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# Groundwater potential zones demarcation in the hard rock province of South India: insights from remote sensing, GIS and AHP techniques

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2 **Groundwater potential zones demarcation in the**

3 **hard rock province of South India: Insights from**

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26

27 **Abstract**

28 The research aims to assess the groundwater potential zones (GWPZs) in

29 the Chinnalapatti firka hard rock region to aid in sustainable groundwater

30 management. The GWPZs were determined with the aid of Analytic

31 Hierarchy Process (AHP) along with remote sensing (RS) and geographical

32 information system (GIS) technologies. These Remote sensing and GIS

33 greatly enhance groundwater potential mapping and assessment, as well

34 as monitoring and conservation efforts. To evaluate groundwater potential  
35 (GWP) in the area of interest, remote sensing (RS) and conventional data  
36 sources were used to construct eight thematic maps. These maps included  
37 lineament density, drainage density, rainfall, geomorphology, geology,  
38 land use/land cover, soil and slope. Using AHP, each thematic layer, along  
39 with its subclasses, was assigned weights based on their influence on  
40 groundwater occurrence. Following this, the GWPZ map of Chinnalapatti  
41 firka was prepared by integrating the thematic layers with weighted  
42 overlay analysis in ArcGIS 10.7. The resulting map classified the study area  
43 into five groundwater potential groups: very good (19.97%), good  
44 (31.78%), moderate (30.61%), poor (17.63%), and very poor (0.01%).  
45 Utilizing the ArcSDM tool within ArcGIS software, the receiver operating  
46 characteristic (ROC) curve analysis showed that the area under the curve  
47 AUC = 0.80, which means that the GWPZ has good model performance.  
48 Planning and implementing artificial groundwater recharge projects,  
49 especially in semi-arid and hard rock terrains, is greatly aided by the  
50 spatial database created in this study. To improve groundwater  
51 sustainability, appropriate locations for recharge activities must be found.  
52 These results provide important information for sustainable groundwater  
53 management and long-term planning of water resources in the  
54 Chinnalapatti Firka region.

55 **Keywords:** Groundwater potential, Analytic Hierarchy Process, GIS, Hard  
56 rock area, receiver operating characteristic (ROC), and area under the  
57 curve (AUC)

## 58 **Introduction**

59 In order to define groundwater potential zones in a semi-arid and  
60 geologically complex area, the current study on groundwater potential in  
61 Chinnalapatti Firka takes a unique integrative strategy that integrates  
62 field validation, GIS-based analysis, and remote sensing. The utilization of  
63 high-resolution satellite imagery and thematic layers such as slope, land  
64 use/land cover, lineament density, drainage density, geology, soil, slope,  
65 and geomorphology, integrated through weighted overlay analysis to

66 create an extensive groundwater potential map, is what makes this work  
67 distinctive. This study uses a GIS and AHP methodology, which offers a  
68 more accurate and spatially explicit evaluation than earlier research [1],  
69 [2] that just used hydrogeological data. To facilitate sustainable water  
70 resource management, well-informed decision-making, and efficient  
71 planning for agriculture and rural development, the primary goal of this  
72 study is to evaluate and map the groundwater potential zones of  
73 Chinnalapatti Firka. It significantly contributes to meeting the needs of  
74 various industries, including residential use, agriculture, industry, and the  
75 drinking water supply, as well as other developmental endeavours [3], [4].  
76 About 34% of the annual water supply comes from groundwater [5], a rich  
77 and plentiful source of freshwater [6], [7], [8]. The GW is a changeable  
78 resource that is difficult to measure in space and time, is found in complex  
79 subterranean formations, and cannot be observed directly from the Earth's  
80 surface [9]. Due to the erratic availability of surface water throughout the  
81 year, residents in semiarid regions rely significantly on groundwater  
82 supplies for their livelihood. Groundwater is an essential resource for  
83 several purposes, including household, agricultural, and industrial [10].  
84 Over time, the unsustainable and unscientific consumption of groundwater  
85 has been the primary cause of the persistent and alarmingly falling water  
86 table. This issue is most apparent in areas with access to fresh  
87 groundwater. Hence, to enhance groundwater recharge, we must  
88 establish and utilize effective management practices of surface water [11].  
89 Geographic Information Systems (GIS) and remote sensing have become  
90 effective tools for mapping groundwater potential zones because they  
91 provide sophisticated capabilities in spatial analysis, data integration, and  
92 acquisition [12], [13]. Critical surface elements like geological structures,  
93 geomorphology, land cover, drainage patterns, and vegetation indices are  
94 revealed by satellite photography and aerial photographs. These features  
95 have an impact on the occurrence of groundwater. By combining these  
96 disparate statistics into a single geographic framework using thematic  
97 layers that describe important variables like geology, slope, soil type, and  
98 lineament density, GIS performs a crucial role [14], [15]. By improving

99 groundwater potential mapping precision and effectiveness, this  
100 integrative method makes resource management more sustainable and  
101 informed. Finding regions that are favourable for groundwater occurrence  
102 and recharge is made possible by merging and analysing these layers using  
103 sophisticated spatial analytic methods [16].

104 The spatial occurrence of groundwater in India is affected by the country's  
105 varied geography, geology, and climate. For groundwater in hard rock  
106 areas, locations of interest are in the form of deeper fractures and joints  
107 in semi-confined settings and shallow unconfined aquifers in the  
108 weathered zone. Severe water scarcity can develop from the extensive  
109 impacts of growing water demand on surface and groundwater resources  
110 [17]. As a result, precise quantitative evaluations based on scientific  
111 principles and bolstered by contemporary methodologies are essential for  
112 the sustainable development and management of groundwater resources  
113 [18]. In regions with limited water resources, groundwater is a crucial  
114 natural resource that supports industrial growth, agricultural production,  
115 and human health. Groundwater has come to be a very important  
116 component of water resource management in light of competition for  
117 water on a worldwide scale and limits on surface water supply, particularly  
118 in semiarid and hard rock areas. However, because of its intrinsic  
119 variability due to a number of geological, topographic, and climatic  
120 reasons, there are considerable challenges to sustainable use. Urgent  
121 need for scientifically informed management techniques in India has  
122 highlighted concerns about extraordinary declines in water tables due to  
123 dependence and unscientific extraction of groundwater. The Analytic  
124 Hierarchy Process (AHP) and other decision-support tools, in conjunction  
125 with recent advances in GIS technologies, may provide credible techniques  
126 for assessing groundwater potential. AHP provides a credible approach to  
127 delineate groundwater potential zones by integrating thematic layers,  
128 namely geology, rainfall, slope, and land use [19].

129 Traditionally, the process of identifying groundwater potential zones  
130 (GWPZ) was performed through lengthy, expensive geological,  
131 hydrogeological, geophysical and or photogeological methods [20]. In the

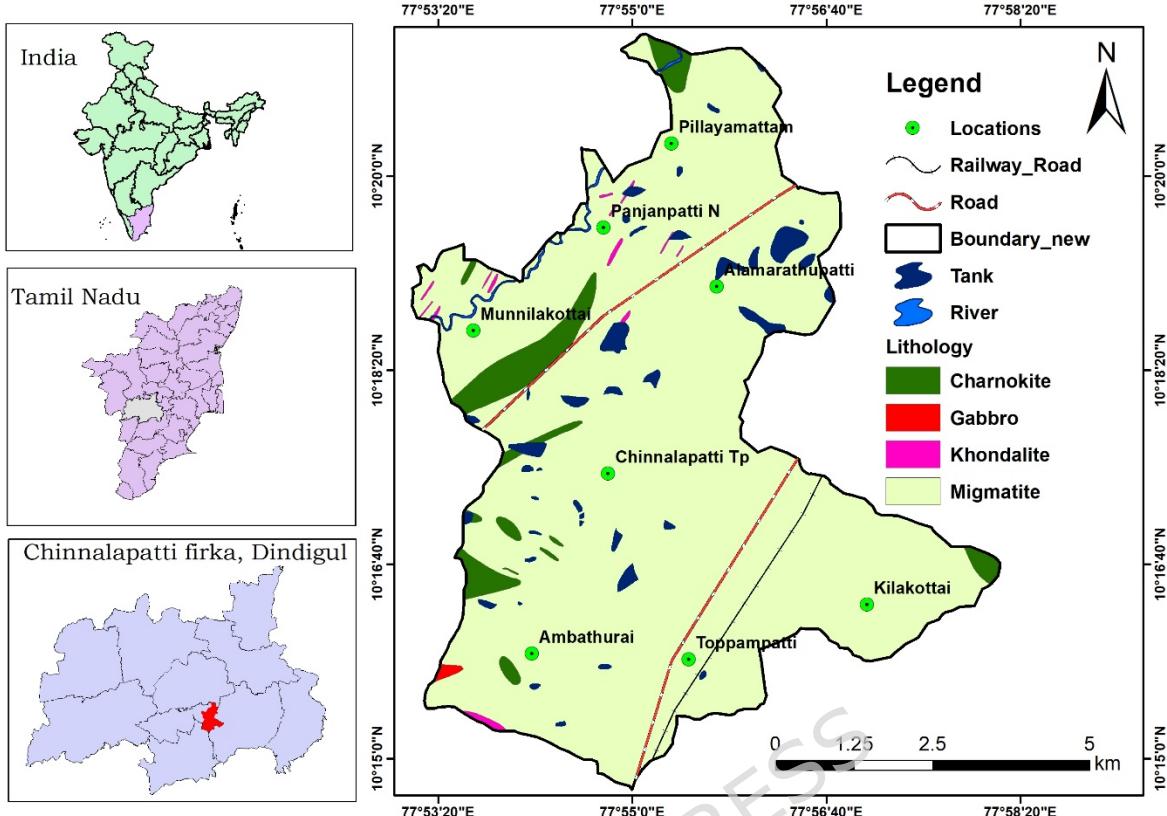
132 last few years, academics from different parts of the world have been  
133 increasingly using geographic information systems (GIS) and remote  
134 sensing (RS) technology for that purpose [21]. These modern-day methods  
135 are less expensive, more reliable and effective, and satellite-based RS data  
136 provide most of the essential data requirements for the GIS applications  
137 [22], [23], [24], [25], [26], [27]. Delineating groundwater zones has proven  
138 to be an effective use of geospatial tools such as Remote sensing data and  
139 GIS in conjunction with Multi-Criteria Decision-Making (MCDM)  
140 methodologies [28]. One of the most popular Multi-Criteria Decision-  
141 Making (MCDM) techniques in water resource planning is Saaty's  
142 Analytical Hierarchy Process (AHP) [29], [30]. As it is effective, simple,  
143 reliable, and cost-saving, AHP can be ideally applied to be utilized in a  
144 Geographic Information System (GIS) and Remote Sensing (RS)  
145 environment. AHP gives appropriate weights to various thematic layers  
146 prior to their incorporation in a GIS environment via expert judgment and  
147 results of previous studies. AHP technique calculates geometric mean and  
148 normalized weights for an attribute by examining large data sets based on  
149 pairwise comparison matrices [31]. Numerous studies demonstrate how  
150 important it is to monitor, assess, conserve, and manage groundwater  
151 resources sustainably for future usage by combining the use of RS, GIS,  
152 and AHP [19], [32], [33], [34]. There are no thorough studies of the  
153 groundwater resources in the study area, and limited research data is  
154 available for effective groundwater governance. Therefore, the study is  
155 significant for researchers, policymakers, and lawmakers who are  
156 interested in improving socioeconomic groundwater resource  
157 management. It was carried out in the Chinnalapatti Firka of Dindigul  
158 district, which is dominated by the Charnockite and Migmatite Gneiss  
159 Complexes governed by hard rocks. Being an interdisciplinary research  
160 with the applied geospatial approach using remote sensing (RS),  
161 geographical information systems (GIS), and the analytical hierarchy  
162 process (AHP), the research is new and innovative. Groundwater potential  
163 zones (GWPZs) were delineated, available data sets were consolidated,  
164 and new thematic layers were created through this procedure.

