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Determination of solar power plant installation areas by AHP and FAHP methods (Burdur case)

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ABSTRACT

In today's world, producing environmental friendly energy from solar power plants has gained great importance. In this study, criteria slope, aspect, proximity to road, proximity to energy transmission line, proximity to fault line for determining the optimal site for a photovoltaic solar power plant are chosen and the weights of these criteria are calculated by Analytical Hierarchy Process (AHP) and Fuzzy Analytical Hierarchy Process methods which are two methods among Multi-Criteria Decision Making (MCDM) methods. The outcome of the AHP and FAHP methods are also compared in the study. The comparison results indicate that there is a neglectable difference (±%1 <) between the criteria weights of the AHP and FAHP methods. According to criteria weights, an availability map for the province of Burdur has been created using QGIS software which is an open-source geographic information system (GIS) software. According to the suitability map is created, 17.37% of the land area of the province of Burdur is suitable for solar power plant (SPP) investments. This study is expected to facilitate and accelerate the decision-making process for SPP investments.

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1. INTRODUCTION

For sustainable regional development, it is necessary to meet the energy need with lower costs. The higher costs of fossil fuels and harmful effects on the environment lead to a search for alternative energy sources. Solar energy is one of the cleanest energy resources and can meet many needs in daily life in a very wide range from domestic use to industrial power generation. According to geographic location, there are some countries that take advantage of benefiting from solar power and Turkey is among those countries.

Solar energy plays a major role in regional development and has economic, social, and environmental benefits [1]. However, many criteria should be taken into account when choosing an appropriate site for the installation of solar power plants. It is known that the choice of location is very important for the reduction of investment costs, and the selection of the appropriate location will offer many advantages, such as improving efficiency, and decreasing operational costs.

Geographic Information Systems (GIS) is a platform used by many professional disciplines. As in other areas, analyzes were carried out in location selection studies for solar power plants and renewable energy systems by using GIS [2-6]. While performing these analyses, many methods such as artificial intelligence, multi-criteria decision-making (MCDM) methods, and fuzzy logic were evaluated together [7-13].

In the literature, analyzes were made in many regions using GIS and MCDM methods [3, 14-20]. Sanchez-Lozano et al. [21] determined investment areas for solar energy systems in Cartegena, Spain, using GIS and Multi-Criteria Decision Analysis (MCDA) methods. Uyan [22] evaluated many criteria in the GIS environment and determined the SPP regions to be built in Konya Karapınar Region. Effat [23] in Egypt, Tercan et al.[24] in Turkey investigated suitable SPP investment areas with similar methods. In addition, Suh and Brownson [25] determined investment areas in Korea using GIS, Fuzzy sets, and AHP. In Burdur Province, which has significant potential, Yalçın and Yüce [26] determined suitable investment areas utilizing GIS software according to the slope of the land, its aspect, proximity to energy transmission lines, and proximity to the road. Yalçın and Yüce [27] performed a spatial analysis of the existing SPPs in Burdur according to the eligibility criteria. Decisions about situations or problems that people face in daily life generally have multiple and often conflicting goals/criteria. Ersöz and Kabak [28] expressed multi-criteria decision-making as the selection process by using at least two criteria within a set of countable finite or uncountable options.

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Some of the multi-criteria decision-making methods are given below.

- Analytic Hierarchy Process (AHP)
- Analytic Network Process (ANP)
- Elimination and Choice Translating Reality (ÉLECTRE)
- Data Envelopment Analysis
- Multi-Attribute Global Inference of Quality (MAGIQ)
- Goal Programming (GP)
- Stochastic Multicriteria Acceptability (SMAA)

This study aims to compare the outputs of the AHP method and Fuzzy AHP (FAHP) methods in terms of five criteria for selecting a suitable site for a solar power plant in the province of Burdur. The spatial data for the province of Burdur such as slope, road, aspect, and active fault zones have been processed in the QGIS software. GIS studies were carried out using open-source QGIS software. Afterward, both AHP and Fuzzy AHP analyzes were performed and these two methods were compared.

