Lineament	Drain Density	Slope	LULC
Geology	**1**	1.52	4.76	4.55	1.89	4	8.33	4.35	2.38
Soil	0.66	**1**	3.03	2.86	1.23	2.38	3.7	3.13	1.54
Rainfall	0.21	0.33	**1**	1.82	1.14	1.54	2.27	1.69	3.23
Water level	0.22	0.35	0.55	**1**	1.14	1.28	2.78	1.39	1.49
Geomorphology	0.53	0.81	0.88	0.88	**1**	2.63	2.22	1.64	1.82
Lineament	0.25	0.42	0.65	0.78	0.38	**1**	2	3.85	2.38
Drain Density	0.12	0.27	0.44	0.36	0.45	0.5	**1**	1.02	1.33
Slope	0.23	0.32	0.59	0.72	0.61	0.26	0.98	**1**	1.89
LULC	0.42	0.65	0.31	0.67	0.55	0.42	0.75	0.53	**1**
SUM	**3.64**	**5.67**	**12.21**	**13.63**	**8.38**	**14.01**	**24.04**	**18.59**	**17.06**

Following the completion of the values and weights allocated to each subfactor and the addition of a substantial component, groundwater potential zones (GWPZs) were developed. The weights assigned to each subfactor were taken into account when reclassifying each thematic layer. After being reclassified, the resulting thematic layers underwent a weighted sum analysis to create a prospective zone using the matching normalized unique weight for each factor. In eq. 4 below, the weighted sum is calculated (Raju et al., 2017; Indhulekha and Jhariya., 2020; Sarvanan et al., 2021):

$$\sum i^{n}(DDw \text{ x } DDr) + (GGw \text{ x } GGr) + (GMw \text{ x } GMr) + (WLw \text{ x } WLr) + (LULCw \text{ x } LULCr) + (LBw \text{ x } LBr) + (RFw \text{ x } RFr)(SLw \text{ x } SLr) + (Sw \text{ x } Sr) \quad (4)$$

where '*w*' and '*r*' represent the weightage and rate of the influencing factors, respectively, while DD is the drainage density, *GG* is the geology, *GM* is the geomorphology, *WL* is the water level, *LULC* is the land use/land cover, *LB* is the lineament buffer, *RF* is rainfall, *SL* is the slope, and *S* is the soil.

Table 5: Relative Weight based on Priority

	Geology	Soil	Rainfall	Water level	Geomorphology	Lineament	Drain Density	Slope	LULC	Normalized Vector	Consistency Vector(λmax)
Geology	0.27	0.27	0.39	0.33	0.23	0.29	0.35	0.23	0.14	0.277	9.917
Soil	0.18	0.18	0.25	0.21	0.15	0.17	0.15	0.17	0.09	0.172	9.896
Rainfall	0.06	0.06	0.08	0.13	0.14	0.11	0.09	0.09	0.19	0.106	9.675
Water level	0.06	0.06	0.05	0.07	0.14	0.09	0.12	0.07	0.09	0.083	9.613
Geomorphology	0.15	0.14	0.07	0.06	0.12	0.19	0.09	0.09	0.11	0.113	9.698
Lineam ent	0.07	0.07	0.05	0.06	0.05	0.07	0.08	0.21	0.14	0.089	9.627
Drain Density	0.03	0.05	0.04	0.03	0.05	0.04	0.04	0.05	0.08	0.045	9.553
Slope	0.06	0.06	0.05	0.05	0.07	0.02	0.04	0.05	0.11	0.057	9.455
LULC	0.12	0.11	0.03	0.05	0.07	0.03	0.03	0.03	0.06	0.058	9.337

Table 6: Rank and weightage of layers for groundwater potential zonation

Thematic Layer	Sub-Classes	Weightage Rank	Normalized Weight
Geology	Shale	1	0.277
	Laterite	3	
	Stromatolitic Dolomitic Limestone	2	
	Stromatolitic Dolomitic Limestone with Sandstone	3	
	Argillaceous Stromatolitic Dolomitic Limestone	2	
	Ferruginous Sandstone	4	
	Shale With Sandstone	3	
Soil	Deep Black Soil	1	0.172
	Laterite Soil	3	
	Medium Black Soil	2	
Geomorphology	Waterbodies-Other	5	0.113
	Flood Plain	4	
	Alluvial Plain	4	
	Quarry and Mine Dump	2	
	Pediment Pedi plain Complex	3	
Landuse/land cover	Settlement and Road	1	0.058
	OpenLand	2	
	Cultivation	4	
	Vegetation	3	
	Waterbodies	5	
Rainfall (mm)	800-900	2	0.106
	900-1000	3	
	1000-1100	3	
	1100-1200	4	
	> 1200	4	
Lineament Buffer Zone (mtr.)	0-50	5	0.089
	50-100	4	
	100-200	3	
	200-300	2	
	> 300-400	1	
Slope (%)	0-3	5	0.057
	03-May	4	
	05-Jul	3	
	07-Oct	2	
	> 10	1	
Drain Density (km/Km^2)	Low	5	0.045
	Low-Medium	4	
	Medium	3	
	Medium -High	2	

