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Feasibility and Zoning of Establishing Solar Power Stations to Produce Sustainable Energy From the Environment in Northwestern Iran

Vahid Safarianzengir[1]*, *Ahmad Fatahi*[2] *and Sahar Amiri Doumari*[3]

[1]*Faculty of Social Sciences, University of Mohaghegh Ardabili, Ardabil, Iran,* [2]*Department of Agricultural Economics, Faculty of Agriculture and Natural Resources, Ardakan University, Ardakan, Iran,* [3]*Department of Natural Resources, Ardakan University, Yazd, Iran*

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****Correspondence:***
Vahid Safarianzengir
safariyan.vahid@gmail.com

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Attention to climatic and environmental potentials for exploitation and meeting human needs has been considered for many years. But the optimal and correct use of this potential requires accurate knowledge and subsequent careful planning. Today, the use of climate and productive energy from the environment is more of a concern for researchers. This investigation aims to appraise the feasibility of establishing solar thermal power plants (solar panels) by examining eight climatic and atmospheric parameters in the environment based on fuzzy logic in northwestern Iran. In this study, the weather datum of 22 Urban Climate Synoptic stations were prepared to evaluate the climatic conditions for the feasibility of establishing a thermal solar power plant for sustainable development using fuzzy logic in the north-west of Iran for each synoptic station during a statistical period of 31 years (1990–2020). This research used eight climatic parameters: average max temperature, average temperature, average min relative moisture, mean relative moisture, total monthly precipitation, and a daily average of Sunny hours, altitude, and wind speed in this systemic model. MATLAB software was used to combine the input data from fuzzy logic and ANFIS Adaptive Neural Network. The climate zoning map for establishing a thermal solar power plant with the scores obtained for each of the parameters and finally the final map was drawn using the ArcGIS. The results show that the fuzzy logic method showed a great variety of options for the establishment of solar thermal power plants using climatic parameters. In total, after obtaining the final rating for each of the 22 stations, Bonab station, with a coefficient score of (0.544–0.589), and Miyaneh station with a score (0.543–0.577), located in East Azarbaijan Province, in the north-west of Iran are appropriate for the establishment of a solar power plant. The Northwest of Iran is suitable to meet the needs of various energies, including domestic electricity, due to the potential stemming from its favorable climatic conditions climate; therefore, it is necessary to take steady steps to develop this important industry. Also, the accuracy of MATLAB and ArcGIS software with a high level of 0.96% confidence in finding a suitable place for the establishment of solar power stations was confirmed. According to the final results obtained from the integration and fuzzification of 8 climatic parameters and zoning of suitable and unsuitable areas for prioritization, Ardabil station with a score of

0.345% in the priority of inconvenient location, and Bonab station with a score of 0.589% in the priority of where the best places were for the establishment of solar power stations. Considering the findings of the present study, the central region and distant locales in mountainous areas were suitable places for the establishment of solar panels. The valuable results of the present study can be given more attention by the sectors that use a lot of sustainable energy. The results of this research in the field of sustainable energy production from the environment are more in the spotlight.

Keywords: solar panel, fuzzy logic, climatic elements, solar energy, neural network

INTRODUCTION

Energy is recognized worldwide as the engine of economic development, and today the main problem facing most societies is its production and consumption (Broesamle et al., 2001). With the growing population worldwide, the need for energy has increased and energy sources are running out with at an increasing rate (IPCC, 2007). Fossil fuels are the main cause of greenhouse gas emissions and global warming (Ani, 2015). Sustainable energy means providing energy fairly for all people and protecting the environment for future generations. The use of renewable energy is a way to achieve these goals (Freitas et al., 2015; Kazemifard et al., 2016). Solar energy is one of the cheapest, cleanest, and most sustainable sources of renewable energy. If only 0.1 percent of the energy of the sun reaching Earth is converted into electrical energy with a 10% efficiency level, 3,000 GW of energy will be produced, which is about four times the annual energy produced worldwide (Jalili et al., 2017; Salimian et al., 2017; Sukumaran and Sudhakar, 2017). The use of renewable energy (wind and solar power plants) in the energy supply of homes and industrial centers is one of the most practical and cost-effective ways to use renewable energy in the world today, and for this reason, most developed and developing countries are looking for large investments in this direction (Megan Day, 2017; Linnet and Kirubakaran, 2020; Selvaraj and Victor, 2021). Solar systems are a new technology used in both power and non-power plants, that can be used to provide heating and cooling, electricity generation, etc (Middelhauve et al., 2021; Kiray, 2021). The energy crisis is one of the most important issues in the world today, and different countries use different solutions to solve this problem (Gupta et al., 2021). Among the renewable energies, the sun has attracted many researchers globally as a source of endless energy (Laseindea and Ramere, 2021). Sunlight has been used for heat, lighting, etc since humanity emerged on Earth (Leforea et al., 2021). Environmental contamination, fluctuating prices, and the ending of fossil fuel sources use in power plants has led to the uptake of environmentally renewable energy resources (Liua and Zhang, 2021; Wang et al., 2021). The increasing growth of electric power consumption and the present low generation of electricity makes it inevitable to build new plants (Seker and Kahraman, 2021). The energy industries have allocated a significant share of energy consumption to the industrial sector in Iran (Wu and Biljecki, 2021). Energy is one of the most important development inputs and is one of the main factors of production in the progress and development of societies (Cavadini and Lauren, 2021; Dahlioui et al., 2022). Today, environmental problems such as global warming result from the increasing emissions of greenhouse gases; the use of less polluting and renewable sources of energy as a potential replacement for fossil fuels and renewable energy (Best, 2022; Ndzibah et al., 2022).

