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Optimization solar site selection by fuzzy logic model and weighted linear combination method in arid and semi-arid region: A case study Isfahan-IRAN

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ABSTRACT

Renewable energy will play a crucial role in the future society of the 21st century. In this way, solar energy, which can be converted into usable energy by solar panels, is known as the most important, accessible and cleanest energy source which has little adverse effects on the environment. However, this kind of energy needs to be used carefully and planned in an optimum location to provide a great opportunity for economic growth and development. The objectives of this paper are optimization site selection based on the fuzzy logic, weighted linear combination (WLC) which has an average risk and able to involve priority layers through their weight, and Multiple Criteria Decision Making (MCDM) Process. In this way after identification, valuation of criteria layers by using fuzzy method because of their uncertainty and determined their importance, the layers combined. Overall, the results showed that the combination of fuzzy logic, WLC and MCDM have a high accuracy and positioning in locating optimal solar sites and, in this way, climatic layers are the most important. But more specific results of this study indicate that some areas in Isfahan, Borkhar, Nain, Shahin Shahr and Meimeh have a higher potential in this regard.

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1. Introduction

1.1. Renewable energy

Today, one of the main problems that societies are facing is energy generation and sustainable utilization [1]. Energy is known as the driving engine for economic development the world over. Global energy resources can be classified into three main groups, namely fossil energies (oil, gas, coal, etc.), nuclear energy, and renewable energies (wind, solar, geothermal, hydro-power, biomass, hydrogen, ocean, etc.) [2]. Most of the energy resources currently relied on are finite and will be depleted because of the increasing demand. In addition, there have been serious local air, water, and soil pollution problems as a result of the consumption of various energy resources. It has become clear that continuing to use fossil fuels is not wise, not only because of the global impacts on climate system, but also the short-term and very long-term impacts on society and the ecosystem [3]. Therefore, the world's agenda focuses on sustainable energy systems in terms of both reliability for economic development and benefits for the environment [1]. The definition of sustainable energy is the combination of providing energy equally to all people and protecting the environment for subsequent generations [4]. Using renewable energy is a way of reaching this target. There are numerous economic and environmental benefits associated with renewable energy sources (RES[1]). RES are characterized by their temporal and spatial variability, which eliminate the problems associated with fossil and nuclear energies such as pollution and environmental damages. In addition, [3] points out that one of the best options is to adopt renewable energy and increase the energy efficiency in order to decrease negative impacts of climate change [3]. At least one local source of renewable energy can typically be found at almost any location on the Earth's surface. As 99.8% of energy at the Earth's surface comes from the Sun, solar energy is one of the cheapest, pollution-free, inexhaustible renewable energy resources [5–8]. Used to provide heat, hot water, electricity, and even the cooling of residential, commercial and industrial centers. If only 0.1% of the solar energy on the Earth can be converted to electrical energy at an efficiency rate of 10%, 3000 GW of power will be generated, which is four times more than the energy consumed annually on a global scale [9]. The amount of irradiance reaching a location on the Earth's surface over a specific time period varies depending on global, local, spatial, temporal and meteorological factors, such as altitude, latitude, fraction of sunshine hours, relative humidity, precipitation, and air temperature [2,10].

1.2. Renewable energy in Iran

Iran, which is located between 25° and 40° north latitude, is in a favorable position with respect to the potential amount of solar energy received. Solar radiation in Iran is estimated to be about 1800–2200 kWh/m^2 per year, which is higher than the global average. An annual average of more than 280 sunny days is reportedly recorded over more than 90% of Iran's territorial land, which yields a highly significant potential source of energy [2].

However, due to the abundant sources of petroleum (oil and gas), the opportunities offered by renewable energy are neglected. Renewable energy is new to Iran and there is still a long way to go [11]. However, according to the approved EIA[2] confirmed scenarios, Iranian oil after 43 years, gas supplies after 167 years and coal after 417 years will dwindle [12]. So, as a result of energy security we are supposed to search for and use alternative sources of renewable energy. Except for the few aforementioned projects, small-scale technologies that bring power to remote villages have a better chance of being adopted than those implemented at the national level [11].

These complex problems require simultaneous evaluation of many criteria. For this purpose, MCDM[3] can assist decision makers in selecting the best alternative [13]. This method is a procedure that consists of finding the best alternative among a set of feasible alternatives. The purpose or ultimate goal of an MCDM method is to investigate a number of alternatives in the light of criteria and conflicting objectives [14]. One of the most popular MCDMs is the AHP[4], which has been accepted by the international scientific community as a robust and flexible MCDM tool for dealing with complex decision problems [15]. This method has been widely applied in solving a variety of problems, among which are the applications related to energy planning and the carrying capacity of renewable energy facilities [16,17]. However, the AHP method is unable to provide the crisp values needed to properly reflect the fuzziness associated with decision-making problems in the real world [18]. Fuzzy set theory is an extension of the classical set theory, which is based on two-valued logic; that is, in or out. In other words, membership is dichotomous: an element is either a member or not. Fuzzy sets, on the other hand, were formulated by Zadeh [19] and based on the simple idea of introducing a degree of membership of an element [19]. The fundamental concept of fuzzy sets, which has relevance and intuitive meaning to the sustainability assessment process, is the 'membership function'.

Alamdari et al. [2] investigated the feasibility of exploiting solar energy in different parts of Iran. For this purpose, and as the first step, average, maximum, and minimum values of solar radiation on a horizontal surface are calculated at different stations. Then, the monthly and average clearness indices are determined using the radiation data obtained from these stations and the average monthly summation of sunshine hours is calculated. Ara´nCarrio´n et al. [20] described the environmental decision-support system based on the AHP for selecting optimal sites for grid-connected photovoltaic power plants. Their research took into account criteria related to the environment, geography, location, and climate. Jaber et al. [21] evaluated space heating systems running on conventional and renewable energy sources in Jordan using fuzzy sets and the AHP. Analyses using both methods showed that heating systems based on renewable energy are most favorable. Gastli and Charabi [22] predicted the solar energy potential for power generation in Oman using GIS[5] maps. In their study, they first reviewed the methods developed for creating solar radiation maps using GIS tools and then developed Oman's solar radiation GIS maps for the months of January and July. They also used a number of methods to calculate the annual electrical energy generation potential. The results showed that the country had the potential to use solar energy all year long. Effat [23] selected potential sites for solar energy farms in Egypt by using Shuttle SRTM[6] and MCE[7]. Eventually, a few sites were selected based on high suitability index values and the area of a site. The methodology proves to be promising for creating zoning maps for developing solar energy infrastructures in the region. Janke [24] used MCE and GIS to model solar and wind farms in Colorado.

