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Modeling and evaluation of Siverek (Şanlıurfa) groundwater potential by GIS and TOPSIS method

Siverek (Şanlıurfa) yeraltı suyu potansiyelinin CBS ve TOPSIS yöntemiyle modellenmesi ve değerlendirilmesi

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ABSTRACT

In addition to being an important part of the hydrological and hydrogeological systems in its area, it is an important strategy in terms of protecting and developing the gradually depleted groundwater within the resources. It is inevitable to evaluate the groundwater potential and quality of the Siverek basin for gains such as determination of water supply and distribution. Therefore, the mechanism of groundwater should be determined by sensitive hydrological and hydrogeological modeling studies. While current groundwater studies can explain groundwater hydraulics and hydrology, there is little literature on groundwater behavior under variable parameters and different scenarios involving surface water and groundwater interactions. In this study, the TOPSIS method based on the GIS program modeling the groundwater flow was used and the evaluation parameter weights were calculated using MCDM methods. By comparing the parameters with each other, the weights of the criteria were determined by the TOPSIS method. A total score was determined according to the evaluation form for 8 different suggestions entered into the system, such as rainfall, aquifer, slope, drainage density, soil type, geology, geomorphology. The highest scoring parameters were ranked in both methods. In the last stage, the parameters were evaluated and an order of superiority was determined for the ideal solution. The study was concluded by comparing the methods among each other.

Key Words: GIS software program, Hydrological and Hydrogeological system, Siverek basin, TOPSIS method

ÖZ

Bölgesindeki hidrolojik ve hidrojeolojik sistemlerin önemli bir parçası olmasının yanı sıra kaynaklar içerisinde giderek tükenen yeraltı sularının korunması ve geliştirilmesi açısından da önemli bir stratejidir. Siverek havzasının yeraltı suyu potansiyeli ve kalitesinin, su temini ve dağıtımının belirlenmesi gibi kazanımlar için değerlendirilmesi kaçınılmazdır. Bu nedenle yeraltı suyunun mekanizmasının hassas hidrolojik ve hidrojeolojik modelleme çalışmalarıyla belirlenmesi gerekmektedir. Mevcut yeraltı suyu çalışmaları yeraltı suyu hidroliğini ve hidrolojisini açıklayabilse de değişken parametreler ve yüzey suyu ile yeraltı suyu etkileşimlerini içeren farklı senaryolar altında yeraltı suyu davranışı hakkında çok az literatür bulunmaktadır. Bu çalışmada yeraltı suyu akışını modelleyen GIS programına dayalı TOPSIS yöntemi kullanılmış ve değerlendirme parametre ağırlıkları MCDM yöntemleri kullanılarak hesaplanmıştır. Parametreler birbirleriyle karşılaştırılarak kriterlerin ağırlıkları TOPSIS yöntemi ile belirlemiştir. Yağış, akifer, eğim, drenaj yoğunluğu, toprak tipi, jeoloji, jeomorfoloji gibi sisteme girilen 8 farklı öneri için değerlendirme için değerlendirme formuna göre toplam puan belirlenmiştir. Her iki yöntemde de en yüksek puan alan parametreler sıralanmıştır. Son aşamada parametreler değerlendirildi ve ideal çözüm için üstünlük sırası belirlendi. Çalışma, yöntemlerin birbirleriyle karşılaştırılmasıyla sonuçlandırıldı.

Anahtar Kelimeler: CBS yazılım programı, Hidrolojik ve Hidrojeolojik sistem, Siverek havzası, TOPSIS yöntemi

Introduction

Groundwater is an important factor that directly affects the hydrological behavior within the basin and plays an important role in water supply and quality. Groundwater contributes to water supply with wells and various water structures, and affects the quality and quantity of surface waters through interactions with streams, lakes, rivers and swamps. Therefore, groundwater reserve, quality and control are of great importance. In order for "Ground water" water resources to be used efficiently, they must be modeled hydrologically correctly. Many characteristics of groundwater must be taken into account in precision groundwater models. One of the most important of these characteristic features is surface water-groundwater interactions that can vary regionally. Surface water-groundwater interactions affect the hydrological behavior and pollution transport between different water sources such as rivers, lakes, streams and aquifers (Sarkar and Mandal, 2024).

In dry and semi-arid areas, groundwater is viewed as a potential alternative to traditional water supply methods. Different kinds of minerals are carried in solution by groundwater, and the kinds and concentrations of these minerals are primarily influenced by things like rock chemistry, interactions between surface water and groundwater, the geological environment (which offers a preferred pathway for groundwater flow), and other potential sources (Sevik and Cetin, 2015; Fehdi et al., 2016). The final result of the interaction between water and rocks from various geological eras is represented by the chemistry of groundwater. This explains why dissolved chemical components of various sorts and amounts are present in groundwater (Akbari et al., 2020).

The availability of groundwater is influenced by factors such as the geology, geomorphology, slope, soil type, drainage density, lineament concentration, rainfall, and land use of a region. The geological and geomorphological nature of an area determines how groundwater forms, moves, and is stored there. Geomorphological and geological elements have an impact on the hydrogeological settlement of the area, either directly or indirectly. In contrast, physiographic elements including relief, slope, and infiltration and seepage rates all affect flow rate. (Das and Pardeshi, 2018; Adiat et al., 2024).

Groundwater quality evaluation, a crucial part of groundwater environmental assessment, has recently attracted a lot of national and worldwide interest. Groundwater quality and quantity are now equally important in the assessment of groundwater resources, rather than only the quantity of groundwater. In several basins, groundwater monitoring network optimization projects are also in progress. These initiatives benefit the monitoring and defense of groundwater quality. Numerous water quality evaluation methods have arisen as a result of the growing demand for water quality assessment and preservation. According to data, there are already at least 60 techniques for determining the quality of water. Each technique has benefits and drawbacks, making it challenging to choose the optimal one. The Water Quality Index method is the one that is most frequently utilized abroad (Ejaz et al., 2024; Karakus, 2023). This study introduces and applies the ranking preference method based on how closely it resembles the ideal answer to groundwater quality assessment, which will serve as the foundation for the choice of groundwater quality assessment methods (Yildirim, 2021)

It is important to reveal the trends of the factors that threaten the potential and quality of groundwater over the years, in terms of carrying out quality status assessments. It will be possible to define the measures to be taken and to establish a regular monitoring system for a groundwater body whose situation has been assessed and the effects on it have been determined. In this context, In order to evaluate and manage the natural resources of the planet, remote sensing, GIS, and MCDM techniques will be extremely important. These methods are now highly efficient in terms of cost and time when attempting to determine a region's potential for groundwater. The definition of groundwater potential regions utilizing various geo environmental special layers has been successfully accomplished by numerous prior studies. Therefore, in this study, a study was conducted to model and evaluate the different groundwater potential and quality of the Siverek basin with the TOPSIS method by using the techniques of positively affecting the groundwater in the GIS environment.