165 Additionally, Receiver Operating Characteristic (ROC) curve analysis and  
166 well yield data were used to confirm the defined GWPZs. This study's main  
167 goal is to identify Groundwater Potential Zones (GWPZs) within the  
168 research region in order to support efficient and sustainable groundwater  
169 resource management. To aid in upcoming groundwater exploration  
170 initiatives, the study also intends to create a projected guide map. Since a  
171 sizable section of the region is used for agriculture, the research also aims  
172 to increase agricultural production and upgrade irrigation systems.  
173 Different groundwater potential zones, from extremely poor to very good,  
174 will be used to categorize the study region. Future groundwater  
175 investigation, artificial recharge projects, and the creation of sustainable  
176 use plans in this water-stressed hard rock terrain would all benefit greatly  
177 from this classification.

178

## 179 **Study Area**

180 Chinnalapatti firka consists of nine villages in the Athoor taluk, and the  
181 study area is 13 kilometres from Dindigul town. The latitude and longitude  
182 extensions are  $10^{\circ}15'00''$  -  $10^{\circ}20'00''$ N and  $77^{\circ}53'20''$  -  $77^{\circ}58'20''$ E,  
183 covering an area of  $54.21 \text{ km}^2$ . The economy relies on textiles and  
184 agriculture, with agricultural activities more prevalent in northern  
185 Chinnalapatti. The study area map is shown in Fig.1.



186

187 Fig.1 Geology Map of the Study area (This figure was prepared using  
 188 ArcGIS Desktop 10.7 Esri; <https://www.esri.com>, and the geology map was  
 189 prepared by GSI <https://bhukosh.gsi.gov.in/Bhukosh/MapView.aspx>).

190 The area sees comparatively high mean temperatures from 27°C to 39°C  
 191 throughout the summer months (April to June). Mean annual potential  
 192 evapotranspiration is 1,470 mm [35], exceeding rainfall, indicating a  
 193 negative water balance. As a result, the total amount of water available at  
 194 this time may be significantly reduced [36]. On the other hand, November  
 195 through January are typically nice months with mild temperatures between  
 196 22 to 31°C. According to the [35] climatic classification, the Chinnalapatti  
 197 Firka lies in a semi-arid sub-region (mean annual rainfall  $\approx$  810 mm).  
 198 Charnockite and migmatite gneiss complexes are found in the research  
 199 region. Charnockite and other high-grade metamorphic rocks are typically  
 200 composed of large quantities of feldspar, quartz, and pyroxene minerals.  
 201 It experiences profound crustal processes and is known for being hard and  
 202 weather-resistant. The migmatites, on the other hand, are mixed rocks that  
 203 were partially melted, a sign of high-temperature metamorphic processes.

204 The study area's geomorphology includes a pediment-plain complex, many  
 205 water bodies, and sharply divided structural hills and valleys. The  
 206 pediment-pediplain combination is becoming more and more noticeable in  
 207 geomorphology. This pediplain represents the last stage of the erosion and  
 208 development process.

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## 210 **Geology and hydrogeology**

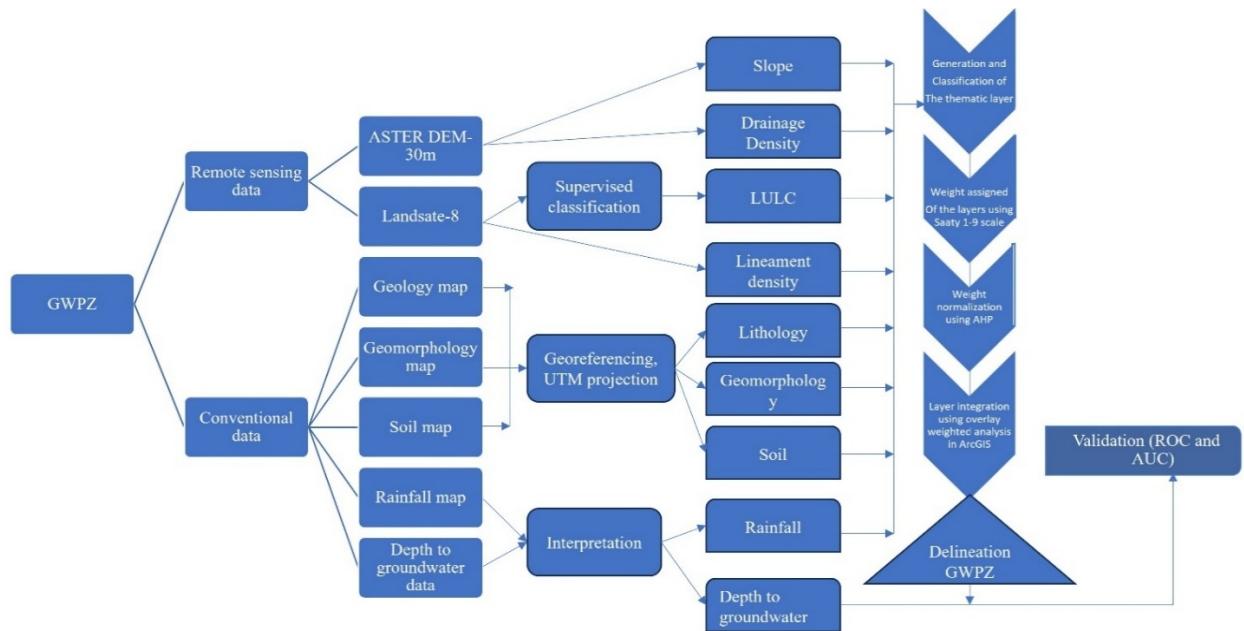
211 The entire firka is underlain by crystalline rocks, which consist of  
 212 Charnockites, Hornblende-Biotite gneiss, and Epidote-Hornblende gneiss.  
 213 The geological unit boundary was derived from GSI 1:50,000 geological  
 214 map (Sheet 58F/12) and field verification (April 2023). Groundwater is  
 215 found in phreatic conditions in weathered and fractured gneiss. The  
 216 weathering processes in the rocks are highly erratic, and the depth of the  
 217 abstraction structures associated with groundwater is dependent on the  
 218 weathering and fracturing norms. The dug wells with large diameters are  
 219 the more common groundwater abstraction structures in this area. The  
 220 dug well is a circular structure of diameter 5 to 10 m, and its depth is  
 221 expected to be between 10 to 18 m. Dug wells can yield 30-100cu.m. The  
 222 yield data correspond to a 6-hour pumping duration, equivalent to 1.4-  
 223 4.6 L s<sup>-1</sup>, from [37], volume in summer, and a few wells came to be dry  
 224 during this period [37]. Dug well yield is sufficient to irrigate one or two  
 225 crops during the monsoon period, but ineffective during summer, as the  
 226 groundwater storage level decreases by the subsequent abstraction [5]

227

## 228 **Methodology**

229 In this study, groundwater potential zones (GWPZ) were delineated by  
 230 integrating both conventional datasets and remote sensing, together with  
 231 GIS-based multi-criteria decision analysis. Key thematic layers like  
 232 lineament density, slope, drainage density and land use/land cover (LULC)  
 233 were extracted using remote sensing data, which comprised ASTER DEM  
 234 (30m resolution) and Landsat-8 imagery. To determine appropriate zones

235 with varied groundwater potentiality, thematic layers have been prepared  
236 with a range of geographical, conventional, and meteorological data  
237 collected from numerous organisations and websites Table 1. To create  
238 precise LULC maps, supervised classification methods were used on  
239 Landsat-8 data. Concurrently, traditional data sources were gathered and  
240 converted to digital format, including soil, rainfall maps, geology,  
241 geomorphology, and groundwater depth data. All raster layers were  
242 resampled to 30 m using bilinear interpolation in UTM Zone 43 N (WGS  
243 84). To ensure uniformity in geographical analysis, all spatial datasets  
244 were georeferenced to a standard UTM projection system. As part of the  
245 Analytic Hierarchy Process (AHP), the resulting thematic layers slope,  
246 drainage density, LULC, lineament density, lithology, geomorphology, soil,  
247 rainfall, and groundwater depth were each given relative priority weights  
248 based on the Saaty 1–9 scale in Table 2. To keep the weights consistent  
249 and to analyze their effects on groundwater occurrence, these weights  
250 were further recalculated. Vulnerable groundwater areas were  
251 subsequently mapped by overlaying all the thematic layers via weighted  
252 overlay analysis using ArcGIS 10.7 (Esri; <https://www.esri.com>). Area  
253 Under Curve (AUC) statistics and Receiver Operating Characteristic (ROC)  
254 curve analysis were subsequently utilized to validate the accuracy and  
255 reliability of the GWPZ map. The flow chart of the methodology is  
256 presented in Fig.2.



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Fig.2 Methodology flow chart present study

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273 Table 1. The information on the data sources used to create the theme  
 274 layers.

S.No.	Thematic Maps	Data Sources	Resolutions	Criterion
1	Rainfall	Public Works Department		Rainfall Distribution Map

		(From 2009 to 2022)		
2	DEM/Slope	SRTM (30 m)/USGS	33m	Slope percentage
3	Drainage density	NRSC Bhuvan	1:50000	Drainage network
4	Lithology	Bhukosh, Geological Survey of India	1:50000	Rock formations types
5	Geomorphology	Bhukosh, Geological Survey of India	1:250000	Landform types
6	LULC	ESRI Sentinel-2/ USGS	10 m	Different landscape Use
7	Soil type	National Bureau of Soil Survey (ICAR) and Department of Agriculture, Tamil Nadu	1:250000	Soil groups, depth, texture, and permeability
8	Lineament density	NRSC-Bhuvan Thematic Services	1:50000	Underground faults and fractures

275

276

277 **AHP method for GWP zoning**

278 This research employs the Analytic Hierarchy Process (AHP), a Multi-  
 279 Criteria Decision-Making (MCDM) technique developed by Saaty in 1980,  
 280 to evaluate the influence of thematic layers and their parameters on  
 281 groundwater occurrence. The method is suited for pairwise comparisons  
 282 to derive ratio scales. AHP approximates the relative importance of each  
 283 factor according to the decision maker's rating of a list of criteria [38].  
 284 Based on the relative importance of every factor, a score of 1 to 9 was  
 285 assigned. Considering multiple criteria and alternatives, the relative  
 286 magnitude of the various factors was determined based on expert  
 287 judgment and literature survey-based evidence from previous studies. The  
 288 criteria were evaluated in depth and compared using the Analytic  
 289 Hierarchy Process (AHP) matrix [39]. Consistent and reliable results are

290 the main issue in resolving multi-criteria decision-making (MCDM)  
 291 problems. This is offered by the Analytical Hierarchy Process (AHP), which  
 292 includes pairwise comparison to determine the relative weights of various  
 293 criteria. AHP uses mathematical computation to offer a systematic matrix  
 294 showing the relative importance of some attributes to others. Saaty  
 295 formulated AHP, where a common scale and systematic method of  
 296 measuring the opinion of an expert exists and determining the optimal  
 297 solution in multi-criteria scenarios. A shortened version of Saaty's initial  
 298 scale was utilized in the AHP analysis of this research to obtain the relative  
 299 weights of the parameters through a series of computational steps. The  
 300 calculation is described below.

301 First, add values in each column of PCM by employing Equation 1:

$$302 L_j = \sum_{i=1}^n C_{ij} \quad (1)$$

303 Here,  $L_j$  = total values in each column of a pairwise matrix and  $C_{ij}$  number  
 304 assigned to each factor at  $i^{\text{th}}$  row and  $j^{\text{th}}$  column.

305 Second, divide each element in the matrix by its column total to generate  
 306 a normalised pairwise matrix by employing Equation 2:

$$307 X_{ij} = \frac{C_{ij}}{L_j}$$

308 (2)

309 Here,  $X_{ij}$  = value at  $i^{\text{th}}$  row and  $j^{\text{th}}$  column in the normalised pairwise  
 310 matrix.

