Modeling of Groundwater Potential and Quality of Harran Plain by GIS Supported AHP and Topsis Methods

Harran Ovası Yeraltı Suyu Potansiyeli ve Kalitesinin CBS Destekli AHP ve Topsis Yöntemleriyle Modellenmesi

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Abstract

Harran Plain supplies all of its drinking water needs and most of its irrigation water needs from wells and groundwater resources that were drilled at various dates. For this reason, in this study, thematic maps and model maps were created by using methods such as MCDM, AHP, TOPSIS and Geographic Information System in order to determine the groundwater potential and water quality in the settlement areas and plains located within the borders of the Harran plain. The data related to the study throughout the basin were obtained from official institutions and operating private drilling companies. In the first stage of the study, groundwater potential was modeled with static water level, dynamic water level, well efficiency and groundwater depth maps. With the obtained thematic maps, they were reclassified according to shallowness, depth and productivity values. Accordingly, it has been determined that the groundwater potential of a significant part of the Harran basin is good, and the static and dynamic levels are at shallow-normal levels.

Keywords : Harran Plain, GIS, Arc Hydro Module, AHP, ANP, Basin Boundary Maps

Özet

Harran Ovası, içme suyu ihtiyacının tamamını ve sulama suyu ihtiyacının çoğunu çeşitli tarihlerde açılan kuyulardan ve yeraltı su kaynaklarından karşılamaktadır. Bu nedenle bu çalışmada Türkiye sınırları içerisinde yer alan yerleşim alanları ve ovalarda yeraltı suyu potansiyeli ve su kalitesinin belirlenmesi amacıyla ÇKKV, AHP, TOPSIS ve Coğrafi Bilgi Sistemi gibi yöntemler kullanılarak tematik haritalar ve model haritalar oluşturulmuştur. Harran ovası. Havza genelinde çalışmaya ilişkin veriler resmi kurumlardan ve faaliyet gösteren özel sondaj şirketlerinden elde edilmiştir. Çalışmanın ilk aşamasında, yeraltı suyu potansiyeli statik su seviyesi, dinamik su seviyesi, kuyu verimi ve yeraltı suyu derinlik haritaları ile modellenmiştir. Elde edilen tematik haritalar ile sığlık, derinlik ve verimlilik değerlerine göre yeniden sınıflandırılmıştır. Buna göre Harran havzasının önemli bir bölümünün yeraltı suyu potansiyelinin iyi olduğu, statik ve dinamik seviyelerinin sığ-normal seviyelerde olduğu tespit edilmiştir.

Anahtar Kelimeler: Harran Ovası, CBS, Arc Hydro Modülü, AHP, ANP, Havza Sınır Haritaları

1. INTRODUCTION

There is a limited amount of usable fresh water resources on earth, which are vital for the progress of civilization, social, economic and for the existence of humanity. In case of beneficial use of water resources, it should be kept at a level that can meet the requirements in terms of quantity and quality. The world population is expected to reach eight billion by 2025. It is stated that food production should be more than doubled in the future to meet the nutritional needs with the increase in population [13]. Therefore, in order to provide basic food needs safely, it is possible to increase the production in agricultural areas and the irrigable areas required for this production [9]. It is also estimated that up to 800 million people in developing countries are at risk of starvation or malnutrition. The solution to the food security problems of the people in these regions depends on good water management [25].

More than 97% of the waters that make up three quarters of the world are salt water and are found in seas and oceans that are less used for drinking and irrigation water purposes. Groundwater, which is limited in fresh water resources, constitutes 0.31% of the total water volume. Today, more than 1.5 billion people meet their drinking water needs and a large part of agricultural irrigation water from groundwater [17],[4].

In recent years, Geographical Information Systems (GIS) methods and related techniques have been used in order to determine the formation of groundwater, groundwater levels and yield conditions, groundwater potential and quality. GIS can be defined as a computer-based tool that includes all spatial information systems and analyzes geographic information, transforms spatial information into digital structure, and a database management system that helps the organization. Remote Sensing, satellite technologies and Geographic Information Systems are techniques that show significant improvement in data collection and management. These techniques are used today as forecasting, planning and modeling tools. These techniques have multi-faceted benefits for modeling studies such as collecting spatial data instead of point observation, collecting and storing all information in the same place, providing high resolution according to time or area, obtaining data in digital form and collecting data even from places that are not accessible. In addition, with this technique, it is possible to create various watershed management scenarios and monitor their results [23], [35].