By using the criteria weights obtained by AHP and Fuzzy AHP methods, a suitability map of Burdur province for SPP investments was created in the GIS environment. This map shows the classification of the lands according to their suitability in terms of related criteria.

2. EXPERIMENTAL

Referring to the Solar Energy Potential Atlas (GEPA) published by the General Directorate of Renewable Energy (gepa.enerji.gov.tr), the solar radiation in Burdur province is 1650-1750 kWh/year. Since there is no significant difference in terms of solar energy radiation across the province, this criterion was not included in the calculation while calculating the criteria weights. Within the scope of the study, calculations were made according to the following criteria:

- The slope of the land
- Aspect of the land
- Proximity to energy transmission lines
- Proximity to roads
- Distance to fault lines

Appropriate site selection for photovoltaic solar power plants (SPP) plays an important role in reducing investment and operational costs, and in the efficiency of the investment. There are many criteria involved in site selection for SPPs such as the solar energy potential of the region, distance to power transmission lines, the slope of the land, etc. In this case, the decision-maker needs to make a consistent assessment. During the evaluation of the criteria, transforming the subjective evaluations made by the decision maker with verbal data such as "less important", "important", and "very important" into numerical and objective evaluations with AHP and FAHP methods will render the decision of choosing the appropriate site for the SPP objective and measurable.

In the study conducted by Yalçın and Yüce, the aspect, slope, and distance to roads and power lines criteria for Burdur province were analyzed in a GIS environment with the AHP method as in Figure 1.

According to the results of the analysis, suitable areas were determined along the *NE-SW* line extending from the central district of Burdur to the district of Gölhisar. In this study, in addition to the data obtained by Yalçın and Yüce, the distance criterion to the fault lines was also added. As it is known, when making large-scale industrial investments, the relationship of the region with the geological structures should also be considered [28, 29]. In addition, agricultural and forest lands, where SPP investments are not allowed due to legal regulations, are also labeled as "unsuitable" on the map. All criteria were re-evaluated together and the decision-making method was expanded.

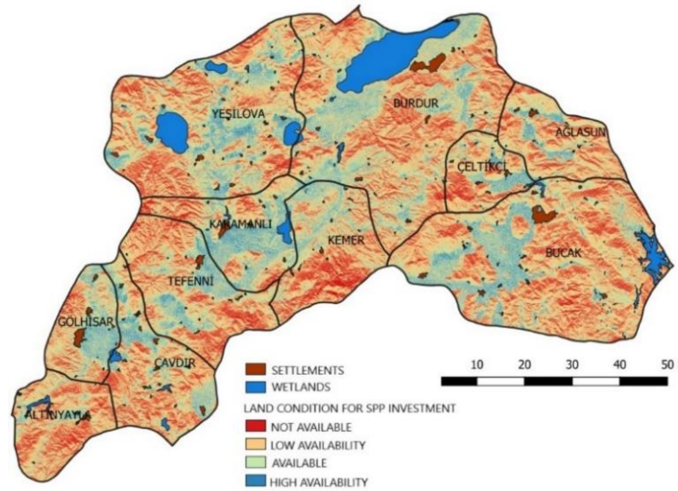

Fig. 1. Province of Burdur suitability map for PV plants.

2.1. AHP Method

The Analytical Hierarchy Process (AHP) was first proposed by Myers and Alpet in 1968 and was developed by Thomas Saaty in 1977 as a usable method for solving decision-making problems [31].

The AHP method allows decision-makers to model complex problems in a hierarchical structure that shows the relationship between the problem's main goal, criteria, sub-criteria, and alternatives. The most fundamental feature of AHP is that the decision-maker can include both objective and subjective judgments in the decision-making process. In other words, AHP is a method in which knowledge, experience, thoughts, and intuitions of the individual are logically combined [32].

In the AHP method, criteria are determined according to the purpose and the importance degrees of these criteria are selected by the decision maker utilizing the importance scale in Table 1. If the importance level of *Criterion 1* according to *Criterion 2* is *k*, the importance level of *Criterion 2* according to *Criterion 1* is *1/k*, in other words, the reciprocal (opposite) of *k* is *1/k*.

Table 1. Fundamental scale of absolute numbers [33].