In a study Tehran (Iran), researchers evaluated the technical and economic values of solar thermal power plants using a linear parabolic power plant, central receiver, and dish sterling power plant, and concluded that the central receiver systems and the linear parabolic system have a higher efficiency than other existing systems (Tamjidtash, 2013). Research was conducted to investigate linear parabolic solar power plants with the predictive model controller and concluded that it shows the fuzzy logic function in establishing the appropriate reference temperature and controlling the predictive model in the control of the temperature of this system (Zabihilaharemi et al., 2016). In a study of the experimental models of estimating daily solar radiation based on air temperature in four climate zones of Iran, it was concluded that the use of an empirical model for estimating daily solar radiation is recommendable in arid areas of the country (Farajimahyari et al., 2016). In the research done to investigate the location of a thermal solar power plant to provide sustainable energy by using fuzzy logic, it was concluded that the 22,524.115 km^2 of Hormozgan province (Iran), and more in the north of the study area, is very suitable to build the thermal solar power plants (Kamangir et al., 2016). In the study (Iran), done by researchers to study power generation hybrid systems based on solar energy, they concluded that the use of these hybrid systems could greatly increase efficiency, save energy, reduce the pollution from fossil fuels, and reduce the costs associated with energy production (Pirkandi et al., 2016). Another study investigated the construction of 500 kW photovoltaic power plant in research on the simulation and evaluation of solar potential in Tehran, Kerman and Yazd (Iran), using the photovoltaics) PVsyst (soft-ward and they found that the city of Yazd would be the optimum site to build this power plant (Badri et al., 2016). In a study (in Iran), performed by researchers to investigate the barriers and approaches for using solar energy for farmers in Hekmataneh region with the Cronbach coefficient, the data was summarized into four factors of information support, policy, technology-cost, and attitude (Naderimehdi and Mahmoudian, 2017). Researchers have also investigated the increase in the performance of the Fresnel straight steam manufacture Solar panel production farm by using nanoparticles and found that the water is boiled faster and the heat transfer coefficient will increase by about 12.5% by adding 0.05% of copper, copper oxide, silver, and titanium oxide nanoparticles (Shahrjerdi et al., 2017). In a study modeling the solar fuel power plant for the climatic conditions of urban Semnan (Iran), it was concluded that the energy of the power plant would be reduced by about 3% for every 5 degrees of increase in collector input temperature. The change in the height of the chimney had a greater impact on the power among the geometric dimensions of the powerhouse and the intensity of the irradiance has the greatest impact on the power of the powerhouse among the parameters (Fallah and Valipoor, 2017). Another Iranian study used polymer solar cells: a novel tool in converting solar energy into electrical energy, and compared the energy alteration productivity in the polymer solar cells with an anode of Indium tin oxide (ITO) and the polymeric solar cells without Indium tin oxide (ITO) (Teimuri et al., 2017). Researchershave also studied the prioritization of renewable power plants in Iran and concluded that the priority of renewable energy production in Iran would be wind power, then thermal sun, and small hydroelectric power, respectively (Kabinejadian and Barimani, 2017). Jahangiri and Soltani (2017) compared computational patterns of solar radiation energy using statistical indices in Bam city (Iran), and concluded that it is possible to model the estimation of radiation intensity at any time of year. In research performed by Mandal and Panja (2016), they carried out design studies and feasibility on a solar network solar power plant dependent on a small network and found that updated knowledge and renewable energy is needed to decrease the electricity costs for consumers with the greatest daily intake, such as commercial buildings, stores, etc. A German study conducted feasibility research on energy completion-case studies of integration facilities close to zero energy and concluded that environmental feasibility compares the greenhouse gas emission reductions from traditional renewal and Nzebr using the Life Cycle Assessment (LCA) Model (Vance et al., 2021). In research performed in China, the authors investigated the feasibility of merging solar energy into an anaerobic hydrogen reactor to improve performance through simulation and concluded that the oscillation of the daily temperature was 0.8°C in hot weather and 2.3°C in cold weather (Badra et al., 2017). One study investigated modeling and emulation of the solar electrical panel powerhouse based on 100 MW (MW) PVUSA Test Conditions (PTC) in the Indian city of Udaipur, and concluded that the design of the solar thermal power PLC and its efficiency investigation shows a new method and expansion of solar thermal powerhouses in India (Bishoyi and Sudhakar, 2017). According to the present studies conducted in the field of the expansion and maximum production of clean energy from the environment, and prevention of excessive use of fossil fuels for energy production, sufficient information was obtained. In the study area, little to no research has been done on energy production, especially energy production from solar panels, in our area of interest. The aim of this investigation is to assess the zoning and feasibility study of establishing solar thermal power plants to produce clean energy without pollution by examining eight climatic parameters in northwestern Iran based on fuzzy logic to expand and develop the use of clean and renewable energy in this region. Therefore, it is possible to conduct detailed and planned studies on the potential of energy production from the environment to establish a solar electrical panel powerhouse in northwestern Iran and the provision of the necessary infrastructure in different seasons provided the grounds for purposeful development for the use of clean energy in the study area.

MATERIALS AND METHODS

Case Investigation

Iran has an area of 1,640,195 square kilometers in the southern half of the northern temperate zone, between 25°, 03′ and 39°, 47′ north and 44°, 05′ and 63°, 18′ east. About 90% of the country's territory is located on the Iranian plateau. Much of Iran, on the scale of general meridional currents, corresponds to an air subsidence zone. In this regard, in a uniform pattern of climate distribution, it is located in the arid and desert regions of the world, however, climatic diversity in Iran is very high. Iran's climate is located in the arid northern region and mid-latitude on the Earth in the equatorial region, while much of the climate of Iran is dry and barren, overall the country contains a range of diverse and differing climates. The stations and places studied for the production of sustainable and renewable energy in the present study are located in the Middle East, in northwestern Iran, with geographical coordinates between 34°57′ and 38°45′ N latitude and 43°4′ to 47°54′ E longditude (Safarianzengir and Sobhani, 2020). Climatic data and information used in this study were received from the MODIS climate sensor at 22 stations over a course of 31 years (1990–2020). The geographical and mathematical location of the studied places and stations is presented in (**Figure 1**), (Sobhani and Safarianzengir, 2020), and the geographical coordinates of the studied synoptic stations were presented in (**Table 1**).

Methodology

In order to establish a solar thermal power plant (solar panel) using fuzzy logic with an adaptive neural network system, the climatic parameters of 22 synoptic stations (over 24 h), with a statistical period of 31 years (1990–2020), were monitored, analyzed and researched. In this study, eight parameters—average max temp, average temp, average min relative moisture, mean relative moisture, total monthly precipitation, the diurnal average of sunny hours, altitude, and wind speed were used. The final score for the parameters was obtained, after obtaining climatic data, normalizing and removing the statistical gap using the fuzzy logic method, and weighing each of the eight parameters. Then, the data were entered into the ArcGIS and the digital map of the area with the position, the coordinates of synoptic stations, and the databases were created. Climatic elements have a high efficacy on the maximum production of energy from the solar panel. According