In this paper, the AHP, as one of the MCDM, FUZZY and WLC[8] methods, will be used to investigate the weight of the criteria or factors and obtain the evaluation of potential and feasibility of

[1] Renewable energy sources.
[2] Environmental impact assessment.
[3] Multiple criteria decision analysis.
[4] Analytic hierarchy process.
[5] Geographic information system.
[6] Radar topography mission.
[7] Multi-criteria evaluation.
[8] Weighted linear combination.

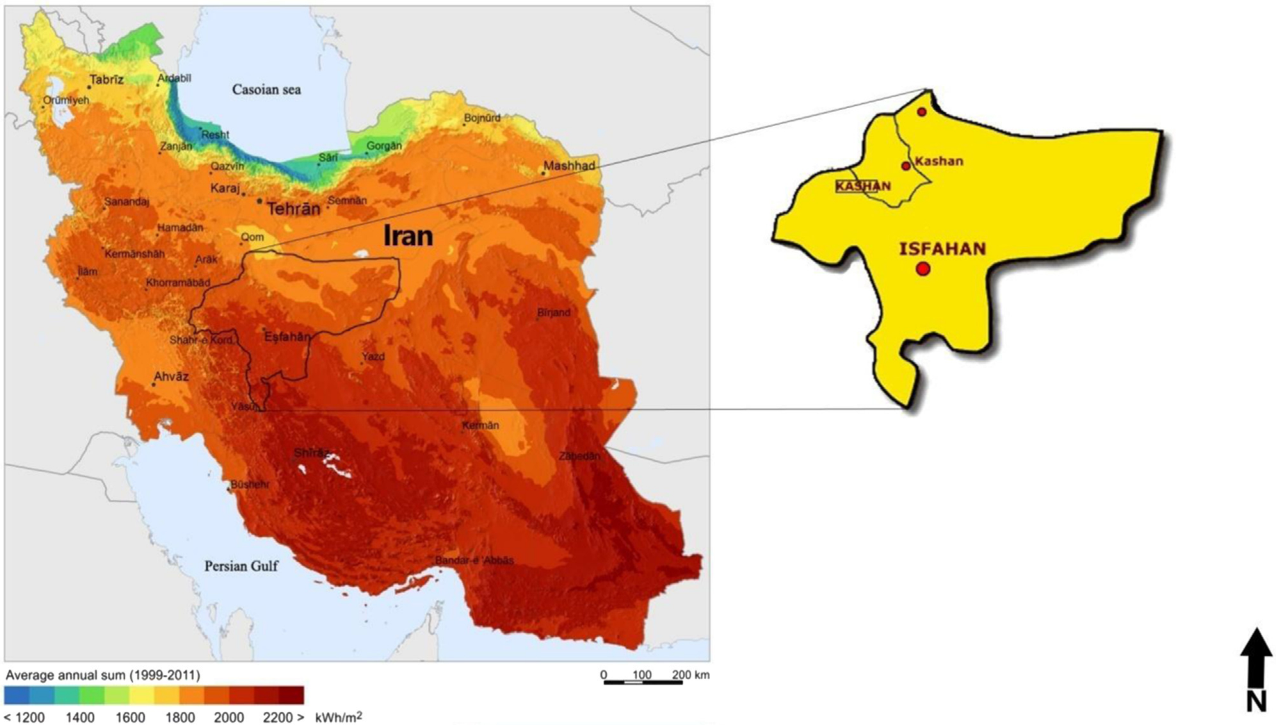

Fig. 1. Introduction of the study area in a term of solar energy zoning. The amount of solar energy received in the southern part of the country and Isfahan province is higher than other parts.

locating solar power plants in different regions of Isfahan province, Iran. This province, which is one of the biggest provinces of Iran, is in the very high radiation zone rate. Therefore, it has a very good potential for using solar energy.

2. Material and methods

2.1. Case studies

Isfahan province is located between latitudes 30° 43′ to 34° 27′ North and longitudes 49° 36′ to 55° 31′ East and covers an area of 107017 square kilometers, equivalent to 0.5% of the total Iran country territory, with 23 cities, 106 towns and 126 villages (Fig. 1). Population counts of this province are 4,879,312 capita for 2011, which is equivalent to 6.49% of the total population in Iran. Because of the number of major industrial workshops and industries and industrial estates, Esfahan is one of the most important industrial Center in Iran. All the factors mentioned above have caused a high consumption for electricity power (about 13,127,860 kWh) in this province [25].

This province is an arid and semi-arid region of the country generally in terms of climate. However, because of a lack of uniformity in the topography conditions, the province's climate varies in different areas. Therefore, the amount of moisture and precipitation decreases and the average temperature rises from west to east. Generally, however, because of the high solar radiation, the more than national and global average and less cloudy and rainy days, Isfahan province is one of the most suitable regions for a solar energy project.

2.2. Definition of criteria and factors

The determination of suitable locations for a solar power plant depends on the complete and accurate understanding of factors and how to choose them. Factors which were selected in this study were based on various research studies and expert opinions. Among the technical, economic, social and environmental factors, those that were relevant and had the ability to prepare and to model had been selected. It was decided to follow the criteria established and justified in: Climatic, Location, Geomorphological and Environmental, which have some subsets as factors Fig. 2.

- Elevation, aspect and slope: Elevation is one of the effective factors in industrial location. It has a regression correlation with coefficient of 95% with temperature and precipitation [26]. The height of the region from sea level is proportional with atmosphere thickness inversely. Thick atmosphere implies more concentration of the compounds or absorption or reflection factors. Since the coarser and thicker materials are collected in the lower classes, the atmosphere is thinner on the tops of the mountains. The atmosphere thickness and compounds control surge power in addition to short wave energy of the sun. Therefore, highlands have more potential than lowlands because of the receiving high energy.
  Slope is another effective layer in selecting the optimum location of solar power plants. This is because land potential for industrial usage can be reduced by an increasing slope [25,26]. Aspect is another important layer in this topic. Due to the particular industry being considered in this study, the solar panels should be such that they receive the maximum amount of solar energy during the day [27].
- Distance to city: according to the role of this industry in the production of residents' requirements of electricity of areas, the proximity to residential areas is very important. This is because it will reduce the transmission cost to that Center and energy dissipation. On the other hand, according to the municipal laws, the development possibility of cities and the inability to locate a solar power plant in the city Center of the mentioned cities, and binding rules for considering a distance of 500 m away from them as their ecologically safe spaces, some inappropriate