311

312 Finally, divide the sum of the normalised row of the matrix by several  
 313 factors used (8 for the current study) to generate standard weights by  
 314 employing Equation 3:

$$315 w_i = \frac{\sum X_{ij}}{N}$$

316 (3)

317 Where  $W_i$  is the Standard weight and  $N$  is the number of factors.

318 "Consistency ratio (CR)" has been calculated to find any discrepancies and  
 319 determine the best weights after the PCM has been finished and the  
 320 weights of its components have been determined. Only when the CR was  
 321 0.1 or less did the AHP analysis move forward. However, inconsistencies

322 in the review process could result in erroneous results if  $CR > 0.1$ . CR was  
 323 established for the matrix by comparing the "consistency index (CI)" and  
 324 "random index (RI)" to evaluate the reliability of relative weights. CI was  
 325 determined utilising Equation 4. RI in the present investigation is 1.12 for  
 326 strong, as indicated in Tables 2 and 3. [31], [40].

327  $CI = \frac{\lambda - n}{n - 1}$  (4)

328 Where  $\lambda$  = consistency vector. n = number of factors used.

329 The consistency ratio was measured by employing Equation 5

330  $CR = CI/RI$  (5)

331 Here, "CI and CR" mean consistency index and consistency ratio,  
 332 respectively.

333 This Random Consistency Index (RCI) was computed using Saaty's  
 334 standard 1-9 scale table. To obtain accurate results, the Consistency Ratio  
 335 (CR) of an AHP analysis should be below 10% [40]. A review of the  
 336 judgments is required to identify and solve any inconsistency in case of a  
 337 value of CR higher than the value [41]. The CR value of this research is  
 338 0.001, which indicates an excellent consistency level and confirms that  
 339 parameters under consideration are appropriate for weight analysis and  
 340 groundwater potential zone (GPZ) demarcation.

341 Table 2: Fundamental scales of AHP [31]

Intensity of importance	Definition	Expression
1	Equally importance	Two activities equally contributed to the objective
3	Moderate importance of one over another	Experience and judgment strongly favour one activity over another
5	Strong importance	Experience and judgment strongly favour one activity over another
7	Very strong importance	An activity is strongly favoured, and its dominance is demonstrated in practice.
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation.

2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
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345 **Table 3.** RI and Saaty's relative importance scale [40].

N	1	2	3	4	5	6	7	8
Scale of Importance	Eq ual	Weakl y	Moderat e	Moderat e plus	Stron g	Stron g plus	Very stron g	Very, very stron g
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41

346

347 **AHP-based weighting and normalisation analysis**

348 The weights assigned to thematic layers employed to delineate  
 349 Groundwater Potential Zones (GWPZ) appear in Table 2. From the effect  
 350 each stratum contributes to groundwater occurrence, and based on the  
 351 research that has been conducted in areas of equivalent characteristics as  
 352 found in Chinnalapatti firka, the weights were obtained. Prior studies by  
 353 [29], [42], [43], [44], [45], [46], [47] included approaches that were  
 354 followed in the weighing procedure.

355 In this study, rainfall has been assigned the largest weight and indicates  
 356 that it may have a far bigger impact on groundwater, while geomorphology  
 357 has been assigned a lower weight because of its less significant  
 358 impact[26]. A pairwise comparison matrix is produced once each element  
 359 has been given a relative weight (Table 3). Every theme was compared to  
 360 every other theme in order to create a pairwise comparison matrix [48],  
 361 [49]. The normalised weights of the eight themes and the subgroups were  
 362 obtained using Saaty's AHP technique [42], [50]. Table 3 shows the  
 363 normalisation of the provided relative weights to eight theme maps using  
 364 a pairwise comparison matrix.

365 Pairwise comparison table employed in the Analytic Hierarchy Process  
 366 [51]. (Table 4) was evaluated on whether it is logically consistent. The  
 367 largest eigenvalue was  $\lambda_{\max} = 8.736$  which gave a Consistency Index of CI

368 = 0.1052. The Consistency Ratio Table 5 was determined using the Saaty  
 369 random Index, with eight criteria (RI = 1.41) and had the value of CR =  
 370 0.0746, which is far below the acceptable ratio of 0.10. In this way, results  
 371 can be said to be consistent and reliable, and the obtained criterion  
 372 weights (34.9%-3.4%) can be used to conduct further analysis of  
 373 groundwater potential.

374 Table 4: Pairwise comparison matrix with normalised relative weights

Factors	Rainfall	Geology	Slope	Drainage density	LULC	Lineament density	Soil	Geomorphology	Normalised principal Eigenvector
Rainfall	1	5	3	3	5	5	5	3	34.89%
Geology	1/5	1	3	3	5	5	5	5	22.50%
Slope	1/3	1/3	1	1	3	3	5	3	12.33%
Drainage density	1/3	1/3	1	1	1	2	3	5	10.66%
LULC	1/5	1/5	1/3	1	1	1	3	1	6.02%
Lineament density	1/5	1/5	1/3	1/2	1	1	3	1	5.41%
Soil	1/5	1/5	1/5	1/3	1/3	1/3	1	1	3.38%
Geomorphology	1/3	1/5	1/3	1/5	1	1	1	1	4.81%

375

376 Table 5: Pairwise comparison matrix and AHP consistency calculations.

Matrix	Rainfall	Geology	Slope	Drainage density	LULC	Lineament density	Soil	Geomorphology
Rainfall	1.0000	5.0000	3.0000	3.0000	5.0000	5.0000	5.0000	5.0000
Geology	0.2000	1.0000	3.0000	3.0000	5.0000	5.0000	5.0000	5.0000
Slope	0.3333	0.3333	1.0000	1.0000	3.0000	3.0000	5.0000	5.0000
Drainage density	0.3333	0.3333	1.0000	1.0000	1.0000	2.0000	3.0000	
LULC	0.2000	0.2000	0.3333	1.0000	1.0000	1.0000	3.0000	
Lineament density	0.2000	0.2000	0.3333	0.5000	1.0000	1.0000	3.0000	
Soil	0.2000	0.2000	0.2000	0.3333	0.3333	0.3333	1.0000	

Gemorphology	0.3333	0.2000	0.3333	0.2000	1.0000	1.0000	1.0000
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### 378 **Sensitivity Analysis**

379 Another experiment to test the strength of the groundwater potential zone  
 380 (GWPZ) model was the perturbation of AHP-derived criterion weights  
 381 (0.05) by +10%. In both cases individual weights were multiplied and  
 382 divided 10 percent keeping the normalized sum equal to 1. All the  
 383 perturbation cases were re-run on the model and the class areas of GWPZ  
 384 were compared with the base map. The highest difference between the  
 385 maximum variation of all the classes was not more than 5, which means  
 386 that the model output is relatively stable and not that sensitive to small  
 387 differences in criteria weights. The specific output of the perturbation  
 388 tests is available in Supplementary Table 6.

389 Table 6. Percentage change in GWPZ classes under  $\pm 10\%$  weight  
 390 perturbation

Criterion perturbed ( $\pm 10\%$ )	Very High (%)	High (%)	Moderate (%)	Low (%)	Very Low (%)	Maximum change (%)
Rainfall	+1.8 / -1.3	+2.1 / -1.7	+1.2 / -1.0	+0.9 / -0.7	+0.6 / -0.4	<b>2.1</b>
Geology	+1.5 / -1.2	+1.9 / -1.6	+1.1 / -0.8	+0.8 / -0.6	+0.5 / -0.3	<b>1.9</b>
Slope	+1.2 / -1.0	+1.6 / -1.3	+0.9 / -0.7	+0.7 / -0.5	+0.4 / -0.3	<b>1.6</b>
Drainage Density	+1.1 / -0.9	+1.5 / -1.2	+0.8 / -0.6	+0.6 / -0.4	+0.3 / -0.2	<b>1.5</b>
LULC	+0.8 / -0.7	+1.1 / -0.9	+0.6 / -0.5	+0.5 / -0.4	+0.2 / -0.2	<b>1.1</b>
Lineament Density	+0.7 / -0.6	+1.0 / -0.8	+0.6 / -0.4	+0.4 / -0.3	+0.2 / -0.1	<b>1</b>
Soil	+0.6 / -0.5	+0.9 / -0.7	+0.5 / -0.4	+0.3 / -0.3	+0.2 / -0.1	<b>0.9</b>
Geomorphology	+0.7 / -0.6	+1.0 / -0.9	+0.6 / -0.5	+0.4 / -0.3	+0.2 / -0.2	<b>1</b>

391

### 392 **Identification of Groundwater Potential Zones**

393 The maps used in the study were converted from vector to raster format  
 394 using the provided ranks and weights. In ArcGIS 10.7, these maps were  
 395 then combined using weighted overlay analysis. The purpose of this

396 analysis was to determine the GWPZs. The GWP map was computed using  
 397 the following formula [52], [53] as shown in Equation 6:

398 
$$GWPI = \sum_{w=1}^m \sum_{j=1}^n W_j \times X_i$$

399 (6)

400 Where,

N total classes of thematic layers

$X_i$  rank associated with classes of the  $i^{\text{th}}$   
 thematic layer

M Number of total thematic layers used

$W_j$  normalised weight of the  $j^{\text{th}}$  thematic  
 layer

401 The main thematic layers that contribute to GW were superimposed to  
 402 create the GWPM. The Groundwater Potential Index (GWPI), which was  
 403 computed by combining all of the thematic layers that affect GW, was used  
 404 to evaluate GW prospect zones.

405

406

407

#### 408 **Cross-validation**

409 The GWPZ map of Chinnalapatti firka was validated in this study using the  
 410 "Ground Water Prospect Study" map, which provides spatial information  
 411 on well yield and is accessible on the Bhujal-Bhuvan portal (<https://bhuvan-app1.nrsc.gov.in/gwis/gwis.php>). The groundwater monitoring well (depth  
 413 to the water table) was given by the Central Groundwater Board (CGWB).  
 414 The Area under the Curve (AUC) and Receiver Operating Characteristic  
 415 (ROC), which were plotted using the ArcSDM tool in ArcGIS software,  
 416 were also used to validate the results. The ROC curve analysis was used  
 417 for quantitative validation by comparing the generated recharge  
 418 groundwater potential map with the real bore well data. One popular  
 419 method for evaluating the dependability of diagnostic tests is the ROC  
 420 curve analysis. For ROC, false positive values are plotted along the x-axis,  
 421 while true positive values are shown along the y-axis. The ROC curve  
 422 describes a balance between the two values. According to the ROC

423 approach, the area under the curve runs from 0.5 to 1, which can be  
 424 divided into the following ranges: "0.5–0.6 (poor). 0.6–0.7 (average); 0.7–  
 425 0.8 (good); 0.8–0.9 (very good); and 0.9–1 (outstanding)".

426

## 427 **Results and discussion**

### 428 **Thematic maps**

429 To create the Groundwater Potential Zonation (GWPZ) map of the research  
 430 area, eight hydrogeological elements were incorporated into thematic  
 431 layers: Rainfall, geology, slope, drainage density, land use/land cover,  
 432 lineament density, soil, and geomorphology.

433

### 434 **Rainfall**

435 The most significant factor in GWPZ mapping is thought to be  
 436 precipitation. According to (Magesh et al., 2012c), surface flow, recharge,  
 437 and infiltration are all greatly impacted by the duration and amount of  
 438 precipitation. The region's main supply of surface and groundwater is  
 439 rainfall, which has a major impact on the basin's recharge volume because  
 440 of its quantity and spatial distribution [30], [55]. The rainfall data from  
 441 2009 to 2022 annual average was taken from the CHIRPS dataset for this  
 442 investigation. For additional study, the precipitation map that was  
 443 produced was then divided into three different classifications: low,  
 444 moderate, and high (Fig. 3a).