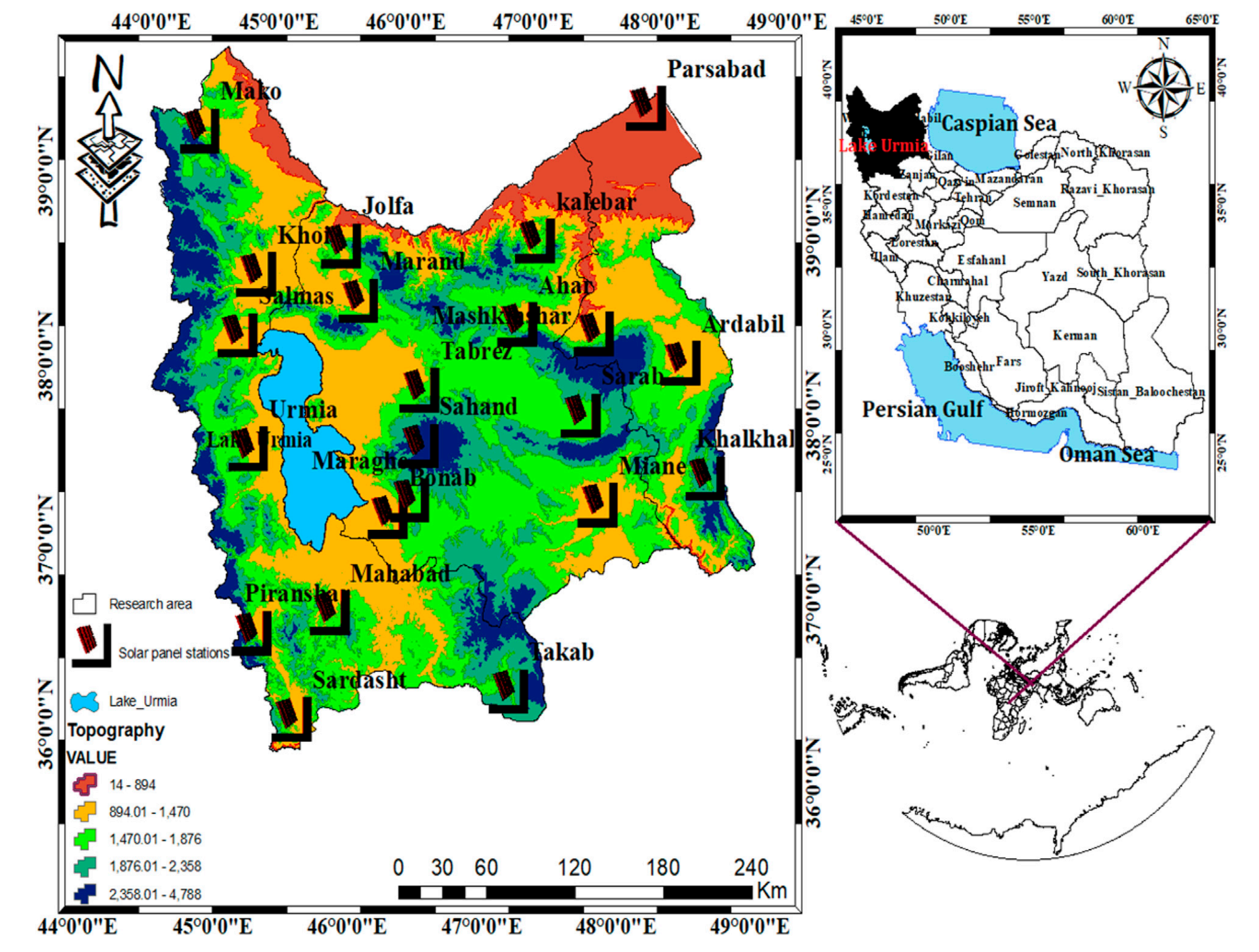


FIGURE 1 | Map of stations and urban places under investigation in globally.

TABLE 1 | Geographical coordinates of the studied synoptic stations

Row	Station	Longitude	Latitude	Row	Station	Longitude	Latitude
1	Ardabil	48.28	38.25	**12**	Marand	45.76	38.46
2	Khalkhal	48.51	37.63	**13**	Miane	47.7	37.45
3	Mashkinshar	47.6	38.38	**14**	Sarab	47.53	37.93
4	Parsabad	47.91	39.62	**15**	Khoi	44.96	38.55
5	Tabrez	46.28	38	**16**	Urmia	45	37.6
6	Ahar	47	38.4	**17**	Mahabad	45.71	36.75
7	Bonab	46.1	37.3	**18**	Mako	44.43	39.3
8	Jolfa	45.6	38.75	**19**	Salmas	44.85	38.21
9	Sahand	46.3	37.7	**20**	Piranshar	45.13	36.6
10	kalebar	47.1	38.86	**21**	Sardasht	45.48	36.15
11	Maraghe	46.26	37.4	**22**	Takab	47.1	36.4

to the extensive studies conducted in this section, eight climatic parameters: average max temp, average temp, average min relative moisture, mean relative moisture, total monthly rainfall, average diurnal hours of sunishine, altitude, and wind speed had the most significant impact on sustainable energy production from the environment. It is worth mentioning that this research has been studied in terms of environment and climate, and significant results have been obtained.

Adaptive Neuro-Fuzzy Inference System and Neural Network Models

In this step, artificial neural networks, created by modeling the functioning system of the human brain, process experimental

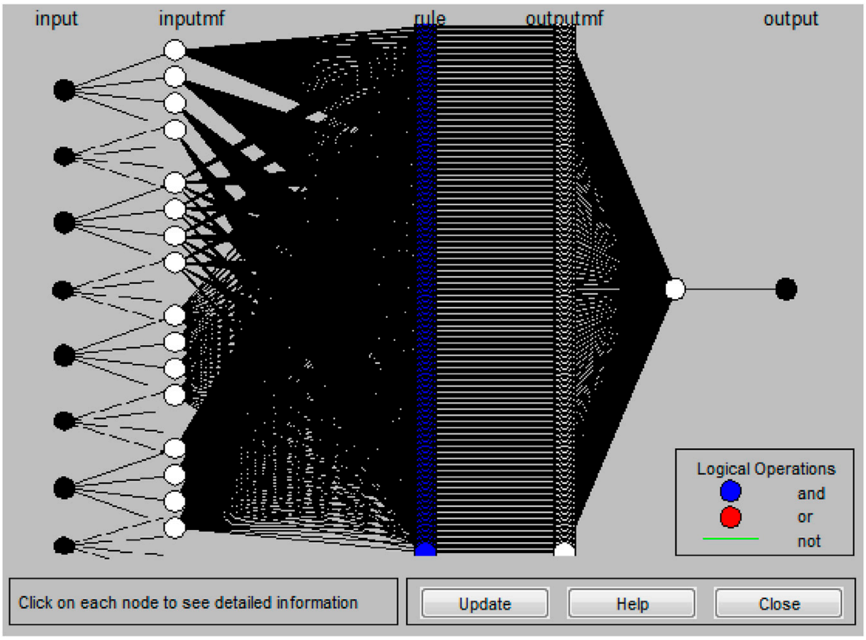


FIGURE 2 | ANFIS model structure.