In recent years, criteria affecting water quality for the solution of water-related problems have been evaluated with the help of alternative solution and evaluation techniques such as Geographic Information System (GIS), Analytic Hierarchy Process(AHP) and Multiple Criteria Decision Making (MCDM) analyses. Evaluation of water quality and accurate analysis of spatial distributions are much easier and more reliable with GIS techniques [37]. Determination of water quality parameters at each location in water resources studies can cause both temporal and financial losses. In addition, GIS is an effective application in terms of expressing risks for water quality and producing alternatives for estimating the water quality value at any location [2]. GIS can also combine spatial data with other data sources [10]. In this way, the data can be organized and the data can be integrated.

Various GIS-based geostatistical methods are used to map groundwater quality over large areas. Unlike classical statistical methods, geostatistical are statistical calculation methods that consider the relationship between samples by taking into account the positions of the samples [36]. Methods such as Kriging, Cokriging, Inverse Distance Weighting, which are geostatistical interpolation methods, are frequently used to estimate the distribution of groundwater quality from various sampling points [18],[8].

In this study, it is aimed to determine the groundwater potential of the Harran plain by using the data of the selected wells in the basin fed by the flow of groundwater. Maps that determine the underground static water level, dynamic water level and yield and potential status of the basin were produced using the Geographical Information System. With the new thematic maps obtained by reclassification, spatially shallow, depth and productivity status classifications were defined.

There are information systems that classify, summarize, analyze, interpret, record and report the outputs of financial transactions in water-related businesses. This information is the basic information that enables the planning, processing, control of the operating activities and the business management to make the right decisions and can be expressed as the language of the business [20].

Today, increasing technological developments in the field of groundwater affect businesses in many important areas such as electronic commerce, enterprise resource planning and information management. Recently, all kinds of water consumption, emptying, filling, electronic commerce and business records based on this are recorded and stored in electronic environment. These records kept in electronic environment and financial statements can be prepared simultaneously. In general, small-scale enterprises use technologically simple accounting software programs in water enterprises, while large and medium-sized enterprises either prefer the software program they have developed or use management information systems that integrate all these processes [33].

On the other hand, with the developing technology in the field of surface and groundwater, there are different package programs that have emerged. Each surface and groundwater program has its own software features and advantages. In this sense, program selection is a very important issue for such businesses and program selection requires multi-criteria decision making. In this study, considering the criteria to be considered in the selection of the most suitable package program, Analytic Hierarchy Process(AHP), Technique For Order Preference By Similarity To An Ideal Solution (TOPSIS) and Elimination Et Choix Traduisan Reality (ELECTRE) methods were used to find the most suitable solution [24].

The source of water flowing from the surface and groundwater is precipitation. However, groundwater contains more minerals than surface waters. The falling precipitation melts the materials it comes into contact with as it slides underground through rock cracks and similar gaps. Minarets are added to the water that flows downwards due to gravity. Chemical substances that make up groundwater; It depends on the physical properties, components and contact time of water. As the contact time of the water with the substances increases, more substances dissolve into the groundwater [29]. Since groundwater in its natural state is generally of high quality, it does not need much treatment. Since groundwater is not found in too deep, it reduces pumping and distribution costs and provides a cheap usage opportunity to its users. Another reason for the need for groundwater is that it is reliable, stable and spread over large areas. Underground watersheds also serve as human-built storage facilities [3].

2. STUDY AREA

Harran Plain, located within the provincial borders of Sanliurfa, is located between latitudes 36° 42' N - 37° 12' N and longitudes 38° 48' E - 39° 12' E (Figure 1). The area of the Harran Plain, located in a graben extending north-south, is approximately 1700 km² when its geomorphological borders are taken into account. The plain has an average width of 32 km and an average length of 53 km [31]. Evation of the plain above sea level generally decreases towards the south and its middle parts. The altitude, which is around 360 m in the southern parts, gradually increases towards the north and approaches 500 m in the northern parts.