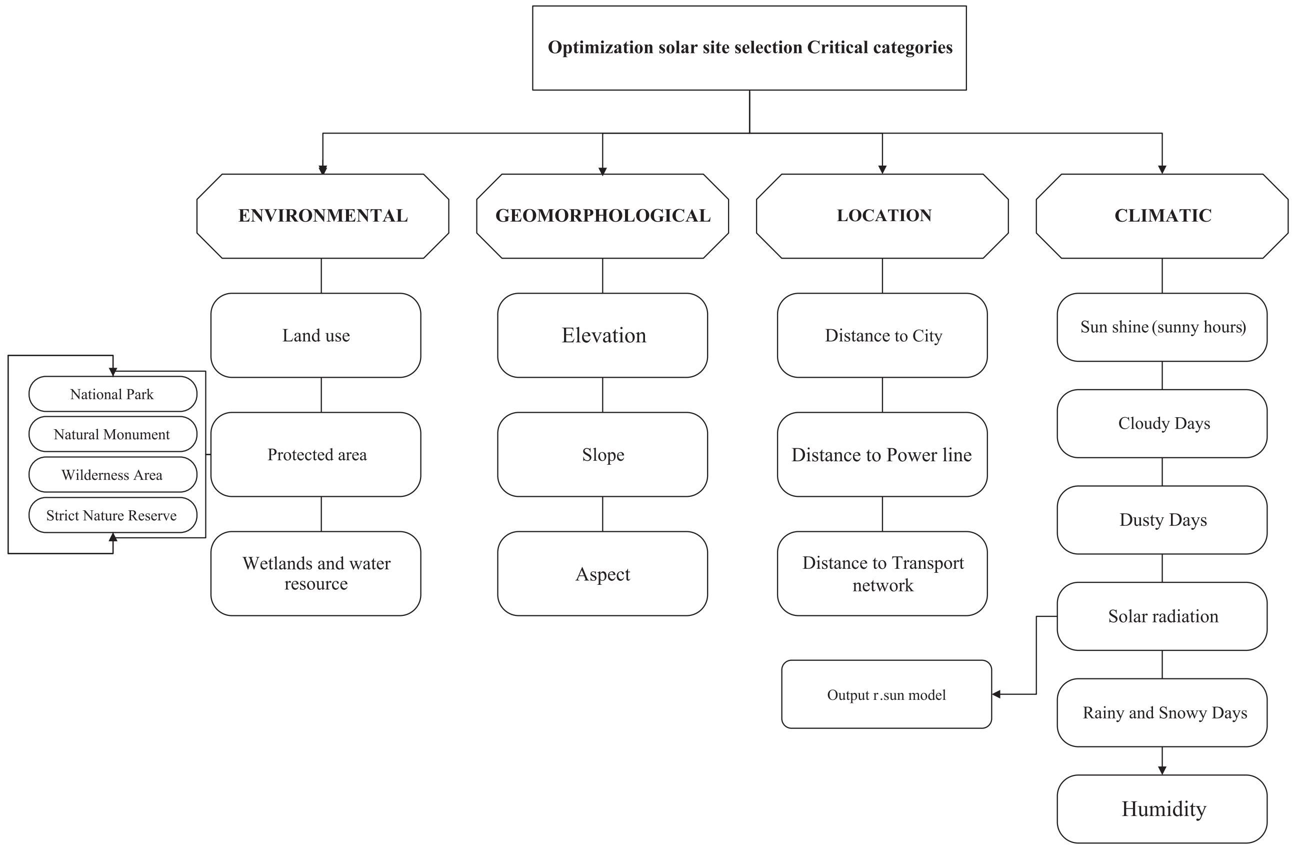

Fig. 2. The criteria and factors for optimization solar site selection.

regions have been considered for the construction of such plants.

- Distance to transport network: transport is considered as one of the most important criteria for locating industries. Proximity of this industry to roads will reduce transportation costs of power plant equipment, personnel transport and plant support. Also, because of the consideration of safety and traffic rules, a distance of 250 m has been considered as a safe space in which to locate the road [28].
- Distance to power lines: an electrical distribution station is one of the effective factors. Avoiding this industrial from of power transmission lines, in addition to the voltage dropping along the way, plus reducing the overall efficiency of industrial processes and wasting more energy, ultimately will lead to environmental pollution [27].
- Sunny hours: the number of sunny hours is the most effective factor. Sunny hours means the number of sunshine hours that are usually measured by special tools. This factor is the most important parameter that represents the amount of energy received from the sun [27].
- Solar radiation: solar radiation is an amount of solar energy intake at one point on the earth's surface depends on various factors including: latitude, longitude, the sundial, humidity, evaporation, air temperature, angle of the sun, and other factors [28,29]. There for this factor can be considered as one of the most important criteria for use of solar energy potential.
- Number of cloudy days: a most important parameter for identifying a potential location for placement of this industry is the number of cloudy days in the study area. This is because clouds return short-wave solar energy, on average 21%.
- Rainy and snowy days: rainfall can be regarded as the most important factor involved in the hydrological cycle directly. So, annual high precipitation of some areas is a testament to the high moisture of the region, which is the most important factor in the absorption of shortwave radiation; on the other hand, it proves the presence of high particulate matters in the atmosphere of that point, which play a role in the absorption and reflection of shortwave radiation.
- Number of dusty days: dust is the major constituent of the atmosphere, especially near the Earth's surface. These particles absorb 15% of the sun's short-wave energy. Thus, the regions with the least days of dust in the year are important in this regard.
- Humidity: water vapor and carbon dioxide are the most important absorbers of solar energy in the atmosphere. As a result, areas with high humidity due to the short-wave solar energy absorption by atmospheric water vapor are not prone to exploitation of solar energy.
- Protected areas: These areas and their ecological safety space, because of their ecological values and their high risk of vulnerability as critical habitats, are considered as areas entirely unsuitable for the construction of solar power plants [26,30].
- Wetlands and dense forest: in terms of ecological value and potential, as well as their role in environmental quality, these regions are considered as completely unusable and non-exploitable regions for the construction of solar power plants.

2.3. Data analysis

For achieving general goals of the plan, by studying and assessing the elements and common techniques of planning and management, GIS tools and a planning and management combination model [31]. Were selected for the ecological assessment. The process of evaluation, determination and selection of

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appropriate points in the concerned area included the following steps Fig. 3.

But process of determination the best suitable site for sun plan was divided in to three steps generally:

2.3.1. *Preparation and valuation of layers by using fuzzy method*

In the process of location, extraction of the needed information layers is the first stage of the practical stages of the study, during which the mapping layers of each criterion and sub-criterion are extracted and entered into the GIS database for the next stages except sun radiation. In this study for preparation of sun radiation layer the r.sun rule as one of the location models of solar energy was used and analyzed. R.sun computes beam (direct), diffuse and ground reflected solar irradiation raster maps for given day, latitude, surface and atmospheric conditions. Solar parameters (e.g. time of sunrise and sunset, declination, extraterrestrial irradiance, daylight length) are stored in the resultant maps' history files. Alternatively, the local time can be specified to compute solar incidence angle and/or irradiance raster maps. The shadowing effect of the topography is optionally incorporated. This can be done either by calculating the shadowing effect directly from the digital elevation model or using raster's of the horizon height which is much faster. The r.sun program works in two modes. In the first, mode which was used in this study, it calculates for the set local time a solar incidence angle [degrees] and solar irradiance values [W.m-2]. In the second mode daily sums of solar radiation [Wh.m-2.day-1] are computed within a set day [32].

