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DETERMINATION OF GROUNDWATER POTENTIAL ZONE USING AHP BASED ON GIS FOR KONYA, TÜRKİYE

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Keywords
Groundwater, Analytical Hierarchy Process, GIS, Konya, Türkiye.

Abstract
Groundwater provides most of the freshwater needs such as drinking, irrigation and industry. As a result of increasing population, urbanization and industrialization, groundwater resources are faced with the risk of decreasing and pollution. In addition, exploited usage of irrigation water from groundwater during agricultural activities causes the formation of sinkholes. For this reason, Konya in Türkiye, having a lot of agricultural activities and common sinkhole formations, was chosen as the study area. This research utilized the analytical hierarchy process (AHP), a type of multi-criteria decision-making analysis, to assess the groundwater potential in Konya, Türkiye. For this purpose, land use, slope, rainfall, topographic wetness index, drainage density, elevation, plan curvature, profile curvature and stream power index thematic maps were created, and their weights were determined with AHP. Groundwater potential map (GWPM) was produced by overlay analysis in GIS environment. The GWPM was validated by comparing it with the groundwater zones (GWZ) map given in the report of “Konya Closed Basin Management Plan” project. As a result of the validation process, the accuracy value was found to be 0.87.

KONYA İÇİN CBS TABANLI AHP KULLANILARAK YERALTI SUYU POTANSİYEL BÖLGESİNİN BELİRLENMESİ

Anahtar Kelimeler
Yeraltı Suyu, Analitik Hiyerarşi Süreci, CBS, Konya, Türkiye.

Öz
Yeraltı suyu, içme, sulama ve sanayi gibi tatlı su ihtiyaçlarının çoğunu karşılar. Artan nüfus, kentleşme ve sanayileşme sonucunda yeraltı suyu kaynakları azalma ve kirlenme riskiyle karşı karşıyadır. Ayrıca tarımsal faaliyetler sırasında yeraltı suyundan sulama suyu kullanılması, obruk oluşumuna neden olmaktadır. Bu nedenle, Türkiye'de çok sayıda tarımsal faaliyetin gerçekleştiği ve yaygın obruk oluşumlarının bulunduğu Konya, çalışma alanı olarak seçilmiştir. Bu araştırmada, Türkiye'nin Konya kentindeki yeraltı suyu potansiyelini değerlendirmek için çok kriterli karar verme analizi türlerinden biri olan analitik hiyerarşi süreci (AHP) kullanılmıştır. Bu amaçla arazi kullanımı, eğim, yağış, topografik ıslaklık indeksi, drenaj yoğunluğu, yükseklik, düzlem eğriliği, profil eğriliği ve akarsu güç indeksi tematik haritaları oluşturulmuş ve ağırlıkları AHP ile belirlenmiştir. Yeraltı suyu potansiyeli haritası (GWPM), CBS ortamında bindirme analizi ile üretilmiştir. GWPM, "Konya Kapalı Havza Yönetim Planı" projesi raporunda verilen yeraltı suyu bölgeleri (GWZ) haritası ile karşılaştırılarak doğrulanmıştır. Doğrulama işlemi sonucunda doğruluk değeri 0.87 olarak bulunmuştur.

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Highlights

- The study targets Konya, Türkiye, a region known for its intensive agricultural activities
- Utilizes the Analytical Hierarchy Process (AHP) for multi-criteria decision-making to evaluate groundwater potential by analyzing various geographic and environmental factors
- Creating a comprehensive map (GWPM) showing areas with high and low groundwater potential by integrating thematic maps into the GIS environment
- By comparing GWPM with GVZ, a high accuracy of 0.87 was obtained, demonstrating the reliability of the AHP method.

Purpose and Scope

The primary objective of this research is to assess and map the groundwater potential in Konya, Türkiye. By identifying regions of high and low groundwater potential, this research seeks to inform sustainable water management practices and mitigate risks.

Design/methodology/approach

This study employs a structured and analytical methodology using the Analytical Hierarchy Process (AHP) within a Geographic Information System (GIS) environment to evaluate and map the groundwater potential in Konya, Türkiye.

Findings

The research findings from the groundwater potential study in Konya, Türkiye, provide significant insights into the distribution and vulnerability of groundwater resources in the region.

Research limitations/implications

In future studies, a groundwater map with higher accuracy can be developed by taking different thematic maps into account.

Practical implications

The findings from the groundwater potential study in Konya, Türkiye, carry substantial practical implications for water resource management, urban and rural planning, and agricultural practices. These implications can guide policymakers, stakeholders, and the community in making informed decisions to ensure sustainable groundwater usage.

Social Implications

The groundwater potential study in Konya, Türkiye, has several social implications that extend beyond technical water management to influence public attitudes, environmental sustainability, and quality of life.

Originality

The groundwater potential study in Konya, Türkiye, brings several original contributions to the field of hydrology and environmental management, emphasizing a comprehensive and locally tailored approach to groundwater assessment. This study uniquely applies the Analytical Hierarchy Process (AHP) within a Geographic Information System (GIS) to assess groundwater resources in a region prone to environmental challenges. The innovative integration of AHP for weighting multiple influencing factors and GIS for spatial analysis and mapping provides a robust and replicable model for groundwater potential assessment. These original elements highlight the paper's contribution to advancing the understanding of groundwater potential in environmentally sensitive and agriculturally intensive regions. The integration of detailed geographic analysis with methodological innovation provides a valuable blueprint for similar studies worldwide.

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1. Introduction

The quality and quantity of water resources, which are inevitable for the continuity of life, are under increasing threat due to population growth, human activities, and changes in climatic conditions. Therefore, optimum use of water resources is required, and groundwater resources are an important alternative to meet drinking and irrigation water needs. Studies on the determination of groundwater potential and quality are very costly and time-consuming studies.

