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Groundwater level estimation with analytical hierarchy method

Analitik hiyerarşi yöntemi ile yeraltı suyu seviyesi tahmini

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Abstract

Groundwater is an important component of the hydrological cycle and a critical resource for ecosystems and human life on Earth. Estimating groundwater levels is important for strategic planning and management in many areas such as agriculture, industry, engineering studies, and drinking water. In particular, it is necessary to determine the groundwater accurately and clearly to carry out both ground and hydraulic works. In this study, the estimation of the groundwater level of Diyarbakır province was made by analytical hierarchy method. Groundwater level estimation was made using slope, geology, geomorphology, land use, precipitation, fault density, drainage density classes. Especially in areas where data supply is short, positive and accurate results can be obtained with AHP, which is a fast and practical application. It is expected that the findings obtained will benefit public and private institutions and organizations for future studies.

Keywords: Analytical hierarchy method, Diyarbakır, Geographic information systems, Groundwater

Özet

Yeraltı suyu, hidrolojik döngünün önemli bir bileşenidir ve Dünya'daki ekosistemler ve insan yaşamı için kritik bir kaynaktır. Yeraltı suyu seviyelerinin tahmini, tarım, sanayi, mühendislik çalışmaları ve içme suyu gibi birçok alanda stratejik planlama ve yönetim için önemlidir. Özellikle hem zemin hem de hidrolik işlerin yapılabilmesi için yeraltı suyunun doğru ve net bir şekilde belirlenmesi gerekmektedir. Bu çalışmada Diyarbakır ilinin yeraltı suyu seviyesinin tahmini analitik hiyerarşi yöntemi ile yapılmıştır. Eğim, jeoloji, jeomorfoloji, arazi kullanımı, yağış, fay yoğunluğu, drenaj yoğunluk sınıfları kullanılarak yeraltı suyu seviyesi tahmini yapılmıştır. Özellikle veri tedariğinin kısa olduğu alanlarda hızlı ve pratik bir uygulama olan AHP ile olumlu ve doğru sonuçlar alınabilmektedir. Elde edilen bulguların ileride yapılacak çalışmalar için kamu ve özel kurum ve kuruluşlara fayda sağlaması beklenmektedir.

Anahtar kelimeler: Analitik hiyerarşi yöntemi, Coğrafi bilgi sistemleri, Diyarbakır, Yeraltı suları

1 Introduction

Groundwater is a valuable natural resource that has a critical role in the life cycle of our planet. Although these deep-water layers are not visibly accessible like surface waters, they are vital for environmental balance and human life. The importance of groundwater is affecting a wide range of areas, from agricultural irrigation to industrial production, to drinking water health to ecosystem balancing. In addition, under increasing pressure from factors such as climate change and human activities, the sustainable use and protection of this substrate water resource is becoming increasingly critical. Groundwater is an issue that needs to be examined for engineering structures to be built, especially in terms of soil engineers.

Due to this situation, many studies have been carried out on issues such as estimating and observing the groundwater level [1-9]. There are many different scientific methods and studies available for estimating groundwater. These include techniques such as hydrogeological investigations, geophysical methods, mathematical modeling, and remote sensing. Hydrogeological investigations are a widely used method of determining groundwater levels and fluid properties. These investigations often include field studies and include drilling and well studies to assess the characteristics of groundwater layers, such as depth, quality, and direction of flow.

Geophysical methods are a set of techniques used in the imaging and characterization of groundwater layers. Techniques such as electrical resistivity tomography, magnetotelluric methods, and gravity measurements are used to map areas where groundwater is present and understand its properties.

Mathematical modeling is another important tool used to understand the complex relationships of groundwater flow and storage. These models can help predict future water levels by taking into account various variables of groundwater movement [10-13].

Remote sensing methods are also increasingly used in estimating groundwater. Technologies such as satellite imagery and weather radar can be used to monitor groundwater resources and identify changes. The groundwater level is of great importance for soil mechanics and hydraulics departments because it is a basic parameter that affects the hydraulic and mechanical behavior of the soil. In terms of Soil Mechanics, groundwater level has a significant impact on the bearing capacity, compressibility and stability of the soil. When the level of groundwater is high, the bearing capacity of the ground can decrease, which can increase the load on the foundations of structures. In

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addition, factors such as the compressibility of the ground and capillary water effects are also factors that should be taken into account in determining the groundwater level [14-18].

Static and dynamic groundwater levels are concepts that evaluate the state of groundwater at a given time from different perspectives.

Static Groundwater Level: It is the term used to determine the water level at a given time. Generally, their levels are determined by means of observation wells, radar, acoustic and ultrasonic measuring devices. This level indicates how close or far groundwater is to the surface at a given moment. Static groundwater level refers to the state when the water table is stable [19-20].

Dynamic Groundwater Level: It refers to the change of groundwater over time. Fluctuations in groundwater level may occur as a result of groundwater being affected by factors such as precipitation, irrigation, runoff, drainage or human interventions. Therefore, dynamic groundwater level refers to the changes that occur in the level of groundwater over a period of time. These changes provide information about the regime and cycle of groundwater and play an important role in applications such as irrigation, agriculture, and well productivity [21-22].

From a hydraulic point of view, the groundwater level is a determining factor in the permeability and hydraulic conductivity of the ground. The groundwater level affects the flow and drainage of water within the ground. High groundwater levels can disrupt the drainage of the ground and cause water to rise towards the surface, which can weaken the foundations of structures and increase ground erosion. In addition, if the groundwater level is low, problems may arise, such as drying out and cracking of the floor. For these reasons, groundwater level is of great importance in terms of civil engineering.

In this context, in this study, the groundwater level of Diyarbakır province was estimated by means of the analytical hierarchy method. Groundwater level estimation and mapping were made and mapped using slope, geology, geomorphology, land use, precipitation, fault density, drainage density classes. AHP is an important method to fill the gap in boreholes, especially in the provision of observation data and the difficulties in obtaining observation data. The data obtained is aimed to help public, private institutions and readership.

2 Workspace

Diyarbakır province was chosen as the study area (Figure 1). The population of Diyarbakır is 1 million 873 thousand people. Its altitude is 675 m. It has a total of 17 districts. Diyarbakır has hot and dry summers and cold winters and often snow. The average annual rainfall in Diyarbakır is around 500 mm, and precipitation is largely concentrated in winter and spring. The summer months are quite dry, and the amount of precipitation is minimal during this period. The prevailing winds in the region generally blow from the north and northwest, and wind speeds can vary seasonally. In the study, the analysis of all districts in the ArcGIS program was not included in the analysis of Kulp, Lice, Silvan and Çermik districts due to the lack of software and hardware of the computer.

The groundwater resources around Diyarbakır are in the form of two separate aquifer systems: the upper basalt aquifer and the deeper limestone aquifer (approximately 300 m deep). The thickness of the upper basalt aquifer varies between 0 and 60 m on average. The natural drainage systems of the groundwater in Diyarbakır are different for basalt and limestone aquifers. The drainage area of the basalt aquifer covers the area from the summit of Karacadağ to the Tigris Valley. The drainage area of the limestone aquifer includes the Silvan-Midyat Formation, which spreads from approximately 30–35 km north of Diyarbakır, and the Midyat Formation, which spreads from 25–30 km south of Diyarbakır. While the groundwater levels around the Tigris River are 1 meter in the upper and lower parts of the river, this depth increases to 55 meters as the altitude increases. In some places, especially in local areas, this depth can exceed 100 meters. In the plain regions, static water levels vary between 2 and 55 meters. Dynamic water levels of the region vary between 11 and 69 meters in basalt fields, alluvial beds of the Tigris River and Silvan Plain, and between 90 and 114 meters in Çınar Ortataş, Kazıktepe and Kavsan regions. In the north of Diyarbakır, water levels vary between 90 and 269 meters in the triangular region between Ergani, Eğil and Kocaköy [23].

