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POSITIONING THE LOCATIONS OF SOLAR DESALINATION PLANTS - CASE STUDY IN MAKRAN COASTAL RANGE

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Abstract: One of the primary needs of humans and industries are accessing adequate freshwater. Desalination of seawater has become increasingly important to provide water supplies. In this context, one of the most significant factors is freshwater's production cost mainly related to energy consumption. The energy factor which is usually produced by fossil fuels can have a significant economic impact on the construction of desalination plants. Moreover, low-cost fossil fuels will be limited in the near future. Therefore, to preserve these valuable sources, to prevent environmental damages, and to provide the demanded energy, there is no approach to the use of clean and renewable energies, such as wind and solar energy. Using solar energy can be the best approach to the power supply. For this purpose, finding the best location to build power plants is necessary because their locations affect the cost of production and transmission of energy. This study aims to find the best locations for constructing the desalination plants that use solar energy based on two sets of parameters: (1) desalination plant construction parameters, and (2) solar power plant construction parameters. In this paper, the initial information is identified through the Fuzzy Analytical Hierarchy Process (FAHP) and the Analytical Hierarchy Process (AHP) decision-making system. Then, the information, locations, and effective parameters to find the best locations for building the solar desalination plants are analyzed using GIS. The results are mapped in the format of a position model. Furthermore, a case study is proposed for the feasibility of the model.

1 INTRODUCTION

One of the primary needs of humans and different industries are accessing adequate freshwater. Recently, due to the global population growth and the limitation in of freshwater resources, desalination of seawater has become increasingly important in order to provide water supplies.

In the desalination of seawater, one of the most significant factors is production cost of freshwater which is related to several parameters, such as input water quality, technology type, plant capacity, and energy consumption. The energy factor which is usually produced by fossil fuels can have a significant economic impact on the construction of desalination plants.

Recently, the energy consumption trend has been dramatically increased, especially in developing countries. For instance, Iran has the energy consumption that is higher than the global average. In fact, low-cost fossil fuels will be slowly but surely limited in the near future. Therefore, to preserve these valuable sources for future generations, to prevent environmental damages, and to provide the demanded energy, there is no approach to the use of clean and renewable energies, such as wind and solar energy.

Using solar energy can be the best approach to the power supply. For this purpose, finding the best location to build power plants is necessary because their locations have effects on the cost of production and transmission of energy. Makran Coastal Range has various problems related to providing the electricity demand and growing the population. However, the Makran Coastal Range has a high potential to use solar energy as renewable energy. This study aims to find the best locations for constructing the desalination plants that use solar energy based on two sets of parameters: (1) desalination plant construction parameters, and (2) solar power plant construction parameters.

In this paper, the initial information related to each province in the Makran Coastal Range is identified through the Fuzzy Analytical Hierarchy Process (FAHP) and the Analytical Hierarchy Process (AHP) decision-making system. Then, the information, locations, and effective parameters to find the best locations for building the solar desalination plants are analyzed using ArcGIS 10.3 software. The results are mapped in the format of a position model. To validate the data and information for statistical studies of various areas, several decision-making methods are used and then the results are compared with each other.

2 REVIEW OF RELATED WORKS

Recently, Multi-criteria Decision Making (MCDM) methods have been used for energy planning, such as finding the locations for the installation of PV panels (Wang, T. and Tsai 2018; Kotireddy, Hoes, and Hensen 2017). The results of the mentioned methods are based on weighted averages, priority setting, and outranking (Aydin 2009). In the MCDM approach, a set of criteria based on the problem of a project are established. Then, the criteria are prioritized based on the assigned weights. After prioritizing the criteria, a method is applied to rank alternatives. Finally, the best-ranked alternative as the optimal solution is proposed. The final decision is the integration of decision-aiding science and formulating recommendations (Haurant, Oberti, and Muselli 2011; Wang, J. et al. 2009; San Cristobal 2012; Li 2013).

