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Groundwater Potential Zone Mapping with An Integrated Approach of Ahp and Gis Techniques for Koraiyar Basin, Tiruchirappalli, Tamil Nadu, India

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Abstract

The overexploitation of groundwater resources and the obvious effects of climate change are putting the world's water supplies under tremendous strain. Evaluating groundwater potential and aquifer productivity is more critical than ever before due to the growing need for drinkable water for people, farms, and factories. Due to its speed and ability to give first-hand knowledge on the resource for future developments, GIS-based studies have lately become quite popular in groundwater research. The purpose of this research is, thus, to identify the groundwater potential. The present investigation made use of a GIS in tandem with the analytical hierarchical process (AHP) method. Lithospheric, geomorphological, land use/cover, lineament density, drainage density, rainfall, soil, and slope were the eight thematic layers that were produced and researched in order to define the groundwater potential zone. Each class in thematic maps is given a weight based on its attributes and water potential capacity, as estimated by the AHP technique. As a result, the groundwater potential zone map was categorized into five levels: very high, high, moderate, low, and very low. A medium groundwater potential zone spanning 180.28 km2 of the river basin was determined by the research. The low groundwater potential zone covers 140.44 km2 and the high groundwater potential zone 117.39 km2. Within the basin, there are 127.57 km2 of territory classified as having very low potential and 97.49 km2 as having very high potential.

Keywords: Ground Water Potential; Weighted Overlay; Remote Sensing; GIS

Introduction

Effective groundwater management is reliant on the availability and quality of groundwater, the most important natural water resource. The lithological properties and porosity of a geological formation have a significant impact on the presence and amount of groundwater (Ghorbani Nejad et al. 2017). Eventually, groundwater finds its way to bodies of water such as lakes, rivers, springs, and even the ocean (Manap et al. 2013). Consequently, its availability is limited, and finding potential groundwater zones is a big challenge in many parts of the globe. Geomorphological features, weathering, lineament density, porosity,

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drainage, land use/cover, rainfall, temperature, and evaporation are some of the elements that impact groundwater storage (Singh et al. 2011).

In hydrogeology, computer technology has been used for a long time. The use of GIS and remote sensing is commonplace in groundwater studies. Groundwater zones are commonly studied via remote sensing since it allows for large-scale monitoring of the earth's surface (Magesh et al. 2012). Ghayoumian et al. (2007) noted that GIS can effectively manage data in multiple thematic layers, including lithology, lineament density, drainage density, topography elevation, slope, geomorphology, and land use/land cover. These layers are all relevant when evaluating groundwater potential and can be integrated with enough precision.

Several researchers from different parts of the world have conducted groundwater investigations using different methods. These methods include models for frequency ratio (FR) and certainty factor (CF), multi influencing factor, weighted spatial probability, and remote sensing and GIS techniques (Jha et al. 2007; Prasad et al. 2008; Chowdhury et al. 2009; Saha et al. 2010; Machiwal et al. 2011; Mukherjee et al. 2012; Teixeira et al. 2013, 2014; Kumar et al. 2016; Ghorbani Nejad et al. 2017). In 2011, Elewa and Qaddah used weighted spatial probability modeling, GIS, watershed modeling system, Enhanced Thematic Mapper Plus (ETM+) imagery, and Egypt's Sinai Peninsula to locate areas with groundwater potential. With the use of GIS and remote sensing data, Ganapuram et al. (2009) were able to identify potential groundwater zones in the Musi basin. These zones included hydro geomorphological, geological, and structural features, as well as drainage, slope, land use/land cover, and groundwater prospect zones.

Integrating GIS with AHP is a powerful tool for analyzing several criteria simultaneously. In 1980, Saaty developed the AHP, a subjective method that lets users select the relative importance of criteria in a multi-criteria issue solution. When comparing criteria pairwise using the AHP approach, inconsistencies may arise at a certain level. According to Cheng (1997) and Chang et al. (2008), it is important to check the logical coherence of pairwise comparisons. According to Lee et al. (2013), the AHP is utilized to handle decision issues including hierarchical fuzzy multicriteria. Weight ratios are determined by the subjective opinions of experts (Tan et al. 2014). According to research by Kahraman et al. (2003) and Lee et al. (2013), the AHP approach uses the numbers instead of weight values to provide realistic and accurate results. To determine the GWPZ, this study considered eight variables: lineament density, lithology, soil, slope, geomorphology, rainfall, drainage density, land use/cover, and land use/land cover. The use of remote sensing allowed for the creation of maps depicting land use/cover, geomorphology, drainage, slope, and lineament. The AHP method was also used to find the importance ratings of the parameters that were used.

Study area

Research focused on Figure 1 shows the Koraiyar basin, which is located in the Tiruchirappalli district of Tamil Nadu. It is profitable and one of India's most important rice-producing regions. A considerable amount of farmland, including agriculture and fallow land, has been kept fallow permanently due to inadequate groundwater over the previous decade. Approximately 663 km2 make up the research area, which is located between 78°15 and 78°50 east longitude and 10°20 and 10°50 north latitude. Topographical maps 58J/06, 58J/07, 58J/09, 58J/10, and 58J/11 from the Survey of India show it at a scale of 1:50,000. This basin, located between 78 and 88 meters above mean sea level, is a headwater basin for a number of rivers that empty into the Bay of Bengal. The north-east monsoon season, which occurs mostly in November and December, accounts for the majority of the year's rainfall (650–919 mm).