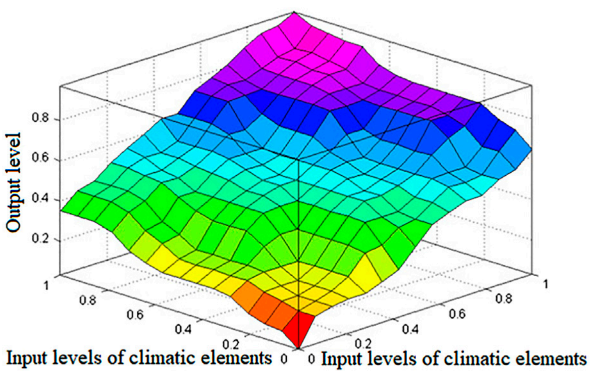


FIGURE 3 | Outline plan for the establishment of a solar panel at the environmental level.

data without regard to the physics of the problem, and extract the law behind this information. Compared to conventional models, these models require less input and less computational effort (Malczewski, 2007; Kianian et al., 2014; Safarianzengir et al., 2019). A fuzzy system is a system based on the logic rules of "condition-result" which, using the concept of linguistic variables and the fuzzy decision-making process, depicts the space of input variables over the space of output variables (Ahmadzadeh et al., 2010; Afrouzi et al., 2011). The combination of fuzzy systems based on logical rules, and the method of artificial neural networks that have the ability to extract knowledge from numerical information, has led to the presentation of a comparative neural-fuzzy inference system (Ansari et al., 2010; Safarianzengir et al., 2020a). **Figure 2** shows a fuzzy Sugeno system with eight inputs, one output, and two equivalent rules and the ANFIS system. With the following rules:

IF x is A1 and y is B1 Then f=p1x + q1y+r1; IF x is A2 and y is B2 Then f=p2x + q2y+r2

In principle, entering data in raw form reduces the speed and accuracy of networks, so to prevent premature saturation of neurons and standardize the value of data for the network; their net input should be in the range of sigmoid function between 0 and 1 take. This prevents the weights from becoming too small and prevents the neurons from saturating too early (Ashouri et al., 2017; Safarianzengir et al., 2020b). This research used eight climatic parameters: average max temp, average temperature, average min relative moisture, mean relative moisture, total monthly precipitation, a diurnal average of sunshine hours, altitude, and wind speed in this systemic model. Based on the classification and changes of the matching eight octaves, the eight inputs are accumulated and output one image using MATLAB software (**Figure 3**), and Each of the parameters was investigated in 9 classes and fuzzy (**Table 2**).

The Set of Fuzzy Concepts and Membership Amount

Fuzzy sets refer to those sets or classes in the form of situations of an event or subject that do not have definite defined limits (In this study, the intensity classes of climate parameters affecting the establishment of thermal solar power plants), (Sharma et al., 2008; Sobhani et al., 2019). In such states, the passage from one

TABLE 2 | The weights are given for effective parameters in the establishment of thermal solar power plants (source: the authors).

Altitude		Total monthly precipitation		Average relative humidity		Average temperature		Average maximum temperature		Minimum relative humidity		Wind speed		Average daily sunny hours	
Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight
31–232	0.1	202–295	0.1	49–51	0.1	8–8.5	0.1	14.5–15.5	0.1	34–39	0.1	2–3	0.1	1332–1677	0.1
233–433	0.2	296–389	0.2	52–54	0.2	9–9.5	0.2	16.5–17.5	0.2	40–45	0.2	4–5	0.2	1678–2023	0.2
434–635	0.3	390–483	0.3	55–57	0.3	100–10.5	0.3	18.5–19.5	0.3	46–51	0.3	6–7	0.3	2024–2369	0.3
636–837	0.4	484–577	0.4	58–60	0.4	11–11.5	0.4	20.5–21.5	0.4	51–56	0.4	7–8	0.4	2370–2715	0.4
838–1039	0.5	571–664	0.5	61–63	0.5	12–12.5	0.5	22.5–23.5	0.5	56–71	0.5	9–10	0.5	2716–3061	0.5
1040–1241	0.6	665–758	0.6	64–66	0.6	13–13.5	0.6	24.5–25.5	0.6	72–77	0.6	11–12	0.6	3407–3062	0.6
1242–1443	0.7	759–852	0.7	67–69	0.7	14–14.5	0.7	26.5–27.5	0.7	73–78	0.7	12–14	0.7	3408–3753	0.7
1645–1444	0.8	943–853	0.8	70–72	0.8	15–15.5	0.8	28.5–29.5	0.8	74–79	0.8	15–16	0.8	3754–4099	0.8
1847–1646	0.9	944–1037	0.9	75–73	0.9	16–16.5	0.9	30.5–31.5	0.9	80–85	0.9	16–17	0.9	4100–4445	0.9

state to another takes place gradually. Fuzzy numbers carry the numerical load of language amount and language terms over a given range of numbers. Each fuzzy number is referred to as a linguistic term and a fuzzy set. Doing routine and logical operations on fuzzy numbers will take a certain routine by converting linguistic amounts to fuzzy numbers. It is assumed that fuzzy numbers have both characteristics of normality and convexity (Feldhoff et al., 2012; Sobhani et al., 2018; Yazdani et al., 2020). They should be normal because the maximum membership in a fuzzy set is equal to 1. Each fuzzy number is a convex fuzzy set. The convexity implies that the membership function is piecewise continual and its tip is evident in the vicinity of the highest point or distance. Therefore, the different formulas are used for each one, because the values of the two indicators are between 0.1 and 0.9. So, **Eq. 1** is used to standardize, so that the range of changes will be the same in both indicators.

$$x_{ij} = \frac{x_j \max - x_j}{x_j \max - x_j \min} \tag{1}$$

The two-Way fault Component Model is used based on the panel datum framework **Eq. 2**.

$$L_n P_{it} = \mu_i + \lambda_t + \beta_i L_n ER_{it} + v_{it} \tag{2}$$

Where LnPit is the logarithm of the amount of each count of the values of Climatic parameters (22 Stations Study cities). The invisible effects are divided into two groups of the impact of the abondance of Climatic parameters and time effects (Broesamle et al., 2001; Fernandez, 2013; Freeman and Hellgardt, 2015). At first, the prediction is described according to a one-way error component model. The best linear predictor for T + S, yi without bias for the forecast of the next course S for the section ith is as **Eq. 3**.

$$\hat{y}_{i' T+S} = Z'_{i' T+S}\delta_{GLS} + w'\Omega^{-1}\hat{u}_{GLS} \text{ for } s \geq 1 \tag{3}$$