Harran Plain, which is within the coverage area of the Southeastern Anatolia Project, Turkey's most important regional development project, is an agricultural land that contributes significantly to the economy of the region and the country in terms of food production and industrial raw material supply as an agricultural production area. Harran Plain is a depression-pit basin formed as a result of active faults. This depression was later filled with fine-grained materials such as clay-silt and sand coming from the environment as a result of atmospheric events and took its present form. While the thickness of this fill is over 400 m in the Kisas Town located in the southeast of Sanliurfa province, it is 250-300 m thick around the Harran Plain. During the filling of the Harran plain, due to the nature of the event, an alignment and succession was formed from the large sized material to the small sized material from the plains to the middle of the plain.

Figure 1. Harran Plain Study Area

Therefore, while there are units composed of coarse-grained silt, sand, and gravel materials, generally on the edges of the plain, a clay-weighted, very heavy-structured material is dominant as you go inland [7].

3. MATERIAL AND METHOD

The study area location map was made to cover a part of the city center and the south of Şanlıurfa in the Southeastern Anatolia Region (Figure 1). Harran Basin has a total drainage area of 5181.4 km², an average annual precipitation of 506.28 mm (falling into the drainage area) and a surface area of 5181.4 Km2 [30]. In the study area, more than 2900 water wells were drilled by SHW, Directorate General of Rural Services and private individuals. As of 20.12.2012, the total of YAS secured reserves allocated to the wells drilled by private individuals in the basin with permission from Şanlıurfa 15. SHW Regional Directorate is 204.549 hm³ / year [1].

3.1. Method

In this study, the Groundwater Potential of the plain was determined by Geographical Information Systems (GIS). Necessary data for this, Sanliurfa State Hydraulic Works XV. Data obtained from around 280 boreholes drilled between 2007-2010 for irrigation or use by the Regional Directorate, Special Administration and drilling companies were used. 194 of them in the study area were evaluated for the study (Figure 2(a)).

3.2 Outline of The Study is As Follows

- By classifying well data, results such as well depth, static water level, dynamic water level, well pump efficiency and opening time were obtained. The data were revealed with the support of 1/1.000.000 and 1/500.000 maps in the study area.

- These maps were digitized and a shape (.shp) file was created for elevation lines, settlement areas, streams and rivers. DEM (Figure 2(b)) map was obtained with the help of numerical 1/100.000 and 1/50.000 map data.
- With Netcad program, Harran Plain Basin Plan (*.ncz) files were converted into shape (shp) format with the help of ArcGIS Data Interoperability program and opened in ARC INFO program.
- Well drilling data were collected in Microsoft Excel program and converted into digital map in GIS program.
- Spatial Analysis, IDW method was used as the GIS model. Bu yöntem ile bilinen bölgedeki veri değerler kullanılarak bilinmeyen bölgelerin verileri ağırlıklı ortalama yöntemi interpolasyon yapılarak elde edilmiştir. Thus, the parts of the plain without data were created with the help of these maps.
- Well data were classified into periods, and separate thematic maps were created for each period. Static Level map (Figure 2(c)), Dynamic Water level map (Figure 2(d)), Pump Efficiency map (Figure 2(e)).
- Obtained data were reclassified and converted to raster map (Figure 3). While preparing the optimum groundwater data, Spatial Analyze-Overlay was performed, as seen in Table 1, with an effect of 40% on pump efficiency, 30% on low dynamic water level, 20% effect on static water levels near part and 10% on groundwater depth. Accordingly, the optimum water map was obtained in Figure 4.
- "UTM Datum 1950 Zone 37" is used as a projection on the map.

Table 1. Weighting of parameters

Criteria	Criterian Weight	Effectrating
Static Water Level	0,20	3
Dynamic Water Level	0,30	4
Well Yield	0,40	5
Groundwater Depth	0.10	2

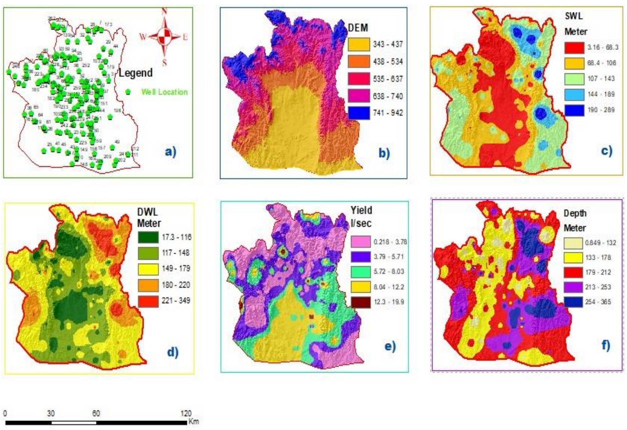

Figure 2. Harran Plain Raster Maps

Figure 2 (a) : The well location map and approximately 194 of them were evaluated in the study area