Material and Method

Siverek located in the north of Sanliurfa province, Kahta District of Adiyaman in the west, Ataturk Dam Lake extending from west to north, Adiyaman's Gerger district, Diyarbakir's Cermik and Cungus districts, and Mardin province with a small border in the southeast are neighbors, as are the counties of Viransehir and Hilvan. Siverek town center is located at the intersection of 37.45 north 39.19 east longitudes. The altitude of Siverek district center from sea level varies between 801 and 840 meters. Its total surface area is 4367 km.

The typical continental climate of Southeast Anatolia prevails in the region. The summers are hot and dry, the winters are cold and rainy. The long-term average of precipitation is 572 mm

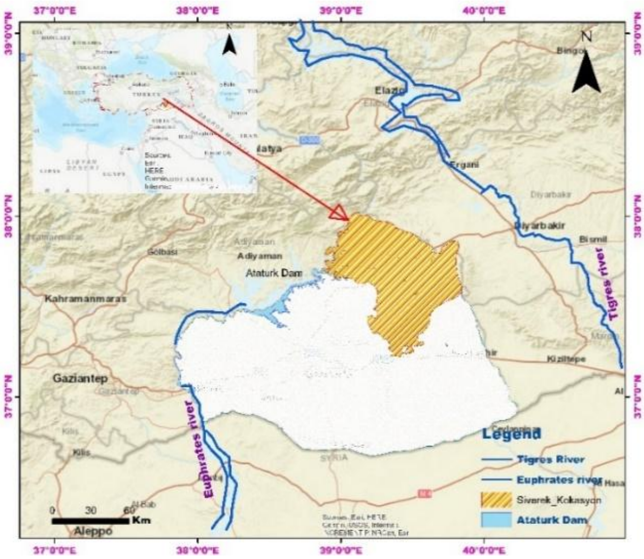

Figure 1. Study site location map

Eocene aged limestone; Miocene clay, sandy clay; Detritic materials consisting of Plioquaternary clay, silt, sand and gravel; Plioquaternary basalt and Quaternary alluvium were detected. There are no notable water streams in Siverek. However, there are streams that reach the Euphrates in the northeast. Since they are fed by these seasonal rains, they tend to dry towards the summer (Ozyilmaz et al., 2018).

Geological Structure of the Study Site

Eocene aged limestone and Miocene aged sandy clay, which are among the units in the study area, show bedding. In both units, the layer slopes are horizontal and close to the horizontal and are around 10°. Fracture systems, which are less common in sections dominated by clayey and chalky limestone levels, are highly developed in basalts and crystallized limestone. Basalts are massive in structure and flow structures and cooling cracks are dominant. Irregular and excessive cooling cracks in basalts cause difficult monitoring of structural and

TOPSIS Method

The TOPSIS approach, one of the Multi-Criteria Decision Making (MCDM) strategies, was created by Hwang and Yoon in 1981 and is frequently used for ranking purposes (Ada and Cakir, 2022). In this method, the aim is to determine the alternative that is the closest to the ideal solution and the farthest to the non-ideal (anti-ideal; negative ideal) solution among many alternatives (Karaatli et al., 2015). Six different stages are followed in the ranking process of the alternatives made according to certain

criteria with the TOPSIS method. These are explained below, respectively (Dehghan Rahimabadi et al., 2024; Aslan and Sepetcioglu, 2022).

Step 1: Making the Decision Matrix: The decision maker creates a mxn matrix for the decision. The columns display the criteria, while the rows provide the options. Matrix elements xij show the value of the i-th alternative according to the j-th criterion, and the general structure of the decision matrix is in the form.

$$D=[X_{ij}],\ i=1,2,3,\cdots,n \qquad (1)$$

Here, row Ai is the success values of the ith alternative according to all criteria, Xj column is the success values of all alternatives according to the j th criterion (Equation 1).

Step 2: Achieving the Normalized Matrix: The normalized matrix is obtained by descaling to evaluate criteria with different scales, and the following equation is used for this;

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{p=1}^{m}(x_{pj})^2}} \quad i = 1, 2, \cdots,m; \quad j=1,2,\cdots,n \qquad (2)$$

Depending on the values calculated with this equation, R= $[r_{ij}]_{mxn}$ normalized decision matrix is obtained.

So in other words; each x_{ij} value is normalized by dividing by the square root of the sum of the values in the column it is in, and r_{ij} values are obtained (Equation 2)

Step 3: Achieving the Weighted Normalized Matrix: At this stage, the criteria weights determined by the decision maker are used and the sum of the weights should be equal to 1. V= $[v_{ij}]$mxn weighted normalized decision matrix.

$$V_{ij}= w_j r_{ij}\ , \quad i = 1, 2, \cdots,m; \quad j=1, 2, 3, , n \qquad (3)$$

obtained by the formula. Here W_j is the weight value of j criterion. It is calculated by multiplying the values in each column of the R_{ij} matrix by the weight of the relevant criteria (Equation 3).

Step 4: Finding Values for Ideal and Anti-Ideal Solutions: At this stage, while determining the ideal solutions, if the goal is benefit, etc. The anti-ideal solution has the least value if the ideal solution has the biggest value. If the goal is cost etc. The ideal solution is the smallest value, and the anti-ideal solution is the largest value. Accordingly, (ideal solution) and (anti-ideal solution) are defined as follows:

$$A^* = \left\{(\max_i v_{ij} | j \in J), (\min_i v_{ij} | j \in J')\right\} = \left\{V_1^*, V_2^*, V_3^*, \ldots, V_j^*, \ldots, V_n^*\right\} \qquad (4)$$

$$A^- = \left\{(\min_i v_{ij} | j \in J), (\max_i v_{ij} | j \in J')\right\} = \left\{V_1^-, V_2^-, V_3^-, \ldots, V_j^-, \ldots, V_n^-\right\} \qquad (5)$$

Here, the maximum value for each column is A^- the minimum value for each column. If the goal is minimization, the situation is the opposite. A^* is the minimum value for each column, the maximum value for each column (Equation 4, 5).