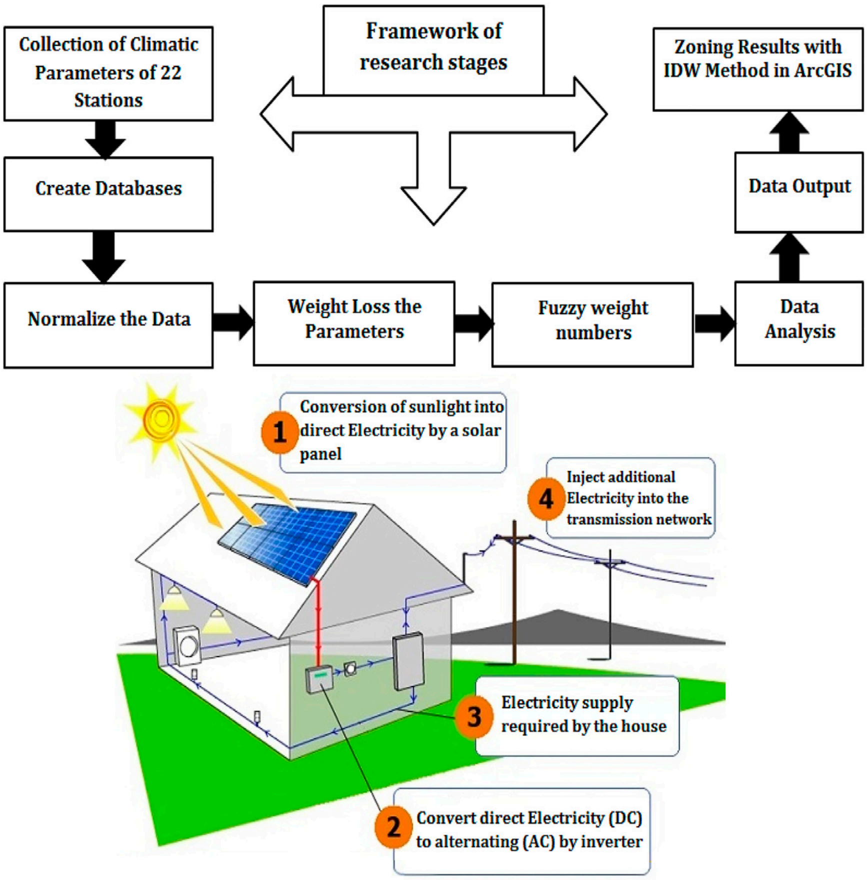
Where Y is a vector with dimensions X'Z = [1 NT'X]'NT × 1, 1 NT'NT × K is a unit vector with a dimension of Ω = δ = (α'β)'NT, $\hat{u}_{GLS} = y - Z\hat{\delta}_{GLS}$ and $w = E(u_{i'T} + S^u)$ are a variance-covariance matrix, respectively, for course T + S **Eq. 4**.

$$u_{i' T+S} = \mu + v_{i' T+S} \tag{4}$$

And $w = \delta_u^2 (l_i \otimes l_T)$, which Li is column it from the unit matrix and it is In. for example, Ii is a vector from 1 for observation with 0 for other observations. So, we will have **Eq. 5**:

$$w'\Omega^{-1} = \sigma_\mu^2\left(l'_i \otimes i'_T\right)\left[\frac{1}{\sigma_1^2}P + \frac{1}{\sigma_v^2}Q\right] = \frac{\sigma_\mu^2}{\sigma_1^2}\left(l'_i \otimes i'_T\right) \tag{5}$$

Given that, $l_i^C \otimes l_i^C P = (l_i^C \otimes l_T^C)$ and $(l_i^C \otimes l_T^C)Q = 0$. According to **eEq. 4**, $w^C\Omega^{-1}\hat{u}_{GLS}$ is converted to $((T\sigma_\mu^2/\sigma_1^2)\hat{u}_{i'GLS})$ that $\hat{u}_{i'GLS} = \sum_{i=1}^{T}\hat{u}_{it'GLS}/T$. So, the best predictor corrects the predictions without bias through the ratio of average residuals for T + S, yi in **equation 4**. In the two-way error component model for each T + S course, we will have **Eqs 6**, **7**, (Marszal et al., 2011; Yang et al., 2011; Nami, 2013).



SCHEME 1 | Study different Process and stages; Graphic source: Iran Comprehensive Energy Clinic.

$$u_{i'T+S} = \mu_i + \lambda_{T+S} + v_{i'T+S} \tag{6}$$

$$i = j\text{for}E\left(u_{i'T+S}u_{jt}\right) = \sigma_\mu^2 \qquad i \neq j\text{for}E\left(u_{i'T+S}u_{jt}\right) = 0 \tag{7}$$

Therefore, $w = E\left(u_{i'T} + s^u\right) = \sigma_u^2\left(l_I l_T\right)$ is consistent for the best predictor without linear bias in **Eq. 2** and Ii is a column with of the unit matrix with $N \times N$ dimensions. So, **Eq. 8** is as follows:

$$w'\Omega^{-1} = \sigma_\mu^2\left(l_i' \otimes i_T'\right)\left[\sum_{i=l}^{4} \frac{1}{\lambda_i} Q_i\right] \tag{8}$$

According to **Eqs 9**, **10**:

$$\left(l_i' \otimes i_T'\right)Q_1 = 0 \quad \left(l_i' \otimes i_T'\right)Q_2 = \left(l_i' \otimes i_T'\right) - i_{NT}'/N \tag{9}$$

$$\left(l_i' \otimes i_T'\right)Q_3 = 0 \quad \left(l_i' \otimes i_T'\right)Q_4 = i_{NT}'/N \tag{10}$$

Equation 11 is obtained:

$$w'\Omega^{-1} = \frac{\sigma_\mu^2}{\lambda_2}\left[\left(l_i' \otimes i_T'\right) - i_{NT}/N\right] + \frac{\sigma_\mu^2}{\lambda_4}\left(i_{NT}/N\right) \tag{11}$$

Therefore, $w^C\Omega^{-1}\hat{u}_{GLS}$ (That $\hat{u}_{GLS} = y - Z\sigma_{GLS}$) is as **Eq. 12**:

$$\frac{T\sigma_\mu^2}{\left(T\sigma_\mu^2 + \sigma_v^2\right)}\left(\bar{\hat{u}}_{i0'GLS} - \bar{\hat{u}}_{00'GLS}\right) + \frac{T\sigma_\mu^2}{\left(T\sigma_\mu^2 + N\sigma_\lambda^2 + \sigma_v^2\right)}\bar{\hat{u}}_{00'GLS} \tag{12}$$

That, $\bar{\hat{u}}_{i'GLS} = \sum_{i=I}^{T}\bar{\hat{u}}_{it'GLS}/T$ and $\bar{\hat{u}}_{...'GLS} = \sum\sum\hat{u}_{it'GLS}/NT$. So, the best predictor without linear bias for T + S, yi lead to correct by using average residuals for the two-way error component model **Eq. 13**:

$$\hat{y}_{i'T+S} = Z_{i'T+S}'\hat{\delta}_{GLS} + \left(\frac{T\sigma_\mu^2}{T\sigma_\mu^2 + \sigma_v^2}\right)\bar{\hat{u}}_{i'GLS} \tag{13}$$