445

### 446 **Geology**

447 The distribution and properties of groundwater occurrences are greatly  
 448 influenced by geology [39]. Geology includes the permeability and porosity  
 449 of aquifer rocks. The type of rock present at the surface significantly  
 450 influences groundwater recharge. [56]. The research area has been found  
 451 to have a variety of lithological units, such as charnockite, gabbro,  
 452 khondalite, and migmatite (Fig. 3b). A weight was given to each of these  
 453 units based on how much of an impact they had on groundwater potential.  
 454 The migmatite was given a higher order priority rating of 4 because it  
 455 contains more fractured and foliated units than other lithological units,

456 which increases its influence on groundwater occurrence. The favourable  
 457 groundwater occurrence in a location determines the high value that is  
 458 assigned.

459 **Slope**

460 According to [57], slope has a direct impact on both surface runoff and  
 461 infiltration rates, making it a significant factor in determining  
 462 groundwater potential. Steeply sloping regions typically have higher  
 463 runoff and less infiltration, which lowers groundwater recharge. Gentle  
 464 sloped areas, on the other hand, allow for longer infiltration time and less  
 465 surface runoff, which increases groundwater recharge. Data from the  
 466 Digital Elevation Model (DEM) was used to create a slope map for the  
 467 current investigation (Fig. 3c). The slope percentage of the area is between  
 468 0% and 30%. Based on the degree of slope, the study area was separated  
 469 into five slope classes: "(a) less than 3%, (b) 3-8%, (c) 8-15%, (d) 15%-  
 470 30%, and (e) > 30%." The area that shows a 3% slope is regarded as "very  
 471 good" because of the almost level topography and very high infiltration  
 472 rate. A highly steep location was categorised as a lower inland area with a  
 473 higher runoff rate, and it was assigned a lower score, whereas a flat terrain  
 474 with a high water-holding capacity was classified with a higher rank.

475

476 **Drainage Density**

477 The relationship between drainage density and permeability is inverse.  
 478 More surface runoff and less infiltration mean less groundwater recharge,  
 479 while low drainage density indicates more precipitation penetration and  
 480 adds more to groundwater potential [39]. Five drainage density classes  
 481 very low (0.0-0.60 km/km<sup>2</sup>), low (0.60-1.21 km/km<sup>2</sup>), moderate (1.21-1.81  
 482 km/km<sup>2</sup>), high (1.81-2.4 km/km<sup>2</sup>), and very high (>2.4 km/km<sup>2</sup>) are  
 483 distinguished within the research area (Fig. 3d). Higher infiltration  
 484 potential is linked to lower drainage density in groundwater assessment.  
 485 As a result, larger drainage density locations were given lower ranks, while  
 486 lower drainage density areas were given higher ranks. The ranking  
 487 matrix's consistency was assessed using the Analytic Hierarchy Process

488 (AHP), and the final weights were determined based on good consistency  
 489 results (Table 7).

490

491 **Land Use and Land Cover**

492 The analysis was conducted using Level 3 classes and the land use/land  
 493 cover map that was retrieved from the GSI portal. The pairwise  
 494 comparison method was used to assess the LU/LC characteristics.  
 495 According to (Acharya et al., 2013). Infiltration, surface runoff,  
 496 evapotranspiration, and groundwater recharge are all significantly  
 497 impacted by land use/land cover (LULC). The geospatial technologies are  
 498 essential for precisely evaluating and mapping LULC across various  
 499 geographies [59]. Studies have indicated that forest regions encourage  
 500 higher infiltration rates than cropland. According to [60], barren land and  
 501 built-up areas typically have lower infiltration rates, which lowers the  
 502 possibility of groundwater recharge. The cropland and forest land are  
 503 given a higher rank than other classes in Table 7 and the spatial  
 504 distribution map, Fig.3e.

505 **Lineament density**

506 A lineament is a linear feature found in a landscape that may be recognised  
 507 by satellite photography and indicates the presence of an underlying  
 508 geological structure, such as a fault. Fractures, cleavages, faults, and  
 509 other discontinuity surfaces are represented by aligned rectilinear or  
 510 slightly curved line features [61]. Lineaments indicate the presence of  
 511 faulting and fracturing zones, resulting in increased secondary porosity  
 512 and permeability [62]. In this work, groundwater potential zones were  
 513 analysed using the GSI lineament map. The ArcGIS platform was used to  
 514 create the lineament density map. Five classifications were then  
 515 distinguished based on their density: very high ( $>1.22$ ), high (0.91 - 1.22),  
 516 moderate (0.61 - 0.91), low (0.31 - 0.61), and very low (0 -0.31). The  
 517 likelihood of groundwater occurrence increases with density. As a result,  
 518 the extremely low ranges were given the lowest weight, and the very high  
 519 ranges the highest. The pairwise comparison matrix's consistency was

520 examined using the AHP analysis, and it was determined to be satisfactory.  
521 The normalised and final weights were used to generate a weighted  
522 lineament density map (Fig. 3f), which is displayed in Table 7.

523

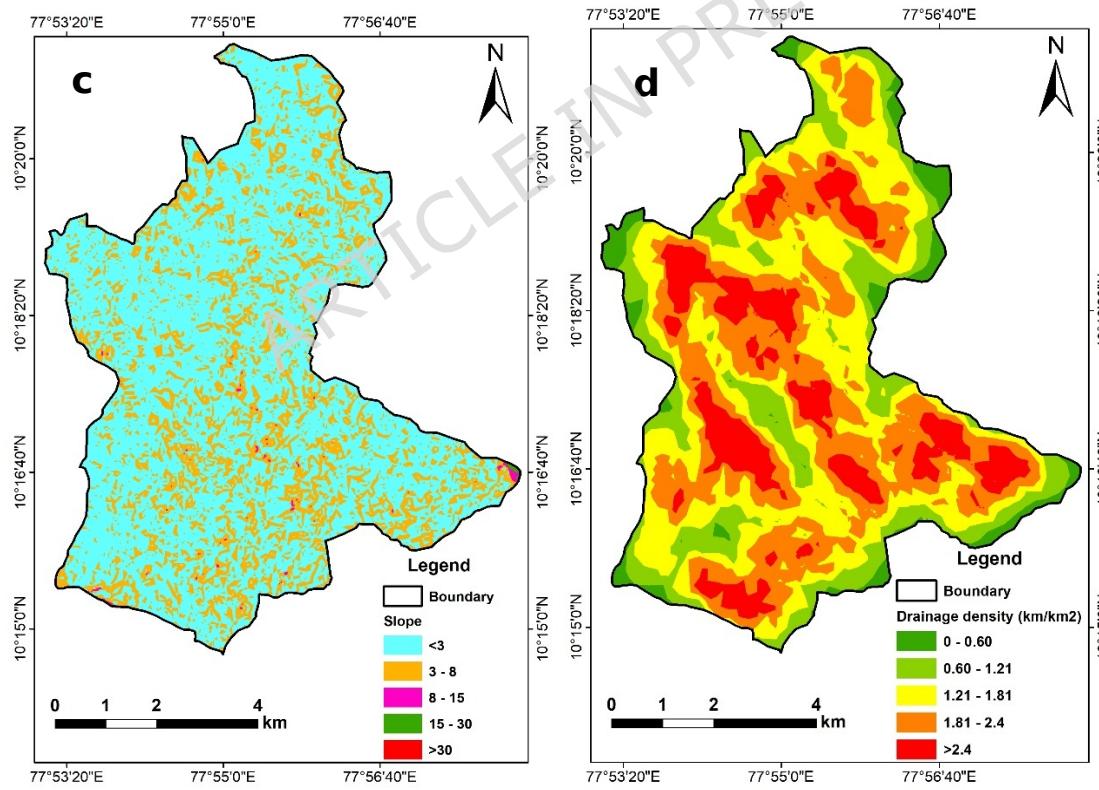
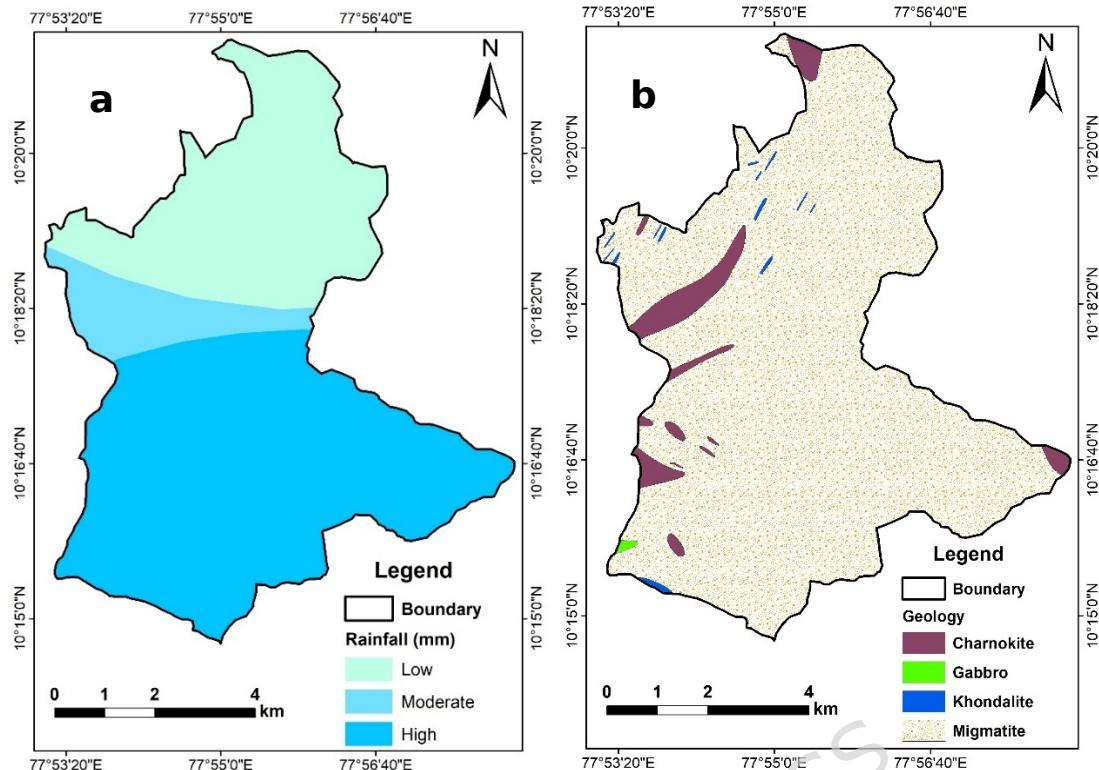
## 524 **Soil**