Step 5: Obtaining the Distance Values from the Ideal and Anti-Ideal Solution: Euclidean metric is used for the distance calculation and the formula is given below (Equation 6, 7):

$$S_i^* = \sqrt{\sum_{j=1}^{n}(V_{ij} - V_j^*)^2}\ , \ i = 1, 2, 3, \ldots, m\ ) \qquad (6)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n}(V_{ij} - V_j^-)^2},\ i = 1, 2, 3, \ldots, m \qquad (7)$$

Step 6: Making the order of preference: Finally, S_i^* is used to calculate how close each decision point is to the ideal answer (Equation 6).

$$C_i^* = \frac{S_i^-}{S_i^* + S_i^-}, \quad 0 < C_i^* < 1, \quad i = 1, 2, 3, \cdots, m \qquad (8)$$

Alternatives are sorted by ordering the C_i^* values from greatest to least (Equation 8).

Where; V^+ is nearest to good and farthest to poor, V^- is Farthest to good, closest to poor.

Results

When previous studies were examined, it was seen that many parameters (5 - 8 parameters) were used comprehensively for the groundwater potential index (GWP_Z) evaluation research. On the other hand, a few studies used more parameters for GWP_Z determination. It was determined that land use (LU), soil type, drainage density, lineament density and geology were standard parameters and basic when GWP_Z studies were examined. Çelik et al. (2024) evaluated the precipitation and drainage density parameters related to groundwater potential. It was stated that the annual average precipitation in Mersin is 613.2 mm and therefore precipitation is an excellent parameter in the determination of GWP_Z in his study.

However, more is needed to determine the groundwater potential. Because a region with high rainfall does not always indicate the presence of groundwater. Soil diversity and texture in a region, land use, geological texture, erosive power of water, water holding capacity, infiltration amount and inflow directly affect the groundwater potential. For these reasons, the specified rainfall parameter and other parameters should be considered together for an optimum GWPZ analysis (Yilmaz et al., 2021).

Thematic maps created with the data-based model and GIS technique for the groundwater exploration criteria selected for the Siverek groundwater potential assessment study (precipitation, aquifer, slope, soil texture, land use, geology, geomorphology and drainage density) are presented in Figures 2 and 3, respectively. As can be seen from these maps, the thematic layers created in the GIS tools on each map are listed according to their effects on groundwater. Individual criteria have been reclassified according to their importance in determining groundwater potential zones. Detailed information on individual criteria is summarized below.

Rainfall

The main source of recharge of groundwater is precipitation. A permeable soil receiving high amounts of rainfall can contribute to the recharge of high stress water. The volume of water stored in the aquifer is a function of the degree and variation of precipitation. Water is stored in the aquifer only if it can be conveyed to the compartment and geological units. The rechargeability of groundwater depends on the empty spaces in the soil, geological structures and topographic conditions in the region. There is a high probability that the rains will continue for a long time and its functioning will reoccur. In potential and permeable aquifers, large amounts of water are stored when rain reaches the water table. The results of the distribution of reclassified precipitation maps on the GIS platform are presented in Figure 3a. The representations of thematic maps revealed almost the same categories in both approaches (Ahmad et al., 2020) (Figure 2a).

As can be seen in the regional precipitation map in Figure 2a, the part of the basin between 347-364 mm/year constitutes 40.25% of the annual precipitation average, while the part between 365-374 mm/year has 31.23% of the basin. The part between 375-382 mm/year has 10.23% of the basin and the part between 383-390 mm/year has approximately 9.30% of the precipitation amount. The precipitation amount between 391-400 mm/year covers only 9% of the basin (Celik, 2019).

Aquifer

Provides vital fluid for humans and other living things. They are geological formations consisting of porous rock, sand and gravel, containing significant amounts of water. The importance of these natural water sources stems from the fact that they contain almost all of the liquid fresh water on the planet.

Slope

Slope is a significant factor in identifying groundwater recharge zones within a basin. Its importance primarily lies in its influence on water retention time - flatter slopes allow more time for water to infiltrate the ground, thereby enhancing recharge potential. The speed of surface runoff, retention time and infiltration capacity of geological units are affected by slope. Flat areas in the basin are good indicators of groundwater potential zones due to their high retention times and infiltration rates. The majority of the lower parts of the basin are classified under steep slopes, and the groundwater potential zone varies from very low to low. Due to the steepness of the topography, the surface flow rate is very high and the retention time is very low. When the slope is flat enough, surface runoff has more time to percolate underground (Tamiru et al., 2022).

SRTM was used to create slope map (in degrees) from DEM in ArcGIS environment. The slope function defines the slope or maximum rate of change in the z value in each cell of the DEM, from 0° to 90°. The slope tool was used to calculate the maximum rate of change of a given cell to neighboring cells. The maximum change in elevation across the distance between the cell and its eight neighboring cells defined the steepest downhill descent from the cell (Figure 2c).

In Figure 2c, in approximately 54% of the basin, the slope is over 10%, in 20% of the basin, the slope is between 10-18%, and the desired slope for groundwater potential is 7%, that is, 13% of the area.

Soil texture

Groundwater is stored in the spaces between soil particles. The volume of water stored in specific hydrological units depends on the texture and size of soil particles. A reclassification was made according to the permeability and infiltration capacity of the soil. However, according to the information obtained from productive wells, the effect of the soil is relatively low if the wells are deep. Therefore, other factors such as rainfall, land use and drainage intensity have played an important role in recharge and contributing to groundwater. One of the interesting features of rain is that it filters through the soil and reaches the water. It is obvious that a large amount of water is stored in the aquifer if there is a possibility of leakage through the soil. Although there is no well-documented information about the aquifer of the sub-basin, it has been determined that there is a high level of infiltration, as can be understood from geophysical studies (Figure 2d).

The soil map of the basin shows that approximately 2% is alluvial soil, 58% is brown forest soil, 39% is brown soil and 2% is reddish-brown soil.

Land Use

Groundwater recharge is the main process by which rainfall infiltrates the aquifer. This process is a function of land use. Compared to areas that were not urbanized in the past, urbanization is increasing in the basin and the rechargeability of groundwater is increasing (Hamed et al., 2018).

The difference between current and past land use typically reflects changes resulting from human activities. These changes can be outlined as follows:

- Urban Expansion and Increase in Settlements: Areas that were previously used for agriculture, forests, or natural landscapes have been converted into residential, industrial, or commercial zones in the new land use.
- Reduction of Agricultural Land: Agricultural areas have been rezoned and

repurposed for other uses such as housing or industrial development.

- Degradation of Natural Areas: Natural landscapes such as forests, pastures, and wetlands have been disturbed or destroyed due to construction, mining, or other anthropogenic activities in the new land use.
- Change in Land Use Intensity: While some areas are now used more intensively (e.g., high-rise buildings, roads), certain natural areas have been lost altogether.
- Environmental Impacts: New land use practices often lead to increased environmental effects, such as erosion, water pollution, and habitat loss.

Reclassified land use thematic maps created with GIS technique are presented in Figures 2e and 3e. There are five dominant land uses in the study area (Figure 2e). The water body and irrigated areas in the discharge area of the basin are quite small and there are generally unirrigated agricultural lands (31%), pastures (17%) and other areas with vegetation.