In these relationships, x_{ij} represents the standardized amount, x_j is the desired index amount, $x_i\,max$ the max value in the number series and $x_i min$ is the least amount in the number series (Chen et al., 2013). First, the corresponding layer was prepared for each of the parameters using the IDW interpolation method to produce the scored maps in each of the eight climatic parameters and then one weight was defined for each of the layers. Each layer was classified into several classes and each class was weighted according to its importance and the corresponding map was prepared for each of the parameters (Gil et al., 2014). A weight between layers was applied according to the importance and effectiveness of each of the layers to obtain a final map representing a region or station with better and greater

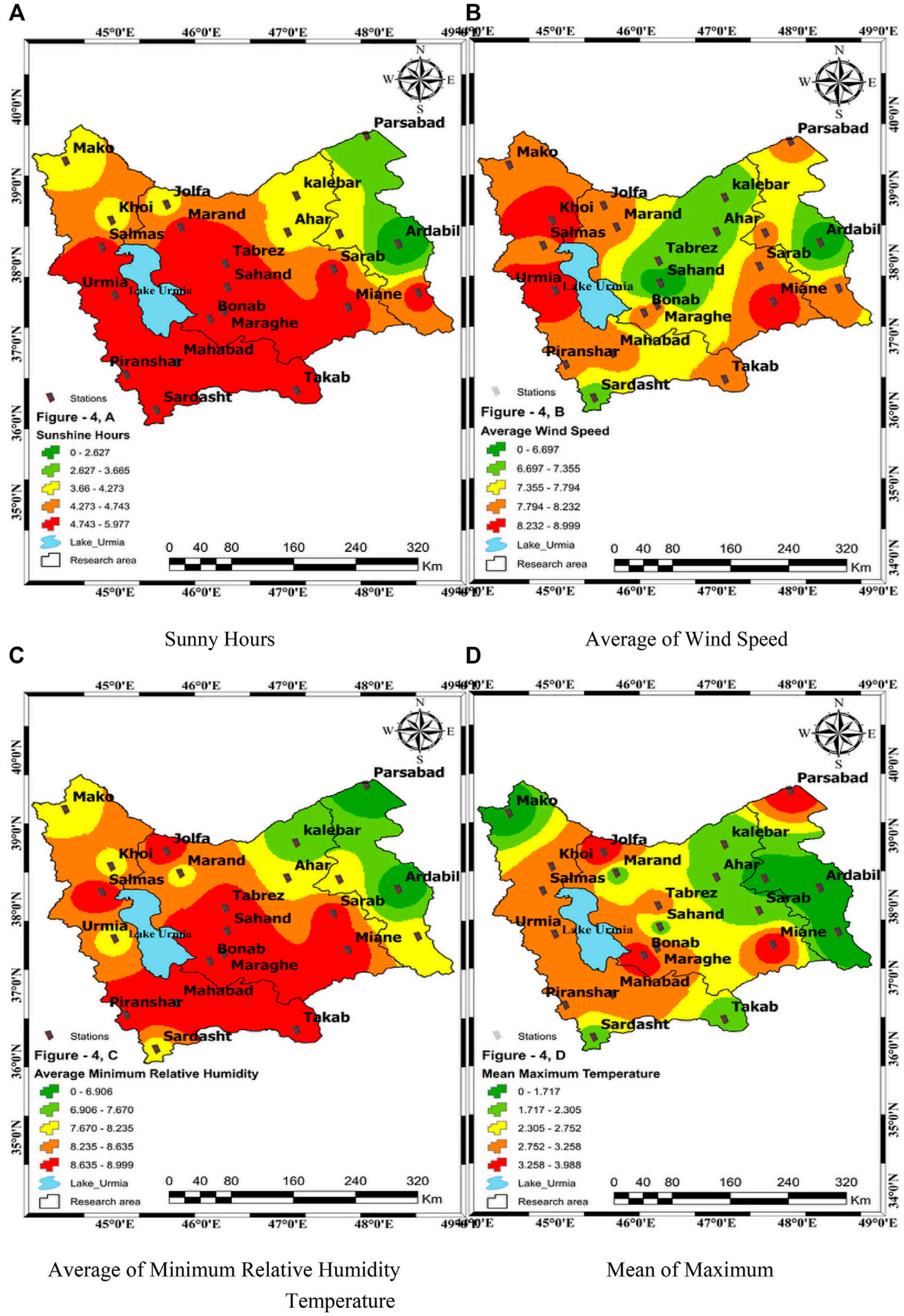


FIGURE 4 | The zoning of the parameters affecting the establishment of thermal solar power plant, Source: Authors. **(A)** Sunny Hours. **(B)** Average of Wind Speed. **(C)** Average of Minimum Relative Humidity. **(D)** Mean of Maximum Temperature. **(E)** Mean Temperature. **(F)** Means of Relative Humidity. **(G)** Total Monthly Precipitation. **(H)** Height.