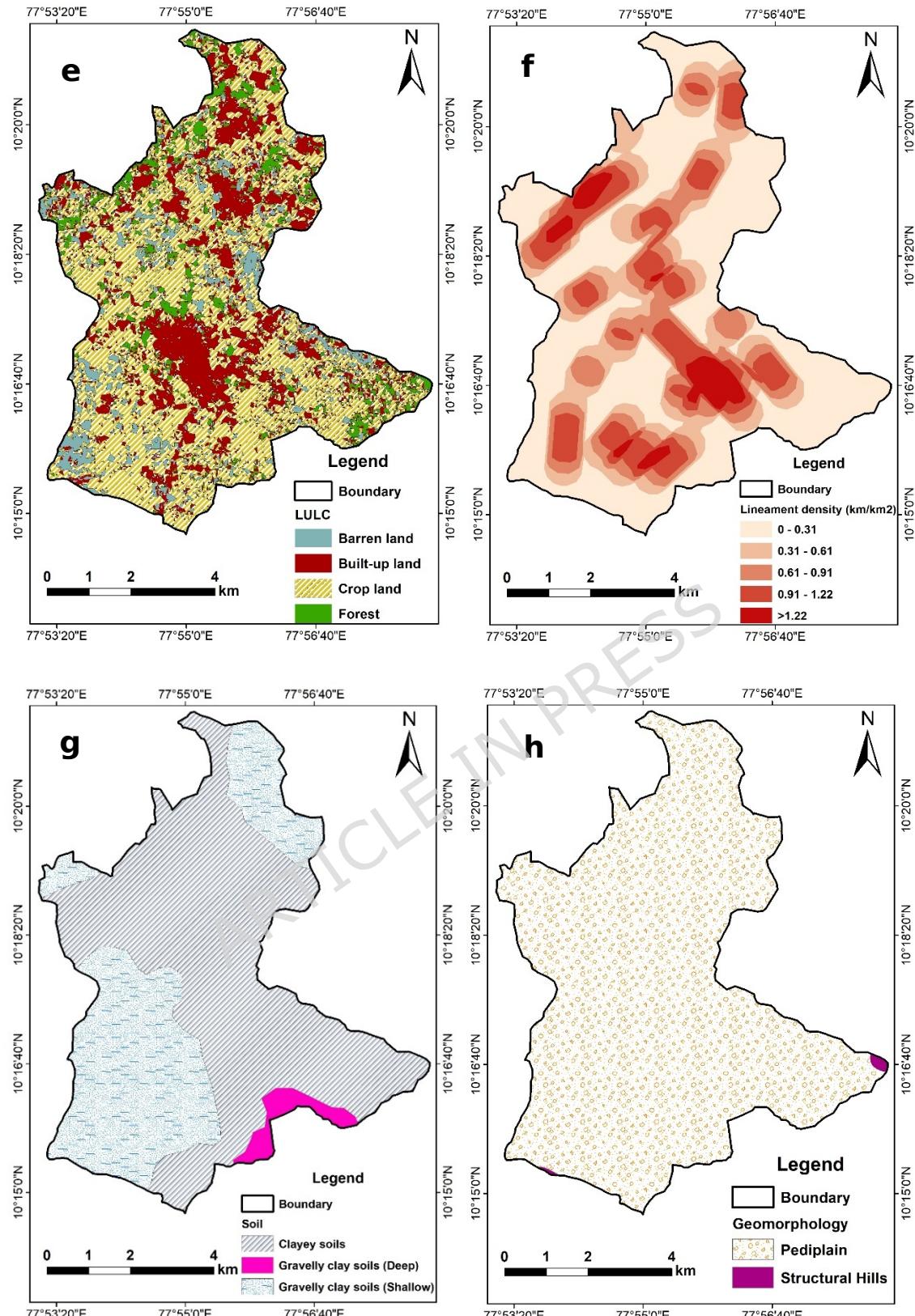
525 Soil is one of the most important key determinants that influences an  
526 area's capacity for infiltration, as it depends on porosity, moisture content,  
527 and density of the soil's texture [63], [64]. Compared to fine-textured soil,  
528 infiltration rates are higher in coarse-textured soil. As a result, soils are  
529 prioritised more highly (Ranked 3). Some soils have a lesser priority and  
530 are classified as ranked 1 because they do not permit water to seep in.  
531 Gravely clay soils, deep soil, for example, well-drained and marginally  
532 erosion-capable soils, were prioritised. A lesser priority was assigned to  
533 clayey soil, which is shallow, gravely clay soil with moderate to severe  
534 erosion. These variables were used to rank and analyse soils using the AHP  
535 approach in order to create the weighted soil map (Fig. 3g) and ascertain  
536 how they impact groundwater conditions (Table 7).

## 537 **Geomorphology**

538 The examination of a region's topography and landforms is referred to as  
539 geomorphology, offering insights into the distribution of various  
540 geographical features, temperature variations, water movement,  
541 geochemical processes, and freeze-thaw cycles. The structural evolution  
542 of the underlying geological formations has a significant impact on it [65]  
543 Study area has two major geomorphological classes, pediplain and  
544 structural (Fig. 3h). Weathered/fractured rocks that are suitable for  
545 groundwater recharge cover the gently sloping plains of the pediment  
546 landform [66].

547





550

551

552 Fig. 3 Groundwater potential zones prepared using the following thematic  
 553 layers: (a) Rainfall, (b) Geology, (c) Slope, (d) Drainage Density, (e) LULC,  
 554 (f) Lineament Density, (g) Soil and (h) Geomorphology. (This figure was

555 prepared using ArcGIS Desktop 10.7 Esri; <https://www.esri.com>, and  
 556 <https://bhukosh.gsi.gov.in/Bhukosh/MapViewer.aspx.>).

557

558 Table 7: The normalised weights of features for the eight thematic maps.

Parameters	Classes	Weight	Normalised Wi	Influence%	Rank
Rainfall	Low	0.35	0.110	35	1
	Moderate		0.309		2
	High		0.581		3
	CI - 0.002	CR - 0.004	RI - 0.58		
Geology	Charnockite	0.23	0.099	23	2
	Gabbro		0.099		1
	Khondalite		0.284		3
	Migmatite		0.518		4
	CI - 0.002	CR - 0.002	RI - 0.9		
Slope	<3	0.12	0.445	12	5
	3 - 8		0.297		4
	8 - 15		0.147		3
	15 - 30		0.073		2
	>30		0.037		1
	CI - 0.068	CR - 0.060	RI- 1.12		
Drainage density	Very low (0 - 0.60)	0.11	0.445	11	5
	Low (0.60 - 1.21)		0.297		4
	Moderate (1.21 - 1.81)		0.147		3
	High (1.81 - 2.4)		0.073		2
	Very high (>2.4)		0.037		1
	CI - 0.068	CR - 0.060	RI- 1.12		
Land use/ land cover	Barren land	0.6	0.122	6	2
	Built-up land		0.057		1
	Cropland		0.263		4
	Forest		0.558		3
	CI - 0.058	CR - 0.065	RI - 0.9		
Lineament density	Very low (0 - 0.31)	0.5	0.045	5	1
	Low (0.31 - 0.61)		0.077		2
	Moderate (0.61 - 0.91)		0.154		3

	High (0.91 - 1.22)		0.274		4
	Very high (>1.22)		0.450		5
	CI - 0.012	CR - 0.010	RI - 1.12		
Soil	Clayey soils	0.3	0.110	3	1
	Gravelly clay soils deep		0.309		2
	Gravelly clay soils shallow		0.581		3
	CI - 0.002	CR - 0.004	RI - 0.058		
Geomorphology	Structural hill	0.5	0.091	5	1
	Pediplain		0.445		2
	CI - 0.00	CR - 0.00	RI - 0.058		

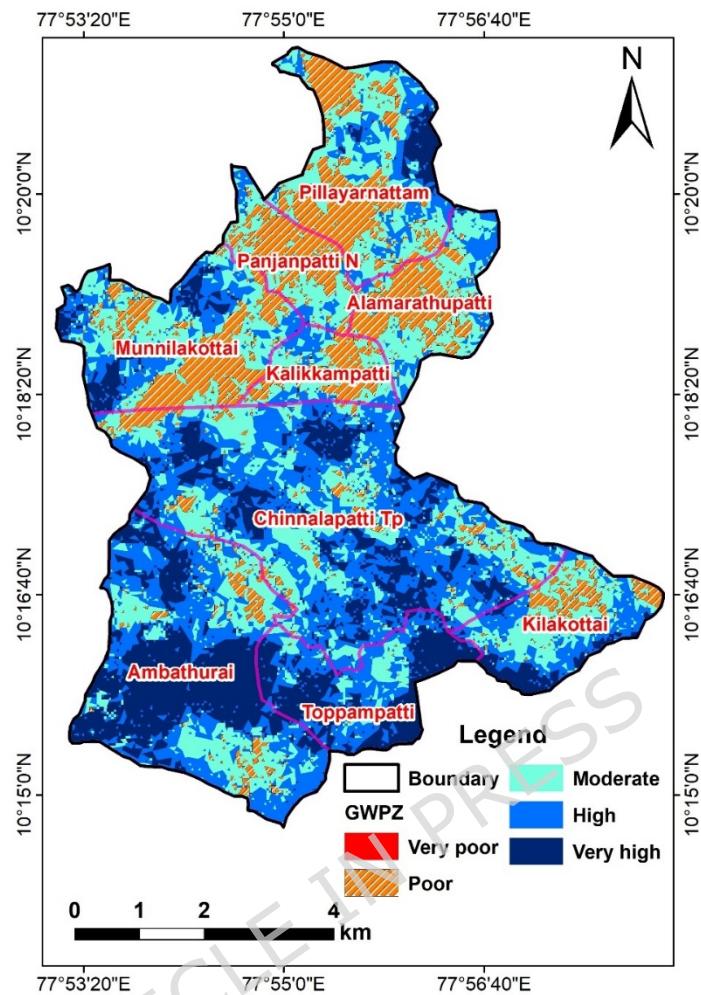
559

560 **Preparing the GWPZ map**

561 No prior research has been conducted on GWPZ mapping in the study  
 562 area.

563 Research data on groundwater resources is lacking for management in the  
 564 future. Consequently, this study is essential for scholars and policymakers  
 565 who want to improve the socioeconomic management of groundwater  
 566 resources. Utilising the weighted overlay method in ArcGIS's spatial  
 567 analysis tool, the GWP map was created by allocating cumulative weights  
 568 to the rainfall, geology, slope, and drainage density. Land use land cover,  
 569 lineament density, soil and geomorphology of eight thematic layers. A  
 570 Groundwater Potential Zonation (GWPZ) map offers important information  
 571 on the groundwater status of a region, which can be used to plan for  
 572 sustainable groundwater extraction. GWPZs were divided into five groups  
 573 within the study area: "very poor", "poor", "moderate", "good", and "very  
 574 good". 54.21 km<sup>2</sup> are covered by these zones, which are as follows: "very  
 575 good (19.97%), good (31.78%), moderate (30.61%), poor (17.63%), and  
 576 extremely poor (0.01%)". There are many locations on the southern margin  
 577 of the study area with an extremely high GWPZ (10.82 km<sup>2</sup>). Different  
 578 GWPZ classifications in the Chinnalapatti firka are depicted in Fig. 4. Table  
 579 8 displays the area and percentage dispersion of the five GWPZ classes.

580



581

582 Fig. 4 Groundwater Potential Zone (GWPZ) map of the study area (This  
 583 figure was prepared using ArcGIS Desktop 10.7 Esri;  
 584 <https://www.esri.com>.