Groundwater Level (mtr.)	High	1	**0.083**
	Shallow	5	
	Shallow-Medium	4	
	Medium	3	
	Medium-Deep	2	
	Deep	1	

RESULTS AND DISCUSSION

The use of both geographic information systems (GIS) and remote sensing in association with GIS has been shown to be an extremely helpful method for estimating the groundwater potential zone. This approach not only saves time and effort but also generates results that are accurate and dependable. In addition, it helps save time and effort. This investigation was carried out using a GIS platform, and it entailed the creation of nine separate theme layers. These layers included LULC, geology, geomorphology, lineament, drainage density, soil, and data concerning rainfall and groundwater levels. These layers were produced using either primary or secondary data that were gathered from a wide number of different sources. These thematic layers served as the foundation for outlining the groundwater potential zones within the watershed.

Drainage Density

The drainage density of a particular watershed can be defined as the ratio of the total length of all rivers and streams that flow into a drainage basin to the overall area of the drainage basin. This ratio is expressed as a percentage. One conclusion that can be drawn from this is that it refers to the combined length of all the rivers and streams that fall into a particular drainage basin. The drainage density of a region is one of the primary characteristics that plays a key role in defining the location of groundwater potential zones. This density can be measured in terms of the number of drains per square kilometer.

After successful delineation of the basin, drainage was extracted from the DEM (Digital Elevation Model) using the Arc Hydro tool from the spatial analyst in ARC MAP (Manmi et al., 2016); thereafter, the density for those drains was calculated using the line density tool in ArcGIS. For the present study, the stream data were created by using SRTM-DEM, which was downloaded from https://earthexplorer.usgs.gov/. After that, the stream drainage density is then divided into five classes as follows: very low, low, medium, high, and very high (Fig. 3). This classification is then reclassified by giving a greater weight to regions with a lower drainage density and a lesser weight to regions with a higher drainage density, as it was assumed that the infiltration rate will be more at places with lower drain density (Jhariya et al., 2016 and Jaiswal et al., 2022).

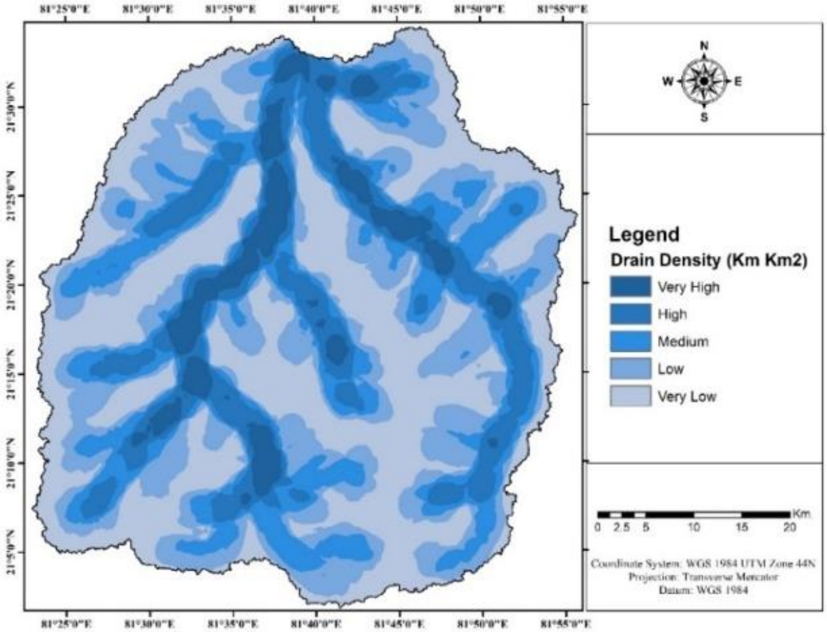

Figure 3: Drainage Density for the Lower Kharun Catchment

Geology

The geology of any given location has a significant impact on both the occurrence of groundwater and its dispersion (Jhariya et al., 2016). According to the information provided by the Geological Survey of India, the entire geology has been categorized into six different types (Fig. 4). Of this area, more than 76% is covered with Stromatolitic Dolomite with Limestone, second is Shale with approximately 371.60 km^2, which is 14% of the total area, Stromatolitic dolomitic limestone with sandstone in an area of 142.36 km^2 with 5% of area cover, and the rest of the area is covered by four types, namely, Ferruginous sandstone in 44.771 km^2, laterite in 25.175 km^2, Argillaceous stromatolitic dolomitic limestone and shale with sandstone in only 1.5 and 0.62 km^2, respectively.