There are no studies on the investigation of groundwater potential with GIS-based AHP in Konya Closed Basin, one of the main agricultural areas of Turkey. Especially in recent years, there has been an increase in groundwater level withdrawal in recent years due to the exploited use of groundwater. This problem has revealed the necessity of investigating the groundwater potential (GWP). Previous studies in the region have been conducted on groundwater quality, usability and its social impacts (Nalbantçılar, 2002; Direk et al., 2006; Bozdağ, 2017 and Şener et al., 2022). Başçiftçi et al. (2013) mapped groundwater level changes in various wells in the Konya closed basin with GIS until 2010. In this respect, the study constitutes an innovation for the region in terms of estimating groundwater potential with GIS-based AHP by considering different parameters. Therefore, answers to the following questions were searched in this study: i) Could AHP be used to determine GWP? ii) What are the effective parameters on GWP? iii) What are the weights of these parameters? iv) How effective is AHP in determining this potential? To answer these questions, GIS based AHP was used to determine GWP in Konya province, Türkiye. For this, data on land use, slope, rainfall, topographic wetness index, drainage density, elevation, plan curvature, profile curvature and stream power index were used. The rest of the manuscript is organized as follows: the data sources used and AHP are mentioned in the next section. In the third part, creation of thematic maps, determination of the weights of thematic maps with AHP, creation of the GWP map and verification process were carried out. In the fourth chapter, the results of the study were examined.

2. Literature Survey

In recent years, studies on the multi-criteria decision making (MCDM) analysis, which depends on expert knowledge, have become increasingly widespread (Kavurmacı and Üstün 2016; Lu et al. 2017; Zuo et al. 2021). Analytical hierarchy process (AHP), one of the MCDM analysis, is a preferred application in hydrological studies (Baykal et al. 2023; Swain et al. 2020; Baykal 2019; Jenifer and Jha 2017; Sinha et al. 2008). The AHP proposed by Thomas Saaty (1980a) is a technique based on a pairwise comparison matrix in which the weight of each parameter is determined by considering its importance relative to the other parameters. It is also used effectively in groundwater studies. Arulbalaji et al. (2019) used AHP to determine a river basin groundwater potential situated on the Western Ghats in India. The groundwater potential capacity of each class in the thematic maps considered in the AHP method was depended on the weights assigned for them. The accuracy of the results was cross validated with the area's groundwater capacity expectations. Overall accuracy 85% was achieved. Kaliraj et al. (2014) applied AHP in geospatial analysis to identify potential zones for recharging artificial groundwater in the Vaigai upper basin located in the Theni district of Tamil Nadu, India. They defined 21.8 km^2 of the total area was a region with high potential for groundwater recharge. Saranya and Saravanan (2020) chose Kancheepuram as study area, where there was a rapid decrease in groundwater level due to urbanization and industrialization. They used geographic information system (GIS) and AHP to describe the groundwater potential of the region. The accuracy of the results for the very high, high, medium, low, and very low classes was compared with the well yield data and a good correlation was obtained. Dar et al. (2021) identified potential groundwater areas with GIS and AHP in the Kashmir Valley, NW-Himalayas using slope, soil texture, drainage density, land/land cover (LULC), lithology, geomorphology, lineament density and rainfall thematic maps. The obtained groundwater potential map was validated with 245 boreholes and the flow direction of the study region. Nithya et al. (2019) investigated groundwater potential zones in Chittar Basin, Tamil Nadu using geo-environmental parameters such as geology, lineaments, geomorphology, slope, drainage density, soil, and rainfall by GIS-based AHP technique. They confirmed the results of the study with optimum yield data collected from 24 wells. They said that remote sensing methodology, GIS and AHP were excellent tools for groundwater investigations.

3. Material and Method

3.1. Study Region and Data

The province of Konya is in the Central Anatolia Region of Turkey between 36°41' and 39°16' north latitudes and 31°14' and 34°26' east longitudes (Figure 1). Konya province has an area of 38873 km^2 and an average elevation of 1016 m. Most of its land consists of plains and plateaus.

The rainfall regime is irregular, there are stream flows with flood regime. Most of these streams disappear in marshes in closed basins. Although the elevations take up little space, they are mostly located in the southern part of the province. The elevations in the north and south of the province extend in the east-west direction and in the west in the north-south direction. Most of the water resources and forests are located on these elevations (Terzi and Ersoy 2018).

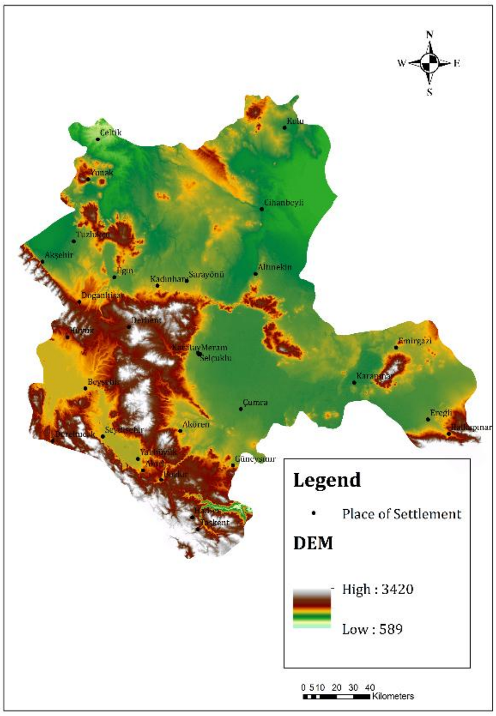

Figure 1. Study region

To determine groundwater potential zones of the province of Konya using the AHP method, data on land use, slope, rainfall, topographic wetness index, drainage density, elevation, plan curvature, profile curvature and stream power index were used (Table 1). The maps of all this data were created using Geographical Information System (GIS) environment.