Geology

One of the most important factors determining the formation of groundwater is geology. Groundwater can only be stored and circulated in the cracks and cavities of the rock. This means that it is the porosity and permeability of materials that ultimately limits groundwater potential. In practice, the challenge often consists of identifying formations that are more likely to hold water. These include, but are not limited to, unconsolidated deposits, weathering products, and fractured and soluble sedimentary rocks (Figure 2f).

The presence of groundwater in an aquifer depends on the nature of the geology and the permeability of the geological environment. When a geological formation captures and transmits percolating water, the water is stored in an aquifer. The amount and volume of water stored in geology is a function of the hydrogeological environment of the region. Water can only be stored if there is sufficient space between geological units. The aquifer is assumed to be potential when there is sufficient space in the hydrogeological environment. Geological units with uniform grain size generally have sufficient porosity and high permeability. Groundwater recharge occurs from surface runoff, precipitation seeping into the soil from lakes and streams (Berhanu et al., 2020).

Geomorphology

There are five dominant landforms in the study area: flats, plains, plateaus, hills and mountains. GIS tools were used to reclassify landforms according to the importance of their contribution to groundwater. In this study, a thematic layer was created and the dominant landforms were reclassified into five groups. The landforms of a geomorphological unit differ in terms of their characteristics and spatial distribution. The formation and movement of groundwater depends on the geomorphological characteristics of the region. Low mountainous and flat plains are indicative of the presence of groundwater if hydrogeological environments conduct water. Landform classification based on slope was applied for a geomorphological unit and a quantitative classification was made.

As seen in Figure 2g, the basin consists of topographic maps showing parts such as flats, plains, plateaus, hills and mountainous areas. While plains and plain parts contain high groundwater potential, hilly and mountainous regions are the parts with the lowest potential. The basin has an area of mountainous areas (16%), hilly areas (17%), plain areas (18%), plains (43%) and plateaus (6%).

Drainage density

The permeability and infiltration rate of rainfall in certain regions is controlled by drainage density. Stream networks and corresponding land surface discharge along the length of the channel may indicate potential groundwater zones. If the drainage density in the basin contributes to the recharge of groundwater, the aquifer is potential. The hydrogeological conditions and moisture retention capacity of the soil initiate drainage density, which in turn supports the rechargeability of groundwater. Drainage density is affected by topographic conditions and the permeability of geological units. If the slope is flat, the permeability is very high and the drainage density is very low.

In the basin, where the drainage density is mostly low, the coefficient of performance is higher and the flow is slower, so infiltration occurs at a higher rate. First of all, raster thematic maps were created in the light of the explanation of the GIS method.

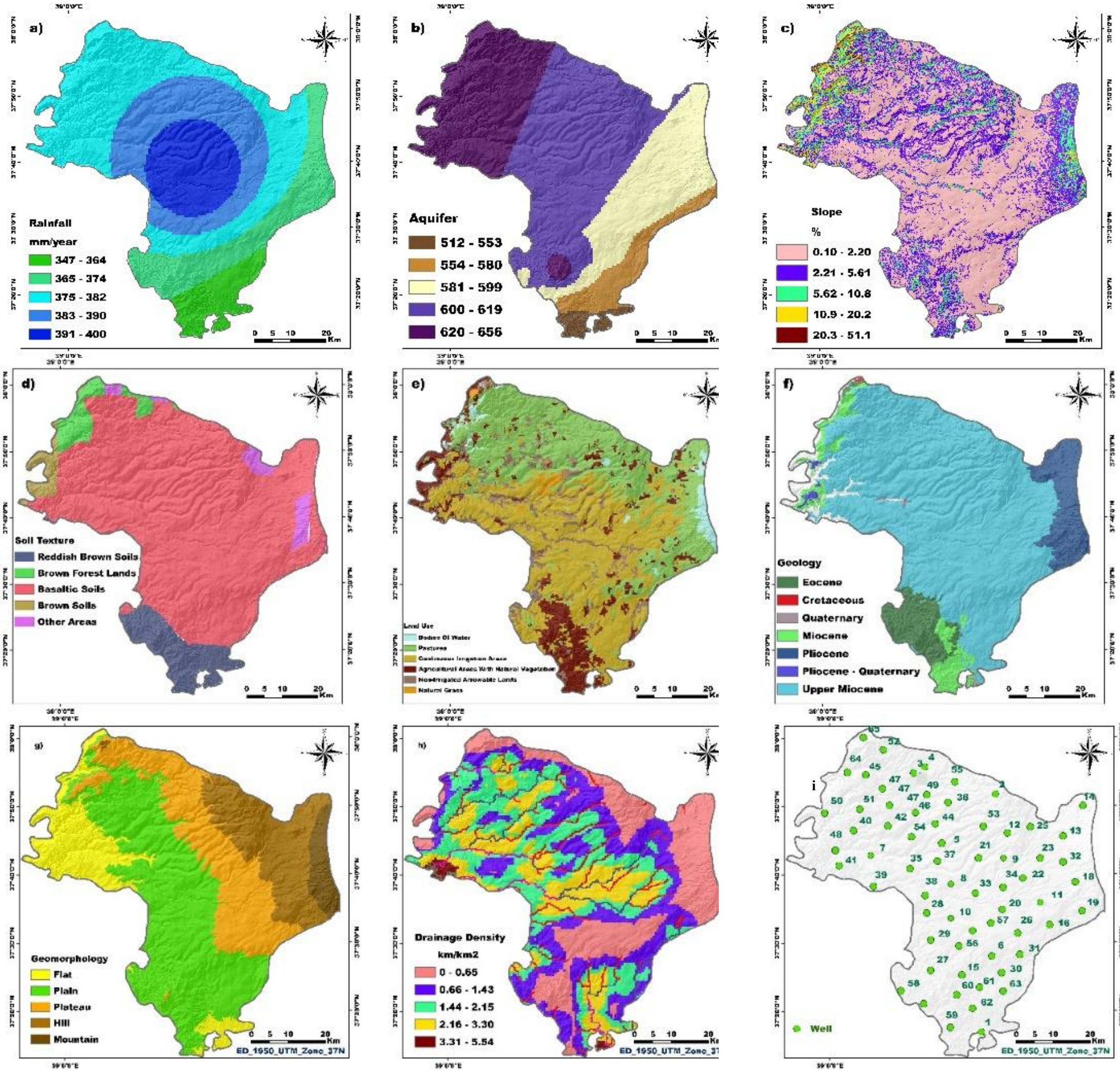

Figure 2. Raster thematic maps created in ArcGis, ArcMap 10.5 software environment (a) Precipitation, b) Groundwater level, c) Slope, d) Soil texture, e) Land use, f) Geology, g) Geomorphology, h) Drainage density and i) Drilling data)