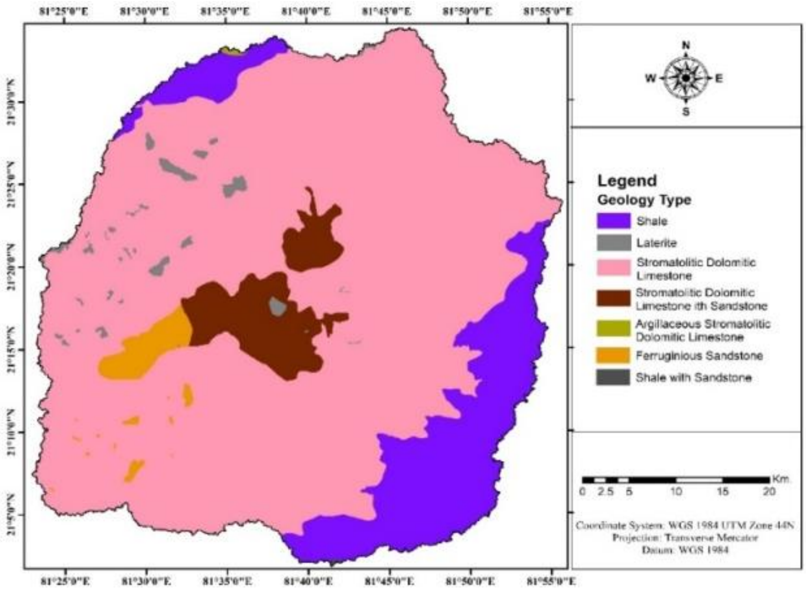

Figure 4: Geology for Lower Kharun Catchment

Geomorphology

The study of the structure of the Earth, which encompasses the examination of a wide range of landforms and features, is referred to as geomorphology. The geomorphology of any given area is entirely dependent on the process that led to its formation, and as a result, it has a significant impact on the amount of groundwater that is available. Overall, five geomorphic structure types have been found in the area (Fig. 5), and the Pediment Pedi plain complex is the dominant type, covering the maximum portion of 2398 km^2 of the study area. Ponds and waterbodies are kept in the waterbodies, which constitute an area of approximately 75.73 km^2. Active flood plain areas cover over 45.20 km^2. Alluvial plains cover 18.27 km^2 of the area, while only 8.34 km^2 is occupied by quarries and mine dumps. Hence, according to the characteristics of these classes, a weightage value was assigned to each class on the basis of its influence on groundwater potential.

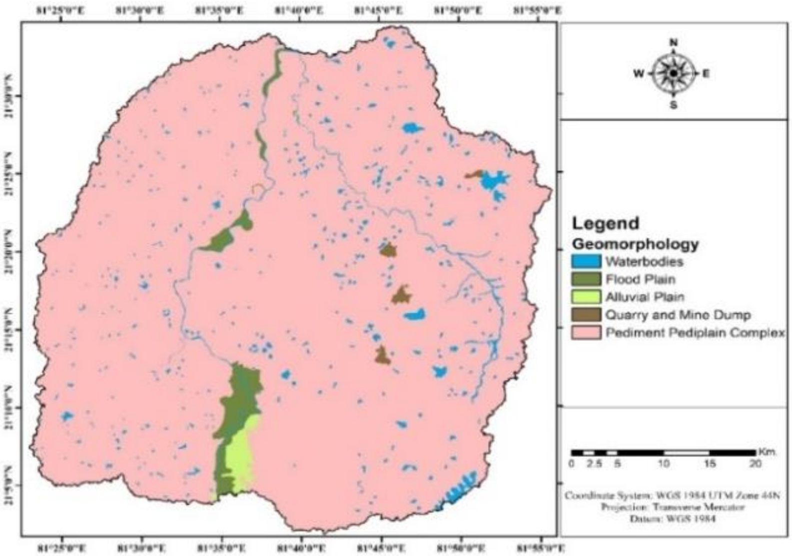

Figure 5: Geomorphology of the lower Kharun catchment

Groundwater Depth

The groundwater level for the area under research was collected for over 200 wells over the area, and groundwater depth maps were created utilizing the method of interpolation under GIS software across the study region. The study area had a groundwater depth that ranged from 1.5 to 20.0 mbgl. According to the variation in depth, it was classified into five classes, where the areas that had a water level lower than 5 and 7 were classified as having a deep to very deep water level, whereas the areas that had a water level between 1.5-5 mbgl were classified as having a moderate, shallow and very shallow water level (Fig. 6).

