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Environmental Planning for Wind Power Plant Site Selection using a Fuzzy PROMETHEE-Based Outranking Method in Geographical Information System

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Abstract
Selection of suitable sites for wind power plants is one of the most important decision on wind resources development. Site selection for the establishment of large wind power plants requires spatial evaluation taking technical, economic, and environmental considerations into account. This study has applied a combination of PROMETHEE and Fuzzy AHP methods in a geographical information system environment to carry out spatial site selection for wind power plants in Lorestan Province of Iran. The fuzzy analytic hierarchy process method is used to determine the weights of the criteria whereas the PROMETHEE method is used to priorities the alternatives based on the weights obtained from the fuzzy AHP. The integration of GIS and MCDM makes a powerful tool for the selection of the best suitable sites because GIS provides efficient manipulation, analysis and presentation of spatial data while MCDM supplies consistent weight of alternatives and criteria. The results showed that about 7.38 % of the area of Lorestan province is most suitable for wind power plants development. Sensitivity analysis shows that suitable zones coincide with suitable divisions of the input layers. The sensitivity analysis showed satisfactory results for the combination of PROMETHEE and Fuzzy AHP methods in wind power plant site selection.

Keywords: Environmental planning. PROMETHEE. Fuzzy AHP. GIS. Wind power plant.

Introduction

Wind energy is one of the most renewable energy resources (Noorollahi et al. 2016, Gul et al. 2018) . It is a fast growing and commercially attractive source to generate electricity (Cashmore et al. 2018) . This energy is attractive for governments and organizations due to its low economic, environmental and social costs (Van Haaren and Fthenakis, 2011) because it is a clean and renewable energy source and can minimizes dependency on fossil fuels (Panwar et al. 2011). The site selection of wind power plants is one of the most important decision on wind resources development (Latinopoulos and Kechagia, 2015, Watson and Hudson, 2015, Baban and Parry, 2001, Talinli et al. 2011) . In recent years geographic information systems integrated with multi criteria decision making (MCDM) models have been widely applied as a decision support system to assist in locating suitable sites for wind farms (Talinli et al. 2011, Asakereh

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et al. 2014, Hansen, 2005, Ayodele et al. 2018). Geographic information system (GIS) as a spatial decision support system (SDSS) affords the functionalities of integrating a large amount of spatial data into the decision-making of wind power plants development (Gorsevski et al. 2013, Simao et al. 2009, Schallenberg-Rodríguez and Montesdeoca, 2018, Mahdy and Bahaj, 2018). Using the MCDM and experts opinion can lead to a more efficient use of GIS in site selection process of wind power plants (Ayodele et al. 2018). Many studies have found evidence for the efficiency of the combination of the satellite data, GIS and MCDM in locating the best sites for wind power plant have located suitable sites for wind power plant (Villacreses et al. 2017, Gigović et al. 2017, Sánchez-Lozano et al. 2016, Ayodele et al. 2018, Bili and Vagiona, 2018, Solangi et al. 2018).

Gorsevsk and et al (2013) demonstrated the benefits of applying a spatial decision support system (SDSS) framework for evaluating the suitability for wind farm siting in Northwest Ohio. The framework integrates environmental and economic criteria and builds a hierarchy for wind farm siting using weighted linear combination (WLC) techniques and GIS functionality.

Asakereh et al (2014) used a fuzzy analytic hierarchy process (Fuzzy AHP) and geographical mapping models using geographical information system to locate the most appropriate sites for energy farms in Shodirwan region in Iran. GIS interpolation showed that annual energy insolation in Shodirwan is very good and can be used for potential energy farm locations.

Latinopoulos and Kechagia (2015) proposed and implemented an integrated evaluation framework for selecting the most appropriate sites for wind-farm development projects. This framework focused on the combined use of geographic information systems and spatial multi-criteria decision analysis, aiming to provide a decision tool for wind-farm planning at the regional level. The proposed decision tool is able to get the optimal locations for future projects, as well as the suitability score of the already licensed projects. The results of this study supported the potential role of planners in designating areas for wind farm development.

Noorollahi et al (2016) analyzed a multi-criteria decision support system to define wind energy resources in western Iran. This study applied geographic information system to determine the potential of wind energy in Markazi province in western Iran. The multiple criteria decision making method and site selection criterion for wind resources assessment is explained and developed for the study area. Criteria of equal importance were investigated, including technical, environmental, economic and geographic standards. The results showed that 28% of the study area has capacity for installing large wind farms.