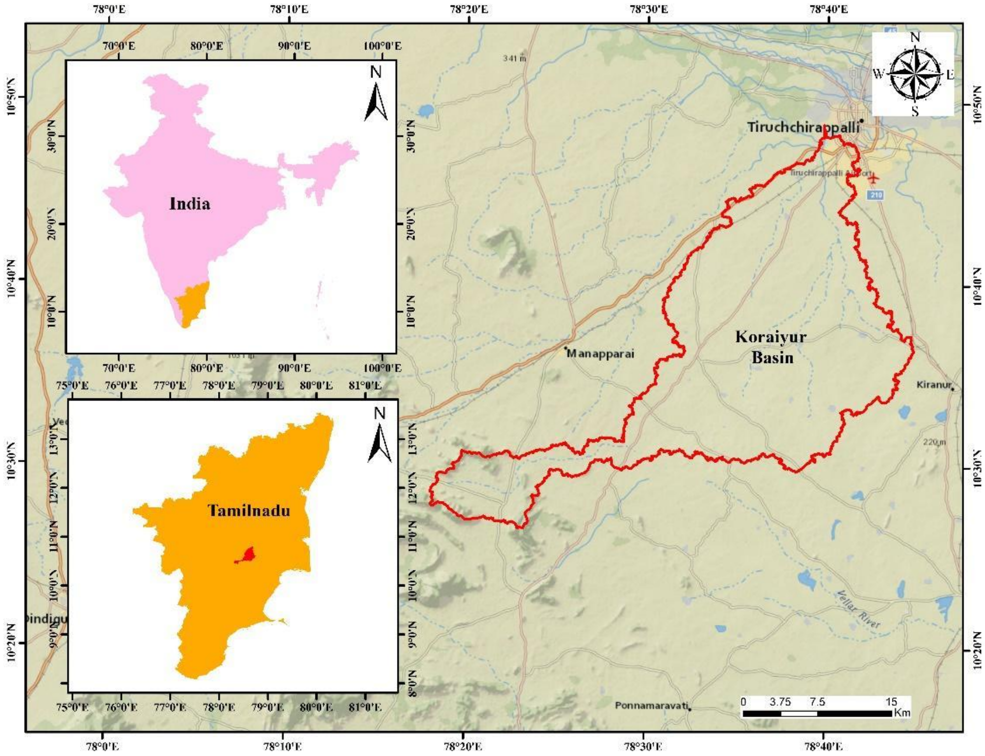

Fig 1. Study area location map

Materials and Methods

The groundwater potential zone (GWPZ) was defined using the following parameters: lithology, lineament density, drainage density, slope, soil, rainfall, and geomorphology. Groundwater potential was mapped using GIS, AHP, and remote sensing methods. The GSI (1:500,000 scale) lithology map of the research region has been meticulously prepared. The National Bureau of Soil Survey and Land Use Planning (NBSS&LUP-1: 500000 scale) created the geography of the soil. Methods for manually digitizing soil and lithology were employed in Arc GIS software. In order to prepare the drainage density and slope of the research region, the DEM data was obtained. In Arc GIS, the hydrology tool was used for drainage and the spatial analyst tool for slope. With the use of the same DEM data and Landsat 8 satellite images obtained from the Earth Explorer website, the lineament was produced using a manual digitization process. Using visual interpretation techniques, the landuse/land cover and geomorphology map was also generated using Landsat 8 OLI satellite images at a resolution of 30 meters. The Public Works Department (PWD) provided the rainfall data, and Arc GIS was used to map the point values using the interpolation approach. The used parameters were analyzed using the AHP approach, and their rating coefficients were derived. In addition, groundwater potential mapping was executed and the groundwater potential zone was evaluated using the parameter ratings and weights.

AHP and Groundwater Potential Zone Method

To combine all geographical layers and find the zones with groundwater potential, a weighted overlay approach was employed. Before the covering procedure, every geographical layer was rearranged to a consistent rating from 1 to 5, where 1 indicated a low groundwater potential and 5 a good one. We used AHP and a pairwise comparisons matrix to give weights (Table 1). After considering the outcomes of stakeholder meetings, field surveys, and expert opinion polls, the different factors were ranked. Table 2 shows that land use/land cover and drainage density were given low weights, whereas geomorphology, slope, lineament density, and lithology were given high weights. After the respective parameters were weighted, the sub-variables were ranked individually. The greatest value characterized the groundwater potentiality at its highest, and vice versa.

Factor	*Geomorphology*	*LD*	*Lithology*	*Rainfall*	*Slope*	*Soil*	*Lu/Lc*	*DD*	*Weightage*	*Normalized Weightage*
Geomorphology	8	7	6	5	4	3	2	1	0.40	0.36
LD	8/2	7/2	6/2	5/2	4/2	3/2	2/2	1/2	0.20	0.18
Lithology	8/3	7/3	6/3	5/3	4/3	3/3	2/3	1/3	0.14	0.13
Rainfall	8/4	7/4	6/4	5/4	4/4	3/4	2/4	1/4	0.10	0.09
Slope	8/5	7/5	6/5	5/5	4/5	3/5	2/5	1/5	0.08	0.07
Soil	8/6	7/6	6/6	5/6	4/6	3/6	2/6	1/6	0.07	0.06
Lu/Lc	8/7	7/7	6/7	5/7	4/7	3/7	2/7	1/7	0.06	0.05
DD	8/8	7/8	6/8	5/8	4/8	3/8	2/8	1/8	0.05	0.04
	TOTAL									1

Table 1. Normalized Pairwise comparison matrix (eight layers) developed for AHP based groundwater potential zoning

Factor	*Weight*	*Rank*	*Over all*
Geomorphology			
Deep Pediment	36	2	72
Moderate Pediment		2	72
Shallow Pediment		3	108
Flood Plain		4	144
River		5	180
Structural Hills		1	36
Tanks		5	180
Lineament Density			
Very Low	18	1	18
Low		2	36