Table 1. Partial well data drilled by institutions, organizations and private sectors

Rank	District	Neighborhood-Village	SWL	DWL	Water Flow 1/sn	Kot No	depth	Coordinate	
								X (East)	Y (North)
1	Siverek	Soydan	80	110	2	1150	210	564498	4180509
2	Siverek	Soydan	50	65	10	1148	220	"-"	"-"
3	Siverek	Soydan	80	110	44	1155	225	563078	4180563
4	Siverek	Soydan	53	102	26	1147	216	559598	4181201
5	Siverek	Soydan	55	67	8	1149	205	"-"	"-"
6	Siverek	Soydan	75	102	1	1151	240	563045	4178724
7	Siverek	Soydan	110	120	11	1152	245	559042	4181050
8	Siverek	Soydan	80	110	1	1153	246	563142	4179136
9	Siverek	Soydan	110	120	10	1151	236	560072	4180198K
10	Siverek	Soydan	110	120	15	1155	253	560042	4180148
11	Siverek	Gedik	60	73	20	1154	270	"-"	"-"
12	Siverek	Karacadag	30	66	15	1115	216	563866	4176509
13	Siverek	Karakoyun	110	120	15	702	120	518656	4171841
14	Siverek	Karakoyun	110	120	10	700	126	420384	4170052
15	Siverek	Karakoyun	110	120	15	701	135	520992	4171541
16	Siverek	Karakoyun	80	90	23	703	140	526975	4172722
17	Siverek	Karakoyun	110	120	15	702	152	520611	4171942
18	Siverek	Karakoyun	7	120	5	705	160	521536	4170092
19	Siverek	Karakoyun	110	120	15	701	150	519915	4172301
20	Siverek	Karakoyun	110	120	5	704	145	519759	4169821
21	Siverek	Karakoyun	110	120	10	703	135	521055	4171510
22	Siverek	Darlicali	110	120	5	702	130	521096	4171693
23	Siverek	Darlicali	18	30	15	692	170	523026	4165087
24	Siverek	Darlicali	40	50	15	691	175	523080	4165123
25	Siverek	Darlicali	30	65	45	693	143	516200	4166400
26	Siverek	Darlicali	20	45	15	069	162	522585	4164603
27	Siverek	Darlicali	20	45	20	695	175	521643	4163806
28	Siverek	Darlicali	55	75	20	693	180	517113	4177799
29	Siverek	Darlicali	60	65	10	690	182	522268	4167968
30	Siverek	Darlicali	40	78	10	692	144	517186	4178696
31	Siverek	Darlicali	110	120	10	691	145	522183	4177869
32	Siverek	Darlicali	60	65	20	695	155	517445	4166306
33	Siverek	Darlicali	55	75	10	693	156	"-"	"-"
34	Siverek	Darlicali	110	120	10	694	148	"-"	"-"
35	Siverek	Darlicali	30	65	45	692	139	518191	4164812
36	Siverek	Darlicali	35	40	10	695	146	522234	4164558
37	Siverek	Darlicali	110	120	39	696	129	523209	4165192
38	Siverek	Darlicali	110	120	30	697	138	523806	4164510
39	Siverek	Darlicali	90	110	13	692	149	524109	4164123
40	Siverek	Darlicali/Kadioglu	30	65	45	691	160	522454	4164883
41	Siverek	Darlicali/Kadioglu	20	55	25	695	154	"-"	"-"
42	Siverek	Darlıcali/Kadioglu	20	48	20	699	157	"-"	"-"
43	Siverek	Darlıcali/Kadioglu	20	65	40	698	138	"-"	"-"
44	Siverek	Darlıcali/Kadioglu	20	45	10	694	156	"-"	"-"
45	Siverek	Darlicali	110	120	1	692	150	517220	4168001
46	Siverek	Karacadag	15	42	1.5		100	"-"	"-"

Well Number	Location	Well Name	License owner	License Status	Elevation	Coordinate		Flow Rate
1	Ataturk Camlik	Exterior 1	Siverek Belediyesi	Existing	720.04	526700.939,	4178597.093	25lt/sn
2	Ataturk Camlik	Bahce 1	Siverek Belediyesi	Existing	718.12	526624.876,	4178597.093	281t/sn
3	Ataturk Camlık	Bahce 2	Siverek Belediyesi	Existing	716.30	526473.007,	4178403.903	201t/sn
4	Ataturk Camlik	Well No. 3	Siverek Belediyesi	Existing	715.77	526473.007	4178299.907	251t/sn
5	Ataturk Camlik	Well No. 4	Siverek Belediyesi	Existing	714.09	526427.256	4178241.163	251t/sn
6	Ataturk Camlik	Well No. 5	Siverek Belediyesi	Existing	42.00	526373.740	4178127.751	251t/sn
7	Sanayi	Ciraklik Okulu	Siverek Belediyesi	Existing	694.96	525635.845	4176938.506	281t/sn
8	Sanayi Park	Well No. 6	Siverek Belediyesi	Existing	696.60	525676.103	4177020.640	281t/sn
9	Camlik Karsisi	Astroturf Field	Siverek Belediyesi	Existing	721.91	526745.018	4178350,818	201t/sn
Spring Waters								
1	Gedik Koyu Karacadag	Gedik Well No. 1	Siverek Belediyesi	Existing	1142.73	561421.424	4180389.075	201t/sn
2	Gedik Koyu Karacadag	Gedik Well No. 2	Siverek Belediyesi	Existing	1143.07	561442.890	4180359.331	201t/sn
3	lleri Koyu Karacadag	Ileri Well No. 1	Siverek Belediyesi	Existing	1248.19	564733.544	4175252.577	15lt/sn
4	lleri Koyu Karacadag	Ileri Well No. 1	Siverek Belediyesi	Existing	1246.72	564645.333	4175230.252	15lt/sn