Solangi et al (2018) used a robust research framework comprising of factor analysis (FA) of techno-economic and socio-political factors, and a hybrid analytical hierarchy process (AHP) and fuzzy technique for order of preference by similarity to ideal solution (FTOPSIS) have been used for the prioritization of sites in the southeastern region of Pakistan. The results of this study reveal economic and land acquisition as the most significant criteria and sub-criteria, respectively. This study provided a comprehensive decision support framework comprising of FA and a hybrid AHP and Fuzzy TOPSIS for the systematic analysis to prioritize suitable sites for the wind project development in Pakistan.

Bili and Vagiona (2018) developed a mechanism for determining and evaluating the suitability of areas for siting wind farms, using a combination of Multi-criteria Data Analysis and Geographic Information Systems (GIS). This study was carried out on the island of Andros, Greece. The process involved a four-step gradual exclusion of unsuitable areas for siting wind farms and an evaluation of compatible areas using criteria both from this country's institutional framework and international literature. During the evaluation of available areas, using the Analytic Hierarchy Process (AHP), pairwise comparison was used in which the weightings were determined by a group of experts. Despite the very favourable wind conditions on Andros, only a small percentage of its total area was given a high score for siting wind farms, due to the strict constraints imposed. The proposed methodology for the optimum siting of wind parks can be used in any study area and at any planning scale (local, regional, national level).

Ayodele (2018) used a geographic information system-based model for wind farm site selection using interval type-2 fuzzy analytic hierarchy process was proposed and implemented to determine the suitable wind farm sites in Nigeria. The model focused on the use of fuzzy sets to represent expert's linguistic judgement with the aim of addressing the issues of uncertainty, vagueness and inconsistency in wind farm site selection decision making. This paper could serve as a first-hand scientific information for decision makers and planners in selecting the optimal suitable site for wind farm development. Although, Nigeria was considered as the case study, the methodology can be severally applied to any region in the world.

PROMETHEE is one of MCDM methods developed by Brans(Brans, 1982). The technique is the outranking method and has been utilized in various fields including regional planning(Ogrodnik, 2017; Juan et al. 2010), energy sources (Oberschmidt et al. 2010, Tabaraee et al. 2017), business (Albadvi et al. 2007; Nassereddine and Eskandari, 2017; Elevli and Demirci, 2004) and indutry(Sen et al. 2015; Govindan et al. 2017). The site selection of wind power plant in Lorestan province and the location of the region in the arid zone of Iran have highlighted the significance of renewable energy in this area. Considering these conditions, the present study aims to use the renewable energy in the region by locating the best sites for wind power plant. Having used the fuzzy analytic hierarchy process(AHP) and PROMETHEE methods in combination with GIS, the optimal zones were located.The fuzzy AHP method is used to determine the weights of the criteria whereas the PROMETHEE II method is used to prioritise the alternatives based on the weights obtained from the Fuzzy AHP. The proposed method can be useful for site selection of wind power plant and in the planning and management of renewable energy resources.

Material and Methods

Case Study

Loresatn province is located in western Iran, bordering the provinces of Ilam, Kermanshah, Hamedan and Markazi. Loresatn province is located at 33°58′18″ north latitude and 48°39′88″ east longitude (Fig. 1). It has an area of 28,392 km^2(1.7 % the area of the country) and has a population of 1.75 million(Ghobadi et al. 2015). The province comprises 11 counties, 24 cities, 29 districts, 85 subdistricts, and 2,864 villages(Rezaee et al. 2018). Loresatn province encompasses parts of the Zagros mountain range, which strongly influences local wind strength. The difference in elevation from the lowest point (Poledokhtar plain at 500 m in elevation) and the highest point (Oshtorankuh summit at 4150 m) is about 3650 m(Ghadirian et al. 2017). This difference is the root of the diversity of climate and weather and is a positive factor for wind generation development. The maximum temperature is 47.4 °C in summer and the minimum is -35 °C in winter(Hatami et al. 2018).