Table 1. Data information

DATA TYPE	SOURCE	PERIOD	SCALE	PURPOSE
SRTM-DEM	http://earthexplorer.usgs.gov	2023	30 m x 30 m	Elevation map
				Slope map
				Topographic wetness index
				Drainage density
				Plan curvature
				Profile curvature
				Stream power index
LAND USE	Corine	2018	30 m x 30 m	Land use map
ANNUAL RAINFALL DATA	Turkish State Meteorological Service	1971 - 2021	Point data	Rainfall map

3.2. Analytic Hierarchy Process

Saaty (1980b) introduced the Analytical Hierarchy Process (AHP), which has become a popular method for multi-criteria decision-making. AHP enables the assessment of both qualitative and quantitative criteria (Mohamed 2020), using a fundamental absolute number scale to indicate individual preferences (Table 2). The importance of each criterion is not uniform, as certain criteria hold more weight than others (Hamlat et al. 2021).

Table 2. AHP pairwise comparisons scale

SCALE / IMPORTANCE LEVEL	DENSITY OF IMPORTANCE DEFINITION
1	Equal importance
3	One criterion is of moderate importance to the other
5	One criterion is of higher importance than the other
7	One criterion is more important than the other
9	One criterion is extremely important over the other
2, 4, 6 and 8	Intermediate values used between previous weights in numerical comparison

AHP uses expert insights and principal eigenvectors to assign weights to parameters, and eigenvalues to rank parameters. A binary comparison matrix is created to assign parameter weights with AHP (Moodley at al. 2022). In order to create a binary comparison matrix, it is necessary to create a matrix A. Matrix A is shown as in Equation 1.

$$A=\begin{bmatrix} a_{11} & a_{1j} & a_{1n} \\ a_{i1} & a_{ij} & a_{in} \\ a_{n1} & a_{nj} & a_{nn} \end{bmatrix} \tag{1}$$

Here, the value of "a" shows the importance of criterion i according to criterion j. After creating matrix A, the weights of each criterion are determined. For this, the B column vector given in Equation 2 is calculated by dividing each criterion forming the comparison matrix by the sum of its own column. n number of B column vectors are combined into a matrix. This matrix is called the normalized comparison matrix (C), and the sum of each column is equal to 1. The W column weight vector is created by taking the arithmetic average of each row in the comparison matrix (Equation 3) and thus the weights of each criterion are calculated.

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \tag{2}$$

$$W_i = \frac{a_{ij} \sum_{j=1}^{n} c_{ij}}{n} \tag{3}$$

The consistency index (CI) and consistency ratio (CR) used to evaluate the consistency of comparisons in the AHP method should be calculated. In order to ensure the consistency of subjective opinions and the accuracy of relative weights, the CI value is calculated using the basic eigenvalue λ_{max} associated with the A matrix. In this calculation process, the D column vector is obtained by multiplying the A matrix with the W weight matrix. Then, the E matrix is created over the ratios of the elements between the D column vector and the W matrix. The arithmetic mean of the E matrix is taken to calculate the basic value of λ_{max} and this value is used in the calculation of CI. E values are calculated from Equation 4, and λ_{max} is calculated from Equation 5 (Güran, 2023).

$$E_i = \frac{d_i}{w_i} \; (i = 1,2,3, \dots, n) \tag{4}$$

$$\lambda_{max} = \frac{\sum_{i=1}^{n} E_i}{n} \tag{5}$$

The consistency index (CI) given in Equation 6 is calculated to evaluate the significance levels determined while creating the pairwise comparison matrices.

$$CI = \frac{(\lambda_{max}) - n}{(n-1)} \tag{6}$$

Here, λ_{max} is the largest eigenvalue of the matrix and n is the number of criteria. To measure the consistency of the pairwise comparison matrix, the consistency ratio (CR) is calculated (Equation 7).

$$CR = \frac{CI}{RI} \tag{7}$$

where, RI is the ratio index and is taken from Table 3 according to the number of criteria.

Table 3. Saaty's ratio index for various *n* values (Saaty, 1980b)

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0	0.58	0.89	1.12	1.24	1.32	1.41	1.45	1.49

4. Results and Discussion

To determine the groundwater potential in the study, the main factors considered within the scope of AHP were selected as land use, slope, rainfall, topographic wetness index, drainage density, elevation, plan curvature, profile curvature and stream power index. Sensitivity analysis was performed for the selected input parameters in the study. All parameters and their impact ratios were obtained as Land use 1, drainage density 0.625, rainfall 0.595, topographic wetness index 0.532, slope 0.487, elevation 0.442, plan curvature 0.142, profile curvature 0.142 and Stream Power Index 0.056, respectively. Spatial analyzes were performed with GIS environment by obtaining relevant data within the scope of the determined factors. The importance levels of the criteria considered (how important one factor is compared to the other) were determined according to the literature (Muavhi et al. 2022; Echogdali et al. 2022; Kumar et al. 2021; Doke et al. 2021; Benjmel et al. 2020; Saranya and Saravanan 2020; Arulbalaji et al. 2019; Mallick et al. 2019; Şener et al. 2018; Razandi et al. 2015) and the weights of the parameters were calculated. Details and thematic maps of each parameter are given below.

4.1. Creation of Thematic Maps

4.1.1. Land use

The role of land use and land cover is critical in determining soil permeability, runoff, and evapotranspiration. Land use practices have an impact on the timing, volume, and quality of groundwater recharge, as well as influencing runoff and evapotranspiration (Rather et al. 2022). Regions covered with forests possess a greater potential for groundwater recharge, whereas areas with concrete structures have less capacity for recharge (Sajil Kumar et al. 2022). In this study (Figure 2), the Corine land use map was utilized to identify the land use of the study area. The land use in the area was categorized into five classes, which include artificial surfaces, agricultural areas, forest and semi-natural areas, wetlands, and water bodies.