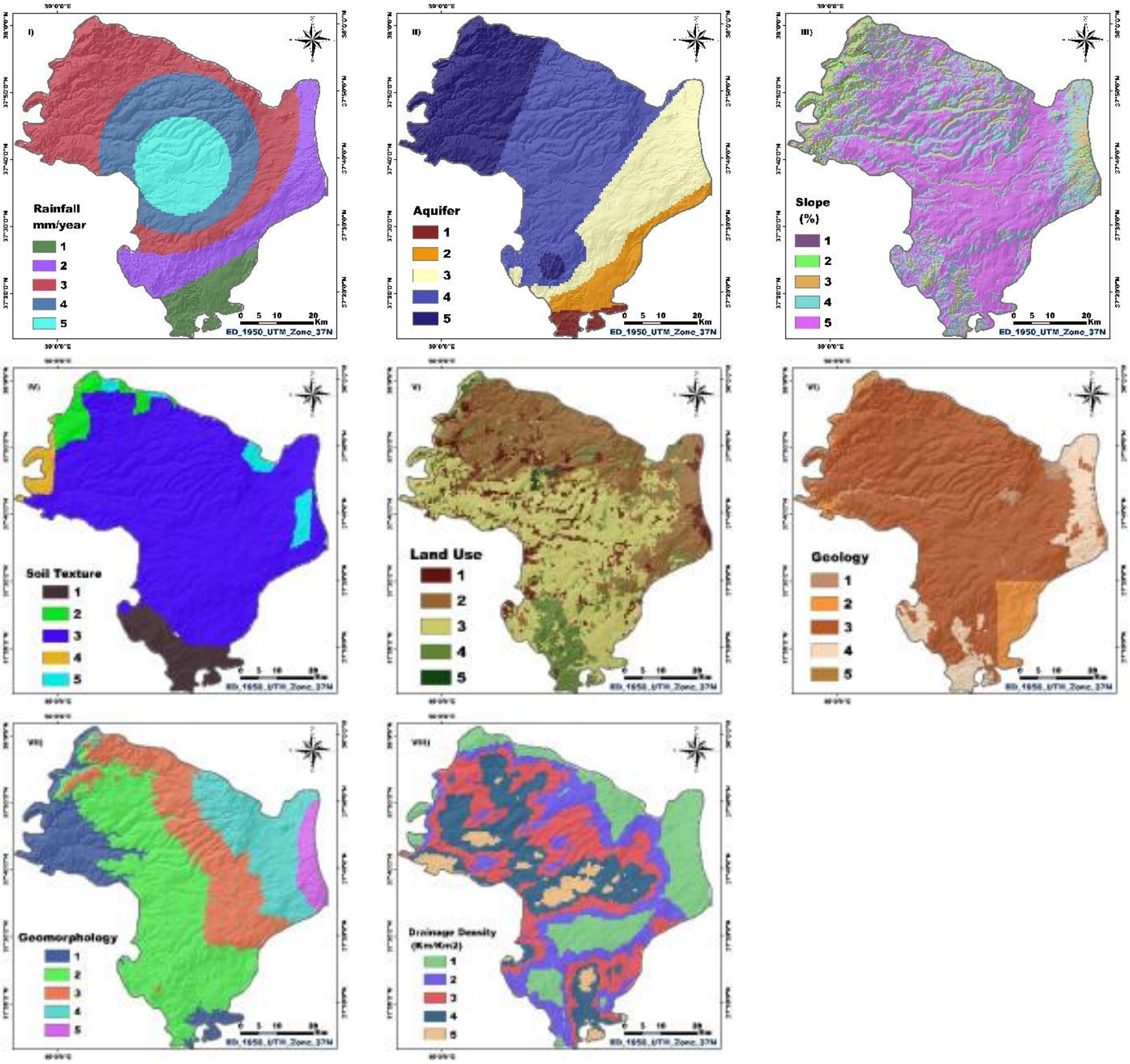

Figure 3. Generated maps of 8 reclassified parameters with ArcMap 10.5 program ((I). Rainfall, II). Aquifer, III). Slope, IV). Soil texture, V). Land use, VI). Geology, VII). Geomorphology, VIII). Drainage density)

Here;

SWL: Static Water Level

DWL; Dynamic Water Level

The reason for creating Table 1 for groundwater potential is;

Providing real data; coordinated drilling data includes real site-specific measurements such as groundwater depth, flow rate, water level and lithology. These data increase accuracy in modeling and analysis.

Validation; the accuracy of the hydrogeological models made on the map is tested by comparing them with existing drilling data. Thus, the reliability of the map is increased.

Understanding groundwater distribution; Measurements at drilling points help to show in which areas water is more abundant and in which areas it is limited.

Determining areas: Drilling data is one of the basic inputs in the classification of areas with high, medium and low groundwater potential.

Increasing map sensitivity; Especially in areas with very wide or heterogeneous geological structures, when drilling data is geographically placed, the potential map is prepared more sensitively and in accordance with local conditions.

A total of 82 data were obtained from wells opened by relevant institutions, organizations and private companies regarding the groundwater potential of the Siverek basin. About 17 of these wells, It was removed because it was out of bounds and because its coordinates were missing. The reason for using the obtained wells in the basin is to create observation wells for the distribution of groundwater potential and quality analysis.

In order to create the infrastructure of the TOPSIS method and the groundwater potential distribution map, the 8 parameters used in the study were reclassified.

Application of TOPSIS Method

The TOPSIS method application was made in the light of the explanations in the methodology section (Table 2).

Table 2. Pairwise comparison matrix

	Benefical Performance	Non-Benefical Cost	Benefical	Benefical Sustainability
Weight Values	0.4	0.2	0.3	0.1
Rainfall	60	55	65	75
Aquifer	50	55	50	45
Slope	40	45	40	35
Soil Texture	30	35	50	30
Land Use	25	30	45	45
Geology	20	25	40	40
Geomorphology	15	20	35	35
Drainage Density	10	15	30	30

By dividing the sum of the squares of the relevant column's values by the square root, the normalized decision matrix is created, with each value in the columns being reduced to a single denominator (Table 3).

Table 3. Obtaining the normalized matrix

	Performance	Cost	Benefical	Sustainability
Weight Values	0.4	0.2	0.3	0.1
Rainfalı	0.601505649	0.513996245	0.504878164	0.601929265
Aquifer	0.627455805	0.599208182	0.449921271	0.452267017
Slope	0.644628082	0.612357456	0.403028963	0.394396246
Soil Texture	0.632349375	0.602408457	0.550466625	0.367867925
Land Use	0.680118897	0.646846494	0.593410447	0.593405150
Geology	0.741977933	0.706722112	0.655304374	0.655310093
Geomorphology	0.829459431	0.798863527	0.759028943	0.759040553
Drainage Density	0.98732505	0.994973736	0.999054489	0.99909052

By multiplying the weights by the values in the standard decision matrix, a weighted standard decision matrix is produced Table 4)

Table 4. Obtaining a weighted normalized matrix

	Performance	Cost	Beneficial	Sustainability
Rainfall	0.240602259	0.102799249	0.151463449	0.060192927
Aquifer	0.250982322	0.119841636	0.134976381	0.045226702
Slope	0.257851233	0.122471491	0.120908689	0.039439625
Soil Texture	0.252939750	0.120481691	0.165139988	0.036786792
Land Use	0.272047559	0.129369299	0.178023134	0.059340515
Geology	0.296791173	0.141344422	0.196591312	0.065531009
Geomorphology	0.331783772	0.159772705	0.227708683	0.075904055
Drainage Density	0.394930020	0.198994747	0.299716347	0.099909052

In order to obtain the ideal solution from each column in the weighted decision matrix, the ideal values for the positive ideal and negative ideal solutions are selected and the solution sets are determined. In the explanation below, the first line shows the positive ideal solution and the second line shows the negative ideal solution set.