585

586 Table 8. The area and percentage dispersion of the five GWPZ classes

Sl.no	Class	Area (km2)	Area%
1	Very poor	0.01	0.01
2	Poor	9.56	17.63
3	Moderate	16.59	30.61
4	Good	17.23	31.78
5	Very good	10.82	19.97
		<b>54.21</b>	<b>100.00</b>

587

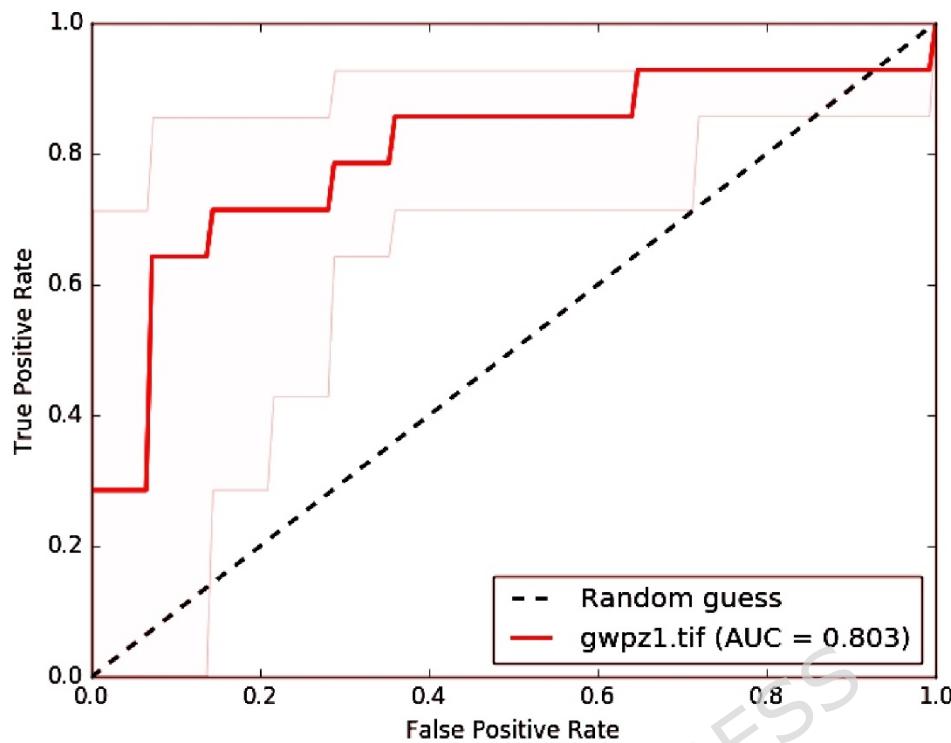
588

**589 Groundwater Potential Zone (GWPZ) Validation**

590 The Chinnalapatti firka GWPZ map was created by combining eight  
591 different thematic maps, including rainfall, geology, slope, drainage  
592 density, land use land cover, lineament density, soil and geomorphology  
593 using AHP, a popular MCDM approach. The "Ground Water Prospect  
594 Study" map, created by CGWB and NRSC, Hyderabad, was used to validate  
595 the GWPZ map, and well yield data was used to confirm the GWPZs. The  
596 findings of this validation approach demonstrated that all groundwater  
597 potential zones in the research region had a correct classification of the  
598 number and percentage of points, which correspond to particular yield  
599 ranges. This affirms that the used strategy produced authentic and notable  
600 results, warranting its use in the present study. Policymakers can apply  
601 the information to assist in the development of effective plans for  
602 groundwater management [51].

603 Agree, agree-less, and agree-excess agreement statuses were used as 1 to  
604 construct the ROC curve, and disagree was used as a value of 0. The ROC  
605 curve graph between GWPZ agreement and well yield data was  
606 constructed using the ArcSDM tool of ArcGIS software (version 10.7). The  
607 area under the curve (AUC) calculated is shown in Fig. 5 and was 80%. In  
608 accordance with [67], the area under the curve (AUC) was within the

609 acceptable range.



610  
611 Fig. 5 The ROC curve for accuracy assessment and AUC.  
612

### 613 Conclusions

614 The study suggested a Groundwater Potential Index (GWPI) map to  
615 demarcate groundwater potential areas of Chinnalapatti firka, Athoor  
616 Taluk, Dindigul district. The current study is an integrated and innovative  
617 approach that harmonizes remote sensing (RS), geographic information  
618 systems (GIS), and the analytical hierarchy process (AHP). The proposed  
619 combined methodology helps in making speedy and effective decisions for  
620 sustainable water resource management. Eight key parameters were  
621 selected prior to overlay analysis since they had the highest contribution  
622 to groundwater potential. Groundwater Potential Zones (GWPZs) of the  
623 study area were categorized into five classes on the basis of them: very  
624 poor, poor, moderate, good, and very good. The corresponding areas  
625 covered by these zones are 54.21 km<sup>2</sup>, very good (19.97%), 10.82 km<sup>2</sup>,  
626 good (31.78%), 17.23 km<sup>2</sup>, moderate (30.61%), 16.59 km<sup>2</sup>, poor (17.63%),  
627 9.56 km<sup>2</sup>, and very poor (0.01%). Low zone refers to a low groundwater  
628 potential zone. Very high zone, on the other hand, refers to the most

629 favourable location for GWP. The accuracy of the GWPZ map is validated  
 630 using well yield data by an agreement scheme on the basis of the  
 631 groundwater prospects map and ROC curve analysis. The outcome reveals  
 632 that the GWPZ map prediction was satisfactory at 80%, respectively. This  
 633 simple but methodical technique has been applied to assess Groundwater  
 634 Potential (GWP) sites effectively. Its methodical character is also as  
 635 efficient and of general application, especially for groundwater studies and  
 636 demarcation of potential areas for artificial recharge in arid and hard rock  
 637 hydrogeology. Hence, it is a valuable technique for long-term sustainable  
 638 groundwater development and aquifer management. Follow-up  
 639 investigations of the model should include field work such as water quality  
 640 sampling and pumping tests to improve the model's precision and  
 641 relevance further. Providing a degree of credibility to the model's  
 642 reliability, the field tests would also help establish whether decisions made  
 643 based on the application of model outputs were scientifically and  
 644 operationally justifiable.

#### 645 **Data Availability**

646 The datasets used and/or analysed during the current study are available  
 647 from the corresponding author on reasonable request.

648

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652

#### 653 **References**

- 654 [1] B. Murugesan, G. Balasumbramaniyan, B. Swaminathan, and S.  
 655 Karuppannan, "Deciphering of groundwater potential zones in hard rock  
 656 terrain using GIS technology with AHP statistical methods: A case study of  
 657 Nilgiri, Tamil Nadu, India," *Sci Rep*, vol. 15, no. 1, pp. 1-16, Dec. 2025, doi:  
 658 10.1038/S41598-025-10948-  
 659 5;SUBJMETA=2151,241,242,704;KWRD=HYDROGEOLOGY,HYDROLOGY.
- 660 [2] A. Awasthi and M. S. Rishi, "Assessing groundwater potential for  
 661 sustainable development in the transboundary aquifers of River Ravi, India:

662 an integrated geospatial and AHP approach," *Environ Earth Sci*, vol. 84, no.  
 663 14, pp. 1-24, Jul. 2025, doi: 10.1007/S12665-025-12415-W/METRICS.

664 [3] V. Kumar Gautam, C. B. Pande, M. Kothari, P. Kumar Singh, and A. Agrawal,  
 665 "Exploration of groundwater potential zones mapping for hard rock region  
 666 in the Jakham river basin using geospatial techniques and aquifer  
 667 parameters," *Advances in Space Research*, vol. 71, no. 6, pp. 2892-2908,  
 668 Mar. 2023, doi: 10.1016/J.ASR.2022.11.022.

669 [4] T. A. Tella, B. Festus, T. D. Olaoluwa, and A. S. Oladapo, "Water and  
 670 wastewater treatment in developed and developing countries: Present  
 671 experience and future plans," *Smart Nanomaterials for Environmental  
 672 Applications*, pp. 351-385, Jan. 2025, doi: 10.1016/B978-0-443-21794-  
 673 4.00030-2.

674 [5] "Central Ground Water Board, 2023 - Google Search." Accessed: Nov. 12,  
 675 2025. [Online]. Available:  
 676 [https://www.google.com/search?q=Central+Ground+Water+Board%2C+2023&oq=Central+Ground+Water+Board%2C+2023&gs\\_lcp=EgZjaHJvbWUyBggAEEUYOTIICAEQABgWGB4yCAgCEAAYFhgeMgolAxAAGIAEGKIEmgolBBAAAGIAEGKIEmgcIBRAAGO8FMgclBhAAGO8FMgclBxAAGO8F0gEJMTk0MGowa jE1qAllsAIB8QVWRM0uj4rNNQ&sourceid=chrome&ie=UTF-8&zx=1762941268586&no\\_sw\\_cr=1](https://www.google.com/search?q=Central+Ground+Water+Board%2C+2023&oq=Central+Ground+Water+Board%2C+2023&gs_lcp=EgZjaHJvbWUyBggAEEUYOTIICAEQABgWGB4yCAgCEAAYFhgeMgolAxAAGIAEGKIEmgolBBAAAGIAEGKIEmgcIBRAAGO8FMgclBhAAGO8FMgclBxAAGO8F0gEJMTk0MGowa jE1qAllsAIB8QVWRM0uj4rNNQ&sourceid=chrome&ie=UTF-8&zx=1762941268586&no_sw_cr=1)

677 [6] N. S. Magesh, N. Chandrasekar, and J. P. Soundranayagam, "Delineation of  
 678 groundwater potential zones in Theni district, Tamil Nadu, using remote  
 679 sensing, GIS and MIF techniques," *Geoscience Frontiers*, vol. 3, no. 2, pp.  
 680 189-196, Mar. 2012, doi: 10.1016/J.GSF.2011.10.007.

681 [7] K. Das *et al.*, "Integrated assessment of fluoride occurrence and  
 682 groundwater usability: a critical concern for drinking water sustainability  
 683 and irrigation in semi-arid region of West Bengal, India," *Discover  
 684 Sustainability*, vol. 6, no. 1, pp. 1-24, Dec. 2025, doi: 10.1007/S43621-025-  
 685 01498-X/METRICS.

686 [8] V. P. Sati, "Water Resource Potential in the Indian Central Himalaya: A  
 687 Study on Its Conservation through Traditional Practices," *Rural and  
 688 Regional Development 2025, Vol. 3, Page 10011*, vol. 3, no. 3, p. 10011,  
 689 Jul. 2025, doi: 10.70322/RRD.2025.10011.

690 [9] S. Ghorbani Nejad, F. Falah, M. Daneshfar, A. Haghizadeh, and O. Rahmati,  
 691 "Delineation of groundwater potential zones using remote sensing and GIS-  
 692 based data-driven models," *Geocarto Int*, vol. 32, no. 2, pp. 167-187, Feb.  
 693 2017, doi: 10.1080/10106049.2015.1132481;REQUESTEDJOURNAL:JOURNAL:TGEI20;C  
 694 TYPE:STRING:JOURNAL.

695 [10] P. Arulbalaji, D. Padmalal, and K. Sreelash, "GIS and AHP Techniques Based  
 696 Delineation of Groundwater Potential Zones: a case study from Southern  
 697 Western Ghats, India," *Sci Rep*, vol. 9, no. 1, pp. 1-17, Dec. 2019, doi:  
 698 10.1038/S41598-019-38567-  
 699 X;TECHMETA=134;SUBJMETA=158,172,242,2459,4081,704;KWRD=ENVIRO  
 700 NMENTAL+IMPACT,FRESHWATER+ECOLOGY,HYDROLOGY.

707 [11] B. S. Chaudhary and S. Kumar, "Identification of Groundwater Potential  
 708 Zones using Remote Sensing and GIS of K-J Watershed, India," *Journal of*  
 709 *the Geological Society of India*, vol. 91, no. 6, pp. 717-721, Jun. 2018, doi:  
 710 10.1007/S12594-018-0929-3.

711 [12] K. Akpoti, M. Dembélé, G. Forkuor, E. Obuobie, T. Mabhaudhi, and O. Cofie,  
 712 "Integrating GIS and remote sensing for land use/land cover mapping and  
 713 groundwater potential assessment for climate-smart cocoa irrigation in  
 714 Ghana," *Sci Rep*, vol. 13, no. 1, pp. 1-21, Dec. 2023, doi: 10.1038/S41598-  
 715 023-43286-  
 716 5;SUBJMETA=172,4081,704;KWRD=ENVIRONMENTAL+IMPACT,ENVIRONME  
 717 NTAL+SCIENCES.

718 [13] A. E. sayed Mostafa *et al.*, "Groundwater Potential Mapping in Semi-Arid  
 719 Areas Using Integrated Remote Sensing, GIS, and Geostatistics  
 720 Techniques," *Water 2025, Vol. 17, Page 1909*, vol. 17, no. 13, p. 1909, Jun.  
 721 2025, doi: 10.3390/W17131909.

722 [14] Y. Ayadi, M. Gentilucci, K. Ncibi, R. Hadji, and Y. Hamed, "Assessment of a  
 723 Groundwater Potential Zone Using Geospatial Artificial Intelligence (Geo-  
 724 AI), Remote Sensing (RS), and GIS Tools in Majerda Transboundary Basin  
 725 (North Africa)," *Water (Switzerland)*, vol. 17, no. 3, Jan. 2025, doi:  
 726 10.3390/W17030331.