Several methods, such as weighted product method (WPM), weighted sum method (WSM), fuzzy set method, and AHP can be applied in the MCDM; however, the most popular one is AHP because in this method prioritizes the alternatives in an understandable and simple way (Wang, J. et al. 2009; Pohekar and Ramachandran 2004; Gastli, Charabi, and Zekri 2010). Therefore, many research projects proposed the best location for solar installation by applying AHP (Sindhu, Nehra, and Luthra 2017; Balo and Sagbansua 2016; Samanlioglu and Ayag 2017; Uyan 2013). However, there is limited research about the fuzzy MCDM approach that includes the FAHP model.

An integrated model based on fuzzy MCDM and Geographical Information System (GIS) proposed to identify the best locations for the solar plant installation (Guptha, Puppala, and Kanuganti 2015). They used FAHP and GIS for determining the relative importance of the criteria and generating the database of the alternatives. Asakereh et al. (Asakereh, A. et al. 2014) studied the use of FAHP and GIS to locate the most appropriate sites for solar energy farms in Iran. In addition, a GIS-based Fuzzy-AHP method presented to install solar photovoltaic farms, based on techno-economic and environmental aspects. They evaluated the locations of solar farms in three steps: (1) creating the criteria layers in the environment of GIS using Fuzzy logic and fuzzy membership functions; (2) using AHP to weigh the techno-economic and environmental criteria; and (3) visualizing the results on the map (Asakereh, Abbas, Soleymani, and Sheikhdavoodi 2017).

3 METHODOLOGY

For positioning the locations of solar desalination plants, the criteria that affect the location of solar plants and desalination plants should be defined. Based on the interviewing experts, and performing a literature review, different quantitative and qualitative criteria, such as technical, economic, environmental parameters can have an impact on positioning the locations of solar desalination plants. The mentioned criteria can be classified into two main classes: (1) parameters of positioning the locations of solar plants, and (2) parameters of positioning the locations of desalination plants, as shown in tables1 and 2.

After defining the criteria, FAHP and AHP methods are applied for determining the priority of criteria and making the decision based on the comparison the criteria (Table 3). Then, the layers of data and criteria should be created in the environment of GIS to consider the mentioned parameters. Finally, the locations of solar desalination plants are determined.

Table 1: Parameters of positioning the locations of solar plants

Parameter (units)	Description
Aerosol (μg/m^3)	A suspension of fine solid particles or liquid droplets in the air. Aerosols scatter and absorb incoming solar radiation.
Elevation (m)	A height from a reference geoid/Mean sea level (MSL) to a geographic location. High elevation locations absorb more solar radiation (Aldobhani 2014).
Sunshine duration (hr)	A climatological indicator, measuring the duration of sunshine in a given period (a month or a year) for a given location.
Temperature (C°)	The efficiency of the solar panel depends on its temperature. The temperature of the solar panel that is related to the temperature of the environment and the intensity of the solar radiation (Dubey, Sarvaiya, and Seshadri 2013).

Table 2: Parameters of positioning the locations of desalination plants

Parameter (units)	Description
Area of coastal region (m^2)	The size and area of the coastal region have an effect on positioning the locations of desalination plants.
Distance from the transportation network (m)	Cost of transporting the water increases based on the distance from the transportation network, such as roads and railroad network (Hodges, Hansen, and McLeod 2014).
Distance to residential areas (m)	Distance to residential areas can have a positive effect on positioning the locations of desalination plants.
Distance from the risky industries (m)	Distance from risky industries, such as petroleum refining and petroleum fuel manufacturing should be maximized because of critical issues.
Distance from vulnerable areas (environmental index) (m)	Desalination plants have a negative impact on the ecological system of the marine environment (Al-Sharrah, Lababidi, and Al-Anzi 2017). Therefore, the distance between desalination plants and the vulnerable environmental areas should be maximized.
Population density (people/km^2)	Population density is one of more important in determining the capacity and location of desalination plants (Gao et al. 2017).
Soil liquefaction	This parameter plays an important role in marine structures because the loss of soil causes catastrophic consequences (De Groot et al. 2006). Therefore, the soil liquefaction of the region should be analyzed.