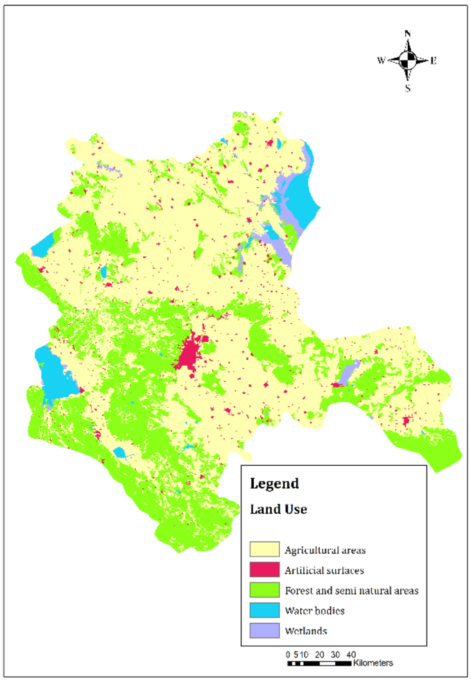

Figure 2. Land use map

4.1.2. Slope

The slope is a significant geomorphological characteristic that influences the potential of groundwater in an area. It is a crucial parameter in assessing the possibilities for groundwater recharge (Sajil Kumar et al. 2022). In places where the slope is low, excessive seepage occurs due to the accumulation of surface water. This situation increases the groundwater potential. On the other hand, as the surface flow rate increases on steep slopes, infiltration decreases. In other words, groundwater potential is less in steeply sloping areas. The slope within the study area ranges from 0 - 69.75 (Figure 3). High slopes are generally located in the middle, west, south, and southeast parts of the study area.

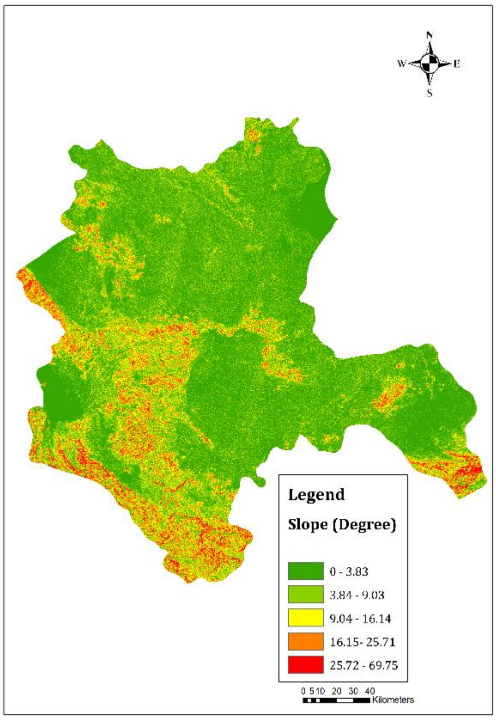

Figure 3. Slope map

4.1.3. Rainfall

Playing a critical role in the hydrological cycle, rainfall is the primary source of groundwater recharge. Rainfall intensity and duration affect the amount of infiltration. Short-term high-intensity rainfall causes more runoff and less infiltration, while long-term less-intensity rainfall affects infiltration more than runoff (Biswas et al. 2020). This research utilized rainfall information covering the time interval of 1971 to 2021. The quantity of annual rainfall ranged from 286 to 625 mm, as illustrated in Figure 4. To generate the rainfall map, the IDW interpolation technique was employed, enabling the representation of the spatial distribution of rainfall.

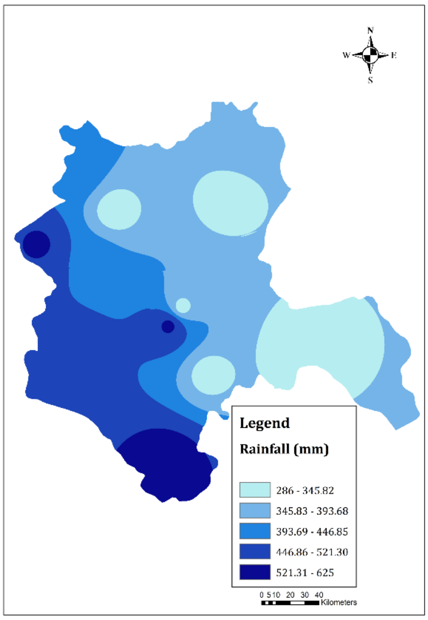

Figure 4. Rainfall map

4.1.4. Topographic wetness index (TWI)

TWI was used to measure the impact of topographic parameters on groundwater recharge (Echogdali et al. 2022; Kumar et al. 2021). Moore et al. (1991) defined TWI as in Equation 8.

$$TWI = \ln\left(\frac{A_s}{tan\beta}\right) \quad (8)$$

where, A_s and β is flow accumulation and slope gradient, respectively.

Regions having low TWI value have a weaker groundwater potential, while regions having high TWI have higher groundwater potential. The TWI map was given in Figure 5.