727 [15] P. Mageshkumar, A. Subbaiyan, E. Lakshmanan, and P. Thirumoorthy,  
 728 "Application of geospatial techniques in delineating groundwater potential  
 729 zones: a case study from South India," *Arabian Journal of Geosciences*, vol.  
 730 12, no. 5, pp. 1-15, Mar. 2019, doi: 10.1007/S12517-019-4289-  
 731 0/FIGURES/12.

732 [16] T. Dar, N. Rai, and A. Bhat, "Delineation of potential groundwater recharge  
 733 zones using analytical hierarchy process (AHP)," *Geology, Ecology, and*  
 734 *Landscapes*, vol. 5, no. 4, pp. 292-307, Oct. 2021, doi:  
 735 10.1080/24749508.2020.1726562;WGROUP:STRING: PUBLICATION.

736 [17] J. K. Thakur, R. K. Thakur, A. L. Ramanathan, M. Kumar, and S. K. Singh,  
 737 "Arsenic Contamination of Groundwater in Nepal—An Overview," *Water*  
 738 *2011, Vol. 3, Pages 1-20*, vol. 3, no. 1, pp. 1-20, Dec. 2010, doi:  
 739 10.3390/W3010001.

740 [18] E. Agarwal *et al.*, "Delineation of groundwater potential zone: An AHP/ANP  
 741 approach," *JESS*, vol. 122, no. 3, pp. 887-898, Jun. 2013, doi:  
 742 10.1007/S12040-013-0309-8.

743 [19] S. B. Kassa *et al.*, "Groundwater Potential Assessment Using Integrated  
 744 Geospatial and Analytic Hierarchy Process Techniques (AHP) in Chemoga  
 745 Watershed, Upper Blue Nile Basin, Ethiopia," *Air, Soil and Water Research*,  
 746 vol. 18, Jan. 2025, doi: 10.1177/11786221241312806.

747 [20] S. L. Suryawanshi, P. K. Singh, M. Kothari, M. Singh, K. K. Yadav, and T.  
 748 Gupta, "Spatial and decision-making approaches for identifying  
 749 groundwater potential zones: a review," *Environ Earth Sci*, vol. 82, no. 20,  
 750 pp. 1-11, Oct. 2023, doi: 10.1007/S12665-023-11149-X/FIGURES/2.

751 [21] I. Ahammed, J. G, P. T.K, and S. S, "Geographical Information System and  
 752 Multi-Influencing Factor techniques for the assessment of groundwater  
 753 potential zones of tropical watersheds: A case study," *Acta Geographica*  
 754 *Debrecina Landscape & Environment series*, vol. 19, no. 1, pp. 15-28, Jun.  
 755 2025, doi: 10.21120/LE/19/1/2.

756 [22] M. Bagyaraj, T. Ramkumar, S. Venkatramanan, and B. Gurugnanam,  
 757 "Application of remote sensing and GIS analysis for identifying  
 758 groundwater potential zone in parts of Kodaikanal Taluk, South India,"  
 759 *Front Earth Sci*, vol. 7, no. 1, pp. 65-75, Dec. 2012, doi: 10.1007/s11707-  
 760 012-0347-6.

761 [23] A. G. Selvarani, G. Maheswaran, and K. Elangovan, "Evaluation of  
 762 groundwater potential zones using GIS and remote sensing in Noyyal Basin,  
 763 Tamil Nadu India," *International Journal of Environmental Technology and*  
 764 *Management*, vol. 17, no. 5, pp. 377-392, 2014, doi:  
 765 10.1504/IJETM.2014.064577.

766 [24] N. S. Kawo and S. Karuppannan, "Groundwater quality assessment using  
 767 water quality index and GIS technique in Modjo River Basin, central  
 768 Ethiopia," *Journal of African Earth Sciences*, vol. 147, pp. 300-311, Nov.  
 769 2018, doi: 10.1016/j.jafrearsci.2018.06.034.

770 [25] S. Karuppannan and N. Serre Kawo, "Groundwater Quality Assessment  
 771 Using Geospatial Techniques and WQI in North East of Adama Town,  
 772 Oromia Region, Ethiopia," *Hydrospatial Analysis*, vol. 3, no. 1, pp. 22-36,  
 773 Jan. 2020, doi: 10.21523/gcj3.19030103.

774 [26] V. Kumar Gautam, C. B. Pande, M. Kothari, P. Kumar Singh, and A. Agrawal,  
 775 "Exploration of groundwater potential zones mapping for hard rock region  
 776 in the Jakham river basin using geospatial techniques and aquifer  
 777 parameters," *Advances in Space Research*, vol. 71, no. 6, pp. 2892-2908,  
 778 Mar. 2023, doi: 10.1016/J.ASR.2022.11.022.

779 [27] A. Rehman *et al.*, "Groundwater potential zone mapping using GIS and  
 780 Remote Sensing based models for sustainable groundwater management,"  
 781 *Geocarto Int*, vol. 39, no. 1, 2024, doi: 10.1080/10106049.2024.2306275.

782 [28] S. Kanji and S. Das, "Assessing groundwater potentialities and  
 783 replenishment feasibility using machine learning and MCDM models  
 784 considering hydro-geological aspects and water quality constituents,"  
 785 *Environ Earth Sci*, vol. 84, no. 1, Jan. 2025, doi: 10.1007/s12665-024-  
 786 11996-2.

787 [29] D. K. Patel, T. K. Thakur, A. Thakur, S. Karuppannan, S. L. Swamy, and R. R.  
 788 Pant, "Groundwater potential zone mapping using AHP and geospatial  
 789 techniques in the upper Narmada basin, central India," *Discover*  
 790 *Sustainability*, vol. 5, no. 1, Dec. 2024, doi: 10.1007/s43621-024-00560-4.

791 [30] D. Diriba, S. Karuppannan, T. Takele, and M. Husein, "Delineation of  
 792 groundwater potential zonation using geoinformatics and AHP techniques  
 793 with remote sensing data," *Helijon*, vol. 10, no. 3, Feb. 2024, doi:  
 794 10.1016/j.helijon.2024.e25532.

795 [31] T. L. Saaty and L. G. Vargas, "Hierarchical analysis of behavior in  
 796 competition: Prediction in chess," *Behavioral Science*, vol. 25, no. 3, pp.  
 797 180–191, Jan. 1980, doi:  
 798 10.1002/BS.3830250303;WGROUP:STRING:PUBLICATION.

799 [32] M. Ghosh and A. S. Sahu, "Delineation of groundwater potential zones  
 800 using AHP and GIS techniques: a case study in Barakar river basin, India,"  
 801 *Arabian Journal of Geosciences* 2023 16:3, vol. 16, no. 3, pp. 1–20, Feb.  
 802 2023, doi: 10.1007/S12517-023-11253-Z.

803 [33] S. K. Roy *et al.*, "Empowered machine learning algorithm to identify  
 804 sustainable groundwater potential zone map in Jashore District,  
 805 Bangladesh," *Groundw Sustain Dev*, vol. 25, p. 101168, May 2024, doi:  
 806 10.1016/J.GSD.2024.101168.

807 [34] R. Sakthi Priya *et al.*, "An application of remote sensing and GIS used in  
 808 groundwater potential zones for sustainable urban development in coastal  
 809 areas between Chettikulam and Kolachal, southern India," *Applied  
 810 Geomatics*, 2025, doi: 10.1007/s12518-024-00604-4.

811 [35] "IMD - Google Search." Accessed: Nov. 12, 2025. [Online]. Available:  
 812 [https://www.google.com/search?q=IMD&oq=IMD&gs\\_lcp=EgZjaHJvbWUyDwgAEEUYORixAxjJAxjABDIGCAEQIxgnMg0IAhAAGIMBLEDGIAEMg0IAxAAGJIDGIAEGloFMgoIBBAAGLEDGIAEMgoIBRAAGLEDGIAEMgoIBhAAGLEDGIAEMgoIBxAAGLEDGIAEMgoICBAAGLEDGIAEMacICRAAGI8C0gEJMjI4NmowajE1qAllsAIB8QVSmK1gQ5IIZfEFUpitYEOSCGU&sourceid=chrome&ie=UTF-8](https://www.google.com/search?q=IMD&oq=IMD&gs_lcp=EgZjaHJvbWUyDwgAEEUYORixAxjJAxjABDIGCAEQIxgnMg0IAhAAGIMBLEDGIAEMg0IAxAAGJIDGIAEGloFMgoIBBAAGLEDGIAEMgoIBRAAGLEDGIAEMgoIBhAAGLEDGIAEMgoIBxAAGLEDGIAEMgoICBAAGLEDGIAEMacICRAAGI8C0gEJMjI4NmowajE1qAllsAIB8QVSmK1gQ5IIZfEFUpitYEOSCGU&sourceid=chrome&ie=UTF-8)

817 [36] K. Fatema, M. Joy, F. Amin, S. S.- Heliyon, and undefined 2023,  
 818 "Groundwater potential mapping in Jashore, Bangladesh," *cell.comK  
 819 Fatema, MAR Joy, FMR Amin, SK SarkarHeliyon, 2023•cell.com*, vol. 9, no.  
 820 3, p. e13966, Mar. 2023, doi: 10.1016/J.HELION.2023.E13966.+.

821 [37] "Home | CGWB." Accessed: Oct. 02, 2025. [Online]. Available:  
 822 <https://www.cgwb.gov.in/>

823 [38] A. Rahaman, B. Biswas, J. Barman, V. M. Suresh, B. Kishor, and J. Das,  
 824 "Delineation of Groundwater Potential Zones Through AHP: A Case Study  
 825 from Tamil Nadu, India," pp. 315–329, 2023, doi: 10.1007/978-3-031-  
 826 15377-8\_21.

827 [39] A. Bera, B. P. Mukhopadhyay, and S. Barua, "Delineation of groundwater  
 828 potential zones in Karha river basin, Maharashtra, India, using AHP and  
 829 geospatial techniques," *Arabian Journal of Geosciences*, vol. 13, no. 15,  
 830 Aug. 2020, doi: 10.1007/S12517-020-05702-2.

831 [40] T. L. Saaty, "How to make a decision: The analytic hierarchy process," *Eur/  
 832 Oper Res*, vol. 48, no. 1, pp. 9–26, Sep. 1990, doi: 10.1016/0377-  
 833 2217(90)90057-I.

834 [41] D. M. Das *et al.*, "Identification of potential groundwater zones in rice-fallow  
 835 areas within the Mahanadi river basin, India, using GIS and the analytical  
 836 hierarchy process," *EES*, vol. 81, no. 15, p. 395, Aug. 2022, doi:  
 837 10.1007/S12665-022-10517-3.

838 [42] D. Machiwal, M. K. Jha, and B. C. Mal, "Assessment of Groundwater  
 839 Potential in a Semi-Arid Region of India Using Remote Sensing, GIS and  
 840 MCDM Techniques," *Water Resources Management*, vol. 25, no. 5, pp.  
 841 1359–1386, Mar. 2011, doi: 10.1007/S11269-010-9749-Y/METRICS.

842 [43] N. S. Magesh, N. Chandrasekar, and J. P. Soundranayagam, "Delineation of  
 843 groundwater potential zones in Theni district , Tamil Nadu , using remote  
 844 sensing , GIS and MIF techniques," *Geoscience Frontiers*, vol. 3, no. 2, pp.  
 845 189–196, 2012, doi: 10.1016/j.gsf.2011.10.007.

846 [44] S. Lee, Y. Hyun, and M. J. Lee, "Groundwater potential mapping using data  
 847 mining models of big data analysis in Goyang-si, South Korea,"  
 848 *Sustainability (Switzerland)*, vol. 11, no. 6, 2019, doi: 10.3390/su11061678.