Table 3: Linguistic terms to compare criteria in AHP and FAHP method for decision-making (Saaty 1980)

Scale	Definition
1	Equally important
3	Weakly important
5	Fairly important
7	Strongly important
9	Absolutely important
2,4,6,8	The intermediate values between two adjacent scales

4 IMPLEMENTATION AND CASE STUDY

In order to illustrate the proposed method, Iran's Makran coast was chosen. Makran is a coastal land in southeastern Iran and southwestern Pakistan, spreading across the Gulf of Oman from Ras al-Khaw in the west of Jask to Las Bela in the southwest of Balochistan, Pakistan.

As mentioned in Section 3, different criteria that affect the locations of solar desalination plants were weighted by AHP and FAHP. For this purpose, solar energy data, desalination parameters, spatial information and digital maps related to the Makran were collected from meteorological stations and Iran National Cartographic Center (INCC). Then, the criteria were weighted based on AHP and FAHP, as shown in Table 4 and 5.

Table 4: Parameters of positioning the locations of solar plants

Parameter	AHP	FAHP
Aerosol (μg/m^3)	0.1685	0.1996
Elevation (m)	0.0499	0.1404
Sunshine duration (hr)	0.6669	0.4950
Temperature (C°)	0.1147	0.1650

* Consistency ratio AHP = 0.18 and consistency ratio FAHP = 0.02

Table 5: Parameters of positioning the locations of desalination plants

Parameter	AHP	FAHP
Airports	0.0407	0.0505
Coastline	0.1609	0.3763
Earthquake-hit area	0.0464	0.0650
Environmental index	0.1902	0.1388
Fault	0.0531	0.0440
Harbor	0.1484	0.0834
Population density	0.0893	0.0951
Railroads	0.0844	0.0606
Roads	0.1866	0.0862

* Consistency ratio AHP = 0.05 and consistency ratio FAHP = 0.10

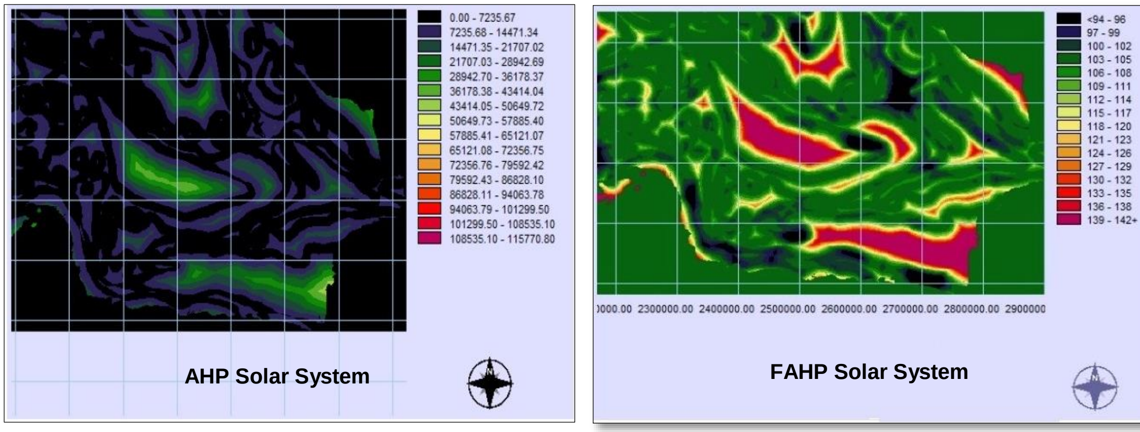


Figure 1: Results of using AHP and FAHP for positioning the locations of solar plants

In the next step, the locations and criteria as input layers were entered into ArcGIS 10.3 for the location analysis. As shown in Figures 1 and 2, the best location for positioning the locations of solar plants and desalination plants were determined using AHP and FAHP methods. Then, the output layers of AHP method, as well as FAHP method, were integrated to have two maps for analyzing the proper locations for solar desalination plants based on the two different methods (AHP and FAHP), as shown in Figures 3 and 4. Finally, the final outputs of solar desalination plants' locations were integrated into the unique layer to visualize the best locations for building the solar desalination plants on the final map, as shown in Figure 5.