Medium		3	54
High		4	72
Very High		5	90
Land use and land cover			
Plantation	5	4	20
Crop Land		4	20
Waste Land		2	10
Fallow Land		3	15
River		5	25
Forest		3	15
Built-up Land		1	5
Tank		5	25
Drainage Density			
Very Low	4	5	20
Low		4	16
Medium		3	12
High		2	8
Very High		1	4
Slope			
<3	7	6	42
3-5		5	35
5-10		4	28
10-20		3	21
20-50		2	14
>50		1	7
Soil			
Calcareous Cracking clay soils	6	2	12
Clayey Soil		1	6
Gravelly Clay Soils		2	12
Loam Soil		3	18
Lithology			
Charnockite	13	3	39
Granite		2	26
Hornblende Biotite Gneiss		4	52
Quartzite		1	13
Rainfall			
650-700	9	1	9
700-750		2	18
750-800		3	27
800-850		4	36
850-919		5	45

Table 2. Weights allocated for different ground water resistor factors

Results and Discussion

The research area's groundwater potential zones are estimated using eight criteria: lithology, lineament density, drainage density, slope, soil, geomorphology, rainfall, land use/land cover, and landforms. Extensive explanations and distribution maps of all relevant parameters are provided in the section that follows.

Determining the hydrogeological qualities of rocks is facilitated by lithology. Charnockite, Granite, Hornblende Biotite Gneiss, and Quartzite formed the lithological unit of the research area. Figure 2 shows that Hornblende Biotite Gneiss covered the majority of this region. Among the basin's aquifers, it was the most crucial. The lithology had a mass of thirteen. Based on field study and their aquifer system, Hornblende Biotite Gneiss was awarded the larger priority. The total mass varied from thirteen and fifty-two kg. The lithology's rating and weightage were detailed in table 2.

Number of Drains: Drainage is one of the best indicators of hydrogeological features. Media with a high drainage density have poor groundwater recharge, as shown by Prasad et al. (2008), Yeh et al. (2009), and Magesh et al. (2012), who found that groundwater recharge is inversely related to drainage density. The drainage density has an inverse relationship with permeability. Very low, low, medium, high, and very high were the five categories into which the research area's drainage density fell (Figure 3). An extremely high infiltration rate is observed with a very low drainage density. Since the drainage density was quite low, a significant weight was given to it. The total weights varied between four and twenty pounds. Table 2 displays the drainage density weightage and AHP rating.