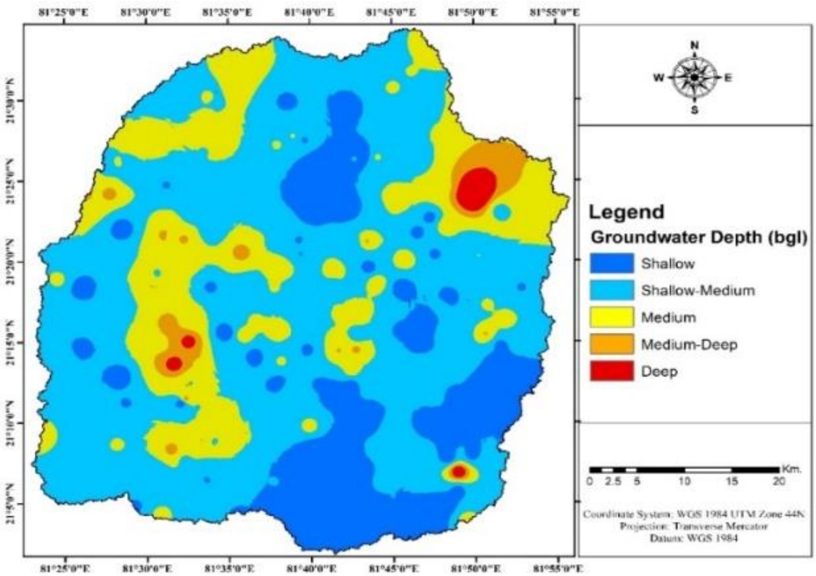

Figure 6: Groundwater Level for the Lower Kharun Catchment

Classification of land use and land cover (LULC)

Studies related to changing land use are among the major aspects that provide an estimate of the amount of groundwater that is needed and how it is used; in addition, these studies are an important indicator in the process of selecting sites for artificial groundwater recharge (Singh et al., 2011). In this study, Landsat-8 data are used for LULC classification. To achieve a high level of accuracy with the classification, Landsat data were visually identified and interpreted. On this basis, the LULC is primarily categorized into five classes, which are as follows: cultivation, which contributes the maximum part of the catchment, which is approximately 80% of the catchment; settlement, which occupies more than 10% of the total area; over open land, which covers approximately 5%; and waterbodies and vegetation, which covers approximately 4% in total. A map based on this classification is shown in Fig. 7. The LULC types are classed according to the amount of water that they are able to hold as well as the amount of runoff that they can support by a value between one and five, which was assigned to each of them (Table 3).

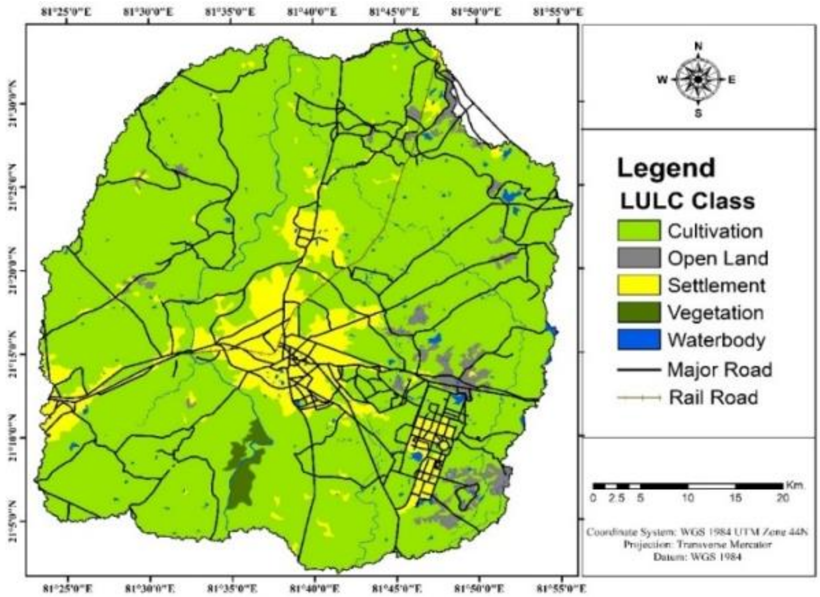

Figure 7: LULC Map for the Lower Kharun Catchment

Lineament Buffer

Lineaments are the linear features of a landscape that have their expression on the geological structure under which they reside; an example of this sort of feature is a fault. Lineaments can be distinguished from other types of features by their linear nature. Lineaments are often depicted as discontinuities found on the surface of the earth. Lineaments are formed by a variety of geological phenomena, such as faults and fractures. These geological elements are responsible for the production of lineaments. A lineament map for the region depicted in Fig. 8 was created for the area on the basis of a WMS layer that was obtained from the Bhuvan website. On the basis of derived information, lineament buffer maps were created, which indicated that buffer areas away from the lineaments have decreased potential for groundwater.