In the next step the method which was selected in order to value the thematic layers was Fuzzy Logic. The fundamental concept of fuzzy sets, that has relevance and intuitive meaning to the sustainability assessment process, is the 'membership function'. The premise of fuzzy logic is that membership in a set is not dichotomous (i.e. in or out); instead, there are degrees of membership ranging between 0 and 1. It means a Fuzzy Set is characterized by a fuzzy membership grade (also called a possibility) that ranges from 0.0 to 1.0, indicating a continuous increase from non-membership to complete membership [19]. In the following in order to prepare fuzzy maps we acted in a manner that for each interval, a value proportional to that distance (from parameter) to be given to that parameter. This initialization (devoting initial value) was given by the numeric representation in fuzzy logic.

2.3.2. *Weighting criteria process*

In the following research to determine the importance of the criteria used multi-criteria evaluation techniques to land planning. Multi-criteria evaluation techniques based on the ideal point analysis. The purpose or ultimate goal of a MCDM method is to investigate a number of alternatives in the light of criteria and conflicting objectives [14]. One of the most popular MCDM is the Analytic Hierarchy Process-AHP. AHP can also be used to generate the weights assigned to the land suitability criteria [33] or to the suitability maps to calculate a 'compound' suitability score [34].

AHP method has been constructed on the foundation of three basics of analysis, comparison judgment and priority composition. Analysis basic needs analyzing decision-making problems to various elements regarding AHP scheme. It means that the first step is to create a tree structure for criteria and sub criteria. The comparison judgment basic describe the comparability for existence of elements in an AHP structure level. These weights could be either calculated individually or an integration of critics judgments which were employed in this study. After several numbers of double comparison and AHP, the results of comparisons were structured for sun plan site selection [35].

The current study used the ideas of 32 experts in Planning and Environmental Management, Environmental Engineering

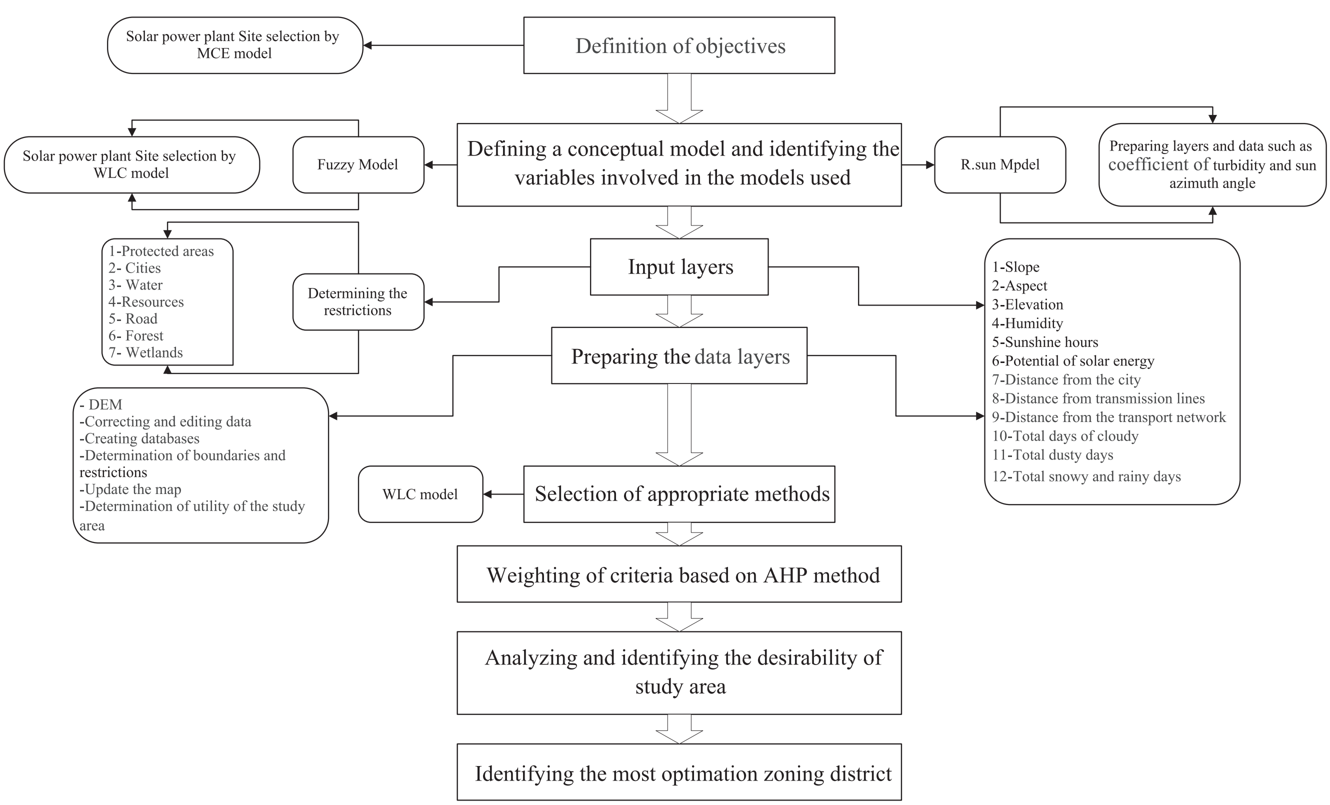

Fig. 3. Conceptual model for optimization site selection for constructing a solar plant.

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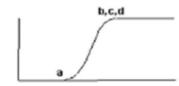
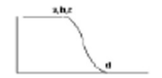
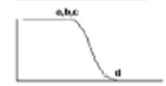
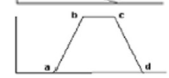
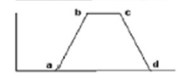
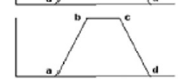
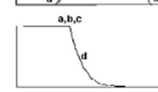
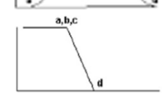
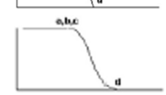
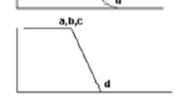
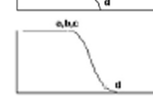
Table 1
The locating of solar power plants spatial parameters for the phase maps with each weight.