Intensity of Importance	*Definition*
1	Equal importance
2	Weak or slight
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong importance
8	Very, very strong
9	Extreme importance

If there are *m* objectives to compare, the AHP performs the multi-objective decision-making process as follows [34].

a) Develop (m ×m) pairwise comparison matrix A for m criteria.

$$A=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ a_{m1} & a_{m2} & \cdots & a_{mm} \end{bmatrix} \tag{1}$$

b) Divide each entry in column j of A by the sum of the entries in column j. This results in a new matrix A_w, in which the sum of the entries in each column will be 1.

$$A_w=\begin{bmatrix} \frac{a_{11}}{\sum a_{i1}} & \frac{a_{12}}{\sum a_{i2}} & \cdots & \frac{a_{1m}}{\sum a_{im}} \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \frac{a_{m1}}{\sum a_{i1}} & \frac{a_{m2}}{\sum a_{i2}} & \cdots & \frac{a_{mm}}{\sum a_{im}} \end{bmatrix} \tag{2}$$

c) Compute c_i as the average of the entries in row i of A_w to yield column vector C.

$$\mathrm{C}=\begin{bmatrix} c_1 \\ c_2 \\ \cdots \\ c_m \end{bmatrix}=\begin{bmatrix} \frac{\frac{a_{11}}{\sum a_{i1}}}{m}+\frac{\frac{a_{12}}{\sum a_{i2}}}{m}+\cdots+\frac{\frac{a_{1m}}{\sum a_{im}}}{m} \\ \cdots \quad \cdots \quad \cdots \quad \cdots \\ \cdots \quad \cdots \quad \cdots \quad \cdots \\ \frac{\frac{a_{m1}}{\sum a_{i1}}}{m}+\frac{\frac{a_{m2}}{\sum a_{i2}}}{m}+\cdots+\frac{\frac{a_{mm}}{\sum a_{im}}}{m} \end{bmatrix} \tag{3}$$

where c_i represents the relative degree of importance of the i_{th} objective.

d) Check the consistency of judgment in the pairwise comparison matrix and the sub-steps as follows:

- Develop *A.C.* matrix.

A.C matrix is simply developed by multiplying each entry in A matrix with criteria weights c_i and summing of each row.

$$A.C=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ a_{m1} & a_{m2} & \cdots & a_{mm} \end{bmatrix}\begin{bmatrix} c_1 \\ c_2 \\ \cdots \\ c_m \end{bmatrix}=\begin{bmatrix} x_1 \\ x_2 \\ \cdots \\ x_m \end{bmatrix} \tag{4}$$

- Compute λ_{max} where λ_{max} is the maximum eigenvalue of the pairwise comparison matrix.

$$\lambda_{max}=\frac{1}{m}\sum_{i=1}^{m}\frac{i\text{th entry in A.C}}{i\text{th entry in C}}=\frac{1}{m}\sum_{i=1}^{m}\frac{x_i}{c_i} \tag{5}$$

- Compute consistency index *(CI)*.

$$CI=\frac{\lambda_{max}-m}{m-1} \tag{6}$$

- Compare *CI* with the random index *(RI)* for the appropriate value of m to determine whether the degree of consistency is satisfactory.

Table 2. Random index (RI) table.

m	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

The reference RI values for different numbers of m are shown in Table 2. If $CI/RI \leq 0{,}10$, the degree of consistency is satisfactory. If $CI/RI \geq 0{,}10$ there are inconsistencies. In this case, AHP may not yield meaningful results therefore the decision maker should reconsider the assessment.

2.2.Fuzzy AHP(FAHP) Method

In the AHP method, the decision maker has to make definite decisions according to the importance scale when determining the importance levels of the criteria relative to each other. However, in the evaluation process, it is often difficult to make definite judgments due to the way a person thinks, and it is necessary to make evaluations within certain intervals. For this reason, the Fuzzy AHP is employed.

The first study on fuzzy AHP was made by Van Laarhoven and Pedrycz (1983) by suggesting the fuzzy logarithmic least squares technique [35]. Buckley (1985) used the geometric mean technique to calculate fuzzy weights [36].