3 Material and methods

3.1 Analytic hierarchy method

The Analytical Hierarchy Process (AHP) is a multi-criteria decision-making approach designed to handle the complexities of decision-making. It is employed to assess various criteria and alternatives based on those criteria. The primary aim of AHP is to simplify the decision-making process and help in selecting the most suitable option. The steps involved in the AHP method are outlined as follows:

1. In a stage where objectives and content are precisely defined, the order of precedence among the parameters to be used is clearly established. Subsequently, comparison matrices are created in pairs. Parameters are rated based on their degree of importance, with scores ranging from 1-9 and 1/2-1/9. These matrices are organized in the form of square matrices with diagonals of 1.

$$A=\begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21}=1/a_{12} & 1 & \cdots & \dots \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1}=1/a_{1n} & a_{n2}=1/a_{2n} & \dots & 1 \end{bmatrix} \quad (1)$$

In this equation a_{ij}, is the value of the comparison of criterion I and criterion J relative to each other, a_{ji}, its value corresponds to the value of 1/ a_{ij}.

2. In this phase, each matrix element is normalized by dividing it by the total of its respective column. As a result, the sum of each normalized column Equation (1) and Equation (2).

$$a_{ij}' = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}, \qquad i,j = 1,2,\dots,n \tag{2}$$

3. The average of the row sums for each normalized matrix is calculated by dividing by the matrix size. The resulting values represent the importance weights of each parameter. These weights constitute the priority vector. (Equation (3)).

$$w_i = \left(\frac{1}{n}\right)\sum_{i=1}^{n} a_{ij}', \tag{3}$$

Percentage distributions are derived using Equation (3), which illustrates the relative importance of the parameters with respect to one another.

4. At this stage, it is essential to determine the consistency ratio of the comparison matrix. This involves calculating a value known as the Consistency Index (CI) (Equation (4), Equation (5)).

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{4}$$

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{\sum_{i=1}^{n} a_{ij} w_j}{w_i}\right) \tag{5}$$

Once the CI and RI values are determined, the consistency ratio is computed using Equation (6). To assess the consistency achieved, it is necessary to have the Random Index (RI) value.

$$CR = \frac{CI}{RI} \tag{6}$$

If the result from Equation (6) is below 0.10, the comparison matrix is considered to be acceptable.

5. To prioritize decision options, a matrix is constructed by comparing the criteria with each other. This matrix can also be described as the weight vector for each criterion. [24].

Figure 1. Study area location map

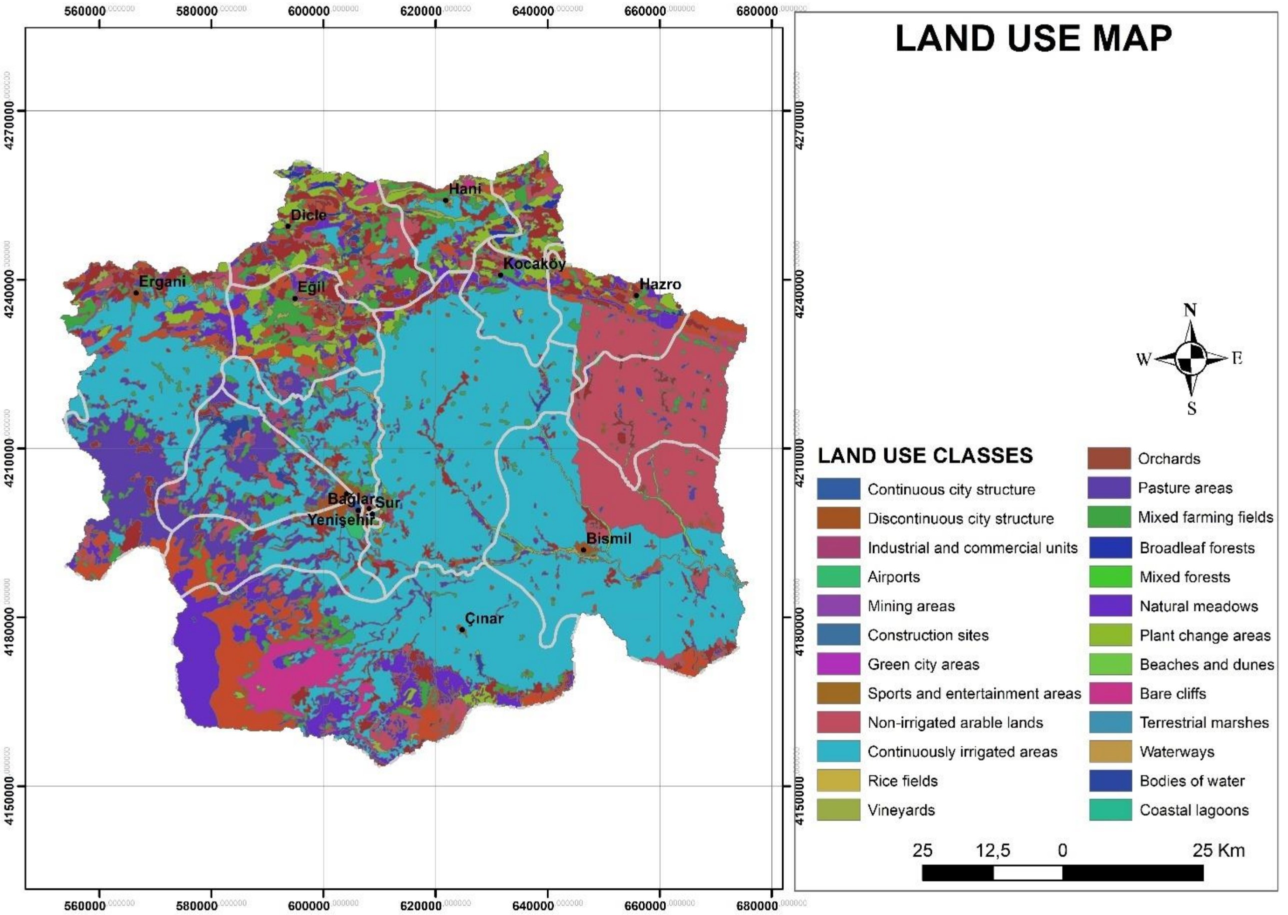

Figure 2. Land use classes

The land classes shown in Figure 2 are classified as (1) urban areas and commercial units, (2) non-irrigated arable areas, (3) continuously irrigated areas, (4) pasture areas, (5) forest areas, (6) bare cliffs, (7) water structures, as seen in Table 1. Land use classes play an important role in the groundwater level. If the general interpretation of these classes is to be made, construction and infrastructure activities in urban areas and commercial units affect the groundwater level, while agricultural practices play a role in non-irrigated arable areas as well as natural factors. Irrigation systems in continuously irrigated areas, and grazing and irrigation in pasture areas, affect the groundwater level. While the root systems of vegetation in forests balance groundwater, forestry practices can adversely affect. Bare cliffs have little potential to affect groundwater levels, but natural water sources can be found here. Water structures directly affect the groundwater level; Dams increase water by accumulating it, while wells can reduce it by drawing it.