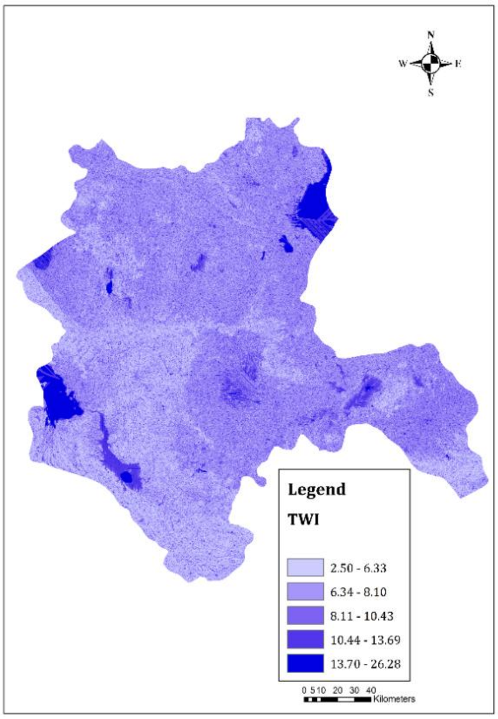

Figure 5. TWI map

4.1.5. Drainage density

The drainage density is defined as the ratio of the total length of the streams within a given area to the total area of that region. This metric provides an indication of the potential for stream flow within the area. As drainage density is linked to the properties of the groundwater aquifer, an indirect relationship exists between drainage density and the groundwater recharge potential (Akbari et al. 2021). Regions characterized by high drainage density often exhibit lower potential for groundwater recharge due to the high flow rate of surface water. Conversely, areas with lower drainage density usually have a higher potential for groundwater recharge (Sajil Kumar et al. 2022; Arunbose et al. 2021; Das 2019). The drainage density map was given in Figure 6.

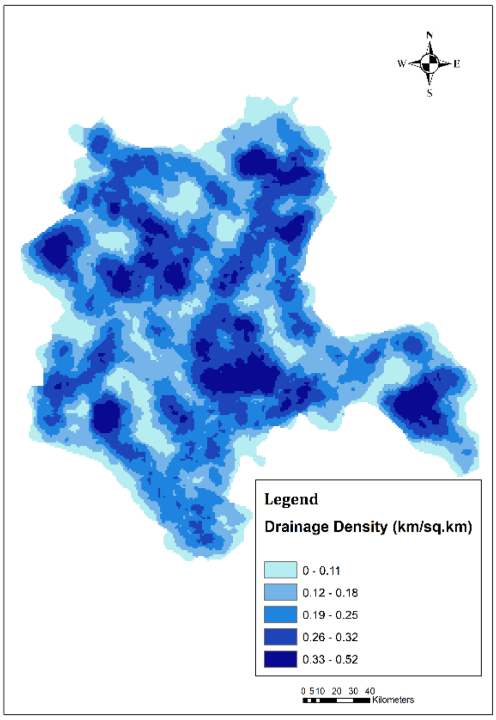

Figure 6. Drainage density map

4.1.6. Elevation

The elevation map clearly reflects the rough terrain, which is an important factor in determining the groundwater potential. The elevation of the study area expresses the changes in ground surface levels that can be utilized for storing water in depressions. Lower parts (flat areas) will typically store water longer and allow the stored water to infiltrate more significantly (Ghosh et al. 2023). In this study, the Digital Elevation Model (DEM) was obtained from SRTM (Figure 7).

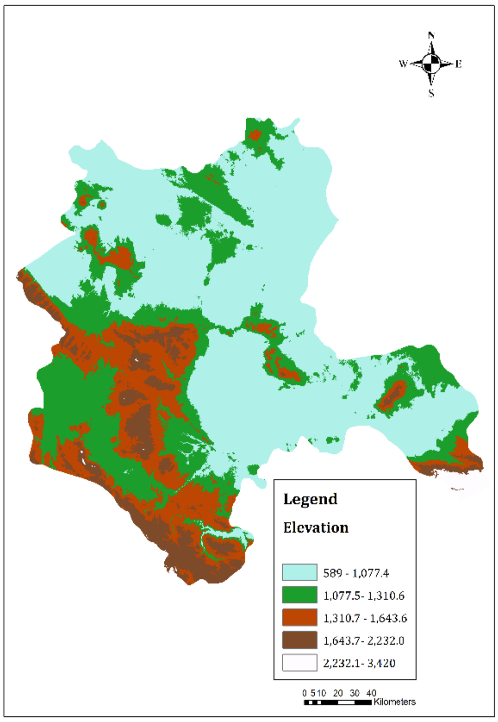

Figure 7. Elevation map

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4.1.7. Plan and profile curvature

The distribution of surface flow is determined by the topography, as represented by the plan and profile curvature (Taher et al. 2023). GIS environment was utilized to produce the plan and profile curvature maps, which are presented in Figures 8 and 9.