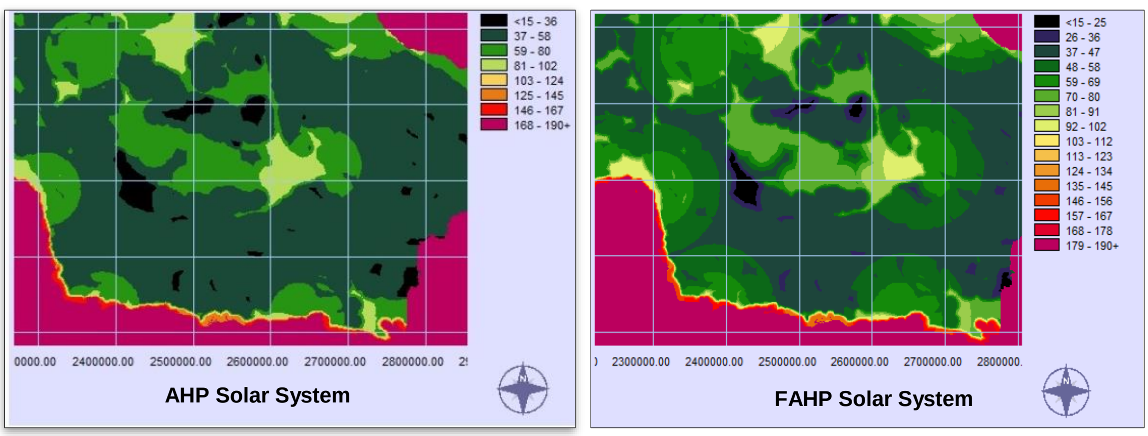


Figure 2: Results of using AHP and FAHP for positioning the locations of desalination plants