In order to create a new hybrid MCDM model that would be able to identify the best space for wind power plant, a set of technical, economic and environmental criteria is selected and a GIS-based approach is developed to spatially represent and analyze the collected data. The proposed methodology for the site selection process of wind power plant is given in Fig. 2. The proposed methodology has six main steps. The first step is the identification of technical, economic, and environmental parameters. All criteria related with wind power plant site selection are identified by searching the literature(Latinopoulos and Kechagia, 2015, Hansen, 2005, Aydin et al. 2013, Noorollahi et al. 2016, Ayodele et al. 2018, Bili and Vagiona, 2018), current Iranian laws and legislations, and interviews with experts.

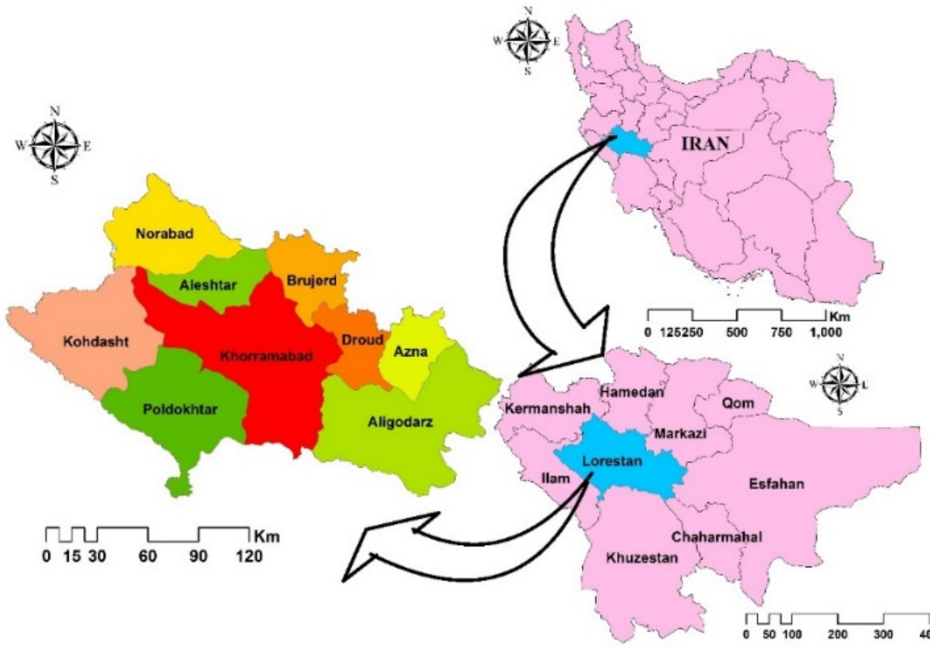

Figure 1. The study region

Methodology

In step 2, Each criterion is represented as separate layers. Fundamental analyses were done on them to build up a database in the GIS. Thirteen information layers are converted to a raster format (Table 1). In step 3, a innovative method has been used to weight the criteria. It mixes fuzzy AHP and PROMETHEE technique to determine the weight of each criteria(Peko et al. 2018, Hanine et al. 2017, Pirdashti and Behzadian, 2009). The calculations were done in MATLAB®.

In step 4, exclusionary areas was prepared to identify those criteria that are capable to describe various constraints related to wind power plant development, and then to create exclusionary map layers corresponding to each constraint criterion. All the weighted layers were added together in the raster calculator to a final suitability map in step 5 and the land suitability map has values into five zones and illustrates the suitability for new wind power plant development based on the criteria as well as the weights chosen in step 6.

Table 1. Data sources for input layers in wind power plant site selection for Lorestan province

Layers	Source
Land cover/use	Images taken from the TM sensor in 2017
Distance from fault lines	1:100,000 geological map prepared by the (National cartographic center of Iran, 2017)
Elevation	
Slope	
Distance from rivers	
Distance from protected areas	1:25,000 topographic maps prepared by the (National cartographic center of Iran, 2017)
Distance from urban areas	
Distance from rural areas	
Distance from the airport	
Distance from main roads	
Wind speed average	
Percentage of windy days	Synoptic station data from Lorestan Province(2017)
Wind power density	