In FAHP basic operations are given below:

Suppose $\widetilde{M}_1=(l_1,m_1,u_1)$ and $\widetilde{M}_2=(l_2,m_2,u_2)$ are two triangular fuzzy numbers;

Addition:

$$\widetilde{M}_1 \oplus \widetilde{M}_2=(l_1+l_2, m_1+m_2, u_1+u_2) \tag{7}$$

Multiplication:

$$\widetilde{M}_1 \otimes \widetilde{M}_2 \approx (l_1 l_2, m_1 m_2, u_1 u_2) \tag{8}$$

Reciprocal:

$$\widetilde{M}_1^{\,-1} \approx \left(\frac{1}{u_1},\frac{1}{m_1},\frac{1}{l_1}\right) \tag{9}$$

a) Perform pairwise comparison and construct pairwise comparison matrix $\tilde{A}=[\tilde{a}_{ij}]$.

$$\tilde{A}=\begin{bmatrix} (1,1,1) & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & (1,1,1) & \cdots & \tilde{a}_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & (1,1,1) \end{bmatrix} \tag{10}$$

b) Calculate fuzzy geometric means.

$$\tilde{r}_i=(\tilde{a}_{i1}\otimes\tilde{a}_{i2}\otimes\ldots\otimes\tilde{a}_{in})^{1/n} \tag{11}$$

c) Calculate fuzzy weights.

$$\widetilde{w}_i=\tilde{r}_i\otimes(\tilde{r}_1\oplus\tilde{r}_2\oplus\ldots\oplus\tilde{r}_n)^{-1} \tag{12}$$

d) For each criterion translate fuzzy weight to criterion weight.

$$w_i=\frac{l_i+m_i+u_i}{3} \tag{13}$$

e)Normalize criteria weight is w_i.

3. CHOOSING APPROPRIATE SITES FOR PV PLANTS USING AHP AND FAHP METHODS

3.1. AHP Method

Comparison Matrix (A)

A pairwise comparison matrix is created for comparing the criteria according to their importance level for the decision maker, using the *Saaty scale* given in Table 1. The comparison matrix shows the importance of the row by column. For example, “Proximity to the Power Transmission Line” was evaluated as two times more important than “Slope”. On the other hand, the evaluation of the “Slope” according to the “Proximity to the Power Transmission Line” is the reciprocal of the previous evaluation, that is, 1/2. A pairwise comparison matrix developed by the criteria for solar power plant site selection is given below in Table 3.

Table 3. Pairwise comparison matrix (A).

Criterion	*Proximity to power transmission line*	*Proximity to road*	*Slope*	*Aspect*	*Distance to fault lines*
Proximity to power transmission line	1	3	2	0,20	8
Proximity to road	0,333	1	1	0,2	7
Slope	0,5	1	1	0,5	7
Aspect	5	5	2	1	9
Distance to fault lines	0,125	0,143	0,143	0,111	1
TOTAL	*6,958*	*10,143*	*6,143*	*2,011*	*32*

Normalized Pairwise Comparison Matrix (A_w)

Each comparison score in the comparison matrix is normalized by dividing by the sum of the column to which it belongs. Then, the average of each row which refers to each criterion yields the criterion weight (C). Normalized pairwise comparison matrix (A_w) and criteria weights were given below in Table 4.

Calculation of Consistency (A.C)

The weighted sums (A.C) are calculated according to the Equation (4). and the results are shown in Table 5.

Calculate λ_{max}

The λ_{max} value is obtained by the sum of the Criterion Weights/Weighted Sum values calculated in Table 6 by the number of criteria (n).

Table 4. Normalized pairwise comparison matrix (A_w).

Criterion	*Proximity to power transmission line*	*Proximity to road*	*Slope*	*Aspect*	*Distance to fault lines*	*Criteria Weights (C)*
Proximity to power transmission line	0,14	0,30	0,33	0,10	0,25	0,22
Proximity to road	0,05	0,10	0,16	0,10	0,22	0,13
Slope	0,07	0,10	0,16	0,25	0,22	0,16
Aspect	0,72	0,49	0,33	0,50	0,28	0,46
Distance to fault lines	0,02	0,01	0,02	0,06	0,03	0,03

Table 5. A.C matrix and weighted sums.