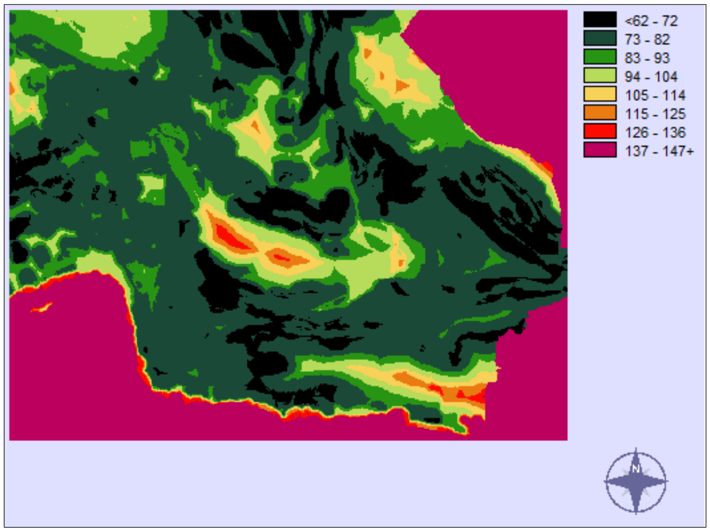


Figure 3: Map of site selection for solar desalination plants using AHP method

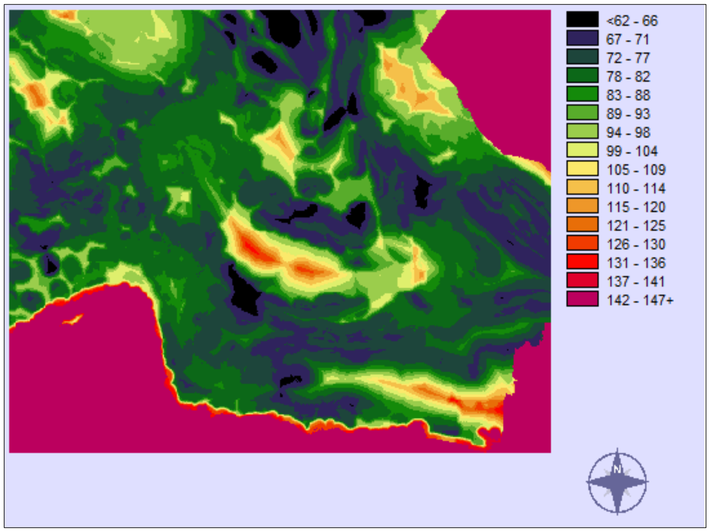
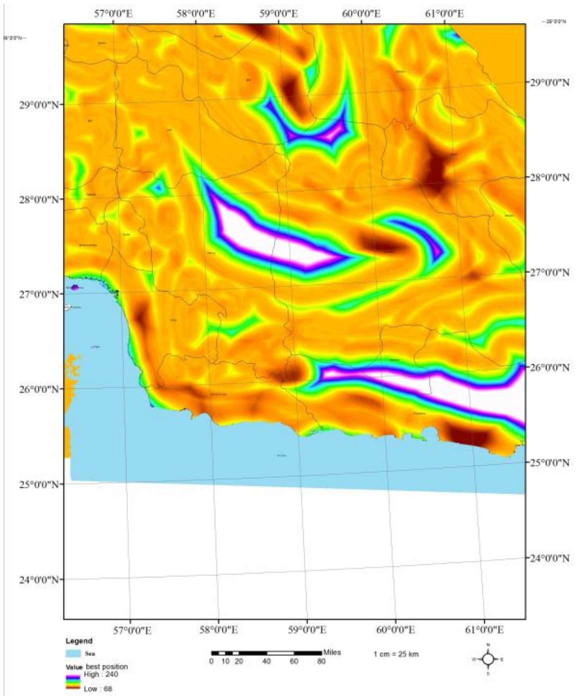
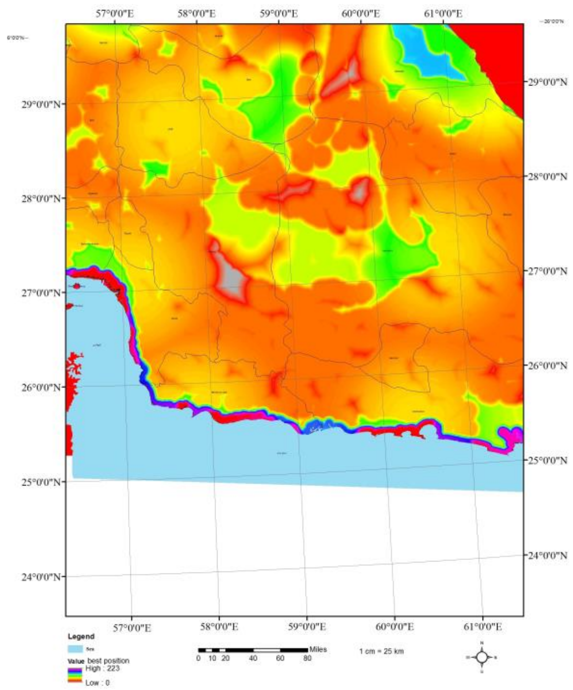


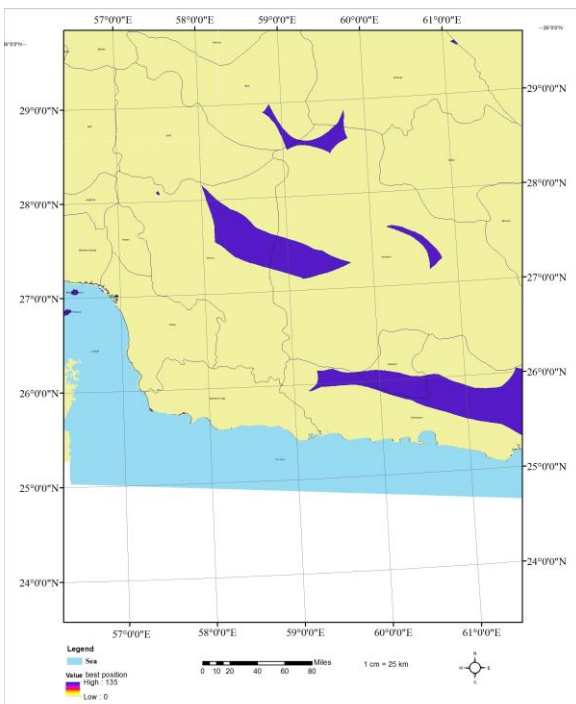
Figure 4: Map of site selection for solar desalination plants using FAHP method