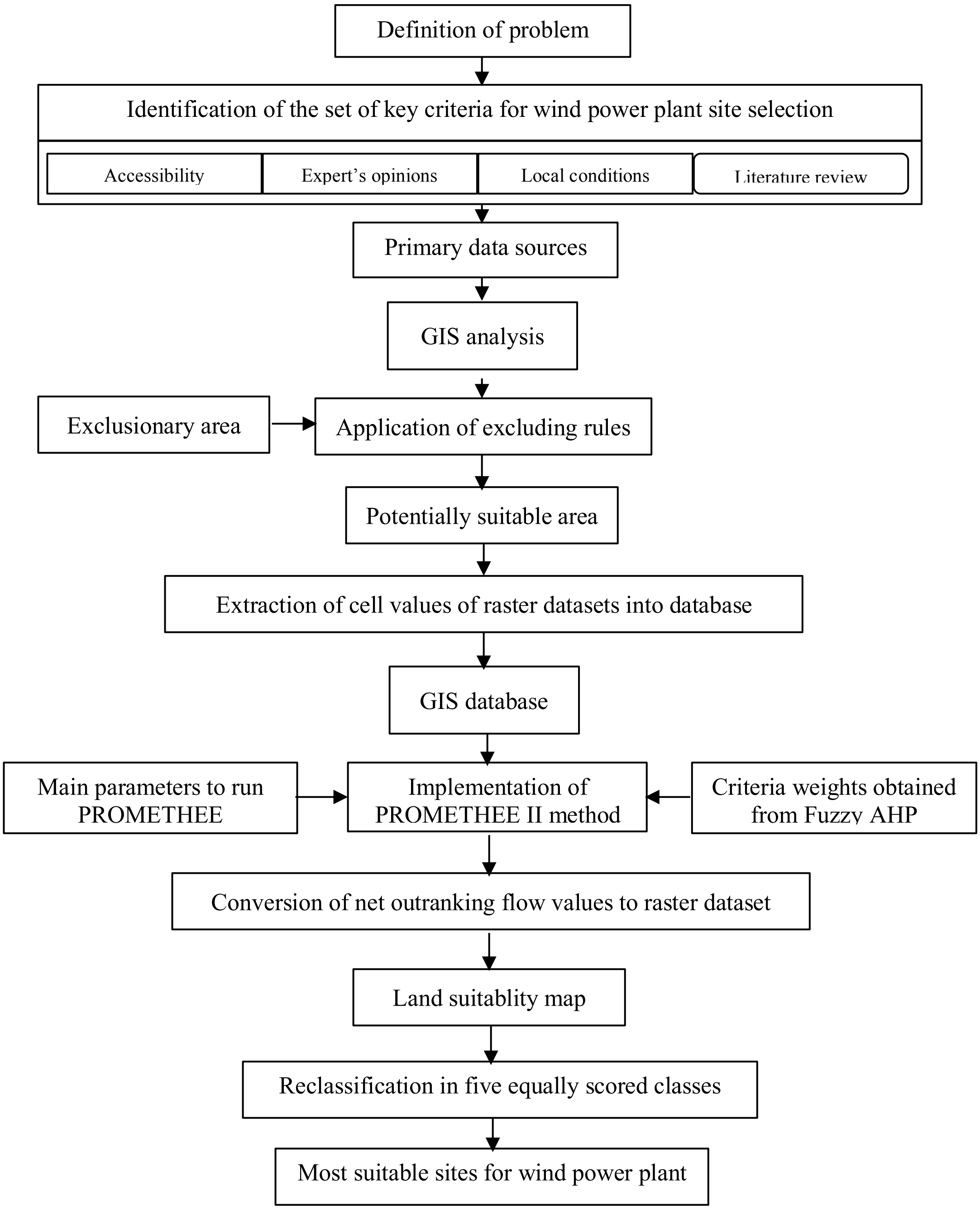

Figure 2. The process of the wind power plant site selection in proposed method

The PROMETHEE is comprehensively utilized in MCDM research. In PROMETHEE, the implementation process is set by Barns(Vincke and Brans, 1985).This technique is utilized in different scenarios such as business, governmental institutions, transportation, healthcare and education(Hanine *et al*. 2017). The second type is one of the most complete types of Prometheus This study used type II to determine weight, which incorporates the fuzzy AHP. The type II is one of the most complete types of PROMETHEE(Vincke and Brans, 1985). Main steps of PROMETHEE conducted in this study are shown as follows(Pirdashti and Behzadian, 2009, Vincke and Brans, 1985, Peko et al. 2018, Hanine et al. 2017):

Step 1: Pairwise comparisons (Fuzzy AHP is implemented in this step)

Step 2: Determine preference function (Fig. 3) (Eq. 1):

$$P_j(a,b) = F_j\left[d_j(a,b)\right] \tag{1}$$

Where Pj (a, b) shows the preference of alternatives a and b, as a function of dj (a, b).