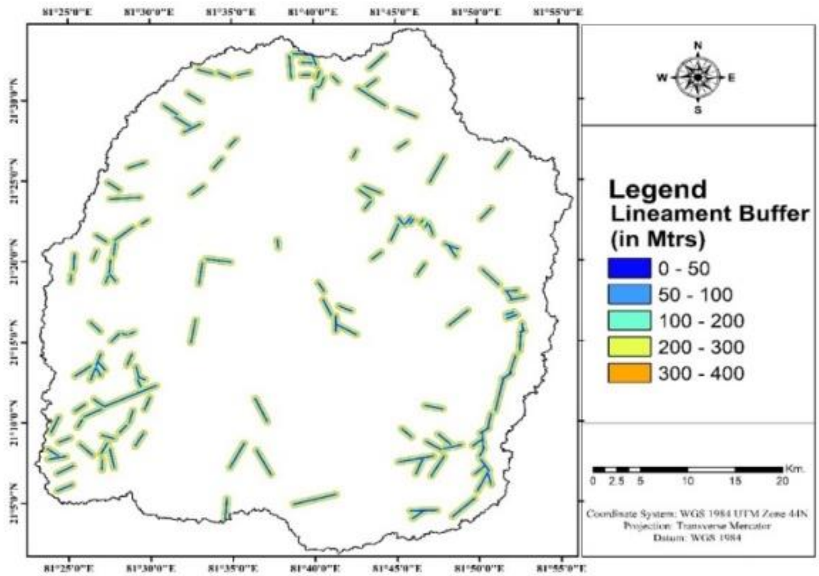

Figure 8: Lineament buffer map of the lower Kharun catchment

Rainfall Distribution

It is one of the most significant factors influencing the sources of groundwater, but the amount that falls at any given location is not constant; rather, it varies according to the differences in the environmental conditions that exist at each location. In addition, the amount of rainfall that falls at any given location not only varies with the environmental conditions of that location but also varies over time. Groundwater is dependent on rainfall in the sense that the likelihood of its occurrence is greater in locations that receive a high quantity of precipitation, whereas the availability of groundwater in areas that receive a smaller amount of precipitation is more likely to be limited.

For the purposes of this study, the annual average rainfall value that was acquired from rain gauge stations in the study area was found to range from 812 to 1279 mm for the area that was being researched. Next, the IDW method was utilized to interpolate this number to calculate the total amount of precipitation that was dispersed across the study region. After the process of interpolation has been finished, the geographical distribution for the rainfall map is generated by first classifying the region into five zones based on an interval of one hundred mm and then reclassifying the data to assign appropriate weightage to each category. This is done so that the map can accurately depict the distribution of rainfall across the region. (Fig. 9).

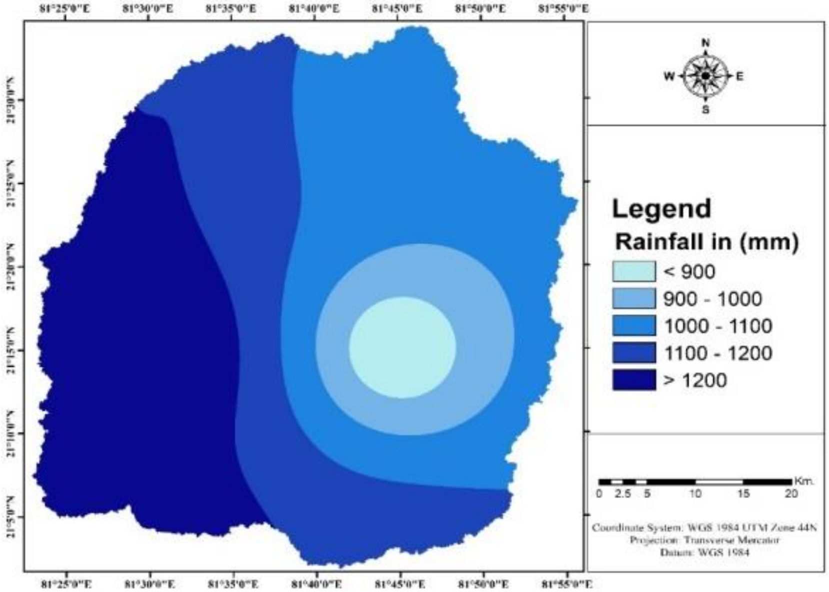

Figure 9: Distribution of rainfall in the lower Kharun catchment

Slope Analysis

The slope of a watershed is what determines its hydrological characteristics. This implies that if the slope angle is low, then there will be low hydraulic gradients, which will result in a high infiltration rate and low run-off. On the other hand, areas with a greater slope angle would have a low infiltration rate due to the increased speed of surface runoff. A watershed's hydrological features can be determined by the slope of the land within the catchment. Depending on the slope of the land, this water holding capacity could result in either a faster or a slower rate of groundwater recharge. For the purposes of this investigation, slope was evaluated based on the percentage rise, which was computed with the help of SRTM-DEM (1 Arc Second) data. Then, the inclination of the slope was used to determine how much weight should be given to each of the five categories created from the slope (as shown in Fig. 10). For instance, a region with a slope that was less steep was awarded a greater weightage value, whereas a region with a slope that was steeper was awarded a lower weightage value.