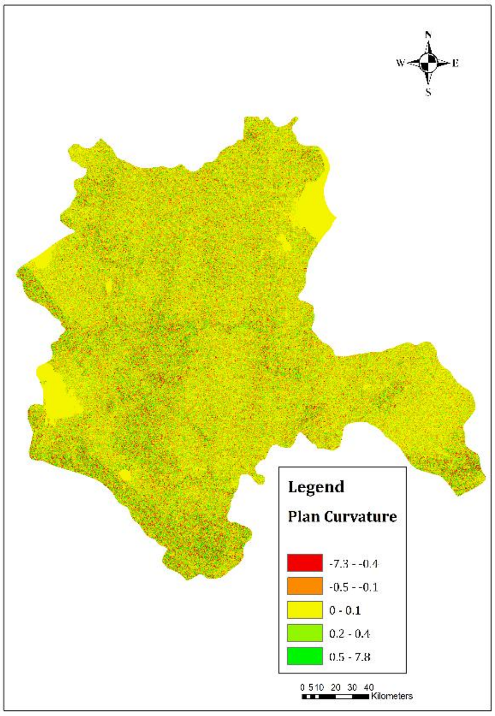

Figure 8. Plan curvature

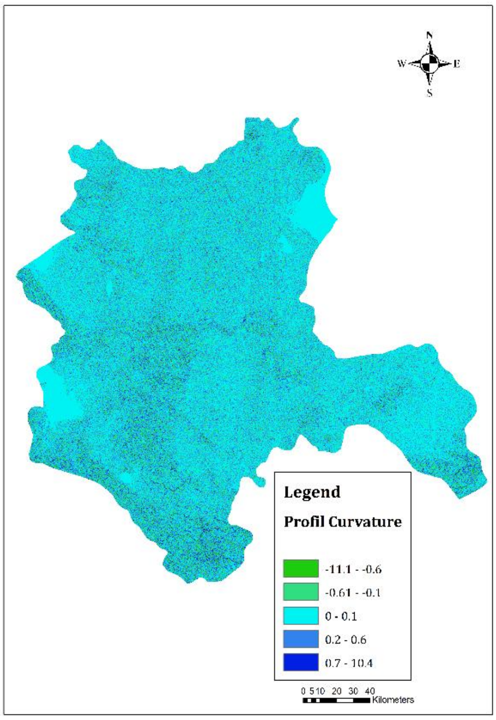

Figure 9. Profile curvature

4.1.8. Stream power index (SPI)

SPI measures the potential of streamflow erosion at a particular point of basin. As flow accumulation and slope gradient within a basin increases, also increases the amount of flow from upstream regions, resulting in an increase in flow rate, SPI, and erosion potential. Thus, it was thought that there is a relationship between SPI and groundwater potential (Moore et al. 1991). SPI was calculated using Equation 9 (Echogdali et al. 2022) and the SPI map was given in Figure 10.

$$SPI = A_s \ x \ tan\beta \qquad (9)$$

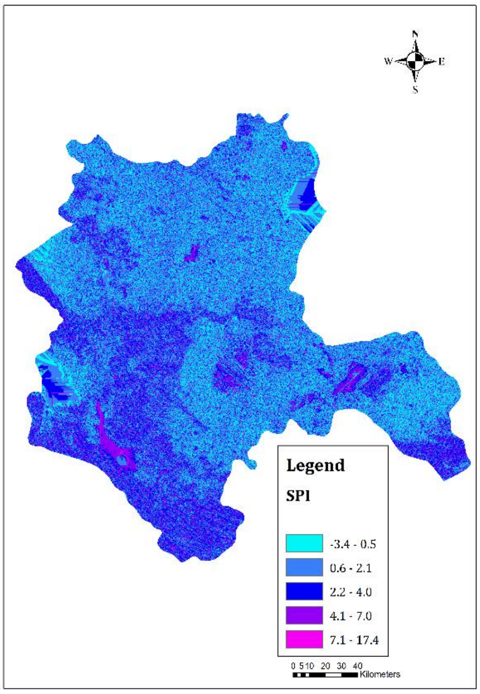

Figure 10. SPI map

4.2. Priority order and Normalized Weights for Thematic Layers

First, a pairwise comparison matrix was created with the criteria (land use, slope, rainfall, topographic wetness index, drainage density, elevation, plan curvature, profile curvature and stream power index) affecting the groundwater potential according to the pairwise comparison scale given in Table 2. The importance level of each parameter was determined by considering the explanations in the Creation of Thematic Maps section. The rank value of each thematic layer was classified as 1 for the lowest impact and 5 for the highest impact on groundwater. Then, to evaluate the consistency of the pairwise comparison matrix, the CI value was calculated as 10.14 and the RI value was determined as 1.45 from Table 3 according to the number of criteria. From Equation 2, the CR value was calculated as 6.99% and the pairwise comparison matrix was found to be consistent and was given in Table 4. Table 5 provides the weights determined for each criterion.

Table 4. A pairwise comparison matrix

	LULC	SLOPE	RAINFALL	TWI	DRAINAGE DENSITY	ELEVATION	PLAN CURVATURE	PROFILE CURVATURE	SPI
LULC	1								
SLOPE	0.2	1							
RAINFALL	0.33	1	1						
TWI	0.33	1	0.33	1					
DRAINAGE DENSITY	0.2	0.33	0.5	0.33	1				
ELEVATION	0.14	0.33	0.2	0.33	0.33	1			
PLAN CURVATURE	0.11	0.2	0.2	0.2	0.14	0.2	1		
PROFILE CURVATURE	0.11	0.2	0.2	0.2	0.14	0.2	1	1	
SPI	0.11	0.2	0.14	0.14	0.11	0.14	0.33	0.33	1

Table 5. The weights determined for criteria affecting groundwater potential

THEMATIC LAYER	NORMALIZED WEIGHTS	CLASSES	RANK
LAND USE	33.49%	Artificial surfaces	1
		Agricultural areas	2
		Forest and semi natural areas	3
		Wetlands	4
		Water bodies	5
SLOPE	12.71%	0- 3.83	5
		3.84-9.03	4
		9.04-16.14	3
		16.15-25.71	2
		25.72-69.75	1
RAINFALL	16.36%	286-345.82	1
		345.83-393.68	2
		393.69-446.85	3
		446.86-521.30	4
		521.31-625	5
TWI	12.58%	2.50-6.33	1
		6.34-8.10	2
		8.11-10.43	3
		10.44-13.69	4
		13.70-26.28	5
DRAINAGE DENSITY	10.77%	0-0.11	5
		0.12-0.18	4
		0.19-0.25	3
		0.26-0.32	2
		0.33-0.52	1
ELEVATION	6.91%	589-1077.4	5
		1077.5-1310.6	4
		1310.7-1643.6	3
		1643.7-2232	2
		2232.1-3420	1
PLAN CURVATURE	2.74%	-7.3 - -0.4	1
		-0.5 - -0.1	2
		0 – 0.1	3
		0.2 – 0.4	4
		0.5 – 7.8	5
PROFILE CURVATURE	2.74%	-11.1 - -0.6	5
		-0.5 - -0.1	4
		0 – 0.1	3
		0.2 – 0.6	2
		0.7 – 10.4	1
SPI	1.69%	-3.4 – 0.5	5
		0.6 – 2.1	4
		2.2 – 4.0	3
		4.1 – 7.0	2
		7.1 – 17.4	1

4.3. Creating of Groundwater Potential Map

To create the groundwater potential map (GWPM), firstly, the thematic maps obtained in the GIS environment were reclassified according to the rank values given in Table 5. Then, using the weight values determined by AHP for thematic maps, GWPM was created by overlay analysis in GIS environment (Figure 11). The GWPM is divided into five classes as very low, low, medium, high, and very high.