Figure 2(b): DEM map. Using the Ground class from the classified. Point Cloud data, a surface model can be created through these points with the help of various GIS software. This numerical model can be colored according to the Elevation information and exported in Raster format to be used with many other software. It is also a numerical model that defines a land surface in 3D and is obtained from the elevation data of the land. In short, it is a digital representation of Topography. This model is a data source for many 3D applications such as field analysis. Features such as land slope, land aspect, basin area, slope length can be determined through the model [32].

Figure 2(c): Static water level map. The static level expressed here is the general static level, not the specific static level in the plain where the well is drilled. If continuous observation is made in the plain, the average of the daily or monthly lowest levels of the surrounding wells is accepted as the general static level. If continuous observation is made in the plain, the average of the daily or monthly lowest levels of the surrounding wells is accepted as the general static level. The second point to be considered about the static level is, if more than one well is to be drilled in the field, wetting the wells outside of each other's influence areas; if there is an obligation in this, it is necessary to calculate the static levels by taking this effect into account [11].

Figure 2(d): Dynamic water level (Pumping Water Level). It is the level at which the water remains constant in the well while the pumping continues at a certain flow rate. In an artesian well, on the other hand, it is the height of the water gushing from the well above the ground [38].

Figure 2(e): Well pumping efficiency. In other words, it is the distance from the ground where the level of the groundwater remains constant as a result of the falling water level in the well while drawing water at a constant flow rate from the pumping well in free aquifers. Well Yield map. It is the volume of water taken from a well by pumping or free flow (artesian) per unit time. It is usually expressed as m^3 /day or l/s [34].

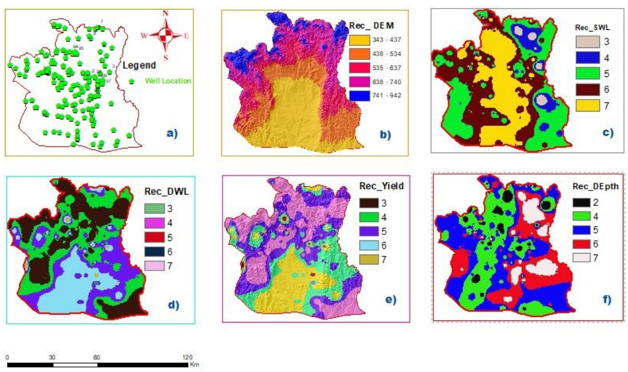

Figure 3. Classification of Harran plain raster maps

Figure 2(f): Well Depth map. As it is known, the efficiency of a well depends on the specific flow rate and the reduction obtained. Since the fall is also subject to the thickness of the aquifer, in principle it is most appropriate to drill a well to the bottom of the aquifer. If the aquifer layers do not have previously known poor quality or inefficiency, each well must be drilled to the bottom of the aquifer. Second, there will be some hydraulic problems that need to be dealt with due to partial penetration in undrilled wells along the aquifer [1].

3.3.Continuation of The Methodology

This research aims to select the best method for sustaining groundwater processes using integrated AHP and TOPSIS techniques in turbid environment. Fuzzy AHP is used to determine the preference weights of the evaluation [15]. Fuzzy TOPSIS is used to improve alternative gaps between actual performance values and reach aspiration levels (demand level) and evaluate the best process based on various characteristics of the groundwater use process [5], [6].

3.3.1 AHP Method

AHP method was developed by Saaty in the 1970s to assist in the decision-making process [16]. This method has been widely used in the literature and has been applied in many sectors [12]. The implementation of the method consists of several stages. First of all, a hierarchical model is created according to the decision purpose [28]. AHP method can be summarized in 3 steps [21].

Step 1: The decision problem is transformed into a hierarchical structure and a comparison matrix is created showing the comparison of criteria to each other. While creating the comparison matrix, the experts/managers made use of Table 3. The comparison matrix (B) is shown in Equation [1].