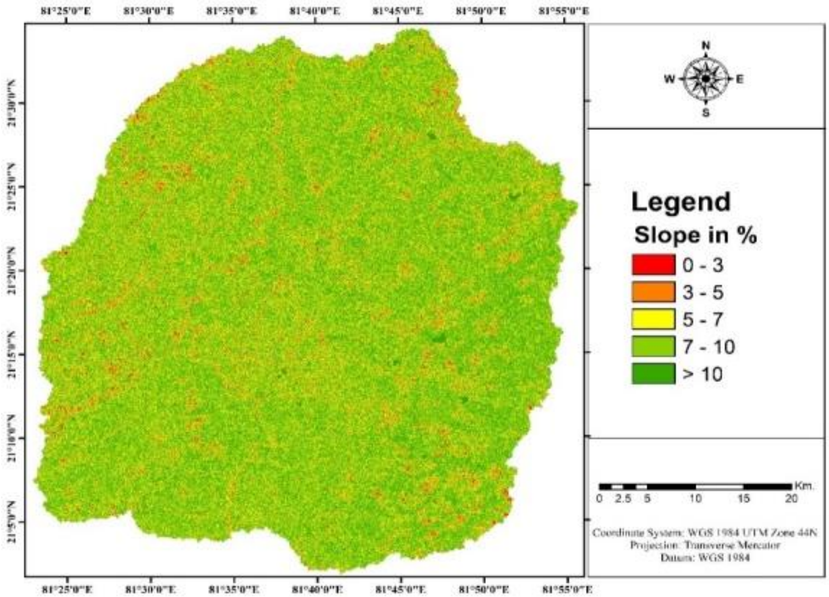

Figure 10: Slope map for the lower Kharun catchment

Soil

Since various types of soil have certain properties that are distinct from themselves and the rate of percolation is reliant on these characteristics, we can determine the water holding capacity as well as the infiltration rate of a particular soil type by studying the various factors that make up that soil type. In determining how much groundwater there is, the soil is one of the most crucial components. It is necessary to conduct research on the characteristics of the soil in any given location to arrive at an accurate estimate of the volume of groundwater that is present there. This is because the movement of groundwater and the infiltration of water into the ground depend on the porosity and permeability of the soil.

The NBSSLUP soil map served as the source for the data that served as the foundation for the soil categorization used in this study. The soil in the research region has been classified as one of three types: deep black soil, which covers the maximum portion of the area, laterite soil, and the rest of the area is occupied by medium black soil. These three types make up the soil classification given in Fig. 11. Because the infiltration rate of each of the three distinct kinds of soil differs in some way, weightage was applied to each of the categories in this study (Table 4).

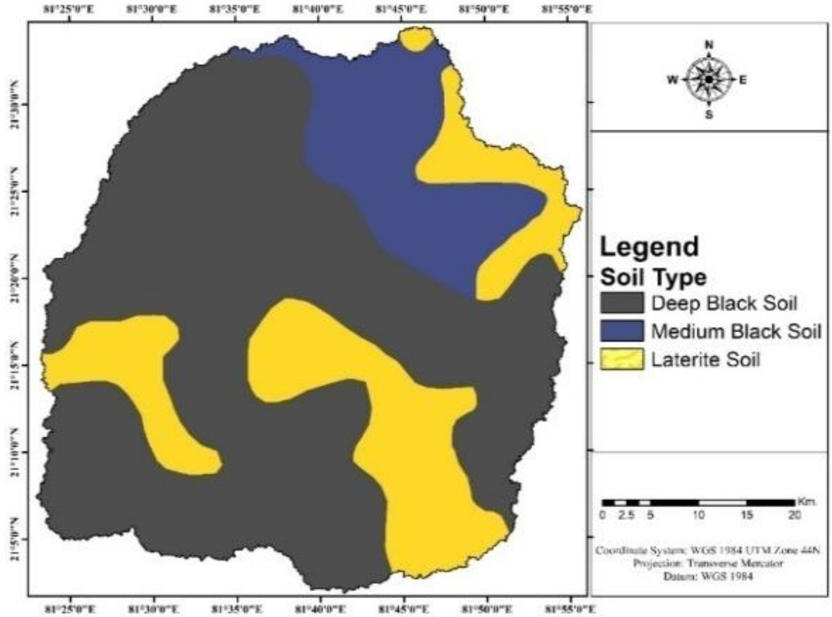

Figure 11: Soil Type of the Lower Kharun Catchment

Implication of Weighted Overlay Technique

The overlay technique is utilized by a number of other researchers, most prominently, generated for several thematic layers, which provide an ability to weight multilayers as that of the input by giving them weights to acquire an integrated analysis that is dependent on the inputs. The weighted sum technique is used within the GIS platform (Ramu et al., 2014, Jhariya et. al., 2016). As part of this inquiry, the weighted sum method was applied to each and every one of the thematic layers after each feature type contained within a particular thematic layer was given its own individual weightage (Table 5).

Groundwater Potential Zone Identification and Classification

A GWPZ map was constructed by applying a weightage ranking method to various thematic layers according to the significance played by each layer in groundwater potential zone mapping. This resulted in the creation of the GWPZ map. After this was complete, the map depicting the potential groundwater was segmented into the following five categories: extremely high, high, medium, and low. On the basis of an evaluation of the groundwater potential, a map was produced (Fig. 12), which led to the discovery that the distribution is, to a greater or lesser extent, a reflection of the drainage density, rainfall, slope, lineament, and soil patterns in addition to the geomorphic and geological features. Specifically, it was observed that the distribution is more or less a reflection of the distribution of the groundwater potential. In particular, it was noticed that the distribution is a reflection of the potential of the groundwater.