Figure 3 shows the drainage density map, and Table 2 shows the comparison matrix.

Table 1. Land use classes comparison matrix

Land use classes	1	2	3	4	5	6	7	Weight Coefficients		Consistency check
1	1	3	1/2	2	2	4	1/3	0.147	14.70%	Consistency OK
2	1/3	1	1/5	1/2	1/3	2	1/6	0.05	5.00%	3%
3	2	5	1	3	2	5	1/2	0.221	22.10%	
4	1/2	2	1/3	1	1/2	3	1/4	0.083	8.30%	
5	1/2	3	1/2	2	1	3	1/4	0.113	11.30%	
6	1/4	1/2	1/5	1/3	1/3	1	1/6	0.038	3.80%	
7	3	6	2	4	4	6	1	0.349	34.90%	

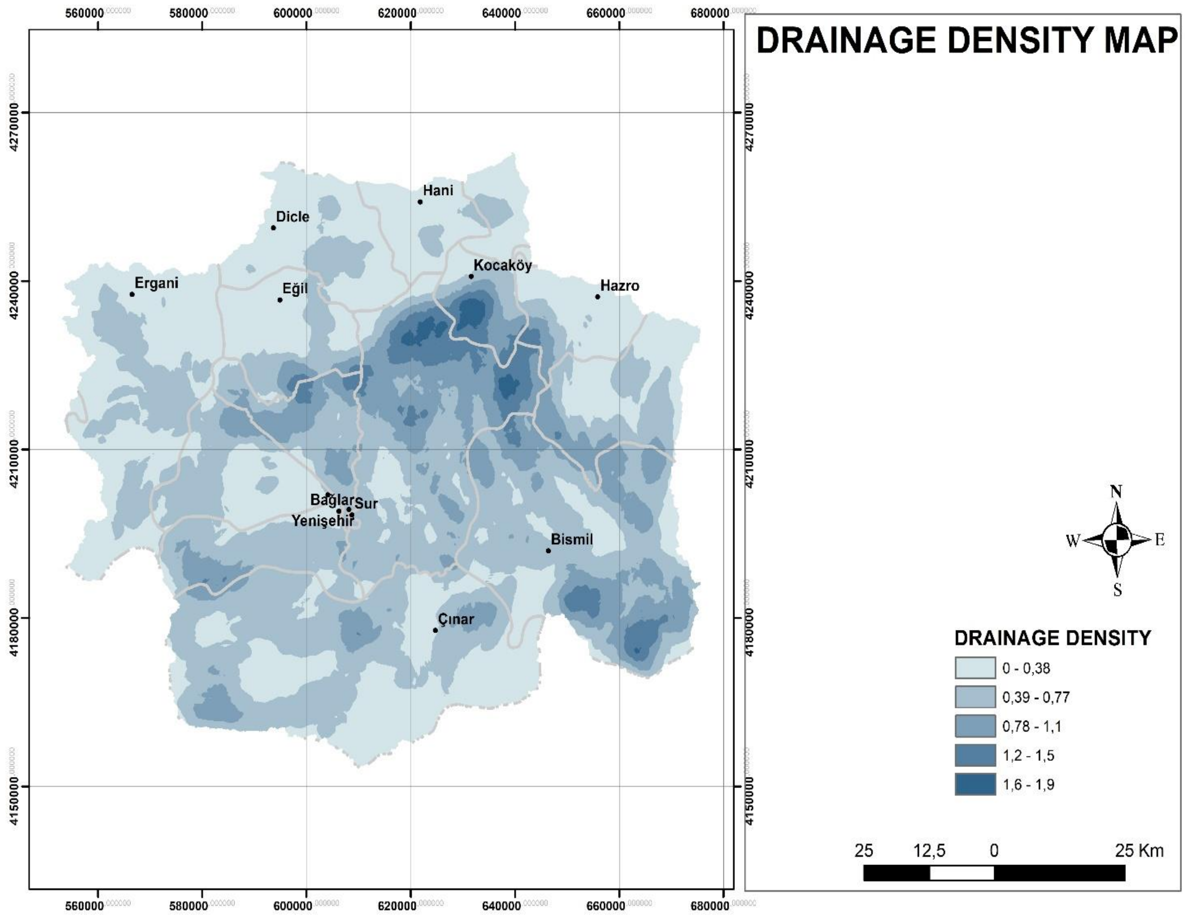

Figure 3. Drainage density map

In Table 2, (1) corresponds to the range of 0-0.38, (2) to the range of 0.39-0.77, (3) to the range of 0.78-1.1, (4) to the range of 1.2-1.5 and (5) to the range of 1.6-1.9. The effect of drainage density on groundwater level is a complex hydrological process and is influenced by a variety of factors. The effect of drainage density on groundwater level occurs primarily through hydraulic connections. In the case of the presence of permeable materials such as sand or gravel between stream beds and groundwater layers, it is possible for stream water to penetrate into groundwater layers and increase the amount of water in these layers. However, excessive water withdrawal or human influence on streams can cause groundwater to decrease or decrease. In particular, human activities such as large-scale dam constructions or agricultural irrigation can increase the impact of drainage density on groundwater levels. In this classification, it was made by taking into account the situation where the groundwater level may be high in places where the drainage network is dense.

Figure 4 shows the slope map, and Table 3 shows the comparison matrix of the slope. In the matrix, it represents (1) >25%, (2) 15-24%, (3) 8.1-14%, (4) 4.1-8%, (5) 0-4%. In low-sloping areas, soil water flows more slowly and can seep into underground water tables.

Table 2. Drainage density comparison matrix

Drainage Density	1	2	3	4	5	Weight coefficients		Consistency check
1	1	1/3	1/4	1/5	1/6	0.048	4.80%	Consistency OK
2	3	1	1/3	1/4	1/5	0.086	8.60%	8%
3	4	3	1	1/3	1/4	0.152	15.20%	
4	5	4	3	1	1/2	0.283	28.30%	
5	6	5	4	2	1	0.432	43.20%	