Step 3: Calculate multicriteria preference degree (Eq. 1 and 2):

$$\pi(\mathrm{a,b}) = \Sigma\, P_j(a,b)W_j \tag{2}$$

$$\pi(\mathrm{b,a}) = \Sigma\, P_j(b,a)W_j \tag{3}$$

Where π(a, b) of a over b is defined as the weighted sum p (a, b) of for each criterion, and wj represents the weight associated with jth criterion.

Step 4: Calculate multicriteria preference flows (Eq. 4 and 5).

$$\Phi^{+}(a) = \frac{1}{n-1}\,\Sigma\,\pi(\mathrm{a,x}) \tag{4}$$

$$\Phi^{-}(a) = \frac{1}{n-1}\,\Sigma\,\pi(\mathrm{a,x}) \tag{5}$$

Where Φ^{+} and Φ^{-} are the positive outranking flow and the negative outranking flow for each alternative, respectively.

The positive and negative preference flows are gathered into the net preference flow(Eq. 6):

$$\Phi(\mathrm{a}) = \Phi^{+}(a) - \Phi^{-}(a) \tag{6}$$

Where Φ(a) is the net outranking flow.

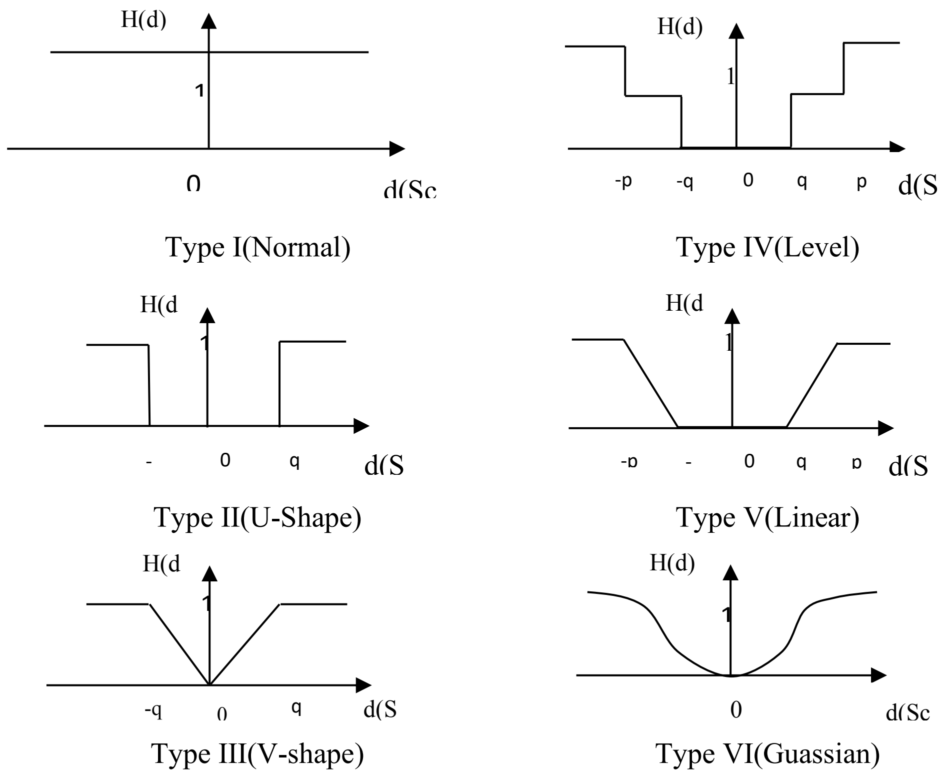

Figure 3. Preference function types of PROMETHEE method (Hanine et al. 2017)

Fuzzy AHP was used in this study to incorporate uncertainties in the expert's opinions. There are three essential steps(Ahmadipari et al. 2018; Mohammadizadeh et al. 2016; Hanine et al. 2017):

Step 1: Evaluating the relative importance of criteria using pairwise comparisons. Table 2 shows Fuzzy assessment scale in Fuzzy AHP.