Table 2. Linguistic Data and Numerical Equivalents Used in AHP [28].

Importance Level	Definition
1	Equally Important
2	Poor
3	A Bit Special Important
4	A Little Important
5	Too Important
6	More Important
7	Very important
8	Extremely Important
9	Absolute Important

$$B = \left[b_{ij}\right]_{nxn} \quad (1)$$

It shows the pairwise comparison value of the bij criterion and the j criterion in Equation (1). Depending on this value, the criterion and bij j is the pairwise comparison value of the criterion, its value is 1/ bij and the bij value is 1.

Step 2: The comparison matrix is normalized by Equation (2). Then, the weight of each criterion is calculated by Equation (3).

$$b'_{ij} = \frac{b_{ij}}{\sum_{i=1}^{n} b_{ij}} \quad (2)$$

$$W_j = \frac{\sum_{i=1}^{n} b'_{ij}}{n} \quad (3)$$

Step 3: The consistency of the matrix is tested. If the Consistency Ratio (TO) is less than 0.1, the matrix is considered consistent; otherwise, experts should be asked for their opinion again. Equation (4) shows the Consistency Index (TI). Equation (5) shows TO [27].

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

$$\mathrm{TI} = \frac{\lambda_{\max} - n}{(n-1)} \quad (4)$$

$$\mathrm{TO} = \frac{\mathrm{T.I}}{\mathrm{RI}} \quad (5)$$

It shows the R.I Randomness Index in Equation (5). This value varies according to the number of criteria. Since six criteria will be included in the calculations in this study, R.I was taken as 1.24 in this study.

Table 3. Random Concistency Index (RI) [26]

n	1	2	3	4	5	6
RI	0	0	0.58	0.90	1.12	1.24
n	7	8	9	10	11	12
RI	1.32	1.41	1.45	1.49	1.51	1.48

Table 4. Pair-wise comparison matrix table of ten thematic layers chosen for the present study

	AW	SWL	DWL	WY	GD
SWL	3	1.00	0.75	0.60	1.50
DWL	4	1.33	1.00	0.80	2.00
WY	5	1.67	1.25	1.00	2.50
GD	2	0.67	0.50	0.40	1.00

AW : Assigned Weight WY : Well Yield , GD : Groundwater Depth

Table 5. Standardized Matrix

	SWL	DWL	WY	GD	GM	NW
SWL	0.272	0.214	0.214	0.250	0.950	0.23
DWL	0.363	0.286	0.286	0.333	1.268	0.31
WY	0.455	0.357	0.357	0.417	1.586	0.40
GD	0.182	0.143	0.143	0.167	0.635	0.16
Total	3.67	3.50	2.80	6.000		

WY : Well Yield , GD : Groundwater Depth,
GM : Geometric Mean, NW : Normalized Weight

Matrix elements prioritize vector elements divides

0.950 / 0.23 = 4.130
1.270 / 0.31 = 4.097
1.590 / 0.40 = 3.980
0.640 / 0.16 = 4.000

For λ_{max} these 5 values averaged.

λ_{max}= 4.01575

Consistency Index

$CI = \frac{\lambda max - n}{n-1} = \frac{4.05175-4}{3} = 0.01725$, RI: 0.90 (for n=4)