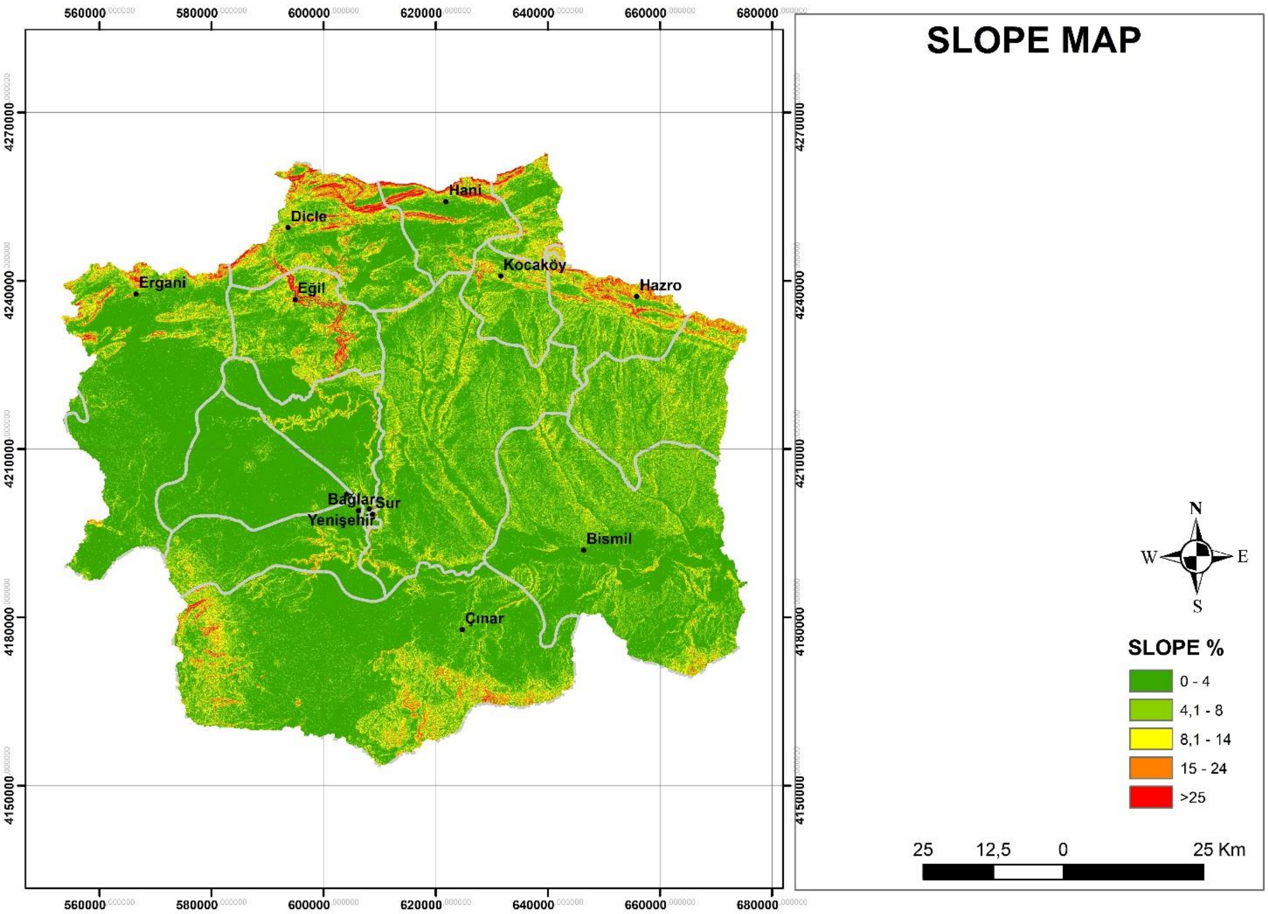

Figure 4. Slope map

This can contribute to the accumulation of rainwater and the rise of the groundwater level. Low-sloping terrains often allow more water to accumulate and remain in the soil, which increases the supply of groundwater layers. On the other hand, in areas with high slopes, the flow of water can be faster and rainwater can move downstream quickly without accumulating on the surface. In this case, water can seep less into the groundwater tables, and the groundwater level can often be lower. In areas with high slopes, groundwater layers may be fed with less water, and the groundwater level may be low at times. In this direction, a matrix has been created in such a way that the groundwater level is higher where the slope is low, and the groundwater level is lower where there is a lot.

Figure 5 shows the fault intensity map, and Table 4 shows the comparison matrix. In the matrix, it represents the classes (1) 0-0.022, (2) 0.023-0.068, (3) 0.069-0.13, (4) 0.14-0.2, (5) 0.21-0.29. Fault lines are fragile regions of the earth's crust and are often the areas where earthquakes occur. The impact of fault lines on groundwater levels varies depending on a variety of factors. Fractures in areas where fault lines are located can cause water leakage, and these leaks can increase or decrease the groundwater level. In addition, ruptures in fault lines can lead to changes in the groundwater regime; In some cases, they can impede or divert the movement of water.

Table 3. Slope comparison matrix

Slope %	1	2	3	4	5	Weight coefficients		Consistency check
1	1	1/3	1/5	1/7	1/9	0.035	3.50%	Consistency OK
2	3	1	1/3	1/4	1/7	0.071	7.10%	8%
3	5	3	1	1/3	1/5	0.137	13.70%	
4	7	4	3	1	1/3	0.251	25.10%	
5	9	7	5	3	1	0.507	50.70%	