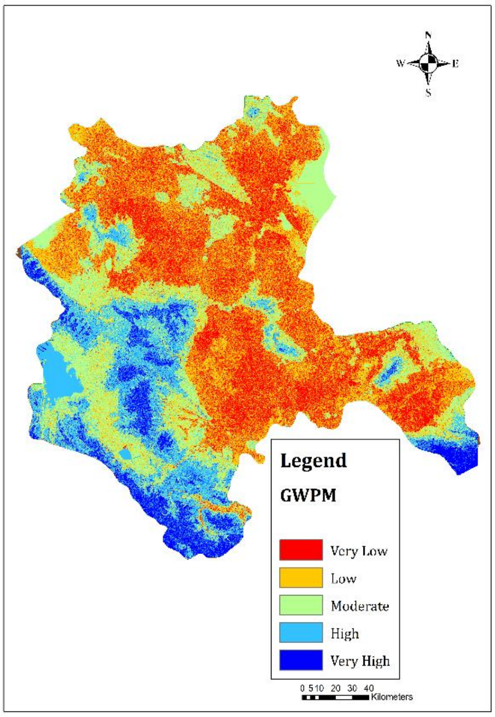

Figure 11. GWPM of Konya province

Upon analyzing Figure 11, it was shown that 23.75% of the total area has very low, 31.15% low, 23.35% medium, 14.78% high and 6.97% very high groundwater potential. For validation, the GWPM created in this study was compared with the "Konya Closed Basin Management Plan" project results carried out by the Ministry of Agriculture and Forestry, General Directorate of Water Management (KCBMP, 2018). In this project, Konya Closed Basin was divided into 18 groundwater zones (GWZ) (Figure 12) and the zones were grouped into two classes as good and poor (KCBMP, 2018). The zones in which GWZ and GWPM overlap are compared and given in Table 6.

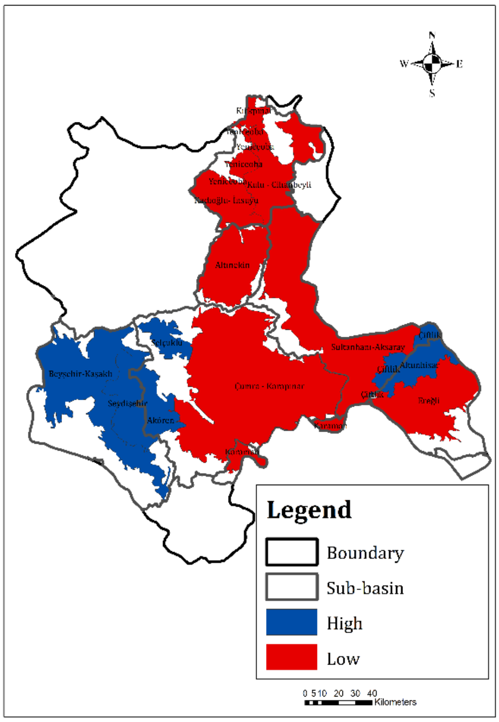

Figure 12. GWZ of Konya Closed Basin

Table 6. Comparison of GWZ and GWPM

GWZ	AREA (km^2)	GWZ	GWPM	RESULTS
BEYŞEHIR-KAŞAKLI	3069	High	Moderate	Agree
SEYDIŞEHIR	925	High	High	Agree
ÇUMRA-KARAPINAR	5719	Low	Low	Agree
SELÇUKLU	426	High	Very High	Agree
AKÖREN	640	High	Very High	Agree
KARAMAN	2696	Low	Low	Agree
EREĞLI	2683	Low	Very Low	Agree
ALTUNHISAR	1620	High	Moderate	Agree
SULTANHANI-AKSARAY	7251	Low	Very Low	Agree
ÇIFTLIK	2612	High	Very High	Agree
ALTINEKIN	1379	Low	Very Low	Agree
YENICEOBA	266	Low	Very Low	Agree
KADIOĞLU-İNSUYU	836	Low	Very Low	Agree
KULU-CIHANBEYLI	1565	Low	Very Low	Agree
KIRKPINAR	748	Low	Moderate	Disagree

When Table 6 is examined, low and very low classes of GWPM overlap with poor water zones, while medium, high, and very high classes overlap with good water zones, in the GWZ. Only in the Kırkpınar water zone, the GWPM was found to be moderate, while the GWZ was determined to be poor. When evaluated in general, it was seen that GWZ and GWPM were similar.

In addition, since the groundwater zone given in the GWZ were divided into two classes as good and poor, the five classes obtained in GWPM had been reduced to two classes in accordance with the GWZ classes given in Table 5 and comparisons were made. While very low and low classes in the resulting GWPM were defined as poor; moderate, high and very high classes were defined as good.

4.4. Evaluation Metrics

The relationship between GWZ and GWPM was determined with evaluation metrics as accuracy, precision, recall, f1-score, confusion matrix and roc curve, respectively.

4.4.1. Accuracy

The ratio between correctly predicted samples and all samples in the dataset. Accuracy is calculated as Equation 10.

$$accuracy = \frac{TP+TN}{TP+TN+FP+FN} \qquad (10)$$

Here, TP is the true positives predicted as true positives, FN is the false negatives predicted as false positives, TN is the true negatives predicted as true negatives, and FP is the false positives predicted as false positives. If the accuracy value is 0, the true values and the predicted values are completely different from each other, and if it is 1, it is completely similar (Chicco and Jurman, 2020).

4.4.2. Precision and recall

While precision expresses the number of correct results according to the number of all results, recall indicates the number of correct results according to the number of expected results. (Fränti and Mariescu-Istodor, 2023).