Table 2. Fuzzy assessment scale in FAHP (Ahmadipari et al. 2018)

Linguistic terms	Fuzzy score
Absolutely strong	(5/2,3,7/2,4)
Very strong	(2.5/2,3,7/2)
Fairly strong	(3/2,2,5/2,3)
Slightly strong	(1,3/2,2,5/2)
Equal	(1,1,1,1)
Slightly weak	(2/5,1/2,2/3,1)
Fairly weak	(1/3,2/5,1/2,2/3)
Very weak	(2/7,1/3,2/5,1/2)
Absolutely weak	(1/4,2/7,1/3,2/5)

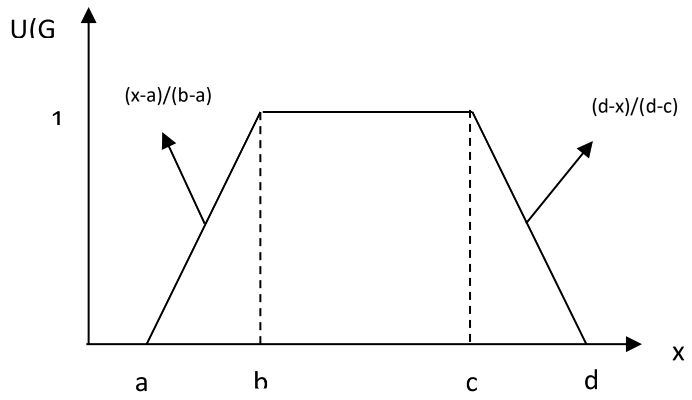

Figure 4. Membership function of triangular fuzzy number (Ahmadipari et al. 2018)

Step 2: Calculate fuzzy weights. The Fuzzy AHP weights used for this study were calculated based on Buckley's method. By collecting W_a^k , W_b^k, W_c^k the fuzzy weight for expert k can be calculated and is obtained as $W_i^k = \left(w_{ia}^k, w_{ib}^k, w_{ic}^k\right)$. Geometric average is used to mix the fuzzy weights of experts (Eq. 7).

$$W_i = (\sum_{k=1}^{k} W_i^k)^{\frac{1}{k}} \tag{7}$$

Where:
W_i: combined fuzzy weight of decision element i of k decision makers.
W_i^k: fuzzy weight of decision element i of decision maker k.
K: number of decision makers.
Step 3: Defuzzify the trapezoidal fuzzy weights. To defuzzify the triangular fuzzy number in Eq. 8, the following equation is used:

$$W_j' = \frac{\frac{a_j}{d} + 2\left(\frac{b_j}{c} + \frac{c_j}{b}\right) + \frac{d_j}{a}}{6} \tag{8}$$

Where W_j' is the defuzzy weight. Now, to normalize the crisp weights Eq. 9 is used:

$$W_i = \frac{W_j'}{\sum_{j=1}^{n} W_j'} \tag{9}$$

Where W_j is a nonfuzzy number.

Results and Discussion

In this study, PROMETHEE’s gaussian function is preferred for quantitative criteria and the V-shape functions is used for qualitative criteria. The preference threshold is obtained through the difference between the maximum and minimum values. Figure 5 shows the hierarchical structure of the criteria, and essential characteristics for the PROMETHEE method is presented in Table 3.