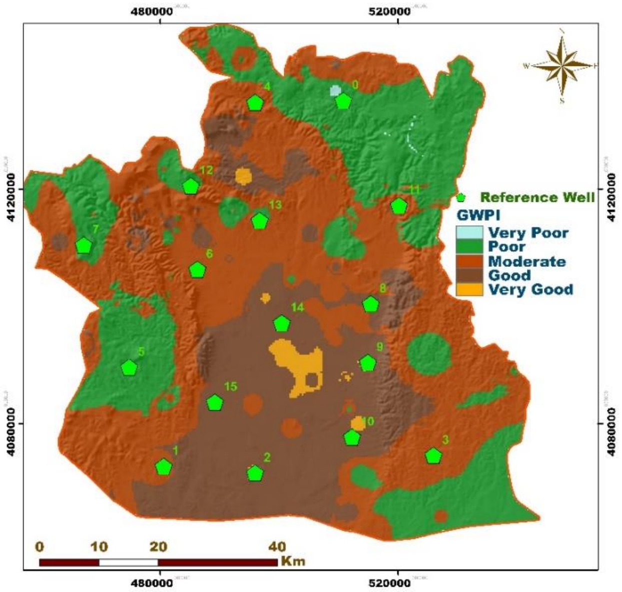

Figure 4. Harran Basin optimum ground water enterprise map

Well yield in most of the basin is between 8-12 litres/sec (Figure 2(e)). On the other hand, Static Water Level (SWL) values appear between 3 - 69 meters, while most of the Dynamic Water Level (DWL) is between 117-148 meters. In the study, from the operational point of view, 40% pump efficiency, 30% Dynamic Water Level (DWL), produced 20% Static Water Level SWL and 10% groundwater depth potential maps were obtained in Figure 4. It can be said that the basin is at a good level in terms of groundwater potential. This means economically obtaining groundwater in the region and that the region has a good groundwater potential. Although the groundwater potential is low in the center of the plain, it is generally moderate in the eastern and western parts of the basin and the north-western parts of the basin. On the other hand, Körkuyu, Koçak, Somak, Oranlı in the northwest and in the west seem poor in terms of groundwater management.

3.3.2. TOPSIS Method

TOPSIS method is one of the Multi-Criteria Decision Making (MCDM) techniques, which is widely used for ranking purposes and developed by Hwang and Yoon in 1981 [19]. 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 [14]. 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 [22].

Step 1: Creating the Decision Matrix: The decision matrix created by the decision maker is a mxn matrix. The rows show the alternatives and the columns show the criteria. 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.

$$D = [X_{ij}], \qquad i = 1, 2, 3, \cdots, n. \qquad (6)$$

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.

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

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{p=1}^{m}(x_{pj})^2}} , \quad i = 1, 2, \cdots, m; \quad j = 1, 2, \cdots, n \quad (7)$$

Depending on the values calculated with this equation, R= [rij]mxn normalized decision matrix is obtained.

So in other words; each xij value is normalized by dividing by the square root of the sum of the values in the column it is in, and rij values are obtained.

Step 3: Obtaining 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= [vij]mxn weighted normalized decision matrix.

$$V_{ij} = w_j r_{ij} , \quad i = 1, 2, \cdots, m; \quad j = 1, 2, 3, \cdots, n \quad (8)$$

obtained by the formula. Here Wj is the weight value of j criterion. It is calculated by multiplying the values in each column of the Rij matrix by the weight of the relevant criteria.

Step 4: Obtaining Ideal and Anti-Ideal Solution Values: At this stage, while determining the ideal solutions, if the goal is benefit, etc. If the ideal solution is the largest value, the anti-ideal solution is the smallest 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:

$$A^* = \left\{ \left(\max_i / \max_i (v_{ij}) | j \in J \right) | \ i = 1, 2, 3, \cdots, m \right\} = \left\{ v_{1,}^* v_2^*, \cdots, v_{j,}^* \cdots, v_n^* \right\} \quad (9)$$

$$A^- = \left\{ \left(\max_i / \max_i (v_{ij}) | j \in J \right) | \ i = 1, 2, 3, \cdots, m \right\} = \left\{ v_{1,}^- v_2^-, \cdots, v_{j,}^- \cdots, v_n^- \right\} \quad (10)$$

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.

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:

$$S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}, i = 1, 2, 3, \cdots, m \quad (11)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, i = 1, 2, 3, \cdots, m \quad (12)$$

Step 6: Making the order of preference: Finally, the relative closeness of each decision point to the ideal solution is calculated and denoted by c_i^*

$$c_i^* = \frac{S_i^-}{S_i^* + S_i^-}, 0 < c_i^* < 1, \quad i = 1, 2, 3, \cdots, m \ (13)$$

Alternatives are sorted by ordering the c_i^* values from greatest to least.

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

Table 6. Pairwise Comparison Matrix

	BP	NBC	BB	BS
WV	0.40	0.20	0.30	0.10
SWL	20	25	20	15
DWL	30	35	30	25
WY	40	30	45	50
GD	10	15	30	10

BP : Benefical Performance , NBC: Non-Benefical Cost :BB. Benefical Benefit, BS:Benefical Sustainability, WV : Wieght Values, WY : Well Yield, GD : Groundwater Depth

Table 7. Obtaining the Normalized Matrix

	P	C	B	S
WV	0.40	0.20	0.30	0.10
SWL	0.365	0.458	0,308	0.255
DWL	0.548	0.612	0.462	0.426
WY	0.730	0.550	0.692	0.851
GD	0.183	0.275	0.308	0.170

P : Performance ,C: Cost :B. Benefit, WV : Wieght Values, WY : Well Yield, GD : Groundwater Depth

A weighted standard decision matrix is created by multiplying the weights with the standard decision matrix values.