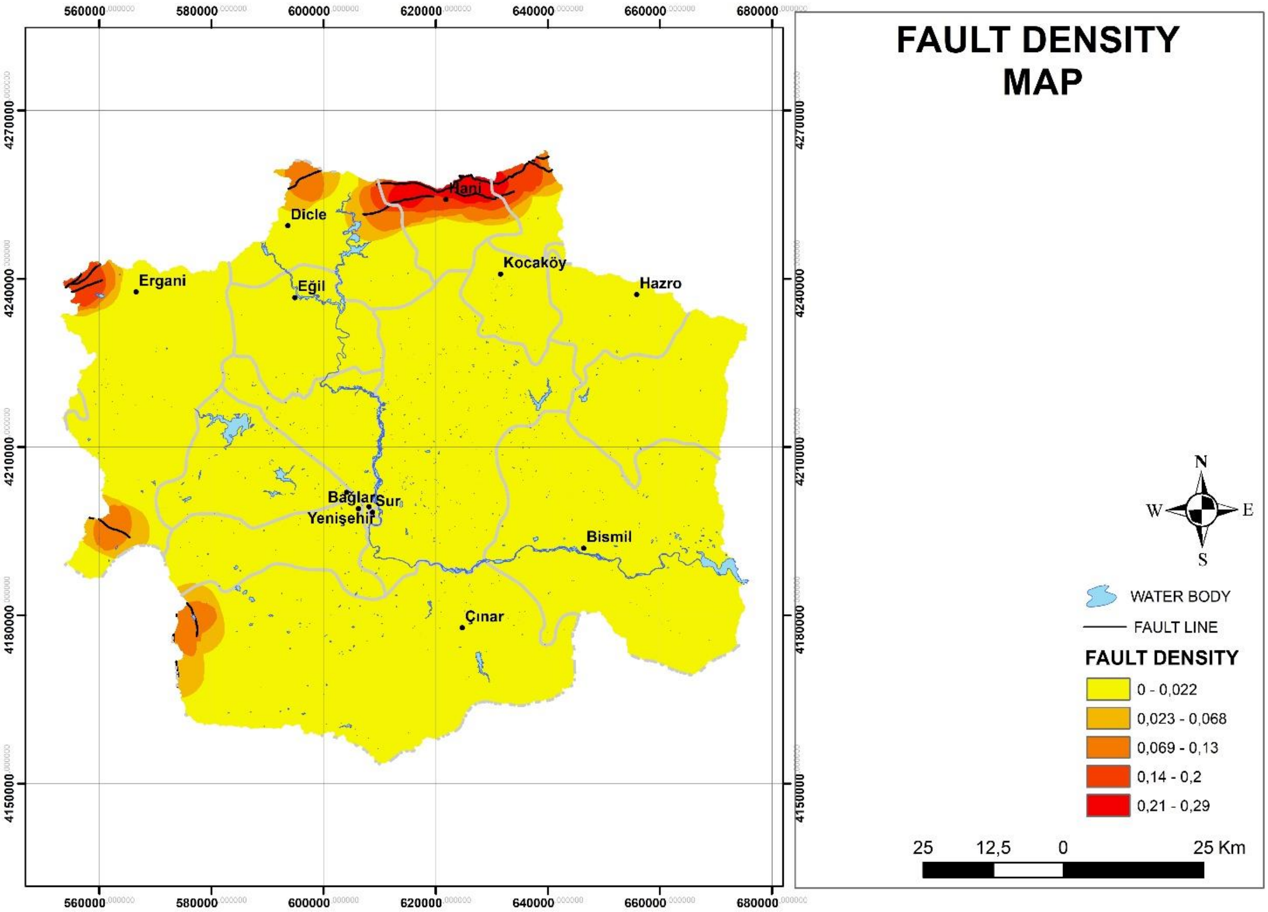

Figure 5. Fault intensity map

This, in turn, can cause groundwater to accumulate or flow in certain areas. Fault lines can also affect the flow of surface water. Fractures along fault lines can alter the flow of surface water, which can affect the groundwater level. In addition, earthquakes along fault lines can cause temporary changes in the level of groundwater. However, these effects are usually short-lived and do not cause long-term groundwater level changes. The effects of fault lines on groundwater levels vary depending on the location of the fault, its size and environmental conditions. In the matrix, a classification is made according to the situation where the groundwater level may be higher in areas close to the fault.

Figure 6 shows the geology map, and Table 5 shows the comparison matrix. The effect of geological classes on groundwater level depends mainly on the degree of porosity, permeability and consolidation of rocks. Sedimentary rocks are generally of sedimentary origin and are permeable. Therefore, in sedimentary formations, groundwater is usually high and the movement of water can be rapid. On the other hand, ultrabasic rocks are tightly consolidated and generally impermeable, which limits the movement of groundwater and can lower the groundwater level. Unconsolidated and semi-consolidated formations, usually composed of sedimentary or volcanic rocks, they are permeable, which allows the movement of groundwater and generally keeps the groundwater level high. Finally, basic rocks also often have a tightly consolidated impermeable structure, which can restrict the movement of groundwater and lower the groundwater level. Therefore, the effect of geological classes on groundwater level varies depending on the basic properties of rocks and plays an important role in determining the movement of water and the groundwater level.

Table 4. Fault intensity comparison matrix

Fault intensity	1	2	3	4	5	Weight coefficients		Consistency check
1	1	1/2	1/3	1/4	1/5	0.059	5.90%	Consistency OK
2	2	1	1/3	1/4	1/5	0.08	8.00%	8%
3	3	3	1	1/3	1/4	0.147	14.70%	
4	4	4	3	1	1/3	0.257	25.70%	
5	5	5	4	3	1	0.458	45.80%	

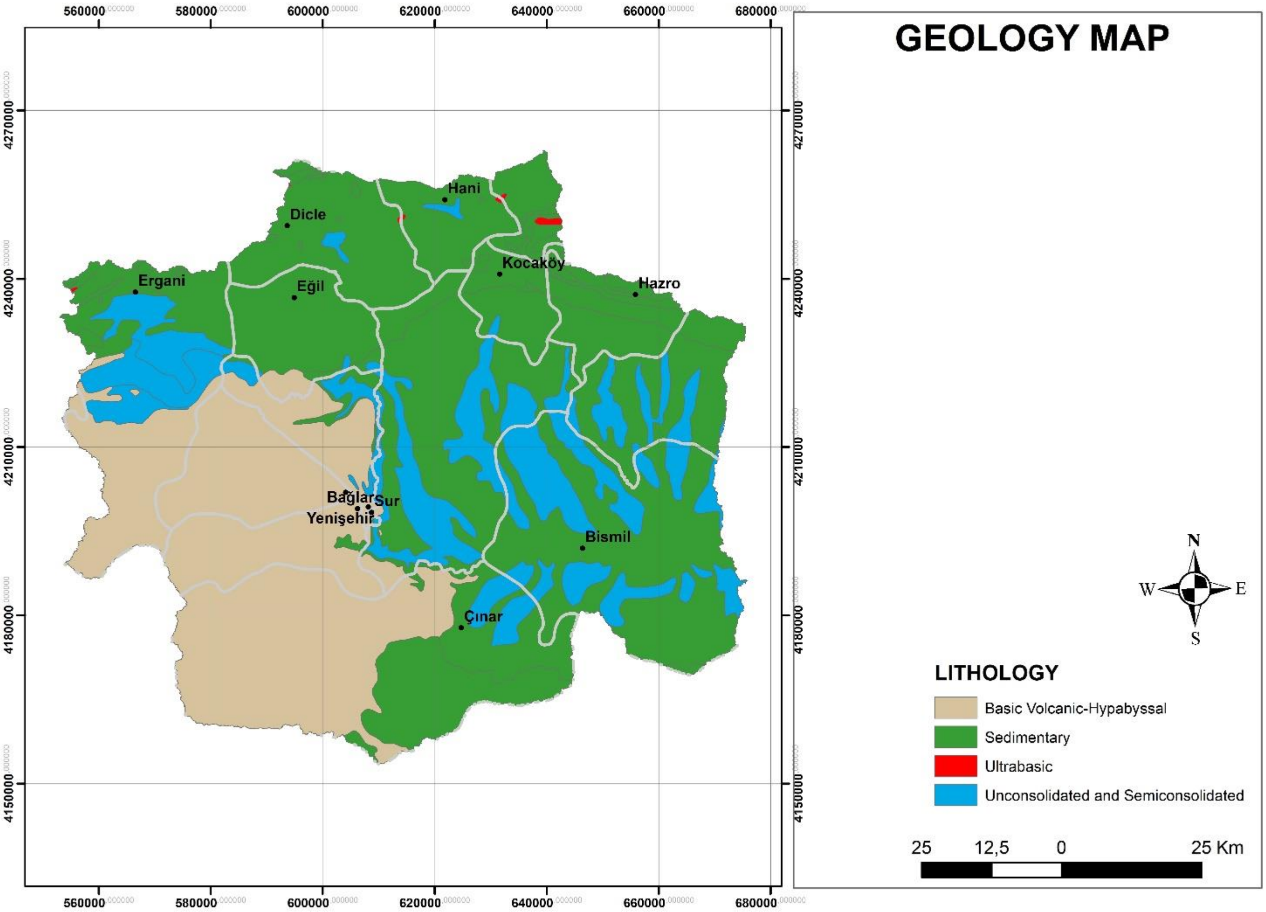

Figure 6. Geology map

If information is given about the underground geology of the Diyarbakır region, the basalt aquifers covering the surface of the region consist of volcanic origin units formed in the Pliocene and Quaternary periods and show a widespread. While the average thickness of these aquifers varies between 20 and 60 meters, they contain important groundwater resources thanks to their high water permeability. Limestone aquifers found at depths are generally Mesozoic-aged formations and are found at a depth of about 300 meters. These limestone formations have high porosity and permeability and are of great importance in terms of groundwater storage capacity; It also shows karst features. Alluvial and sedimentary layers in river valleys and lowland areas, on the other hand, affect surface water flows and drainage systems; These layers are usually in the form of fine-grained sedimentary deposits and are especially observed in lowland regions.

The geomorphology map is given in Figure 7 and the comparison matrix is given in Table 6. Regions with geomorphological characteristics such as valleys, plateaus, hills and mountainous areas have different factors that affect the groundwater level. Valleys are usually areas where water accumulates and the groundwater level is high. Valleys, where surface water is easily collected and percolated underground, can contribute to groundwater replenishment and therefore an increase in groundwater level. For this reason, valleys are generally known as areas where groundwater resources are located and water is easily accessible. Plateaus are high plains that are flat or gently sloped. The groundwater level in these areas is generally lower compared to the valleys. Because plateaus are usually made up of compacted rocks that block the flow of surface water and restrict the infiltration of water underground.