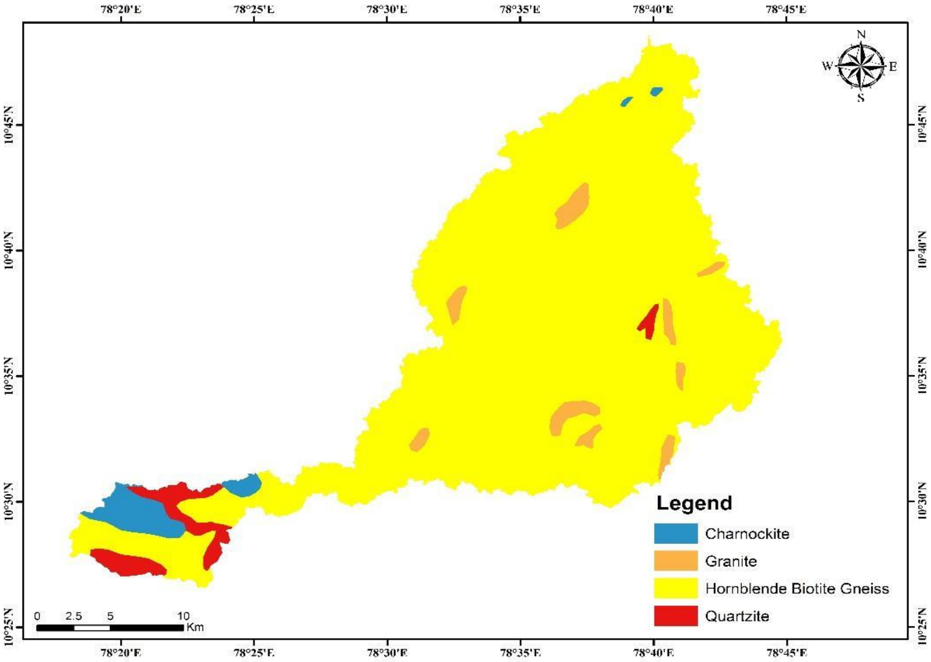

Figure 2. Lithology map of the tudy area

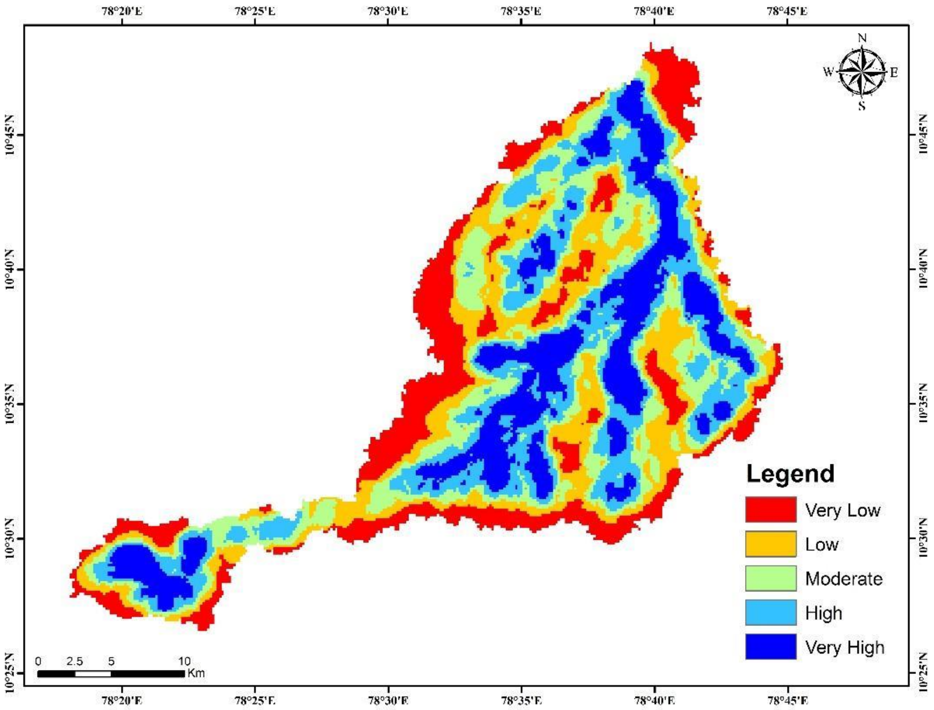

Figure 3. Drainage density map of the study area

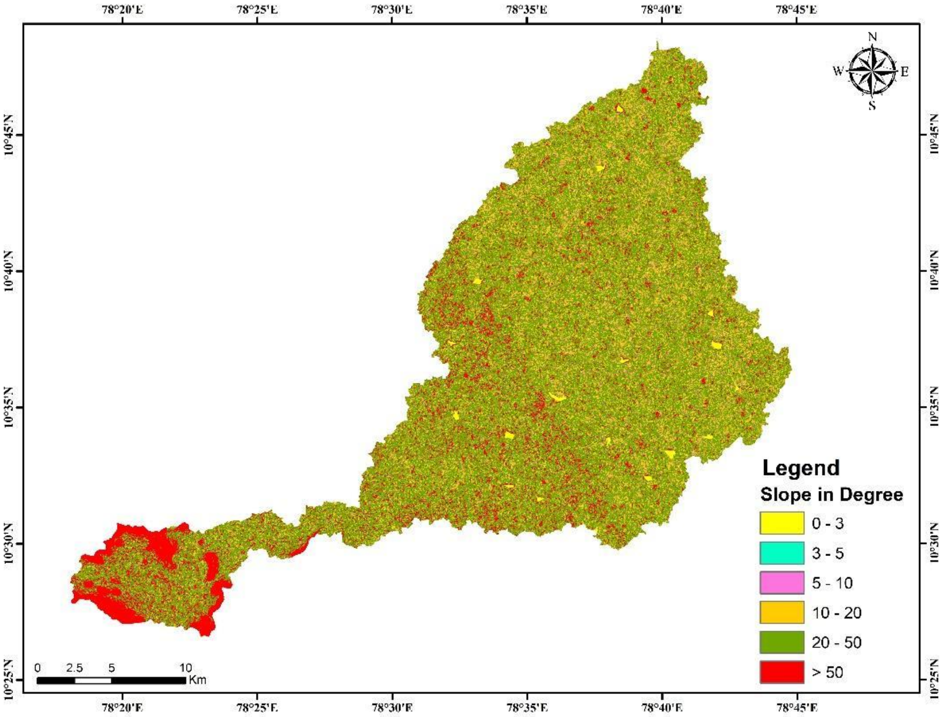

Figure 4. Slope map of the study area

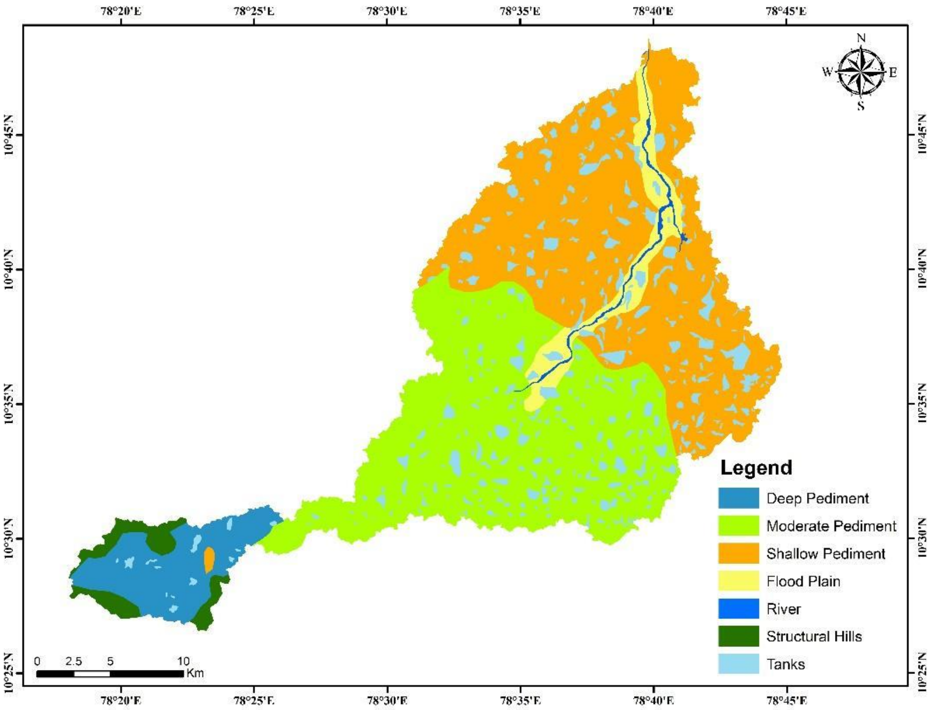

Figure 5. Geomorphology map of the study area

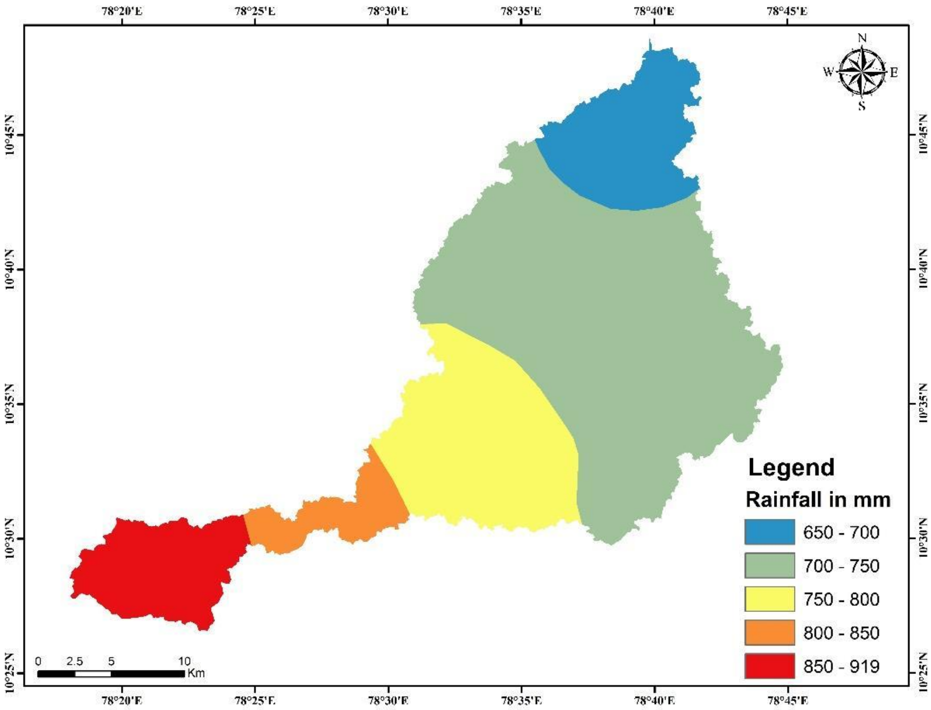

Figure 6. Rainfall map of the study area

Surface water infiltration rates vary depending on the slope. Slope is one of the parameters that influences how much water may seep into the subsurface. In the region of the mild slope, surface runoff is minimal and infiltration is strong. However, there is a lot of runoff in the high slope area, which means that infiltration is rather low (Prasad et al. 2008; Magesh et al. 2012). Figure 4 shows that the research area had a slope ranging from 0° to 87°. Because of low runoff and high infiltration, the lowest slope range of less than 3° has been given the most weight. This slope's total weightage is detailed in table 11.

In geomorphology, the landforms of the area under study are referred to. See Figure 5 for a visual representation of the research area's geomorphology, which included characteristics such as deep pediment, moderate pediment, shallow pediment, flood plain, river, structural hills, and tank. Since there was a lot of infiltration and the area was very close to the river, the flood plain region's groundwater potential zone was considered very important. Table 2 shows that the total weightage was between 36 and 180 kg.