Obtaining Ideal and Anti-Ideal Solution Values Worst and best (closest to good and farthest from bad)

V^{+}0.240602259 0.198994747 0.299716347 0.099909052

V^{-}0.394930020 0.102799249 0.120908689 0.036786792

Table 5. Ordering the choice (C_i^*) and calculating the distances between the ideal and anti-ideal solutions (S_i^* ve S_i^-)

	S_i^*	S_i^-	C_i^*	Rank
Rainfall	0.047510749	0.308255572	0.866455181	1
Aquifer	0.048809111	0.312439149	0.864887623	2
Slope	0.04883046	0.312507471	0.864862071	3
Soil Texture	0.053559419	0.327290145	0.859368568	4
Land Use	0.062979911	0.354908189	0.849290010	5
Geology	0.075502852	0.388594523	0.837312478	6
Geomorphology	0.096610229	0.439568492	0.819817114	7
Drainage Density	0.147690169	0.543489041	0.786321454	8

The distance values to the positive ideal and negative ideal solution were calculated by subtracting the positive ideal and negative ideal values from the values in the column of each parameter (Table 5).

According to the application in the TOPSIS method, the ideal solution is respectively; rainfall, aquifer, slope, soil texture, land use, Geology, Geomorphology, drainage density.

In TOPSIS implementation, indices for groundwater potential and quality assessment are often artificially chosen based on subjective experience, which greatly reduces the relevance, accuracy and reliability of assessment results.

Verification of Siverek Basin Groundwater Potential Index (GWPI) Results with Field Well Data

Normally, it is very costly to obtain up-to-date data from wells in the field. Therefore, it is shorter and more economical to determine the groundwater potential and quality of a site with multi-criteria decision making methods. Therefore, it is necessary to determine the parameters and weights that affect the groundwater correctly. GWPI area distribution map was produced with the method mentioned above in ArcGIS ArcMap 10.5 environment by using the data of 11 of the wells drilled before, by checking the determined method and the results obtained in the field.

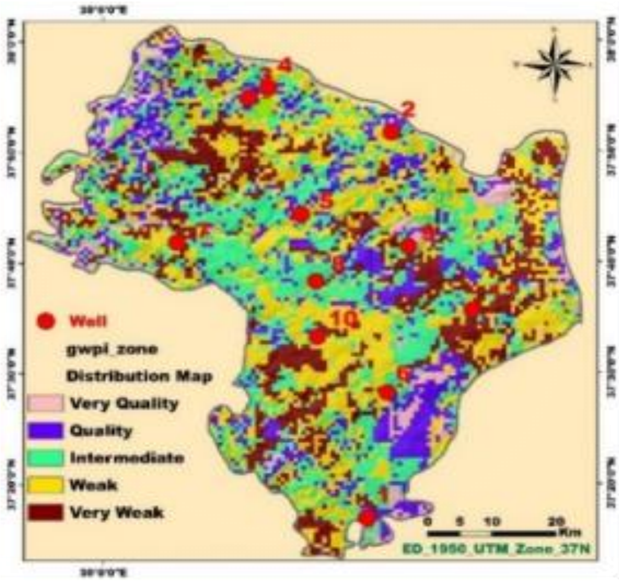

Figure 4. Groundwater potential distribution map of the Siverek basin survey site

Table 6. Definition of Siverek basin according to GWPI values

GWPI Value	Definition	Rate (%)	Covered area (km2)
204 - 257	Very Well	8,00	356,08
258 - 293	Well	22,00	987,17
294 - 311	Moderate	35.07	1515,37
312 - 361	Poor	23.03	1002,22
362 - 395	Very Poor	11,93	508,12

The eight parameters used for the groundwater potential index distribution map were first reclassified, and then a precise map of the groundwater potential zone (GWP_Z) was produced in Arctoolbox, Spetial Anlyist Tools, Overlay, Weighted Overlay (Figure 4).

Groundwater potential and quality distribution values were obtained between approximately 204 and 361, and as explained in Table 6, it can be said that the groundwater potential and quality are partially at a good level in the scattered regions of the basin (Table 6).

Groundwater potential index distribution (GWPI) is a map showing the groundwater potential of the study area. This map shows the possibility of obtaining groundwater resources for the study area. GWPI for the study area changes according to the variability of the characteristics that constitute the groundwater potential. This GWPI map produced for the study shows groundwater discharge zones for very poor: very low, poor: low, medium, quality: medium low, quality: high rate and very high rate: very high quality.

Accordingly, when the description of the evaluation of the basin's GWPI map in Table 6 is examined; very poor (508.12 km2; 11.93%), poor (1002.22 km2; 23.03%), medium (1515.37.22 km2; 35.07%), good (987.17 km2; 22%) and very good (356.08 km2; 8%). When the basin's GWPI map is examined, it is seen that the average potential is around 35%.

Validity (Verification)

Groundwater potential value data from 11 observation wells in the basin shown in Figure 4 represent water well locations. Almost all of the irrigation pump wells were evaluated in terms of groundwater potential area with very good, good, medium, weak, very weak categories. In the evaluation, 11 of these wells were found to be compatible

Table 7. Comparison of well data

Number Sequence	Town	X	Y	Z	Depth	SWL	DWL	Yield	GWPI	Evaluation	Coherence
1	Siverek	520611	4171942	512	216	30	66	3	201	Poor	Conformable
2	Siverek	521536	4170092	681	120	110	120	2	214	Moderate	Conformable
3	Siverek	519915	4172301	583	126	110	120	1	226	Good	Conformable
4	Siverek	519759	4169821	735	135	110	120	5	247	Poor	Conformable
5	Siverek	521055	4171510	577	140	80	90	1	279	Good	Conformable
6	Siverek	521096	4171693	735	152	110	120	3	312	Moderate	Conformable
7	Siverek	523026	4165087	666	160	7	120	1	351	Good	Conformable
8	Siverek	523080	4165123	713	150	110	120	1,5	384	Weak	Conformable
9	Siverek	516200	4166400	664	145	110	120	4	397	Good	Conformable
10	Siverek	522585	4164603	712	135	110	120	1	405	Weak	Conformable
11	Siverek	521643	4163806	856	130	110	120	0,1	414	Moderate	Conformable