849 [45] M. Rajasekhar, B. Upendra, G. S. Raju, and Anand, "Identification of  
 850 groundwater potential zones in southern India using geospatial and  
 851 decision-making approaches," *SpringerM Rajasekhar, B Upendra, GS Raju,  
 852 AnandApplied Water Science, 2022•Springer*, vol. 12, no. 4, Apr. 2022, doi:  
 853 10.1007/S13201-022-01603-9.

854 [46] V. Govindaraj, S. Thirumalasamy, J. I. Sankar, and S. Gopi, "Groundwater  
 855 potential mapping and natural remediation through artificial recharge  
 856 structures in Vellore District, Tamil Nadu, India using geospatial  
 857 techniques," *Desalination Water Treat*, vol. 254, pp. 229–237, Apr. 2022,  
 858 doi: 10.5004/dwt.2022.28351.

859 [47] Z. A. Khan and B. Jhamnani, "Identification of groundwater potential zones  
 860 of Idukki district using remote sensing and GIS-based machine-learning  
 861 approach," *Water Supply*, vol. 23, no. 6, pp. 2426–2446, Jun. 2023, doi:  
 862 10.2166/ws.2023.134.

863 [48] P. Murmu, M. Kumar, D. Lal, I. Sonker, and S. K. Singh, "Groundwater for  
 864 sustainable development delineation of groundwater potential zones using  
 865 geospatial techniques and analytical hierarchy process in Dumka district,  
 866 Jharkhand," *India Groundw Sustain Dev*, vol. 9, p. 100239, Oct. 2019, doi:  
 867 10.1016/j.gsd.2019.100239.

868 [49] K. P. Kom, B. Gurugnanam, and V. Sunitha, "Delineation of groundwater  
 869 potential zones using GIS and AHP techniques in Coimbatore district, South  
 870 India," *SpringerKP Kom, B Gurugnanam, V SunithaInternational Journal of  
 871 Energy and Water Resources, 2024•Springer*, vol. 8, no. 1, pp. 85–109,  
 872 Mar. 2024, doi: 10.1007/S42108-022-00188-Y.

873 [50] D. Machiwal and P. K. Singh, "Comparing GIS-based multi-criteria decision-  
 874 making and Boolean logic modelling approaches for delineating  
 875 groundwater recharge zones," *Arabian Journal of Geosciences*, vol. 8, no.  
 876 12, pp. 10675–10691, Dec. 2015, doi: 10.1007/S12517-015-2002-  
 877 5/FIGURES/10.

878 [51] S. L. Suryawanshi, P. K. Singh, M. Kothari, M. Singh, K. K. Yadav, and T.  
 879 Gupta, "Assessment of groundwater potential zones for hard rock area of  
 880 sabi river basin using an integrated approach of remote sensing, GIS and  
 881 AHP techniques," *Physics and Chemistry of the Earth*, vol. 137, Feb. 2025,  
 882 doi: 10.1016/j.pce.2024.103820.

883 [52] J. Malczewski, *GIS and multicriteria decision analysis*. 1999. Accessed: Jun.  
 884 05, 2025. [Online]. Available:  
 885 <https://books.google.co.in/books?hl=en&lr=&id=ZqUsEAAAQBAJ&oi=fnd&p>  
 886 g=PA393&dq=Malczewski,+J.+(1999).+GIS+and+multicriteria+decision+a  
 887 nalysis.+New+York:+Wiley.&ots=6I085kIA9-  
 888 &sig=kkjuzK6knpCe2BTZ75zSn6gtP6c

889 [53] I. Jasmin and P. Mallikarjuna, "Delineation of groundwater potential zones  
 890 in Araniar River basin, Tamil Nadu, India: an integrated remote sensing and  
 891 geographical information system approach," *Environ Earth Sci*, vol. 73, no.  
 892 7, pp. 3833-3847, Apr. 2015, doi: 10.1007/S12665-014-3666-Y.

893 [54] N. S. Magesh, N. Chandrasekar, and J. P. Soundranayagam, "Delineation of  
 894 groundwater potential zones in Theni district, Tamil Nadu, using remote  
 895 sensing, GIS and MIF techniques," *Geoscience Frontiers*, vol. 3, no. 2, pp.  
 896 189-196, 2012, doi: 10.1016/j.gsf.2011.10.007.

897 [55] Z. Ahmed, M. Ansari, M. Zahir, ... U. S.-J. of G., and undefined 2020,  
 898 "Hydrogeophysical investigation for groundwater potential through  
 899 Electrical Resistivity Survey in Islamabad, Pakistan," [jgss.uob.edu.pkZ](http://jgss.uob.edu.pkZ)  
 900 *Ahmed, MT Ansari, M Zahir, U Shakir, M SubhanJournal of Geography and*  
 901 *Social Sciences (JGSS), 2020•jgss.uob.edu.pk*, Accessed: Jun. 05, 2025.  
 902 [Online]. Available:  
 903 <http://jgss.uob.edu.pk/journal/index.php/jgss/article/view/16>

904 [56] H. F. Yeh, Y. S. Cheng, H. I. Lin, and C. H. Lee, "Mapping groundwater  
 905 recharge potential zone using a GIS approach in Hualian River, Taiwan,"  
 906 *Sustainable Environment Research*, vol. 26, no. 1, pp. 33-43, Jan. 2016,  
 907 doi: 10.1016/J.SERJ.2015.09.005.

908 [57] S. Kumar Singh *et al.*, "Integrated assessment of groundwater influenced  
 909 by a confluence river system: concurrence with remote sensing and  
 910 geochemical modelling," *SpringerSK Singh, PK Srivastava, AC Pandey, SK*  
 911 *GautamWater resources management, 2013•Springer*, vol. 27, no. 12, pp.  
 912 4291-4313, Sep. 2013, doi: 10.1007/S11269-013-0408-Y.

913 [58] T. Acharya, S. N.-E. Resour, and undefined 2013, "Study of groundwater  
 914 prospects of the crystalline rocks in Purulia District, West Bengal, India  
 915 using remote sensing data," *researchgate.netT Acharya, SK NagEarth*  
 916 *Resour, 2013•researchgate.net*, doi: 10.12966/er.07.03.2013.

917 [59] S. Bhattacharya, S. Das, S. Das, M. Kalashetty, · Sumedh, and R. Warghat,  
 918 "An integrated approach for mapping groundwater potential applying  
 919 geospatial and MIF techniques in the semiarid region," *SpringerS*  
 920 *Bhattacharya, S Das, S Das, M Kalashetty, SR WarghatEnvironment,*  
 921 *development and sustainability, 2021•Springer*, vol. 23, no. 1, pp. 495-  
 922 510, Jan. 2021, doi: 10.1007/+S10668-020-00593-5.

923 [60] P. Singh, P. Dahiphale, K. Yadav, ... M. S.-: S. P. of, and undefined 2018,  
 924 "Delineation of groundwater potential zones in Jaisamand basin of Udaipur  
 925 district," *SpringerPK Singh, P Dahiphale, KK Yadav, M SinghGroundwater:*  
 926 *Select Proceedings of ICWEES-2016, 2018•Springer*, pp. 3-20, 2018, doi:  
 927 10.1007/978-981-10-5789-2\_1.+.

928 [61] D. O'LEARY, ... J. F.-G. S. of, and undefined 1976, "Lineament, linear,  
 929 lineation: some proposed new standards for old terms,"  
 930 *pubs.geoscienceworld.orgDW O'LEARY, JD FRIEDMAN, HA POHNGeological*  
 931 *Society of America Bulletin, 1976*•*pubs.geoscienceworld.org*, Accessed:  
 932 Jun. 05, 2025. [Online]. Available:  
 933 <https://pubs.geoscienceworld.org/gsa/gsabulletin/article-abstract/87/10/1463/201929>  
 934

935 [62] P. Arulbalaji, D. Padmalal, and K. Sreelash, "GIS and AHP Techniques Based  
 936 Delineation of Groundwater Potential Zones: a case study from Southern  
 937 Western Ghats, India," *Sci Rep*, vol. 9, no. 1, Dec. 2019, doi:  
 938 10.1038/s41598-019-38567-x.

939 [63] C. B. Silwal, M. Nepal, D. Pathak, B. Karkee, K. Dahal, and S. Acharya,  
 940 "Groundwater potential zonation in the Siwalik of the Kankai River Basin,  
 941 Eastern Nepal," *Water Supply*, vol. 23, no. 6, pp. 2332-2348, Jun. 2023, doi:  
 942 10.2166/WS.2023.137.

943 [64] K. N. Sayl, S. O. Sulaiman, A. H. Kamel, and N. Al Ansari, "Towards the  
 944 Generation of a Spatial Hydrological Soil Group Map Based on the Radial  
 945 Basis Network Model and Spectral Reflectance Band Recognition", doi:  
 946 10.18280/ijdne.170514.

947 [65] M. Waikar, A. N.-I. J. of Innovative, and undefined 2014, "Identification of  
 948 groundwater potential zone using remote sensing and GIS technique,"  
 949 *researchgate.netML Waikar, AP NilawarInternational Journal of Innovative*  
 950 *Research in Science, Engineering, 2014*•*researchgate.net*, vol. 3297, no. 5,  
 951 pp. 2319-8753, 2007, Accessed: Jun. 05, 2025. [Online]. Available:  
 952 [https://www.researchgate.net/profile/Akash-Anand-8/post/Water\\_level\\_and\\_soil\\_moisture\\_is\\_important\\_to\\_predict\\_peatland\\_fir\\_e\\_can\\_we\\_use\\_Remote\\_sensing\\_to\\_estimate\\_water\\_level\\_and\\_soil\\_moisture/attachment/59d6537b79197b80779ab609/AS%3A517522317611008%401500398343281/download/22\\_Identification.pdf](https://www.researchgate.net/profile/Akash-Anand-8/post/Water_level_and_soil_moisture_is_important_to_predict_peatland_fir_e_can_we_use_Remote_sensing_to_estimate_water_level_and_soil_moisture/attachment/59d6537b79197b80779ab609/AS%3A517522317611008%401500398343281/download/22_Identification.pdf)

957 [66] A. Kumar and A. P. Krishna, "Assessment of groundwater potential zones in  
 958 coal mining impacted hard-rock terrain of India by integrating geospatial  
 959 and analytic hierarchy process (AHP)," *Taylor & FrancisA Kumar, AP*  
 960 *KrishnaGeocarto International, 2018*•*Taylor & Francis*, vol. 33, no. 2, pp.  
 961 105-129, Feb. 2018, doi: 10.1080/10106049.2016.1232314.

962 [67] I. Alrawi, J. Chen, and A. A. Othman, "Groundwater Potential Zone Mapping:  
 963 Integration of Multi-Criteria Decision Analysis (MCDA) and GIS Techniques  
 964 for the Al-Qalamoun Region in Syria," *ISPRS International Journal of Geo-*  
 965 *Information 2022, Vol. 11, Page 603*, vol. 11, no. 12, p. 603, Dec. 2022, doi:  
 966 10.3390/IJGI11120603.

967

968

969

970

971 T Takele, A Mechal, B A Berhe (2025) Assessing Groundwater Potential in  
972 the Ziway Lake Watershed Using Geographical Information  
973 System, Analytic Hierarchy Process, and Drinking Water Quality  
974 Index. *Global Challenges* **9** (6), 2400354

975 T Takele, A Mechal, BA Berhe (2025) Evaluation of groundwater recharge  
976 potential using geospatial analysis in the Ziway Lake watershed,  
977 Ethiopian Rift: A GIS and AHP-based methodological framework.  
978 *Environmental and Sustainability Indicators*, 100692.

979 A Yacob, A Hussien, F W Tesema, B A Berhe (2025) Delineation of  
980 Groundwater Potential Zones Using Analytical Hierarchy Process  
981 (AHP) and GIS in Weserbi Sub-Catchment, Oromia, Ethiopia.  
982 *Water Practice & Technology* **20** (4), 983-[page end—if  
983 available]. DOI: 10.2166/wpt.2025.050.

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990