This examination concluded that the entire research region might be broken up into five distinct groundwater potential zones. The following percentages represent each zone: very low (7.98%), low (23.63%), medium (32.01%), high (26.60%), and very high (9.78%). A comparison was made between the derived output for the GPZ map (Fig. 12) that was developed using the aforementioned method and the bore well yield data that were taken from the CGWB yearly report for 2020-2021 to check the accuracy of the results.

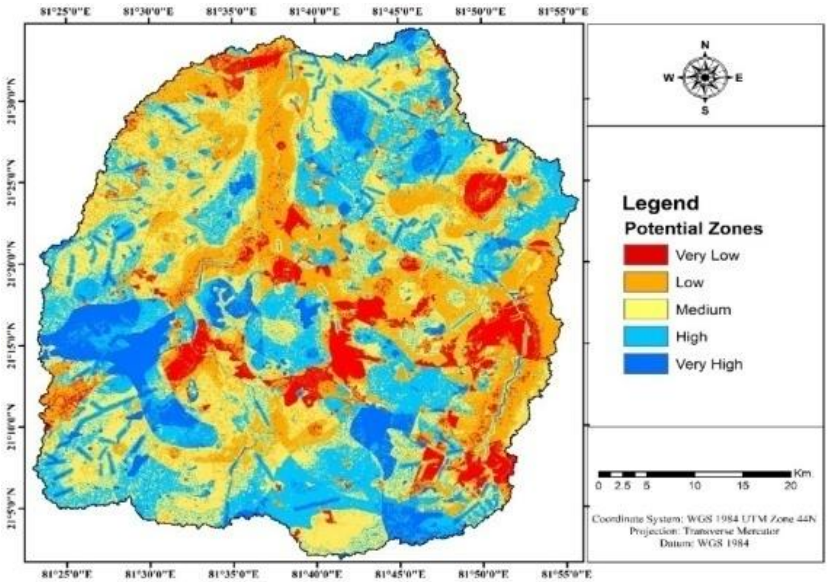

Figure 12: Groundwater Potential for the Lower Kharun Catchment

Borehole data used for validation

The discharge data from bore wells were collected from 950 various locations across the watershed, as shown in Fig. 13. This was done to evaluate the groundwater potential zones that were analyzed using remote sensing and GIS techniques. This was done so that data could be collected from various locations within the watershed (given in Table 6). The information on borehole yield that was used for the validation came from the report that was compiled by the CGWB. Based on the value of the borehole yield, this information was separated into three categories: regions with yield values of less than three lps have a low yield, regions with yield values between three and six lps have a medium yield, and regions with borehole yield values of more than six will have a high yield.

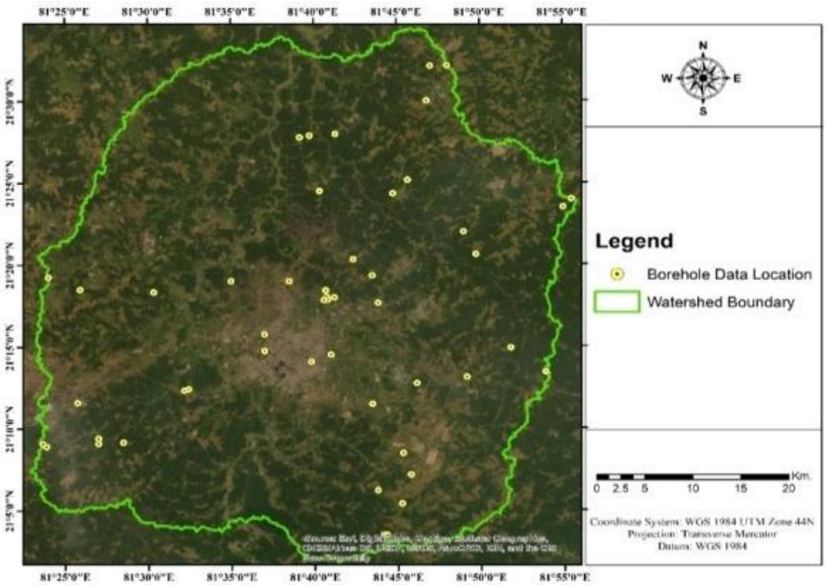

Figure 13: Borehole locations in the study area

In the process of studying the GWPZ, a success rate of 80% was certified as having been achieved. This is a result of the fact that out of a total of 50 bore well data, it was discovered that 39 matched the projected outcome. This indicates that the derived result, which was calculated using Eq. 5, is accurate to a degree of 78%. It lends credence to the idea that the methodology that was adopted for the groundwater potential zones was appropriate and accurate, and as a result, it is something that can be employed for future research:

$$\text{Overall accuracy} = 100 \times \frac{\text{No of mathed wells}}{\text{Total number of wells}} = 100 \times \frac{39}{50} = 78\% \qquad (5)$$