Trying to validate the groundwater model using the terrain-based groundwater potential map of the study area, this puts forward the

assumption that water is the main factor affecting the groundwater potential quality and generally the amount of water available for runoff

Table 8. Classification of parameters affecting the groundwater potential zones

Sequence No.	Parameters	Rank	Sub - Parameters	Land Coverage Area	Area Covered (%)	Groundwater View	Degree
1	Rainfall	9	347 - 364	347	0.19	Very Weak	3
			365 - 374	354	0.18	Weak	4
			375 - 382	384	0.20	Moderate	5
			383 – 390	391	0.21	Quality	7
			391 - 400	399	0.22	Very Quality	8
2	Aquifer (Hydrogeology)	8	512 - 553	655	0.23	Very Weak	4
			554 - 580	648	0.22	Poor	5
			581 - 599	629	0.20	Moderate	6
			600 - 619	637	0.21	Quality	7
			620 - 656	511	0.16	Very Quality	8
3	Slope	7	0,10 - 2,20	70315	0.29	Very Good	9
			2.21 - 5.61	68706	0.27	Very Good	8
			5.62 - 10.8	40455	0.17	Good	7
			10.9 - 20.2	25572	011	Moderate	5
			20.3 - 51.1	37852	0.15	Poor	3
4	Soil Texture	6	Reddish Brown Soils	2488	0.30	Very Good	8
			Brown Soils	681	0.08	Good	6
			Brown Forest Lands	1183	0.14	Moderate	5
			Other Areas	874	0.11	Poor	4
			Basaltic Soils	2994	0.36	Very Weak	3
5	Land Use	5	Vineyards	3272	0.14	Very Good	7
			Irrigated Arable Lands	8151	0.34	Good	6
			Orchards	3587	0.15	Moderate	5
			Meadows and Pastures	5032	0.21	Poor	4
			Natural Grassland	3778	0.16	Very Poor	3
6	Geology	6	Eocene	2543	0.15	Very Good	6
			Miocene	2284	0.13	Good	5
			Pliocene – Quaternary	159	0.009	Moderate	4
			Pliocene	3244	0.18	Poor	3
			Upper Miocene	8957	0.52	Very Poor	2
7	Geomorphology	5	413 – 667	154223	0.06	Very Good	7
			668 – 835	374528	0.19	Good	6
			835 –1030	555164	0.29	Moderate	5
			1031–1311	572161	0.30	Poor	4
			1312-1793	278014	0.14	Very Poor	3
8	Drainage Density	7	0,10 - 0,65	17	0.001	Very Poor	3
			0,66 – 1,43	374	0.012	Poor	4
			1.44 – 2,15	542	0.017	Moderate	5
			2,16 – 3,30	1347	0.043	Good	6
			3,31 – 5,54	28779	0.93	Very Good	7

As a result of the classification of the parameters affecting the groundwater potential regions in the ArcMap environment, both classification and weighting of these parameters according to their effects on groundwater were provided (Table 8).

Conclusion and Recommendations

In the determination of the underground water potential and change of the Siverek basin with the geographical information system, the well data obtained firstly was arranged in accordance with the purpose of the study. In the study, 8 raster maps were created using Spatial Analyst Tools, Interpolation, IDW methods and other techniques in GIS environment in order to determine the formation of groundwater in the basin, where and how much groundwater is found and its usage possibilities. After that these thematic maps were reclassified and the ground was prepared for the potential status of groundwater. These parameters, which were obtained as a result of the application of the TOPSIS method, were matched with the percent values in their ideal order in the ArcMap program. With this map, which was created as a result of overlapping (Figure 4), a database was provided in order to be able to control the groundwater level in the future and to make hydrogeological evaluations.

In the study, the operating performance of Siverek groundwater potential was evaluated with the GIS supported TOPSIS method and the success status of each parameter was listed. According to the effects of the eight parameters used in the study on the groundwater, the method was applied in the rate analysis in the process. With the applied method, the examination rates were converted into a single concrete value mathematically and the results were expressed numerically. In this context, it was observed that the most successful parameter of the method application was precipitation (approximately 8.7%), while the parameter with the lowest success rate was drainage density (approximately 7.9%). (Table 5).

sBy using multi-criteria decision making methods, it can be ensured that the decisions are effective in the groundwater potential of the institutions and organizations, and the working performance can be increased by choosing the right alternatives. Evaluating the business with other performance criteria and other businesses and comparing it with the method may be more meaningful for decision makers on behalf of the business. Studies for decision makers and researchers at all levels can contribute to the measurement and evaluation of business success.

Considering the usable water potential per capita, Siverek is a district experiencing water pressure. It is pointed out that there will be water shortages at medium and high levels in many parts of the basin. This situation shows that, contrary to popular belief, it is a candidate basin to face serious water problems in the near future. What to do in the short and long term; In order to determine the groundwater reserves correctly and healthily, the hydrogeological studies of the district-wide groundwater basins should be completed quickly, the groundwater potential of the basins should be determined, and the groundwater allocations should be followed by establishing a monitoring system. In addition,

Preventing excessive and uncontrolled water withdrawal; preventing unlicensed and uncontrolled use of underground water wells,

Using Efficient Irrigation Techniques; switching to drip or sprinkler irrigation methods instead of traditional wild irrigation.

Detection of illegal wells; carrying out strict inspections by water management institutions.

Informing the public; Providing them with training on water saving and groundwater protection.

Serious and deterrent measures should be taken, especially for the protection of groundwater, and the opening of uncontrolled and unlicensed groundwater wells, the number of which is increasing day by day, should be prevented Groundwater aquifers research program should be initiated, the existence and characteristics of groundwater aquifers should be revealed.

Major problems such as desertification, disappearing wetlands and pastures, unplanned agricultural policies and unplanned hydroelectric power generation, and the effects of global climate change should also be taken into account.

Waste water should be made reusable and measures should be taken to prevent leakages in city and irrigation networks.

In industrial sectors with high water use, water savings should be achieved by expanding the use of advanced technology and waste water.

It causes salinization and sterility due to excessive irrigation in agricultural production areas. In order to prevent this, the use of the flood irrigation method should be changed rapidly, and the irrigation system of agricultural areas should be changed by using advanced technology methods or drip irrigation methods. In addition, water conservation should be ensured and the necessary support and training should be given to the farmer in this regard.

Necessary sensitivity should be shown in the protection of groundwater resources, wells should not be drilled in a way that affects each other, excessive drafts should be controlled to prevent wastage of water.

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Conflict of interest

The author declares no conflict of interest

Author's Contributions

Veysel ASLAN conceptualized the study, developed the methodology, validated the results, and wrote the original draft.

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