	criteria	weight	Fuzzy function				Chart type	Chart type
			a	b	c	d		
criteria	Potential solar radiation	0.250	$8*10^5$ (wh/m^2/y)	$1.5*10^6$ (wh/m^2/y)	–	–	Sigmoidal /Monotonically increasing	
	Total hours of sunshine	0.19	2500 (h)	3500 (h)	–	–	Sigmoidal - Monotonically decreasing	
	Humidity	0.043	30%	–	–	50%	Sigmoidal - Monotonically decreasing	
	Slop	0.042	3%	10%	20%	100%	Linear/Symmetric	
	Aspect	0.066	N,NE (0–45)	S,F (< 0,180)	SW, SE,W (225,135)	E, NE (90,45)	Linear/Symmetric	
	Elevation	0.059	500 (m)	1500 (m)	2000 (m)	4500 (m)	Linear/Symmetric	
	Distance from city	0.014	15 (Km)	350 (Km)	–	–	J-shaped/Monotonically decreasing	
	Distance from power lines	0.050	500 (m)	10 (Km)	15 (Km)	60 (Km)	Sigmoidal/Symmetric	
	Distance from transport network	0.032	20 (Km)	–	–	200 (Km)	Linear/Monotonically decreasing	
	Total days of cloud cover	0.11	20 (day)	–	–	50 (day)	Sigmoidal - Monotonically decreasing	
	Total days of snow and rain	0.091	40 (day)	–	–	60 (day)	Linear/Monotonically decreasing	
	Dusty days	0.053	20 (day)	–	–	50 (day)	Sigmoidal - Monotonically decreasing	
Constraint Parameter								
		Urban	Transport network	Wetland	Protected areas		Water Resources	Dense forest
	Privacy	500 m	250 m	500 m	1000 m		–	–

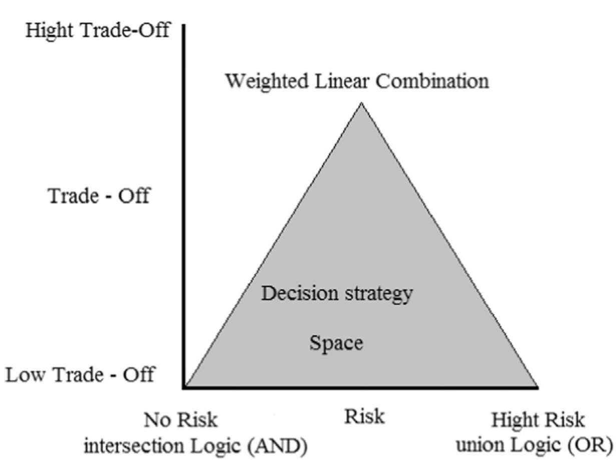


Fig. 4. Decision strategy of WLC.

(Renewable Energy), Warm and Dry Areas (Desert) Management specialties in weighting and prioritization of criteria as well as land use planning and evaluation by Multi-criteria evaluation and Paired comparison. Weighting were scored in terms of the hourly rate of between 1 and 9, so that the interaction among weights and priorities took place according to expertise ideas on the basis of technical and administrative rules for solar power plants as well as environmental regulations. Then, weight matrix was prepared and the final weight of each layer was calculated and normalized with respect to its degree of importance and obtained weight was applied to each layer in combination stage using one of the MCE method.

As the result intervals of fuzzy values associated with obtained weight are presented in (Table 1) for each measure using AHP Method in terms of fuzzy values.

2.3.3. *Final combination of criteria*

To combine the layers obtained by using the calculated weights, Multi Criteria Evaluation (MCE) method is used. This evaluation is most commonly achieved by one of three procedures [36]. The first involves Boolean overlay, whereby all criteria are reduced to logical statement of suitability and then combined by means of one or more logical operators such as intersection (AND)

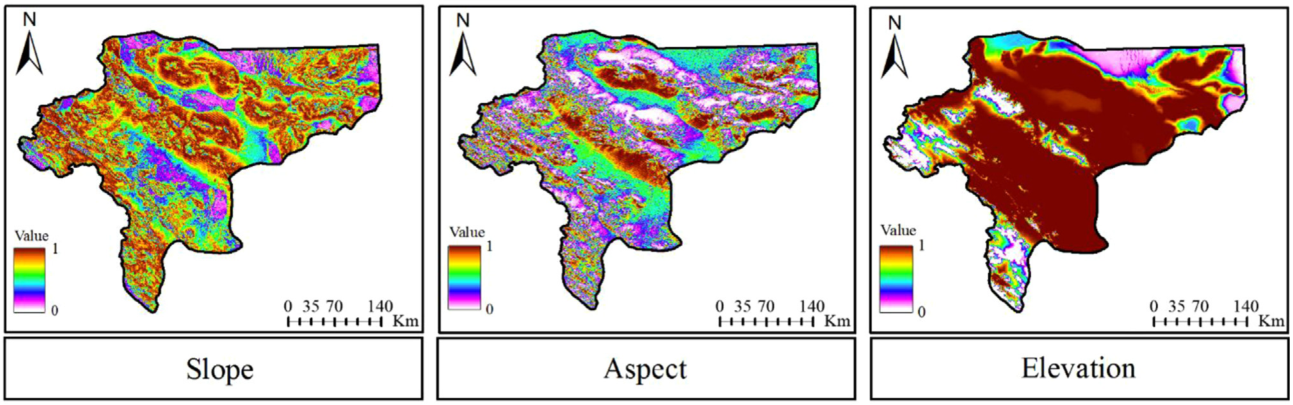


Fig. 5. Fuzzy slope, aspect and elevation indexes. Zero Value indicates low potential and one value represents the highest proportion in accordance with the purpose (solar power plant locating).