The final result is:

$$\text{Overall accuracy} = 100 \times \frac{39}{50} = 78\%$$

Table 7: Validation of Output with Borehole Yield Data

S.No	Location	Lat.	Long.	Discharge (lps)	Potential Zone	Agreement Results
1	Dundera-I	21.151	81.394	0.27	Low	Agree
2	Gorhi	21.321	81.4	0.5	Low	Not Agree
3	Purana	21.193	81.429	3	Low	Agree
4	Okhra	21.308	81.432	0.8	Low	Not Agree
5	Pachpedi	21.157	81.45	3.2	Medium	Agree

6	Pachpedi	21.157	81.45	3.3	Medium	Agree
7	Pahndore	21.152	81.45	4	Medium	Agree
8	Gabhara	21.153	81.475	0.5	Low	Not Agree
9	Kapasada	21.306	81.506	3.15	Medium	Agree
10	Pahanda	21.206	81.536	3	Low	Agree
11	Pahanda	21.207	81.54	0.5	Low	Not Agree
12	Urla	21.317	81.583	1.75	Low	Not Agree
13	Kota	21.263	81.617	2.1	Low	Agree
14	Shankarna gar	21.246	81.617	3.5	Medium	Agree
15	Rawabhata	21.317	81.642	0.2	Low	Agree
16	Pandarbha ta	21.463	81.653	0.5	Low	Agree
17	Pandarbhatta	21.465	81.662	1	Low	Not Agree
18	Shyamnaga r-II	21.235	81.664	3.5	Medium	Agree
19	Dharsiwa	21.408	81.672	1	Low19	Agree
20	RGI- I OW	21.297	81.676	0.24	Low20	Agree
21	RGI-IV EW	21.297	81.677	4.5	Medium	Agree
22	RGI -III EW	21.301	81.679	1	Low	Agree
23	Telibandha	21.242	81.683	10	High	Agree
24	RGI -II EW	21.3	81.687	0.5	Low	Agree
25	Sakri	21.322	81.725	1	Low	Agree
26	Mana	21.192	81.725	10	High	Agree
27	Kendri	21.104	81.73	0.8	Low	Agree
28	RGI	21.294	81.731	4.18	Medium	Not Agree
29	R.G.I- OW	21.294	81.731	0.24	Low	Agree
30	R.G.I.- 2	21.294	81.731	0.37	Low	Agree
31	R.G.I.- 3	21.294	81.731	0.37	Low	Agree
32	R.G.I. -1	21.294	81.731	1	Low	Agree
33	Baroda	21.294	81.731	2.83	Low	Agree
34	R.G.I.- 4	21.294	81.731	4.5	Medium	Agree
35	Baroda OW	21.294	81.731	8.9	High	Agree
36	RGI OW-V	21.294	81.731	9.86	High	Agree
37	RGI OW-IV	21.294	81.731	13.14	High	Agree
38	Abhanpur	21.058	81.736	3.1	Medium	Agree
39	Taresar	21.406	81.746	5	Medium	Agree
40	Tuta	21.142	81.755	1.2	Low	Agree
41	Tuta PZ III	21.419	81.761	0.9	Low	Agree
42	Uperwara	21.12	81.763	0.5	Low	Agree
43	Mandir Hasaud	21.213	81.769	0.8	Low	Agree
44	Tilda	21.535	81.784	2	Low	Agree
45	TulsiNeora	21.536	81.801	0.4	Low	Agree
46	Saragaon	21.367	81.817	1	Low	Not Agree
47	Adsena	21.344	81.829	1.5	Low	Not Agree
48	Seoni	21.249	81.864	0.5	Low	Agree
49	Nawagaon	21.392	81.917	10	High	Not Agree
50	Kharora	21.4	81.925	2	Low	Agree

CONCLUSION

On the basis of the above study, it is possible to draw the conclusion that RS and GIS techniques are an effective tool for analyzing groundwater potential zones as a result of the recent research that was carried out because it enables us to extract information using both visual and spatial analysis. The tool is combined with the analytical hierarchy technique so that the desired rankings and values for the layers can be obtained. The groundwater potential zones were obtained by overlaying all the thematic maps in terms of weighted overlay methods using the spatial analysis tool in GIS software, and it was found that approximately 7.97% of the area was in the high potential zone, 23.59% was in the high to medium potential range, 31.95% of the area was in the moderate potential zone, and 26.59 and 9.90% were in the medium to low and low potential zones, respectively. The application of geospatial techniques along with the integration of AHP for the delineation of the ground water potential zone is a practical approach to groundwater prospecting and can be used in a similar environment.

This conclusion was reached as a direct result of the findings that were gained from earlier investigations. Because these strategies allow us to obtain accurate results, they are suitable for application in locations where artificial recharge is either already present or must be introduced to ensure the continuous management of groundwater resources. This is because artificial recharge is either already present or must be introduced to ensure the continuous management of groundwater resources.

The fact that this result was obtained lends credence to the notion that the method that was described carries some degree of value and that it is possible to successfully implement it in a variety of contexts by making appropriate modifications to it. As a direct result, it is also possible to demonstrate that the study may be used by other researchers for the purpose of conducting studies that are comparable to these. This is because it is possible to establish that other researchers can use the study.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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