Table 8. Obtaining a Weighted Normalized Matrix

	P	C	B	S
SWL	0.146	0.092	0.092	0.026
DWL	0.219	0.122	0.139	0.043
WY	0.292	0.110	0.208	0.085
GD	0.073	0.055	0.092	0.017

P : Performance , C: Cost :B. Benefit, S: Sustainability, WY : Well Yield, GD : Groundwater Depth

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

V+	0.073	0.122	0.208	0.085
V-	0.292	0.055	0.092	0.017

Table 9. Obtaining the distance values from the ideal and anti-ideal solution (S_i^* *ve* S_i^-) and ordering the preference (c_i^*)

S_i^*	S_i^-	c_i^*
0.1522	0.1618	0.5153
0.1669	0.1127	0.4031
0.2399	0.1284	0.3486
0.1502	0.2190	0.5932

3.4.Continuation of The Methodology

By making use of the decision matrix, a standard decision matrix is created. The elements of the standard decision matrix are created with the following formula.

Table 10. Generating a standard decision mat (defining and normalizing in the 0-1 range)

WV	W1: 0.40	W2: 0.20	W3: 0.30	W4: 0.10
C	K1	K2	K3	K4
SWL	0.5217	0.4658	0.5619	0.6507
DWL	0.4523	0.5499	0.6328	0.4763
WY	0.5444	0.5108	0.5314	0.4132
GD	0.4764	0.4687	0.5913	0.4309

WV : Wieght Values, C : Criteria, WY : Well Yield, GD : Groundwater Depth

A weighted standard decision matrix is created by multiplying the weights with the standard decision matrix values.

Table 11. Generating a weighted standard decision matrix

WV	W1: 0.40	W2: 0.20	W3: 0.30	W4: 0.10
C	K1	K2	K3	K4
SWL	0.20868	0.09316	0.16857	0.06507
DWL	0.18092	0.10998	0.18984	0.04763
WY	0.21776	0.10213	0.15942	0.04132
GD	0.19056	0.09374	0.17739	0.04309

WV : Wieght Values, C : Criteria,
WY : Well Yield, GD : Groundwater Depth

The sets of harmony and discord are determined according to the formula C(p,q)={j, ypj ≥ vqj}. The formula is basically based on comparing the elements in the row according to each other's sizes. In multiple decision problems, the number of fit sets (m.m-m) is one. The number of elements in the fit set can be the maximum number of evaluation factors (n). Each concordance set (C(p,q)) corresponds to a discordance set (D(p,q)).

Table 12. Concordance Interval Matrix

	SWL	DWL	WY	GD
SWL	-	50	40	50
DWL	50	-	60	60
WY	60	40	-	60
GD	50	40	40	-

WY : Well Yield, GD : Groundwater Depth

Table 13. Disconcordance Interval Matrix

	SWL	DWL	WY	GD
SWL	-	50	60	50
DWL	50	-	40	40
WY	40	60	-	40
GD	50	60	60	-

WY : Well Yield, GD : Groundwater Depth

Conformance and unconformance matrices are created. Conformance matrix is created by using the weights corresponding to the values.

<u>Conformance Set</u>	<u>Unconformance Set</u>
C12 = {1, 4}	C12 = {2, 3}
C13 = {3.4}	C13 = {1, 2}
C14 = {1, 4}	C14 = {2, 3}

Value in the numerator shows the absolute largest of the differences found, and the value in the denominator shows the largest difference found by comparing all the differences when comparing two rows.

Unconformance matrix

$$D_{pq} = \frac{\left(\sum_{j=0}\left|V_{pj^0}-V_{qj^0}\right|\right)}{\left(\sum_j\left|V_{pj}-V_{qj}\right|\right)},,$$

is found by the formula.