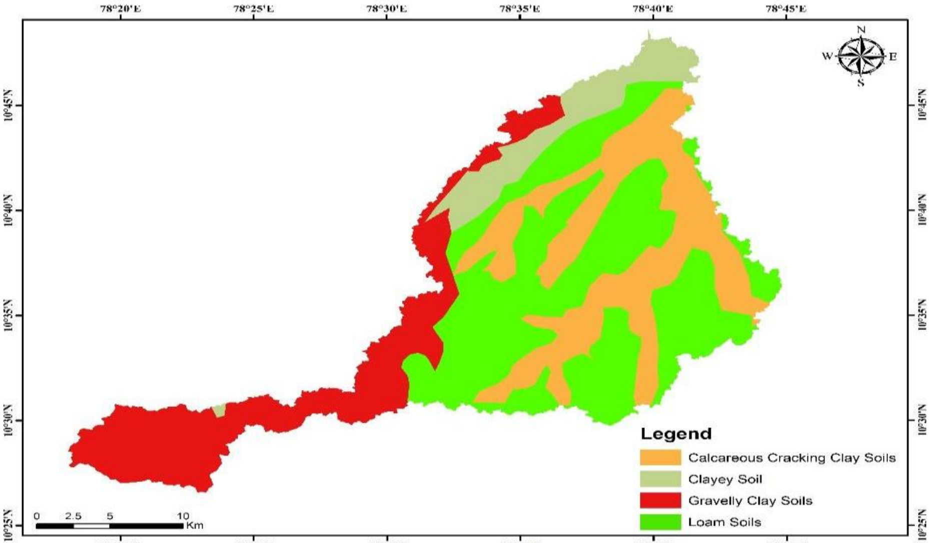

Figure 7. Soil map of the study area

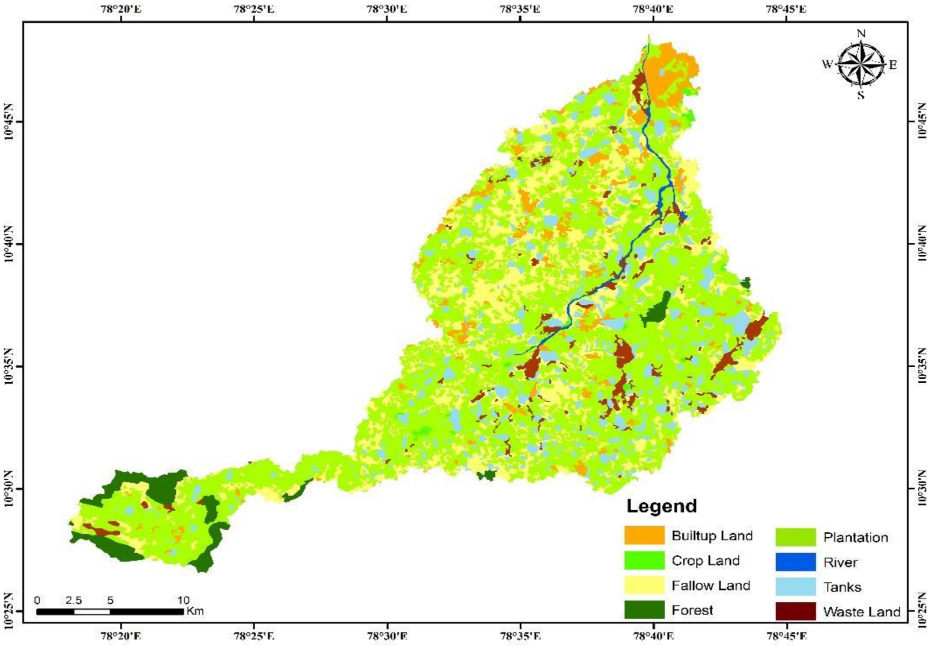

Figure 8. Landuse/ land cover map of the study area

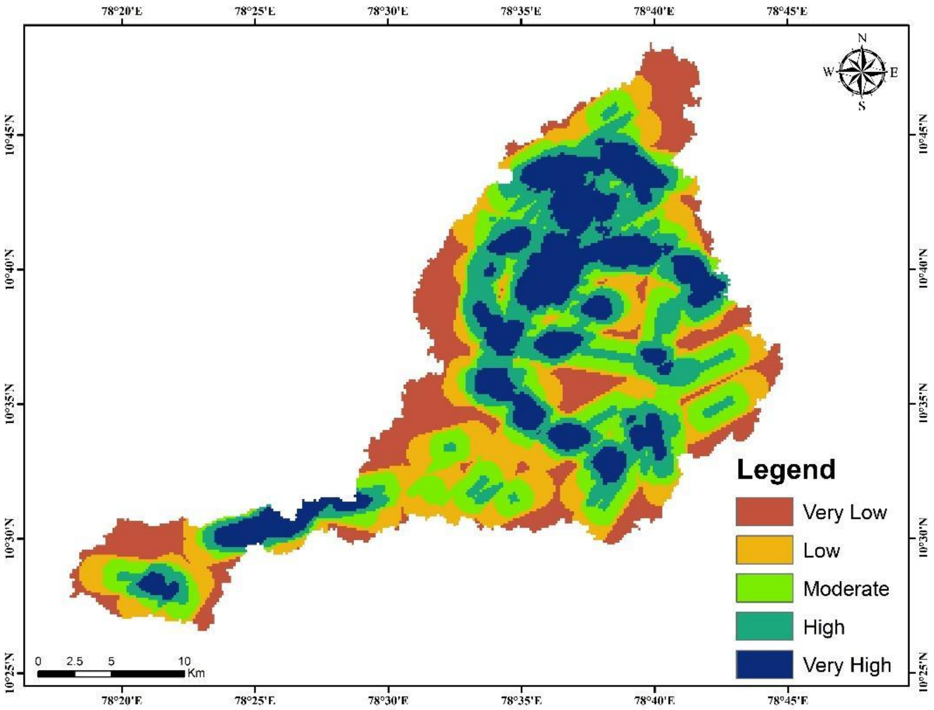

Figure 9. Lineament density map of the study area

Rainfall: Rainfall is the primary source of recharge for aquifer units. As a result, the possibility of groundwater potential zones grows as rainfall distribution changes. The rainfall of the study area distributed from 650 to 919 mm (Figure 6). The highest rainfall areas have higher amount of groundwater potential zone. The areas fall under 850 to 919 mm rainfall area have assigned high weightage (45). The overall weightage of the rainfall was ranged from 9 to 45 and the same was mentioned in table 2.

Soil: The amount of groundwater recharge is directly proportional to the soil type. The rate of infiltration is determined by the porosity of the soil (Chitsazan and Akhtari 2009). The soil type of the study was listed in table 2. The higher overall weightage was assigned loam soil (18) based on their infiltration rate. The overall weightage of this features ranged from 6 to 18. Figure 7 shows the soil map of the study area.

Landuse/ land cover: The Landuse/ land cover is shows the surface of the earth. The study area occupied built-up land, waste land, forest, crop land, fallow land, plantation, river and tank (Figure 8). These features have assigned weightage as 1, 2, 3, 4, 3, 4, 5 and 5 respectively. The overall weightage of this features ranged from 5 to 25. Table 2 shows the sub parameter and their rating and weightage of the landuse/ land cover.

Lineament Density: Lineaments are a type of subterranean geological feature that can be discovered through remote sensing of fractures or structures (Pradhan et al. 2006; Pradhan and Youssef 2010). Groundwater yields in regions where lineaments intersect and lineaments parallel to drainage networks intersect can be higher than in other areas. As a result, lineaments provide information about groundwater transport and storage, as well as aid in the identification of groundwater zones in hydrogeological studies (Subba Rao et al. 2001). The lineament density of the study area classified as five classes from very low to very high (Figure 9). Their overall weightages are ranged from 18 to 90. The high lineament density area was gave a high importance of groundwater potential zonation because of their high infiltration.

Groundwater potential zonation

Using GIS-based ahp and overlay analyses of the aforementioned features, a groundwater potential map of the research region was constructed. First, we used the ahp technique to determine the rating values of each sub-parameter and the weight values of the used parameters. Each parameter's raster file was assigned the rating and weightage that was multiplied by it.