Table 5. Lithology comparison matrix

	Sedimentary	Ultrabasic	Unconsolidated and semi-consolidated	Basic	Weight coefficients		Consistency check
Sedimentary	1	7	1/3	3	0.287	28.70%	Consistency OK
Ultrabasic	1/7	1	1/7	1/2	0.057	5.70%	6%
Unconsolidated and semi-consolidated	3	7	1	5	0.551	55.10%	
Basic	1/3	2	1/5	1	0.104	10.40%	

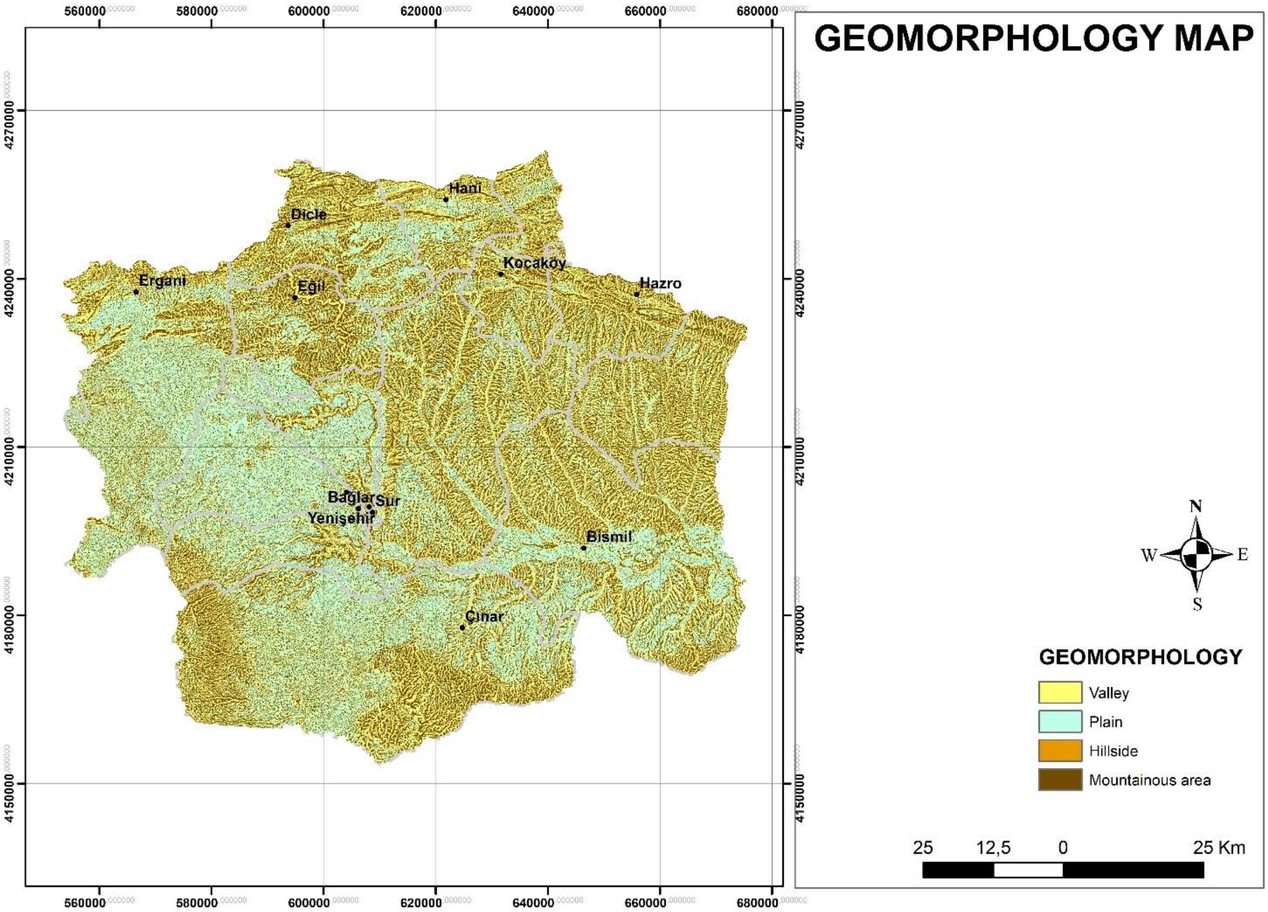

Figure 7. Geomorphology map

Thus, plateaus can often be more constrained in terms of groundwater resources. Hill and mountainous areas have topographically varied slopes and elevations. The groundwater level in these areas can vary depending on geological features, the amount of precipitation, and other factors that affect the flow of groundwater. In some cases, rocks in hill and mountainous areas can be porous and permeable, allowing the movement of groundwater and increasing the groundwater level. However, in other cases, the rocks may be more tightly consolidated and restrict the movement of groundwater, which can lead to a decrease in the groundwater level.

A precipitation map is given in Figure 8 and a comparison matrix is given in Table 7, and a classification is made according to the decrease in precipitation towards 5.sn, with the 1st class being the highest rainfall class.

Precipitation is an important factor determining the groundwater level and directly affects the groundwater regime. The amount and distribution of precipitation determine the feeding and replenishment of groundwater layers. In areas with heavy and regular rainfall, surface water percolates under the ground and feeds the groundwater layers, which can lead to an increase in the groundwater level. However, in areas where rainfall is low or irregular, the groundwater layers are not adequately nourished and the groundwater level decreases. In addition, the amount of precipitation affects the rate of refilling of groundwater. Heavy rainfall rapidly replenishes groundwater layers and raises the groundwater level, while during prolonged dry periods, the groundwater level decreases.

Table 6. Geomorphology comparison matrix

	Valley	Plain	Hill	Mountainous	Weight coefficients		Consistency check
Valley	1	1/2	5	7	0.364	36.40%	Consistency OK
Plain	2	1	4	6	0.465	46.50%	9%
Hill	1/5	1/4	1	3	0.116	11.60%	
Mountainous	1/7	1/6	1/3	1	0.055	5.50%	