Value in the numerator shows the absolute largest of the differences found, and the value in the denominator shows the largest difference found by comparing all the differences when comparing two rows.

$$D_{12} = \frac{(0.09316-0.10998)(0.16857-0.18984)}{(0.20868-0.18092)(0.09316-0.10998)(0.16857-0.18984)(0.06507-0.04763)}$$

$$D_{12} = \frac{0.02127}{0.02776} = 0.76$$

Conformance superiority (F) and incongruity superiority matrices are created.

Conformance (C), $C= \frac{1}{m(m-1)}(\sum C_{pq})$

and mismatch.

Conformance superiority (F) and unconformance superiority matrices are created.

For concordance (C), $C= \frac{1}{m(m-1)}(\sum C_{pq})$

and unconformance (D) for

$$D = \frac{1}{m(m-1)}\left(\sum D_{pq}\right)$$

equal values are determined.

$$C = \frac{1}{12}(50+40+50+50+60+60+60+40+60+50+60+60) = 53{,}33$$

Conformance Set

$$D = \frac{1}{12}(50+60+50+50+40+40+40+60+40+50+60+60) = 50$$

Unconformance Set

Table 14. F Matrix formed after comparison (Conformance superiority)

	SWL	DWL	WY	GD
SWL	-	0	0	0
DWL	0	-	1	1
WY	1	0	-	0
GD	0	0	0	-

WY : Well Yield, GD : Groundwater Depth

Table 15. Matrix G formed after comparison (Unconformance superiority)

	SWL	DWL	WY	GD
SWL	-	1	1	1
DWL	1	-	0	0
WY	0	1	-	0
GD	1	1	1	-

WY : Well Yield, GD : Groundwater Depth

Conformance superiority and unconformance superiority matrices are multiplied and the total dominance matrix is formed.

Table 16. Total dominance matrix

	SWL	DWL	WY	GD
SWL	-	0	0	0
DWL	0	-	0	0
WY	0	0	-	0
GD	0	0	0	-

WY : Well Yield, GD : Groundwater Depth

1= means superior. However, since all values are zero in the total dominance matrix table, it is not necessary to order the decision points in order of importance.

4.CONCLUSIONS AND RECOMMENDATIONS

While all people and units take their share of the developments in technology, the resulting diversity increases the number of alternatives that can be used. This situation both requires making a choice and makes this choice difficult.

In this study, the selection process of these package programs, which have an important place in the professional lives of private institutions and individuals, as well as institutions and organizations related to the groundwater of the Harran plain are discussed. AHP and TOPSIS methods, which are widely used among multi-criteria decision making techniques, were used in the selection process.

a. The consistency rate of the evaluations made with the AHP technique for the weights of the criteria that are effective in the selection process for the package program for groundwater was examined and it was seen that the results obtained were reliable. Among the evaluated criteria, the criteria with the highest importance were the reporting ability and the ease of use of the menus, respectively. The most suitable package program for professionals is the program symbolized by E with an index value of 88.37% in the TOPSIS method.

b. Using the values given for groundwater potential assessment, TOPSIS method, which are multi-criteria decision making methods in AHP, and error types are prioritized. These methods were preferred to determine the criterion weights to be used in TOPSIS method. By making use of the advantages of Multi-Criteria Decision Making methods, it has been ensured that the calculations can be used more successfully in prioritizing error types. The comparative investigation of the priority order of the errors with these three methods provided the opportunity to cross-check the results of groundwater operations. In the results of the TOPSIS method, the ranking and superiority order of the alternatives were found to be the same. Therefore, it can be said that the two methods support each other.

c. The criteria and methods used in the study are a method that businesses operating in different professions can also use in choosing a package program and get results. In future studies, using the criteria used in this study, different multi-criteria decision making techniques can be applied and the results of the studies can be compared.

d. In addition, the study can be repeated in a different region and they can investigate the effect of the place, in other words, the culture in the selection of the package program.

e. Different studies can be put forward by using methods such as Fuzzy Relational Analysis, ENTROPY, VİKOR, AHP, TOPSIS separately and/or together.

f. In the studies, it can be aimed to find more effective and comparative error rankings in order to detect errors and reduce their effects.

g. Different studies can be put forward by using methods such as Fuzzy Relational Analysis, ENTROPY, VIKOR, AHP, TOPSIS separately and/or together. In the studies, it can be aimed to find more effective and comparative error rankings in order to detect errors and reduce their effects.

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