F1 score: It is defined as the harmonic mean of precision and recall and is calculated as follows (Chicco and Jurman, 2020).

$$F_1\ score = 2\ x\ \frac{precision\ x\ recall}{precision + recall} \qquad (11)$$

4.4.3. Confusion matrix

Confusion matrix is widely used to evaluate the performance of a classification algorithm by providing a detailed breakdown of predicted and true class labels. The eigenvalues of a confusion matrix provide insights into the underlying structure and properties of the classification results. Eigenvalues are a mathematical concept used to analyze linear transformations, and in the context of confusion matrices, they can reveal information about the behavior of the matrix. The distribution of eigenvalues provides a quantitative measure of the spread and density of information in the matrix. Understanding the distribution of eigenvalues of a confusion matrix can be valuable for a variety of purposes, including model evaluation, variable selection, high-dimensional analysis, dimensionality reduction, model comparison, anomaly detection, and generalization or overfitting problems (Olaniran et al., 2024).

4.4.4. ROC curve

ROC curve is a performance measure for a classification problem at various threshold settings. The curve is plotted between the true positive rate (TPR) and the false positive rate (FPR) in the ROC space, where TPR is on the y-axis and FPR is on the x-axis. In the ROC space, a ROC curve is constructed by connecting all TPR and FPR pairs at each threshold for a given classifier. The area under the ROC curve (AUC), which ranges from 0 to 1, is a common measure of classifier performance. A higher AUC indicates a stronger ability to discriminate between classes. There are several methods available to perform computational analysis of AUC estimators. The way we use in our analysis is to apply trapezoidal estimators (Miao and Zhu, 2022).

The accuracy value between GWZ and GWPM was calculated as 0.87. Precision, recall and f1-score for each class were given in Table 7, confusion matrix in Figure 13 and roc curve in Figure 14.

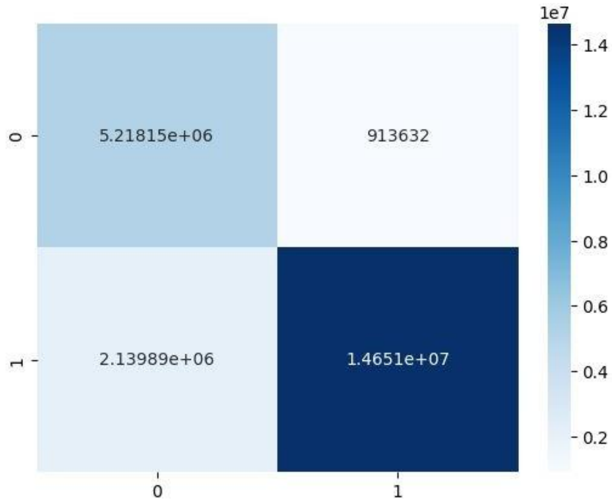

Figure 13. Confusion matrix

Table 7. Results of evaluation metrics

	PRECISION	RECALL	F1-SCORE
GOOD	0.71	0.85	0.77
POOR	0.94	0.87	0.91

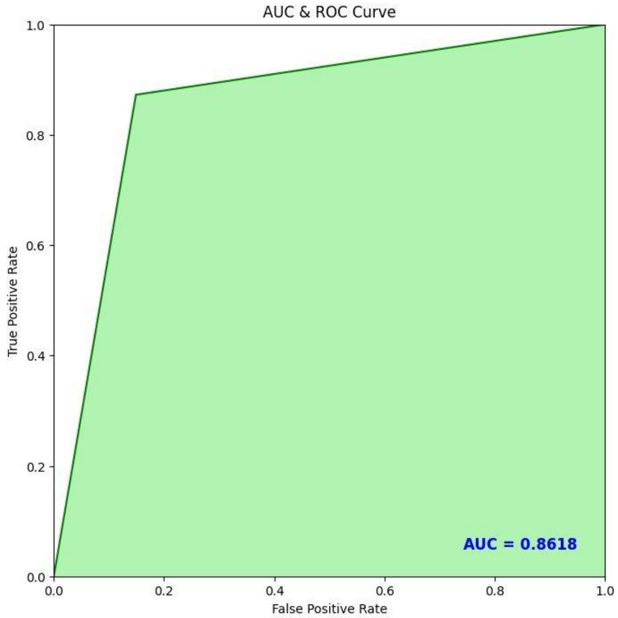

Figure 14. Roc curve

When Table 7 was examined, f1-score values for good and poor classes were found as 0.77 and 0.94, respectively. Also, in Figure 11, AUC was determined as 0.8618. In addition, these values indicated that GWPM and GWZ had a good fitness.

5. Conclusions

It is important to determine the changes in the groundwater level due to the unconscious consumption of groundwater and the increase in irrigation water needs due to the excess of agriculture in the study area. Therefore, this study focuses on the determination of groundwater potential (GWP) using GIS-based AHP. For this purpose, nine thematic maps, including rainfall, elevation, slope, drainage density, plan curvature, profile curvature, land use, TWI, and SPI, were used. The weights of each thematic map were determined by AHP analysis. GWPM was obtained by overlaying the thematic maps using overlay analysis in the GIS environment according to the determined weights. The map has been created according to classes with groundwater potential, the area of which varies from very low to very high. Validation of this map was examined by accuracy, precision, recall, F1 score, and roc curve. It has been observed that there is a high accuracy (87%) between the groundwater zones (GWZ) given in the Konya Closed Basin Management Plan and the potential defined in the GWPM. Previous studies on groundwater in the region have focused on groundwater quality, usability and social impacts. There are limited studies on groundwater quantity mapping. In this context, the study has a novelty for the region in terms of estimating groundwater potential with GIS-based AHP by considering different thematic parameters. Results provide a detailed, quantified insight into the factors affecting groundwater potential and will aid in effective water resource management strategies. Therefore, it is thought that GWPM should be considered by local governments in the use of groundwater.

Conflict of Interest

No conflict of interest was declared by the authors.

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