Following the integration of all layers in Arc GIS using the weighted overlay analysis approach, the groundwater potential zone was found. All parameters have weightages ranging from 5 to 416. The quantile classification approach was used to categorize this into five groups. Very low, low, moderate, high, and very high are the names of the categories. The corresponding areas for these groups were 127.57, 140.44, 180.28, 117.39, and 97.49 km2. A low potential area covers the southern portion of the research region, whereas a very high potential zone covers the northern section. Moderate potential zonation covers the remaining portions of the research. In Figure 10, we can see the research area's groundwater potential zone.

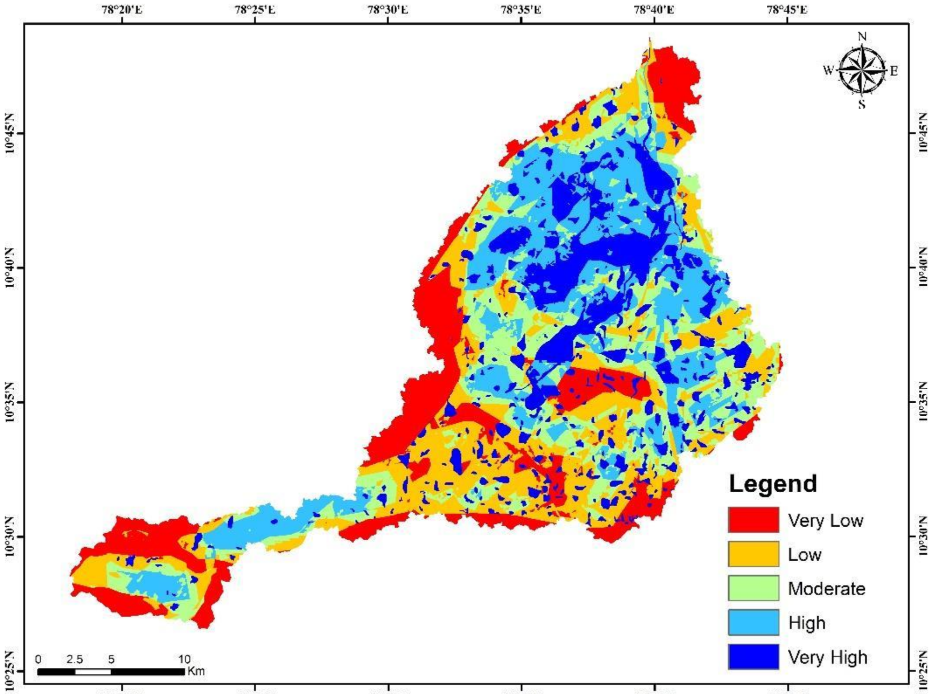

Figure 10. Groundwater Potential Zone map of the study area

Conclusion

This study utilized the AHP approach, which is based on GIS, to map the groundwater potential in the study region. Factors such as lithology, lineament density, drainage density, landuse/cover, slope, soil, geomorphology, and rainfall were among those taken into account and studied in order to identify possible zones. Maps of the study area's geomorphology, lineament density, slope, drainage density, landuse/land cover, and other features were also created using remote sensing techniques. Using the AHP method, we calculated the rating and weight values for each parameter. With the weights and ratings of each parameter, the GWPZ was computed, and it falls somewhere between 5 and 416. There were five zones utilized to characterize the research region: very low, low, moderate, high, and very high groundwater potential. The northern portion of the research area (97.49 km2) was primarily covered by the high GWPZ. For local governments' usage of groundwater and the research region's long-term management, the study's results are crucial. In particular, water budgeting initiatives for watershed planners and effective watershed management will benefit from the results.

Declarations

Ethical approval: Not applicable
Consent to participate: Not applicable
Consent for publication: Not applicable
Funding: Not applicable
Competing interests: The authors declare no competing interests.
Availability of data and materials: All data generated or analyzed during this study are included in this published article.

References

1. Chang DY (1992) Extent analysis and synthetic decision. Optim Tech Appl 1:352
2. Chang DY (1996) Applications of the extent analysis method on fuzzy AHP. Eur J Oper Res 95:649–655
3. Chang NB, Parvathinathan G, Breeden JB (2008) Combining GIS with fuzzy multicriteria decision-making for landfill siting in a fast growing urban region. J Environ Manag 87(1):139–153
4. Cheng CH (1997) Evaluating naval tactical missile systems by fuzzy AHP based on the grade value of membership function. Eur J Oper Res 96(2):343–350
5. Chitsazan M, Akhtari Y (2009) A GIS-based DRASTIC model for assessing aquifer vulnerability in Kherran Plain, Khuzestan, Iran. Water Resour Manag 23:1137–1155
6. Chowdhury A, Jha MK, Chowdary VM, Mal BC (2009) Integrated remote sensing and GIS-based approach for assessing groundwater potential in West Medinipur district, West Bengal, India. Int J Remote Sens 30:231–250
7. Elewa HH, Qaddah A (2011) Groundwater potentiality mapping in the Sinai Peninsula, Egypt, using remote sensing and GIS-watershedbased modeling. Hydrogeol J 19(3):613–628
8. Erhan Şener, Şehnaz Şener, Ayşen Davraz (2018) Groundwater potential mapping by combining fuzzy-analytic hierarchy process and GIS in Beyşehir Lake Basin, Turkey. Arabian Journal of Geosciences. 11:187. https://doi.org/10.1007/s12517-018-3510-x.
9. Ghayoumian J, Saravi MM, Feiznia S, Nouri B, Malekian A (2007) Application of GIS techniques to determine areas most suitable for artificial groundwater recharge in a coastal aquifer in southern Iran. J Asian Earth Sci 30(2):364–374
10. Ghorbani Nejad S, Falah F, Daneshfar M, Haghizadeh A, Rahmati O (2017) Delineation of groundwater potential zones using remote sensing and GIS-based data-driven models. Geocarto Int 32(2): 167–187
11. Jha MK, Chowdhury A, Chowdary VM, Peiffer S (2007) Groundwater management and development by integrated remote sensing and geographic information systems: prospects and constraints. Water Resour Manag 21:427–467
12. Kahraman C, Cebeci U, Ruan D (2004) Multi-attribute comparison of catering service companies using fuzzy AHP: the case of Turkey. Int J Prod Econ 87:171–184