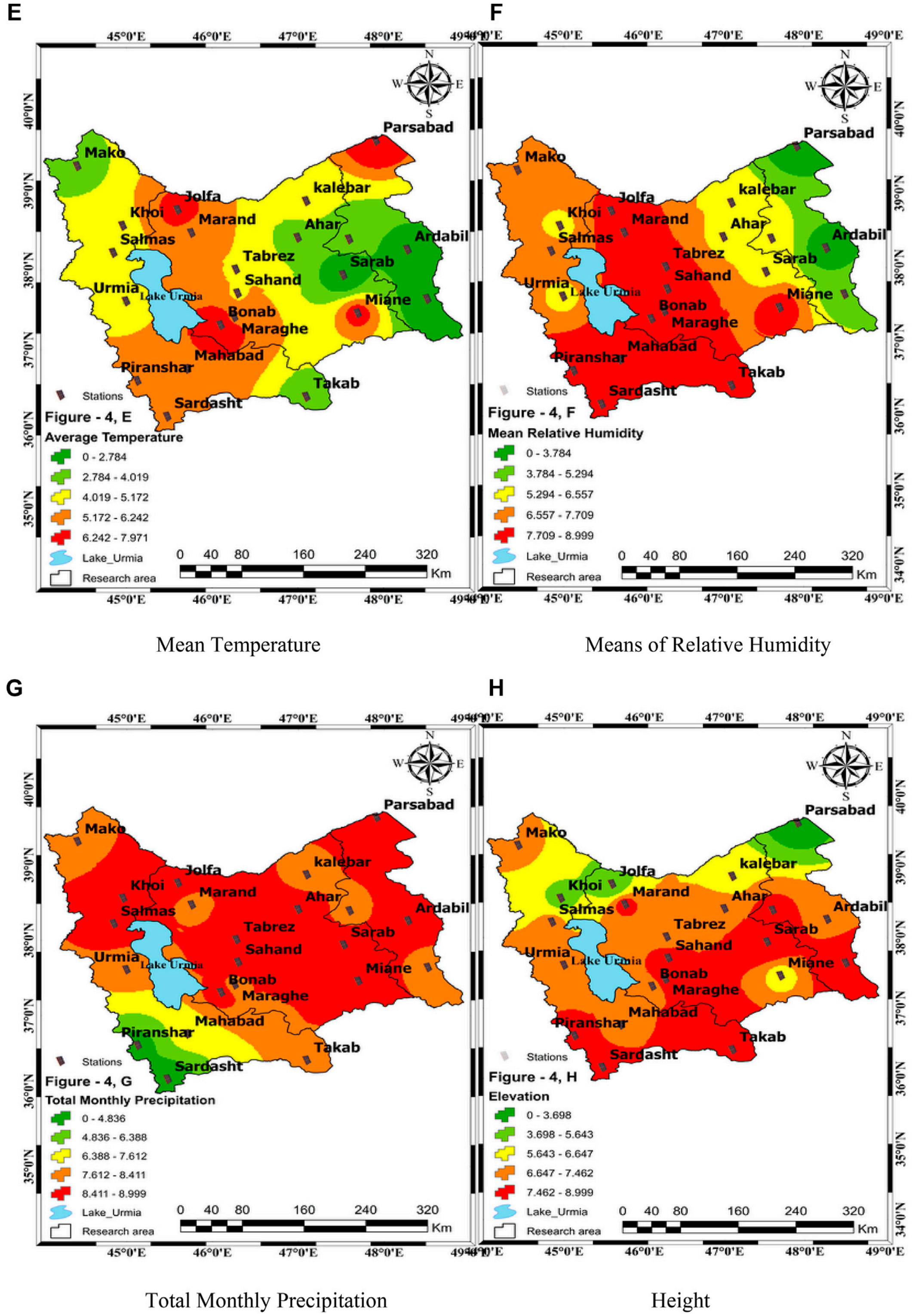


FIGURE 4 | Continued

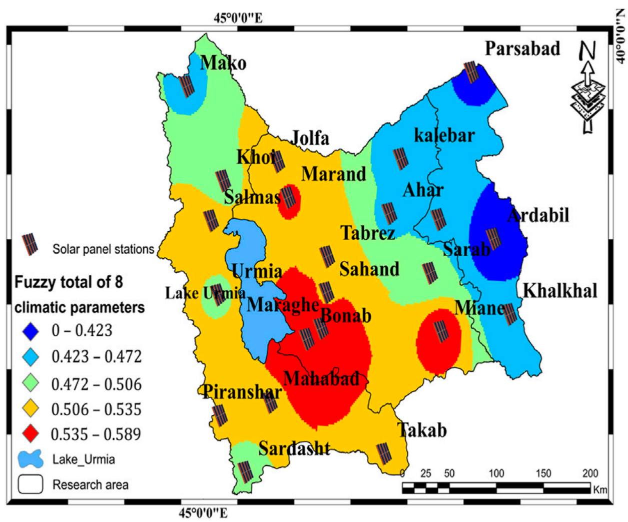


FIGURE 5 | Final zoning of the parameters affecting the establishment of the thermal solar power-house, Source: Authors.

potential. Then, the final map was obtained by combining the scores of each of the parameters for each of the 22 stations in the study area, indicating the high potential region for establishing a solar electrical panel plant in the north-west of Iran, and Zoning maps in the results were designed by the authors using the ArcGIS software. The schematic form of the method is presented in (**Scheme 1**).

RESULTS AND DISCUSSION

The score of each of the climatic parameters was obtained for 22 stations after doing the necessary calculations for the eight climatic parameters, and then the IDW was used to interpolate all stations using ArcGIS software. Efficiency and reliability of ArcGIS and MATLAB software in data processing for fuzzy and zoning of suitable places to establish solar panel power plants at a confidence level of 0.96% were tested. In the present study, in order to obtain a near-realistic estimate of the selection of a suitable location for the establishment of a solar power plant (solar panel) of the efficiency of MATLAB and ArcGIS software as one of the tools that analyze the methods of artificial intelligence with high accuracy and analyzes, was used. First, different compounds in terms of the eight climatic parameters were considered as input parameters of the ANFIS artificial neural network. Then, by training the network and determining the desired structure based on the type, the number of membership functions, and related rules with the help of MATLAB software, the most appropriate model based on statistical indicators; Mean squares error, model efficiency, and coefficient of determination and explanation were obtained. As a result, the one-dimensional combination with Sugeno inference system with two triangular membership functions was introduced as the most suitable model, and finally, the ANFIS method in MATLAB software was more accurate. Also, the efficiency of ArcGIS software in zoning a suitable place for establishing a solar power plant (solar panel) by considering 8 climatic parameters of the input in the ANFIS neural-artificial network using the Inverse Distance Weight (IDW) model. The degree of correlation and similarity between neighbors with the distance between them was proportional, applied inversely to the distance from each point of the neighboring points in the output zoning of the maps. The output of this study in the field of production of clean and renewable energy from the environment with an emphasis on climatic parameters in the study area provided valuable results that in the continuation of all these important results is mentioned. Natural and legal persons, organizations, and bodies that work in the field of sustainable energy production from the environment can benefit from these valuable results.