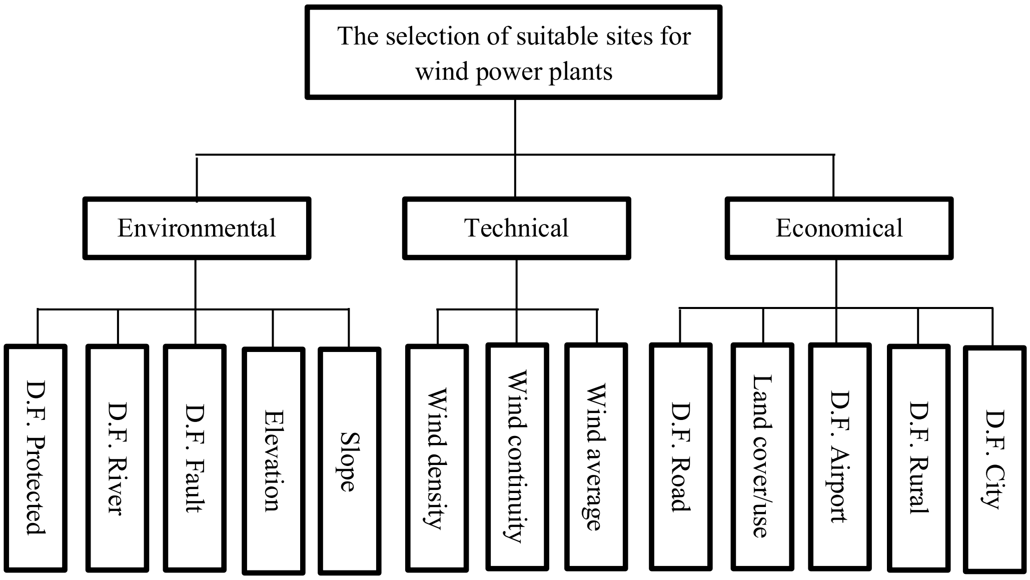

Figure. 5. The hierarchical structure of criteria

Table 3. Essential parameters for criteria to run PROMETHEE II

Criteria	Unit	Max/min	Preference function	weight
Slope	Percent	Minimize	Gaussian	0.077
Elevation	Meter	Minimize	Gaussian	0.062
D.F. fault lines	Meter	Maximize	Gaussian	0.013
D.F. rivers	Meter	Maximize	Gaussian	0.017
D.F. protected areas	Meter	Maximize	Gaussian	0.024
Wind speed average	m/s	Maximize	Gaussian	0.271
Percentage of windy days	Percent	Maximize	Gaussian	0.091
Wind power density	w/m^2	Maximize	Gaussian	0.129
D.F. urban areas	Meter	Maximize	Gaussian	0.057
D.F. rural areas	Meter	Maximize	Gaussian	0.043
D.F. airport	Meter	Maximize	Gaussian	0.038
D.F. main roads	Meter	Maximize	Gaussian	0.035
Land cover/use	-	Minimize	V-Shape	0.143

Data analysis for wind power plant development were divided into technical, economic and environmental data layers. The collected data related to the thirteen criteria(Slope, Elevation, Land cover/use, Distance from fault, Distance from urban areas, Distance from rural areas, Distance from rivers, Distance from protected areas, Distance from roads, Distance from the airport, Wind speed average, Percentage of windy days, Wind power density) was analyzed in this study (Figure 6). The layers were prepared in GIS. Data analysis was applied to create land suitability map. Then, the final weights of the PROMETHEE method were used. In this study, MATLAB® was used to calculate weights. Finally, the calculated values were affected in the layers.