13. Kahraman C, Cebeci U, Ulukan Z (2003) Multi-criteria supplier selection using fuzzy AHP. Logist Inf Manag 16(6):382–394
14. Kumar P, Herath S, Avtar R, Takeuchi K (2016)Mapping of groundwater potential zones in Killinochi area, Sri Lanka, using GIS and remote sensing techniques. Sustain Water Resour Manag 2(4):419–43
15. Lee SK, Mogi G, Hui KS (2013) A fuzzy analytic hierarchy process(AHP)/data envelopment analysis (DEA) hybrid model for efficiently allocating energy R&D resources: in the case of energy technologies against high oil prices. Renew Sust Energ Rev 21:347– 355
16. Machiwal D, Jha MK, Mal BC (2011) Assessment of groundwater potential in a semi-arid region of India using remote sensing, GIS and MCDM techniques. Water Resour Manag 25:1359–1386
17. Magesh NS, Chandrasekar N, Soundranayagam JP (2012) Delineation of groundwater potential zones in Theni district, Tamil Nadu, using remote sensing, GIS and MIF techniques. Geosci Front 3(2):189–196
18. Magesh NS, Chandrasekar N, Soundranayagam JP (2012) Delineation of groundwater potential zones in Theni district, Tamil Nadu, using remote sensing, GIS and MIF techniques. Geosci Front 3(2):189–196
19. Manap MA, Nampak H, Pradhan B, Lee S, Sulaiman WNA, Ramli MF (2013) Application of probabilistic-based frequency ratio model in groundwater potential mapping using remote sensing data and GIS. Arab J Geosci 6:1621–1637
20. Mukherjee P, Singh CK, Mukherjee S (2012) Delineation of groundwater potential zones in arid region of India—a remote sensing and GIS approach. Water Resour Manag 26(9):2643–2672
21. Pradhan B, Singh RP, Buchroithner MF (2006) Estimation of stress and its use in evaluation of landslide prone regions using remote sensing data. Adv Space Res 37:698–709
22. Pradhan B, YoussefAM(2010) Manifestation of remote sensing data and GIS for landslide hazard analysis using spatial-based statistical models. Arab J Geosci 3(3):319–326
23. Prasad RK, Mondal NC, Banerjee P, Nandakumar MV, Singh VS (2008) Deciphering potential groundwater zone in hard rock through the application of GIS. Environ Geol 55(3):467–475
24. Prasad RK, Mondal NC, Banerjee P, Nandakumar MV, Singh VS (2008) Deciphering potential groundwater zone in hard rock through the application of GIS. Environ Geol 55(3):467–475
25. Rahmati O, Samani AN, Mahdavi M, Pourghasemi HR, Zeinivand H (2015) Groundwater potential mapping at Kurdistan region of Iran using analytic hierarchy process and GIS. Arab J Geosci 8(9):7059– 7071
26. Saaty TL (1980) The analytic hierarchy process. McGraw-Hill, New York, p 287
27. Saha D, Dhar YR, Vittala SS (2010) Delineation of groundwater development potential zones in parts of marginal Ganga Alluvial Plain in South Bihar. East India Environ Monit Assess 165:179–191
28. Shekhar S, Pandey AC (2015) Delineation of groundwater potential zone in hard rock terrain of India using remote sensing, geographical information system (GIS) and analytic hierarchy process (AHP) techniques. Geocar Int 30(4):402–421
29. Singh CK, Shashtri S, Singh A, Mukherjee S (2011) Quantitative modeling of groundwater in Satluj River basin of Rupnagar district of Punjab using remote sensing and geographic information system. Environ Earth Sci 62:871–881
30. Subba Rao N, Chakradhar GKJ, Srinivas V (2001) Identification of groundwater potential zones using remote sensing techniques in and around Guntur Town. Andhra Pradesh, India 29 (1&2):69–78.
31. Tan RR, Aviso KB, Huelgas AP, Promentilla MAB (2014) Fuzzy AHP approach to selection problems

in process engineering involving quantitative and qualitative aspects. Process Saf Environ Prot 92(5):467–475

32. Teixeira J, Chaminé HI, Carvalho JM, Pérez-Alberti A, Rocha F (2013) Hydrogeomorphological mapping as a tool in groundwater exploration. J Maps 9(2):263–273
33. Teixeira J, Chaminé HI, EspinhaMarques J, Carvalho JM, Pereira AJSC, Carvalho MR, Fonseca PE, Pérez-Alberti A, Rocha F (2014) A comprehensive analysis of groundwater resources using GIS and multicriteria tools (Caldas da Cavaca, Central Portugal): environmental issues. Environ Earth Sci 73(6):2699–2715
34. Tseng ML, Lin YH, Chiu ASF, Chen CY (2008) Fuzzy AHP approach to TQM strategy evaluation. IEMS 7(1):34–43.
35. Van Laarhoven PJM, Pedrycz W (1983) A fuzzy extension of Saaty's priority theory. Fuzzy Sets Syst 11:229–241
36. Yeh HF, Lee CH, Hsu KC, Chang PH (2009) GIS for the assessment of the groundwater recharge potential zone. Environ Geol 58:185–195