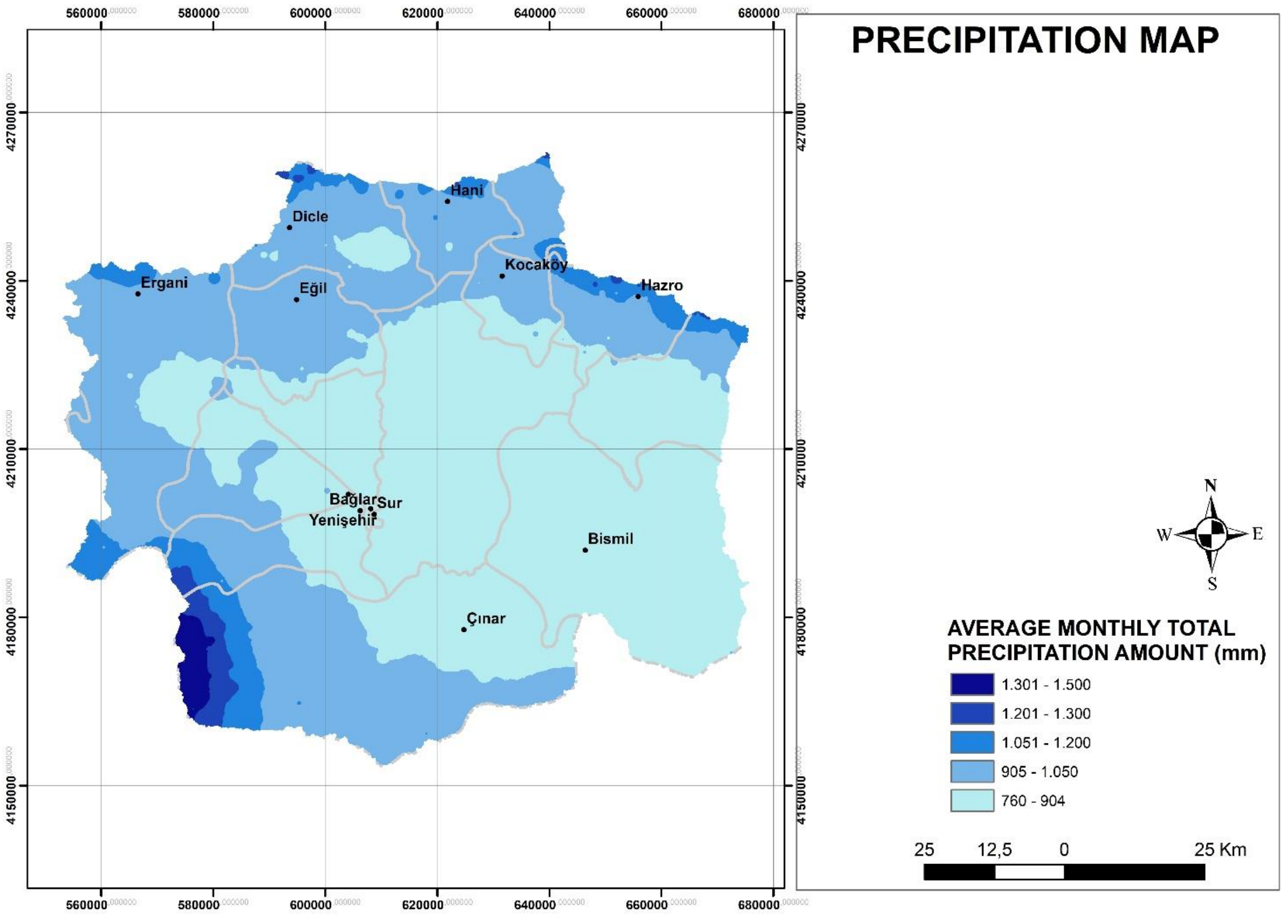

Figure 8. Precipitation map

However, the amount and distribution of precipitation can also determine seasonal fluctuations of groundwater level. The groundwater level usually rises, especially during the rainy seasons, while it decreases during the dry seasons. However, excessive rainfall can also adversely affect the groundwater level. Excessive rainfall can cause soil erosion, leading to erosion and contamination of groundwater layers. In this case, the groundwater level may decrease or its quality may deteriorate.

Figure 8 shows the groundwater level map, and Table 8 shows the comparison matrix. As can be seen in Figure 8, the groundwater level is specified in 5 classes: very low, low, medium, high and very high. Table 8 shows (1) drainage density, (2) slope, (3) precipitation, (4) geology, (5) land use, (6) geomorphology, (7) fault density. Drainage density and precipitation were chosen as the most influencing causes, while slope and geology were chosen as the classes with the least impact. As can be seen in Figure 9, the areal distribution of the groundwater level in hectares according to the classes shown in Figure 8 is given. It is seen that the class that covers the most area is the low level, and the class that covers the least area is the groundwater level at the very high level. It is also seen that the groundwater level height of Sur, Yenişehir, Kayapınar and Çınar districts, which are among the central districts, is better than other places.

Table 7. Precipitation comparison matrix

mm	1	2	3	4	5	Weight coefficients		Consistency check
1	1	3	5	7	9	0.503	50.30%	Consistency OK
2	1/3	1	3	5	7	0.26	26.00%	8%
3	1/5	1/3	1	3	5	0.134	13.40%	
4	1/7	1/5	1/3	1	3	0.068	6.80%	
5	1/9	1/7	1/5	1/3	1	0.035	3.50%	

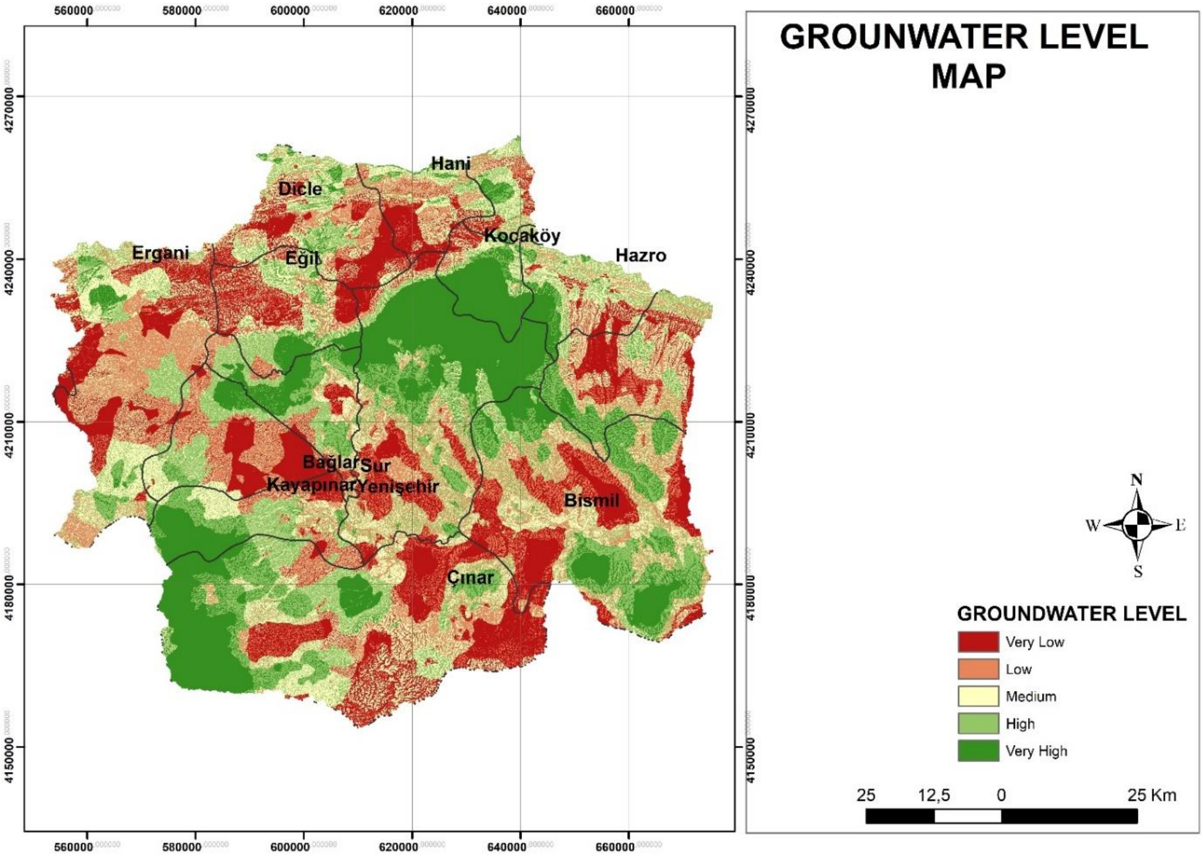

Figure 9. Groundwater level map

Table 8. Groundwater level comparison matrix

	1	2	3	4	5	6	7	Weight coefficients		Consistency check
1	1	6	2	5	3	4	7	0.352	35.20%	Consistency OK
2	1/6	1	1/5	1/2	1/4	1/3	2	0.047	4.70%	3%
3	1/2	5	1	4	2	3	6	0.239	23.90%	
4	1/5	2	1/4	1	1/3	1/2	3	0.071	7.10%	
5	1/3	4	1/2	3	1	2	4	0.155	15.50%	
6	1/4	3	1/3	2	1/2	1	3	0.101	10.10%	
7	1/7	1/2	1/6	1/3	1/4	1/3	1	0.034	3.40%	