Criterion	*Proximity to power transmission line*	*Proximity to road*	*Slope*	*Aspect*	*Distance to fault lines*	*Weighted Sums*
Proximity to power transmission line	0,22	0,38	0,32	0,09	0,23	1,24
Proximity to road	0,07	0,13	0,16	0,09	0,20	0,65
Slope	0,11	0,13	0,16	0,23	0,20	0,83
Aspect	1,11	0,63	0,32	0,46	0,26	2,78
Distance to fault lines	0,03	0,02	0,02	0,05	0,03	0,15

Table 6. Criterion weight/weighted sum.

Criterion	*Criterion weight (C)*	*Weighted sum (A.C)*	*A/A.C*
Proximity to power transmission line	0,22	1,24	9,08
Proximity to road	0,13	0,65	7,21
Slope	0,16	0,83	7,85
Aspect	0,46	2,78	10,91
Distance to fault lines	0,03	0,15	8,47
	Total		*27,15*

$$\lambda_{max} = \frac{\sum(Criterion\ Weight/Weighted\ Sum)}{n} = \frac{27,15}{5} = 5,43 \qquad (14)$$

Consistency Index (CI)
The consistency index is calculated as 0,107 using Equation (6):

$$CI = \frac{\lambda_{max} - n}{n-1} = \frac{5,43-5}{5-1} = 0,107 \qquad (15)$$

Consistency Ratio(CR)
Referring to Table 2, for the 5 criteria the random index (RI) is 1,12. Therefore using Equation (7) the consistency ratio is calculated below.

$$CR = \frac{0,107}{1,12} = 0,096 \qquad (16)$$

Since the CR is 0,096 thus it is below 0,10 the evaluation is consistent.

3.2. Fuzzy AHP (FAHP) Method

Comparison Matrix ($\tilde{A}$)
The comparison matrix in Table 3 is reconstructed in terms of fuzzy numbers and the result is given in Table 7.

Table 7. Comparison matrix ($\tilde{A}$).

Criterion	*Proximity to power transmission line*	*Proximity to road*	*Slope*	*Aspect*	*Distance to fault lines*
Proximity to power transmission line	(1,1,1)	(2,3,4)	(1,2,3)	$(\frac{1}{6},\frac{1}{5},\frac{1}{4})$	(7,8,9)
Proximity to road	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(1,1,1)	(1,1,1)	$(\frac{1}{6},\frac{1}{5},\frac{1}{4})$	(6,7,8)
Slope	$(\frac{1}{3},\frac{1}{2},\frac{1}{1})$	(1,1,1)	(1,1,1)	$(\frac{1}{3},\frac{1}{2},\frac{1}{1})$	(6,7,8)
Aspect	(4,5,6)	(4,5,6)	(1,2,3)	(1,1,1)	(9,9,9)
Distance to fault lines	$(\frac{1}{9},\frac{1}{8},\frac{1}{7})$	$(\frac{1}{8},\frac{1}{7},\frac{1}{6})$	$(\frac{1}{8},\frac{1}{7},\frac{1}{6})$	$(\frac{1}{9},\frac{1}{9},\frac{1}{9})$	(1,1,1)

Geometric Mean ($\tilde{r}_i$)
Geometric Mean values are calculated using Equation (12) and given in Table

Table 8. Fuzzy geometric mean ($\tilde{r}_i$).

Criterion	*l*	*m*	*u*
Proximity to power transmission line	1,18	1,57	1,93
Proximity to road	0,76	0,86	1,00
Slope	0,92	1,12	1,52
Aspect	2,70	3,39	3,96
Distance to fault lines	0,18	0,20	0,21

Fuzzy Weights ($\tilde{w}_i$)
Calculated fuzzy weights according to Equation (13) are and are shown in Table 9.

Table 9. Fuzzy weights($\tilde{w}_i$).

Criterion	*l*	*m*	*u*
Proximity to power transmission line	0,1374	0,2202	0,3364
Proximity to road	0,0879	0,1203	0,174
Slope	0,1070	0,1567	0,2637
Aspect	0,3134	0,4754	0,6888
Distance to fault lines	0,0210	0,0273	0,0371

True weights (w_i)
True weights are calculated according to Equation (14) and are given in Table

Table 10. True weights (w_i).