Interpolation Maps Based on Scores

Sunlight is considered an important factor in the production of heat, and it can have a large impact on energy production. The Sahand stations and Tabriz have the most appropriate conditions to establish a solar power plant with scores of 5.99 and 5.23 in East Azerbaijan province given the sunshine hours. In total, the highest sunshine hours to establish the thermal solar power plants belong to East Azerbaijan province with two stations (**Figure 4A**). The effect of the wind variable dependence on the air temp has a negative impact on the hot weather due to vaporization and cooling. In this parameter, Khoy station with a score of 8.99 and Urmia with a value of 8.46 has the highest score in West Azarbaijan province, but Mianeh station has a value of 8.88 in East Azarbaijan Province. The highest score was allocated to the West Azarbaijan province with two stations to build the solar thermal plants given the wind parameter (**Figure 4B**). The average minimum relative humidity has a negative effect on the establishment of thermal solar power plants with high amounts. East Azarbaijan province with six stations (Takab, Tabriz, Sahand, Bonab, Sarab, and Mianeh) and West Azarbaijan with three stations (Mahabad, Salmas, and Piranshahr) have suitable climatic conditions according to the obtained point for each station for this climatic parameter. In total, East Azarbaijan Province has the highest rating and conditions for the establishment of a solar power plant with six stations compared to the other two provinces (**Figure 4C**). The increase of the average maximum temperature has a positive effect on this subject and the method used, and East Azarbaijan province with three suitable stations (Bonab, Jolfa, and Mianeh) and Ardebil province with two suitable stations (Parsabad and Ardabil) were ranked second by considering this parameter (**Figure 4D**). Therefore, the East Azarbaijan province has a suitable condition to build the thermal solar power plant with three stations (Bonab, Jolfa, and Mianeh), but the Ardabil province was ranked second with one station (Parsabad). In total, East Azarbaijan Province with three stations was considered as the first station to establish the power plant in terms of the average temperature parameter (**Figure 4E**). The average relative humidity parameter in the establishment of solar power plants was considered a negative factor. Appropriate stations in East Azarbaijan province were Marand, Sahand, Bonab, Maneh and in West Azarbaijan province were Sardasht and Piranshahr stations that were selected as suitable sites (**Figure 4F**). The precipitation parameter in this method has a negative effect on the intended purpose of establishing a thermal solar power plant. Considering this parameter as a measure of appropriate stations, i.e., low rainfall stations, compared to other stations (Khoy and Salmas) from West Azarbaijan province and stations of Bonab, Jolfa, Tabriz, Sahand, Ahar, Sarab, Mianeh) from East Azarbaijan province and Ardebil station from Ardebil province are appropriate stations for the establishment of a thermal solar power-house (**Figure 4G**). In terms of the height parameter, East Azarbaijan Province, with two suitable stations (Sarab and Takab) and Ardabil province, with an appropriate station (Khalkhal), was ranked as first and second suitable conditions for the establishment of thermal solar power-houses (**Figure 4H**). In terms of the height parameter, East Azarbaijan province with the two suitable stations (Sarab and Takab) and Ardabil province with the appropriate station (Khalkhal) in the first and second place are suitable conditions for the establishment of solar thermal plants (**Figure 4**).

The mean layers of max temp, average temp, average min relative moisture, mean relative moisture, total monthly precipitation, average diurnal Sunny hours, height, and wind speed were integrated together based on weight overlap and score. The result is a map of areas with regional potential, in which different zones have been separated to use solar energy and the establishment of thermal solar power-houses (**Figure 5**). Accordingly, Mianeh station with a final score of (0.543–0.577) and Bonab (0.544–0.589) in East Azarbaijan province are proposed as suitable areas for establishing a solar thermal power-house.

Discussion and Validation of Research Results

Monitoring and feasibility of the establishment of thermal solar power-houses were carried out by studying eight climatic parameters in the northwest of Iran based on fuzzy logic in this study. This method has been used as a suitable method for research in most studies. Including research: (Guney, 2016), Solar power and application methods; (Holopainen et al., 2016), Feasibility studies of energy retrofits—case studies of Nearly Zero-Energy Building renovation; (Teimuri et al., 2017), Polymer Solar Cell: A New Instrument for Solar Energy Conversion to Electricity Energy; (Fatahi, 2018), Valuation of Solar Power Generating Potential in Iran Desert Areas, and finally, (Navid et al., 2021), Fault Diagnostic Methodologies for Utility-Scale Photovoltaic Power Plants: A State of the Art Review. The researchers mentioned confirmed the efficiency of the models used in the present study. With the comparisons made, the methods used in the present study, i.e., feasibility and zoning of solar power stations to produce sustainable energy from the environment had acceptable efficiency. Considering the acceptable and accurate results obtained from the present study and comparing it with the findings of other researchers and the high reliability of the use of adaptive neuro-fuzzy inference system (ANFIS). It is suggested that the model and method used in this study in other areas are also used. In this study, in addition to fuzzy research data; using ArcGIS software, suitable areas and areas with restrictions and unsuitable for the establishment of the solar panel were identified. The value of this research is that in the study area, due to the pollution caused by power generation, with the establishment and expansion of solar power stations to produce clean and sustainable energy, pollution from energy production has decreased and from high consumption of fossil fuels and pollutants are prevented. Also, in most similar studies, it is only the efficiency of solar panels that has mostly been discussed, while in this study, appropriate regions for the establishment of solar power stations in the study area have been identified and expanded. Those who work in the field of production and development of solar panels can use this research. The results of this research can be used by relevant organizations and power stations in the production of clean and sustainable energy.

CONCLUSION

Solar energy is one of the clean and inexpensive energies, and easily accessible worldwide without any environmental degradation, and a better alternative for fossil fuels for generating and supplying energy for the entire planet. In this research, the monitoring and feasibility of the establishment of thermal solar power plants were investigated by analyzing eight climatic parameters in the northwest of Iran based on fuzzy logic. Each of the parameters was separately studied and classified in nine classes, scored, weighted and the percentage of the impact of each one was applied in the final map. The ranges with a higher value are more important. Each of the eight parameters was separately analyzed based on the obtained points so that the East Azarbaijan province in the first rank, West Azarbaijan province in the second rank, and Ardabil province in the third rank were suitable stations with better conditions to establish the thermal solar powerhouses in the northwest of Iran. In total, both Bonab station with a score (0.544–0.589) and Mianeh (0.543–0.577) is recommended for the establishment and construction of a solar electrical panel power plant.

In terms of sunny hours and wind speed parameters, Urmia and Miyaneh stations were jointly located in suitable places for the establishment of solar panel powerhouses, while Ardabil station was located in an unsuitable place. But in terms of the parameters of the mean minimum relative humidity and the mean maximum temperature, the middle and Bonab stations were jointly prioritized in the appropriate place. While Kleiber and Ardabil stations were jointly located in an unsuitable place for the establishment of solar panel power-houses. In terms of parameters of average temperature and average relative humidity of Bonab, Miyaneh, and Jolfa stations in a suitable position and Ardabil and Khalkhal stations were in an unfavorable position for the installation of a solar panel power plants. But in terms of total monthly rainfall parameters and altitude of Bonab and Maragheh stations were most of all, in the right place, so priority was given to the establishment of solar panel power plants. According to the final results obtained from the integration and fuzziness of 8 climatic parameters and zoning of suitable and unsuitable areas for prioritization, Ardabil urban station with franchising of 0.345% in the superiority of unsuitable location and Bonab station with a score of 0.589% in the priority the best places were in the establishment of solar panel power plants.

In today's turbulent world, fossil fuel resources are dwindling due to population growth, so humans are looking for ways to replace fossil fuels with renewable energy. With the spread of science and technology, solar panels entered the field. Solar energy is one of the free resources of clean energy without any environmental damage, which is used today due to the energy crisis and the minimization of pollution. Basically, solar systems are also equipped with an auxiliary system so that they can be used when necessary when the value of solar energy is not enough to supply the energy required by the building. Considering the findings of the present study, the central part and distant places from mountainous areas were suitable for the establishment of solar panel powerhouses. The valuable results of the present study can be given more attention to the sectors that use a lot of sustainable energy.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

All authors contributed to the study conception and design. Material preparation and data collection and analyses were performed by VS. The first draft of the manuscript was written by AF and was edited by SA. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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