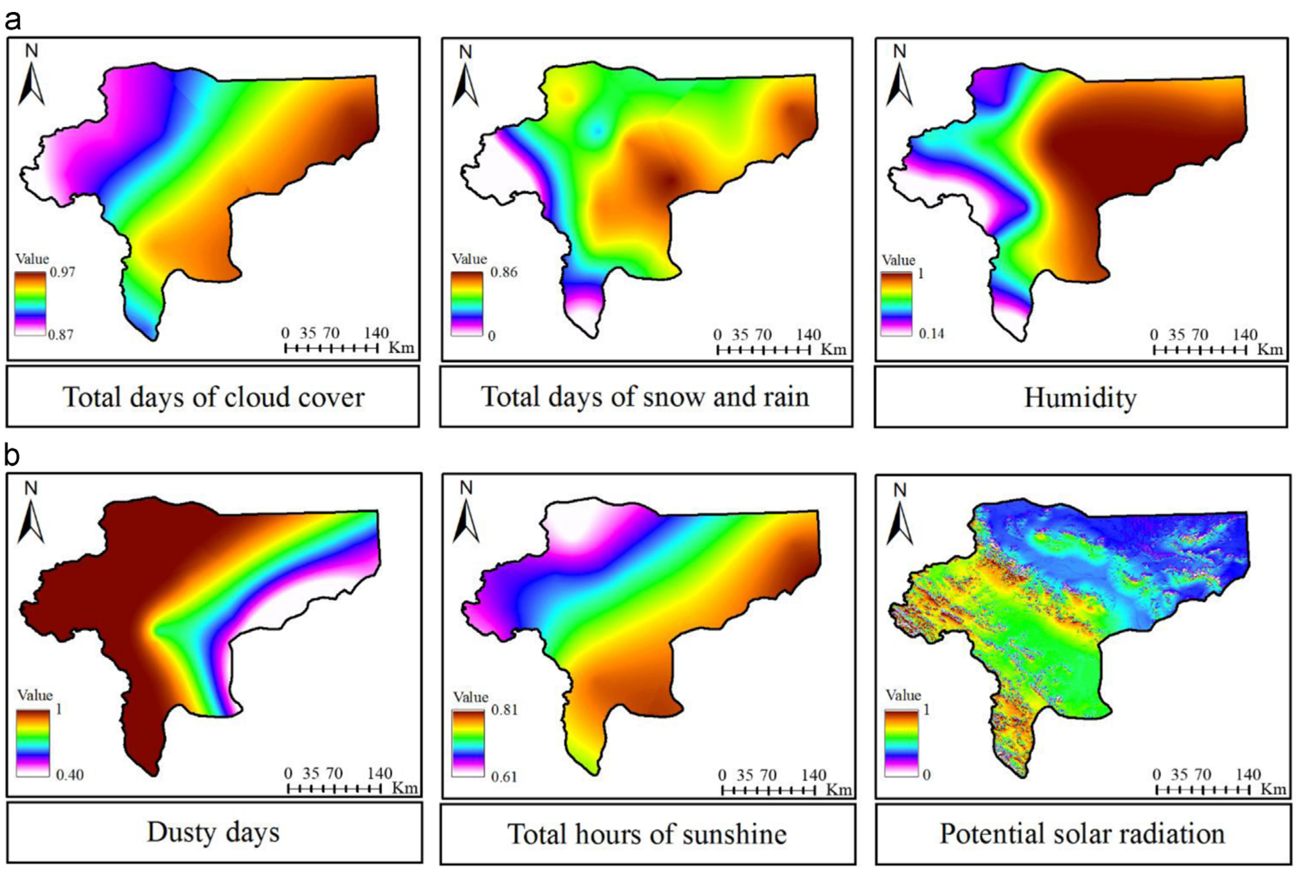


Fig. 6. (a). Atmospheric and climatic factors influencing the location of solar energy. Due to the circumstances, in some cases the zero value (totally inappropriate) and one value (perfect) is not observed in the region. Fig. 6 (b). Atmospheric and climatic factors influencing the location of solar energy.

and union (OR). If the criteria are combined with a logical AND (the intersection operator), a location must meet every criteria for it to be included in the decision set. If only a single criterion fails to be met, the location will be excluded. Such a procedure is essentially risk-averse, and selects location based on the most pessimistic strategy possible – a location succeeds in being chosen to the extent that is worst quality passes the test. On the other hand, if a logical OR (union) is used, the opposite applies – a location will be included in the decision set if only a single criterion passes the test. This is thus a very optimistic strategy, with (presumably) substantial risk involved.

The second is known as weighted linear combination (WLC) which exactly is applied in this study, is an analytical method that can be used when dealing with multi-attribute decision making (MADM) or when more than one attribute must be taken into consideration. Every attribute that is considered is called a criterion. Each criterion is assigned a weight based on its importance. The results are multi-attribute spatial features with final scores. The higher the score, the more suitable the area [37]. With WLC, factors are combined by applying a weight to each followed by a summation of the results to yield a suitability map:

$S = \Sigma wi\ xi$, where $S=$ sustainability
$W_i =$ weight of factor i
$X_{i=}$ criterion score of factor i

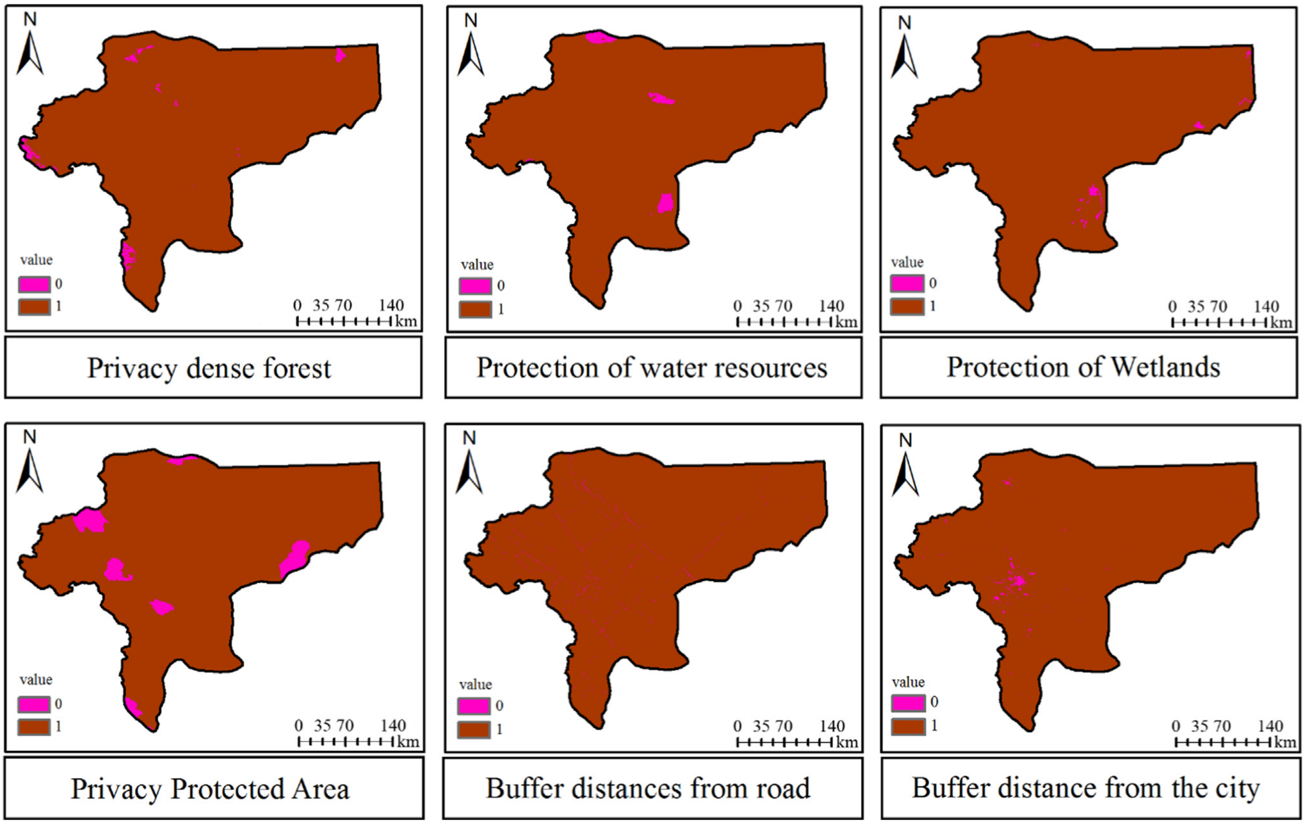


Fig. 7. Constraint parameter influencing the location of solar energy.