Criterion	$\boldsymbol{w_i}$
Proximity to power transmission line	0,231
Proximity to road	0,1274
Slope	0,1758
Aspect	0,4925
Distance to fault lines	0,0284
TOTAL	*1,0555*

Normalized Weights
The true weights given in Table 10 are divided by the total and normalized weights are obtained. Normalized weights are given in Table 11.

Table 11. Normalized weights.

Criterion	*Normalized Weights*
Proximity to power transmission line	0,219
Proximity to road	0,121
Slope	0,166
Aspect	0,467
Distance to fault lines	0,027

4. CREATING A SUITABILITY MAP FOR PV PLANTS

In this study, a suitability map for SPP investments was created in Burdur by using QGIS which is an open-source GIS software. The digital elevation model of Burdur province was obtained from 30 m resolution SRTM (Shuttle Radar Topography Mission) raster images. Using digital elevation models, the slope and aspect maps were created by the slope and aspect analysis feature of the QGIS software.

Maps of power transmission lines, roads, forest and agricultural lands, water bodies, residential areas, and fault lines were obtained from Turkey National Geographic Information System Infrastructure, the General Directorate of Mineral Exploration and Research, and Openstreetmap (www.openstreetmap.org) services [37]. Among these maps, water bodies and residential areas were not included in the calculations, but these entities were shown on the land suitability map.

Vector files were converted to raster format in the QGIS environment and then reclassified in the range of 0-10 using the QGIS raster calculator. The purpose of reclassification is to numerically evaluate any piece of land namely a pixel on the map in terms of SPP investment. For example, if the proximity to power transmission line is considered, the piece of land that is less than 500 meters away from the power transmission line takes the value of 10, while the value of the piece of land that is 1000-3000 meters away from the power transmission line.

In addition, since agricultural and forest lands are not officially allowed for SPP investment, they are reclassified with a value of 0, and non-agricultural/forest lands with a value of 1.

The weighted value of a land piece for a given criterion is calculated by the multiplying related numerical value (Table 12-Table 16) of the piece of land with the weight of related the criteria obtained by the AHP method (Table 4), and then the suitability value of that land piece is calculated by adding the weighted values for all of the criteria. This calculated value is masked by multiplying the agricultural and forest land values. The purpose of the masking process is to express numerically that the piece of land on the agricultural land or forest land is not suitable for SPP investment by multiplying it with the value of 0.

Table 12. Values for proximity to power transmission line.

Proximity to power transmission line	*Value*
<=500	10
501-1000	7
1001-3000	4
3001-5000	1
>=5001	0

Table 13. Values for proximity to road.

Proximity to road (m)	*Value*
<=500	10
501-1000	7
1001-3000	5
3001-5000	3
>=5001	0

Table 14. Values for distance to fault line.

Distance to fault lines (m)	*Value*
<4999	0
5000-9999	2
10000-14999	4
15000-19999	6
20000-29999	8
>30000	10

Table 15. Values for slope.

Slope (%)	*Value*
<1	10
1,1-2	9
2,1-3	8
3,1-4	7
4,1-5	6
5,1-6	5
6,1-7	4
7,1-8	3
8,1-9	2
9,1-10	1
>10.1	0

Table 16. Values for aspect.

The direction	*The Direction of Land*	*Value*
0-44	Northwest	0
45-89	West	3
90-134	Southwest	6
135-179	South	10
180-224	Southeast	10
225-269	East	6
270-314	Northeast	3
315-359	North	0

The suitability map reclassified due to the result of the calculations is given in Figure 2. According to the results of the calculations, the distribution of the percentage of the lands in terms of land suitability is given in Table 18.