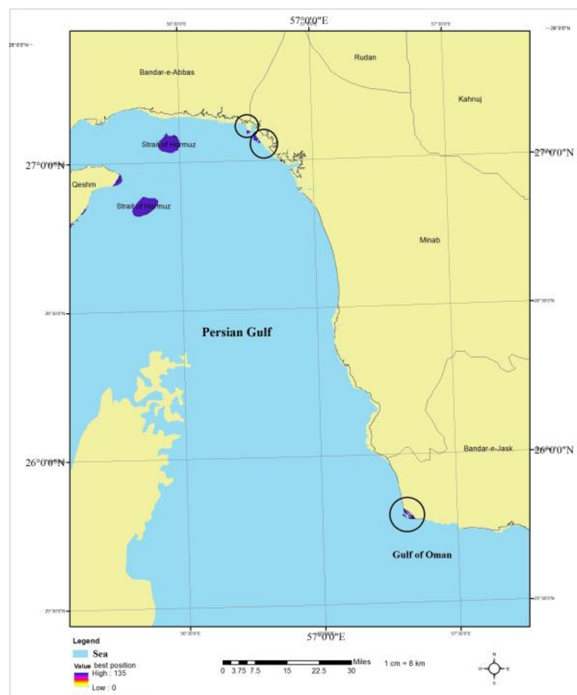
(a) Solar plants' locations



(a) Desalination plants' locations



(c) High important locations of solar desalination plants



(d) Acceptable locations of solar desalination plants

Figure 5: Final results of site selection for solar desalination plants

As shown in Figure 5 (C), some sites were identified as high important locations. However, three sites are acceptable for building solar desalination plants because they are located in the coastal area. The spatial details of the mentioned locations are shown in Table 6.

Table 4: Spatial details of high important coastal locations for building the solar desalination plants

No.	City	Starting Latitude	Starting Longitude	Ending Latitude	Ending Longitude
1	Minab	X=2274098.484	Y=389815.648	X=2274265.172	Y=388251.957
2	Minab	X=2276646.427	Y=388601.208	X=2279480.120	Y=385203.951
3	Jask Port	X=2332941.332	Y=248403.183	X=2337500.641	Y=244377.275

Among the three ideal location, Jask port can be the best location due to the three reasons: (1) the area of location is large enough to build the solar desalination plant; (2) Jask port is one of the major ports in Iran that several facilities, such as equipment and human resource can be available quickly; and (3) the transfer of the seawater from the solar desalination plant is easy and reasonable due to the distance of plant to the port.

5 CONCLUSION AND FUTURE WORK

Site selection for the solar desalination plants requires the decision making processes based on both quantitative and qualitative criteria. To find the best location, MCDM model have to apply on multiple criteria. In this study, the effective criteria related to building the solar plants and desalination plants in the Makran Coastal Range were identified by using AHP and FAHP. Then, the high important locations for the solar desalination plants were determined using the analysis in GIS. Finally, three ideal locations were selected in the coastal area.

The proposed criteria and method improves the posting the locations of solar desalination plants. Also, this study demonstrated the using of spatial analysis in the GIS for identifying potential solar and desalination plants' locations.

Availability of other information, as well as additional criteria, could further improve site selection results. Therefore, future work will also include new criteria and models for positioning the locations of plants.

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