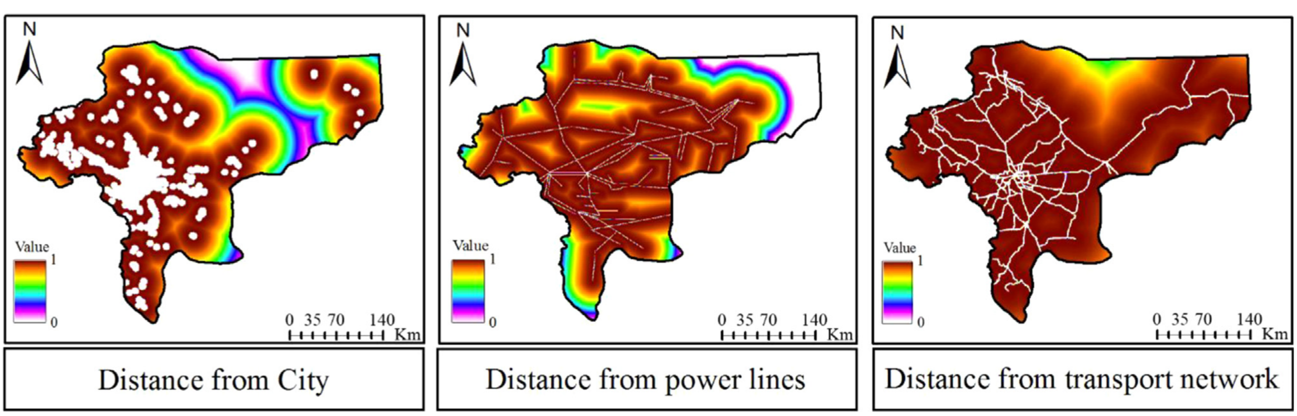


Fig. 8. Urban infrastructure influencing the location of solar energy. Since the solar power plants are intended to supply energy to cities and human activity, these criteria are considered as an important element in determining the suitable location of the solar power plant.

$S = \Sigma w_i x_i^* \prod c_j$ where $C_j =$ criterion score (0/1) of constraint j
$\Pi =$ product

WLC allows factors to trade off their qualities. A very poor quality can be compensated for by having a number of very strong qualities. This operator represents neither an AND nor an OR – it lies somewhere in between [38]. It is neither risk averse nor risk taking. Rather, it lies in between the extremes of complete pessimism and complete optimism (Fig. 4).

The third option for multi-criteria evaluation, known as an ordered Weighted Average (OWA) for Multi-Criteria Evaluation has the ability to offer a complete spectrum of decision strategic along primary dimension of the degree of risk aversion in the solution.

2.3.4. Extracting the restrictive layer

The last step in identifying the suitable areas for sun plan site selection was to remove protected areas, Wetlands and dense forest from the final map of combination of the layers by Boolean overlay method which has explained above, known as unsuitable applications for the site selection. It means that these areas which the value of their pixels are 0, are not suitable for the goal.

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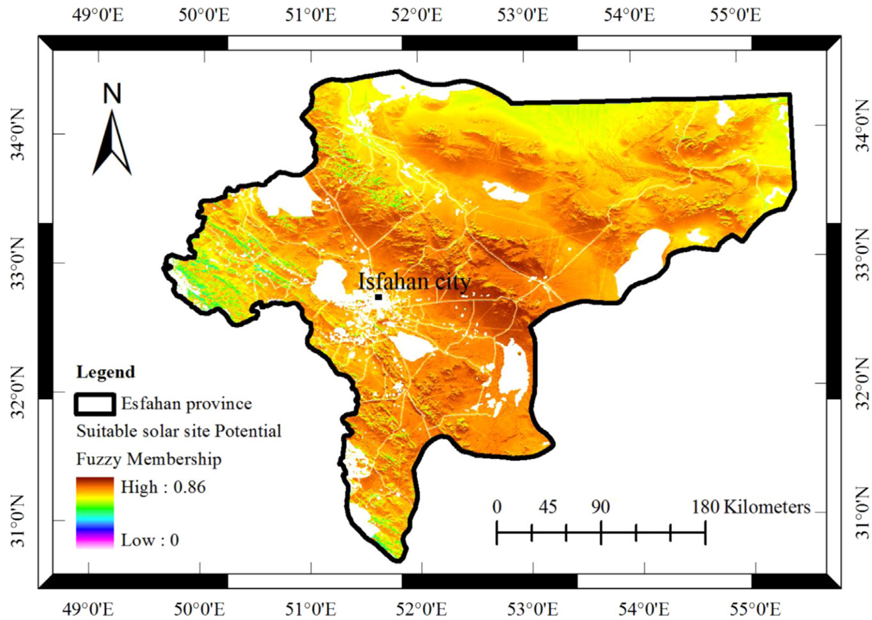

Fig. 9. Land suitability of Isfahan province in order to locate solar power plant. Based on this, areas with zero value have no capacity and land values above 0.7 are the best places for development and construction of solar power plants.