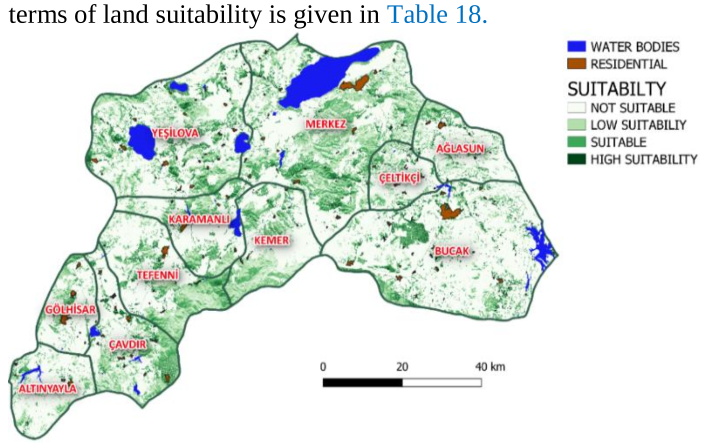

Fig 2. Province of Burdur suitability map for PV plants.

Table 17. Values for land suitability.

Value	*Suitability*
0-2.5	Not suitable
2.5-5	Low suitability
5-7.5	Suitable
7.5-10	High Suitability

Table 18. Percentage of the lands according to suitability.

Percentage(%)	*Suitability*
69,04	Not suitable
13,59	Low suitability
11,96	Suitable
5,41	High suitability

5. DISCUSSION

Using AHP and FAHP methods the weights of the criteria for selecting a suitable site for SPP investments are calculated and the results are shown in Table 19. As seen in the table, the differences between the two methods are below 1%. Therefore, it is seen that the two methods yield very close results compared to each other.

Table 19. Comparison table of criteria weights between AHP and FAHP.

Criterion	*AHP*	*FAHP*	*Difference(%)*
Proximity to the power transmission line	0,222	0,219	0,43
Proximity to road	0,135	0,121	0,42
Slope	0,160	0,166	-0,57
Aspect	0,463	0,467	-0,41
Distance to fault lines	0,028	0,027	0,11

Different analysis methods have been developed for SPP investment areas in many fields. Mostly, suitable investment sites were determined in the GIS environment by utilizing AHP and Fuzzy AHP methods. In addition, a spatial general decision-making procedure was developed by Weighted Linear Combination (WLC) method, and the entire data set was transformed into a digital decision-making map [7, 11]. GIS and multi-criteria decision-making methods are used to analyze all the important criteria at the same time for the determination of SPP investment sites [3, 15-20]. For the province of Burdur Yalçın and Yüce; and for the province of Karabük Arca and Çıtıroğlu determined suitable investment areas for SPP investments with similar methods [38]. However, the data of these studies were not compared with the fuzzy AHP method.

In large-scale areas, Aly et al. in Tanzania and Tercan et al., in Turkey determined suitable sites using the analytical hierarchy process (AHP) method and GIS. Sabah et al.[39] created regional risk maps with similar methods and compared the data obtained from AHP and fuzzy logic methods. Similar studies were later used in earthquake risk studies of both the Burdur and Çanakkale industries[40, 41].

Many studies in the literature have used fuzzy logic in recent years. Although the focus of these analyses is mostly on energy sources, they have also been performed on hybrid AC grid-battery charging drive systems [42]. Furthermore, research on the distribution of solar charge stations was conducted using spatial analyses [43]. Gülmez et al. [44] investigated the parameters employed in AHP for the establishment of SPP. These papers propose critical approaches for site selection and feasibility assessments in the energy sector.

6. CONCLUSION

GIS analyzes, which provide great advantages in the selection of the appropriate location of SPP investments, are made by data sets with many criteria. When these criteria are evaluated by applying different methods together, the decision-making process is accelerated. When the AHP method, which is used in many decision-making processes, is compared with the FAHP methods, a different approach emerges. In this study, the criteria that are important for the SPP installation were digitized and analyzes were carried out with both AHP and FAHP methods. It has been determined that there are neglectable differences between both methods and that site selection can be made in a GIS environment with both methods.

This study which is conducted in the province of Burdur has shown that SPP installation sites can be determined by both AHP and Fuzzy AHP. It will also provide the opportunity to compare with all future studies related to the subject. In addition to the data obtained in the province of Burdur, geological criteria can be expanded. At the same time, if the locations of groundwaters are obtained, different interpretations may emerge.

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