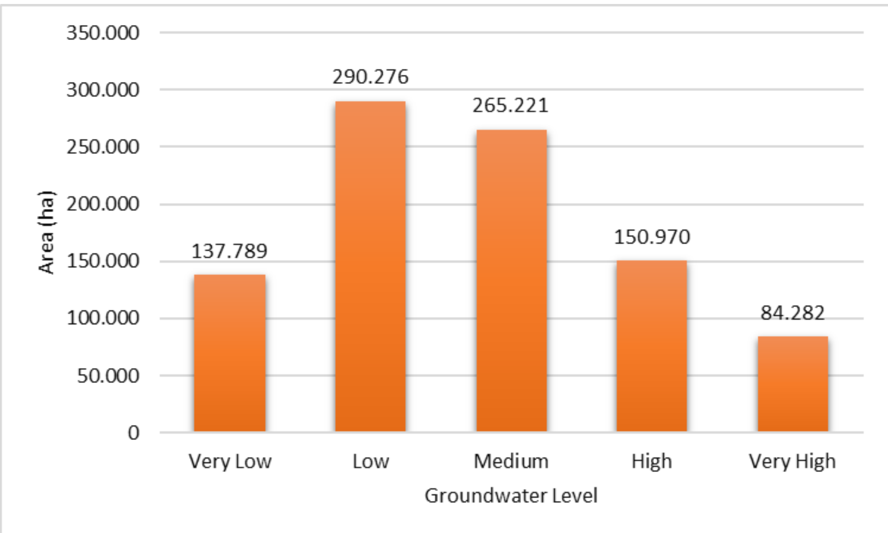

Figure 9. Areal distribution of groundwater level classes

There are different spatial distributions of groundwater levels as shown in Figure 9. There are many reasons for the heterogeneous and different distribution. Differences in groundwater levels in a region occur due to the effects of geological, hydrological, environmental and surface reservoir factors. Geological structure is one of the main reasons for these differences. Groundwater levels are determined by the presence and properties of different aquifer types such as basalt and limestone. While basalt aquifers show high permeability and wide distribution, limestone aquifers contain high porosity and karstic structures, which cause differences in water carrying capacities. In addition, porosity and permeability properties of rocks are important factors affecting water levels; formations with high permeability provide higher water levels, while low permeability can reduce water levels.

It is an effective factor on the variability of groundwater levels in hydraulic conditions. Water pressure and elevation determine how fast and how high aquifers can carry water. The direction and speed of water flow have a direct effect on groundwater levels; Water transfer and movement between aquifers can affect water levels. Topographic features also play an important role; water levels are generally deeper in high mountain regions, while shallower levels can be observed in plains and valleys. Surface runoff and drainage systems also affect groundwater levels; in lowland regions, intense surface runoff can increase groundwater levels.

Climate and rainfall conditions are other important factors that cause changes in water levels. The amount and distribution of rainfall in a region directly affects water levels in aquifers; high rainfall can increase water levels, while low rainfall and drought periods can cause water levels to fall. Temperature and evaporation rates also have an effect; high temperatures and evaporation can lead to a decrease in surface water and thus to a decrease in groundwater levels.

Aboveground reservoirs also have a significant effect on groundwater levels. Aboveground reservoirs are areas where water is stored on the surface, and these reservoirs affect groundwater levels in various ways. Large reservoirs, dams and water storage facilities can have an indirect effect on groundwater levels. For example, the construction of a dam or the formation of a reservoir can increase or regulate groundwater levels, as such reservoirs affect surface runoff and the infiltration of water into the ground. In addition, changes in the water level of these reservoirs can indirectly affect groundwater levels; higher reservoir levels can increase groundwater levels, while lower reservoir levels can reduce groundwater levels.

4 Conclusion

In this study, it was aimed to determine the groundwater levels for the study area of Diyarbakır province by using the analytical hierarchy method (AHP) in estimating groundwater levels. The data obtained in hectares were used to identify groundwater levels in five different categories: very low, low, medium, high, and very high.

The results obtained show that there is a certain distribution in the region that the research focuses on. The findings of our study revealed that groundwater levels are particularly concentrated in the "Medium" and "High" categories. However, it has been determined that there are fewer regions in the "Very Low" and "Very High" categories. This distribution shows that the groundwater in the region is heterogeneously distributed.

Groundwater levels being high, medium, very high or low depending on the interaction of various geological, hydrological and environmental factors. High water levels are usually seen in aquifers with high permeability and in regions with high rainfall. For example, karst and volcanic layers and large plains allow water to accumulate easily and be held at high levels. In addition, high rainfall amounts and continuous water supply also increase these levels. Medium water levels are usually observed in aquifers with medium permeability and in balanced rainfall conditions, which have a limited effect on water movement and accumulation.

Low groundwater levels are associated with formations with low permeability, arid climates and low rainfall amounts. For example, clay layers restrict water movement and reduce water levels. In addition, intensive water abstraction and human activities can also reduce water levels. Topographic features can affect the capacity of water to infiltrate into the ground, and this becomes more pronounced in regions with low slopes. All of these factors determine the variability in groundwater levels, leading to different classes of water levels.

We see that AHP is an effective method for estimating groundwater levels. However, it may benefit that future research be done using more data and more advanced analysis methods to improve the accuracy of the model.

Our results can be an important reference point for local governments and other organizations that manage water resources. The use of this data in the sustainable management of water resources and environmental planning processes is important to better adapt to the changing nature of groundwater levels.

This study highlighted the usability of AHP for the determination of groundwater levels and how this information can be reflected in environmental and societal impacts. Future research is expected to contribute to further steps in the field of groundwater management.

In future studies, more detailed modeling of different aquifer types and geological formations can be done, which will increase the accuracy of the results obtained in groundwater level estimations. In addition, the effects of climate change and precipitation regimes on groundwater levels can be better understood by analyzing long-term climate data. In addition, comprehensive field studies examining human impacts, especially pumping rates and water use, can be conducted, so that the effects of these factors on the estimation results can be better evaluated. In order to increase model accuracy, machine learning and artificial intelligence techniques can be integrated into existing estimation methods. These approaches can increase the accuracy and reliability of groundwater level estimations by expanding data sets and performing more dynamic analyses. In addition, changes in groundwater levels can be monitored more effectively by integrating different data sources and establishing continuous monitoring systems.

Conflict of interest

The authors declare that there is no conflict of interest.

Similarity rate (iThenticate): 10%

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