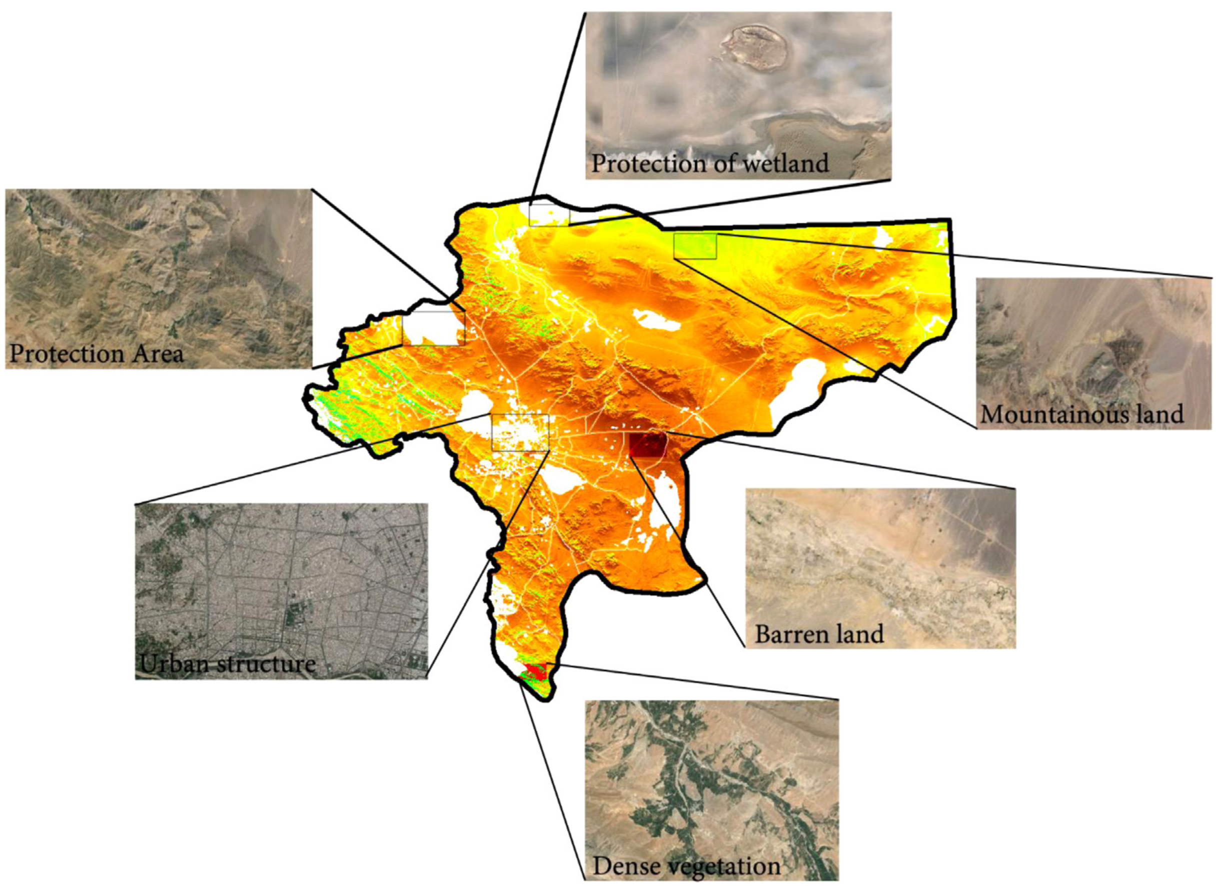

Fig. 10. Compare the ability of different types of zones with their current land use.

3. Result

Based on maps derived from the factors contributing to the construction of solar power plants, Isfahan province, considering its special topography that is due to the presence of mountainous terrains, vast plains and lowland desert regions, is quite heterogeneous in terms of direction and gradient. Thus, the study area in terms of direction measure in most parts, and the prevailing directions of North, Western North, East and North West, enjoys little desirability for this application. An altitude of over 2000 m of Western and Southern mountainous terrains of the province has reduced desirability of these regions. This is while, the more we move to the east of the region, the height of the region is reduced because of the approaching desert regions, and its desirability for constructing a power plant will increase as a result Fig. 5.

Western parts of the region, due to them having a higher altitude, have higher humidity. Approaching the East and North and consequently desert regions and the reduction of height will lead to a decrease in moisture content and an increase in desirability of the region in terms of this factor. East of the province, due to it having moisture content of less than 30%, is the best area for this application in terms of its climatic factor. A reduction of descending trend of moisture from West to East, and the temperature increase in the meantime, will reduce rainfall and cloudy days and the days with snow and rain. As a result, Western and Southern regions exhibit lower levels of suitability in the number of cloudy, snowy and rainy days and total hours of sunshine.

This is while the number of days with snow and rain in the West and South of the province are more than 60 days.As a result, the potential of these areas for contributing to this project is very little. But the Eastern parts of the province, due to the lower number of rainy days, enjoy higher desirability.

Reducing the moisture content and subsequent reduction of rainfall and cloudiness of the region from West to the East, and South to the North of the region, as well as approaching the desert regions, have caused the dusty days in these areas to increase and their desirability to be less than the southern and western half of the area under study. The climatic factors listed in the western half of the region decrease this measure to less than 20 days in the year, which make this part quite appropriate for the solar power plant construction in terms of this climatic factor (Fig. 6). The general increasing trend in the amount of radiation is visible as we move north to south and east to west. The reason is that the latitude decreases along north to south and the elevation increases along east to west and north to south.

The total sunshine hours have increased from West to East of the region due to the increase of the sun angle, and have enhanced the desirability of this part of the province. This is while, because this measurement is more than 2500, the desirability of this region for this application is more than 0.61. Also, due to there being with 3211 h/y sunny hours, the potential of the region does not reach to maximum in any part.

It has been considered that the total municipal laws, environmental and ecological requirements and safety have caused the city cores, protected areas, forests, transportation roads, water resources, wetlands in the province and appropriate ecological space for network of roads, power transmission lines and cities to be viewed as areas without power and, thus, are unusable for solar plant construction (Fig. 7) (Fig. 8).

The final map obtained by adjusting the above-mentioned maps, considering the weight of each one and reducing the mentioned limitations show that, because of the existence of climatic factors, solar radiation in most areas and the seasons of the year, as well as topography conditions, all areas of the province have a moderate to high potential for constructing solar power plants. But more specific results of this study indicate that, the more we approach from the western half to the eastern half and from north to south, the desirability and potential of the area for construction of solar power plants increases. This is because consideration of all climatic, environmental, geomorphologic and regional factors, especially the number of sunshine hours and solar energy potential and the number of cloudy days, among other included factors, have more weight and desirability in these areas. It can also be stated that, in terms of the administrative and political divisions, Isfahan, Borkhar, Nain, ShahinShahr and Meimeh towns are located in these zones Fig. 9.

According to Fig. 10, vulnerable areas are in arid lands, while areas without power are in the zones that have ecological value or urban areas. Therefore, this confirms correctness of the criteria used and the obtained final map.

4. Conclusion

With economic development and population growth, the global demands and domestic requirements of Iran are increasing based on widespread use of fossil fuels. Due to the use of new energies such as solar energy, providing a portion of the electrical and thermal energy required for cities and villages in order to achieve the goals of sustainable development and reduction of fossil fuel consumption is essential. One of the early studies on the utilization of this energy is the identification of suitable areas with high potential.

In this study, the potential in the Esfahan province for locating solar panels was investigated based on a number of interrelated factors of environmental, geomorphological, location, climatic and constraints criteria by using AHP, FUZZY and WLC methods. The results show that the maximum value that is reached is 0.86 and the minimum value of the ranking is 0 (the worst alternative).

Generally in studies about site selection after identifying appropriate sites and areas, social indicators such as population density, income level, and the dominant livelihood are involved to prioritize the right place option. therefore, these indicators were not direct priority in this study, but indirectly were considered in parameters such as distance from the city, distance from roads and industrial centers that should be directly met in the choice of the best location which is not the ultimate goal of this study.

The varying carrying capacity of the region under consideration shows that 11.9% of the valid surface (12,735 km^2) is not adequate to implement a solar plant, 8.18% (8754 km^2) has good carrying capacity, and 76.8% (82,189 km^2) has very good ability. Finally, the remaining 3.12% (3339 km^2) is excellent for this purpose, which is located in the central, eastern and south-eastern sections. Therefore, this province has a high potential and suitability to install solar plants.

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