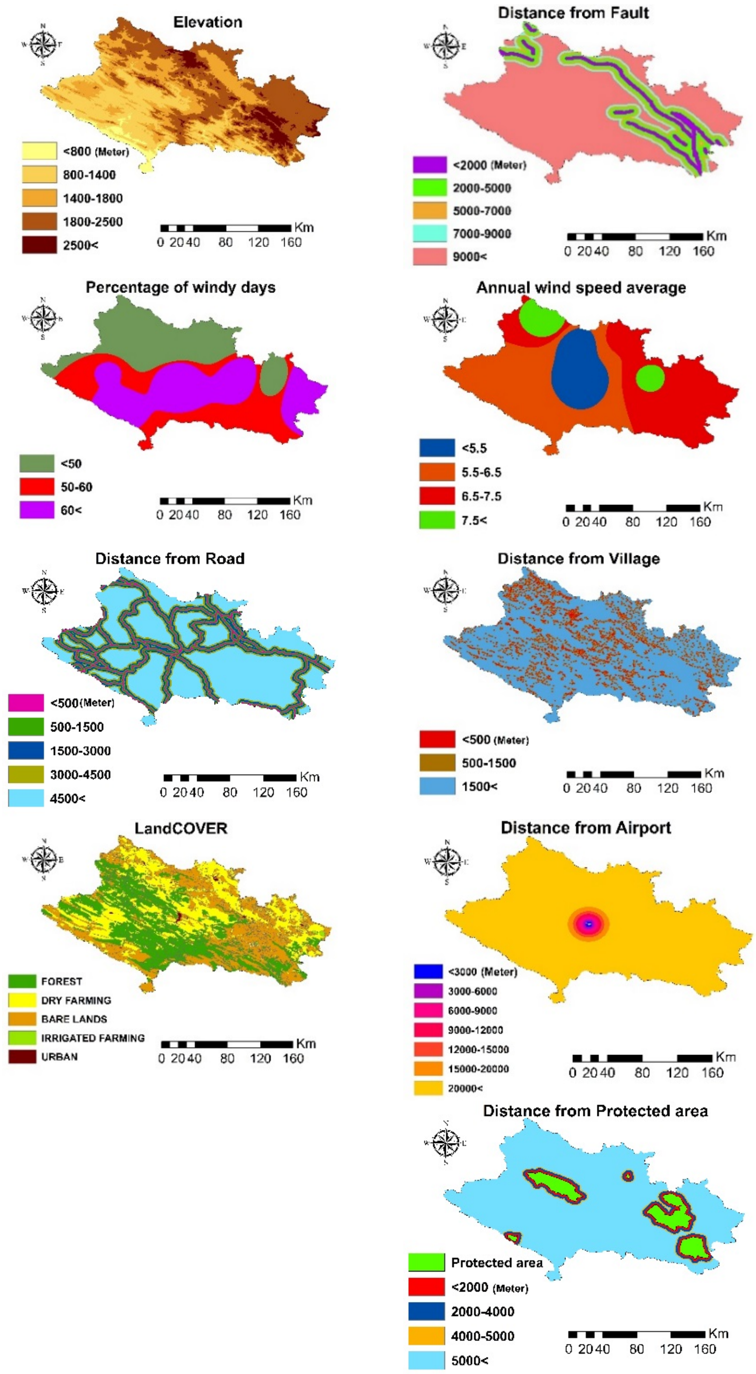

Figure 6. Input data layers in wind power plant site selection for Lorestan Province

The final land suitability map for wind power plant development is shown in the Figure 7. Overlapping layers were zoned into five classes: less suitable, suitable, moderate suitable, high suitable and extremely suitable.

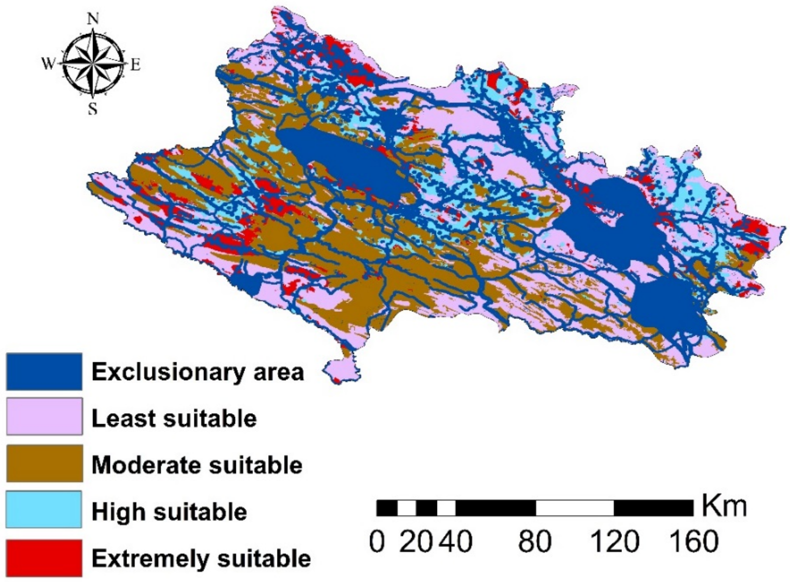

Figure 7. Final map in fuzzy PROMETHEE method for Lorestan province

Table 4 shows the five zones derived from the fuzzy PROMETHEE model in square kilometer and percent.

Table 6. The areas of classes of final land suitability map by fuzzy PROMETHEE model

Classes	Areas	
	(km^2)	(%)
Exclusion zone	9970.18	34.23
Less suitable	7232.23	24.83
Moderate suitable	6448.71	22.14
High suitable	3326.31	11.42
Extremely suitable	2149.57	7.38
Total	29127	100

According to the final zoning map, the least suitable class covers 7232.23 km^2, moderate suitable class 6448.71 km^2, high suitable class 3326.31 km^2 and extremely suitable class 2149.57 km^2 of the Lorestan province. The results of the study show that the most suitable areas are in the west of the region (Figure 7).

Conclusion

Suitability site selection for wind power plants is one of the major technical challenges on wind resources development. Planning process of wind power plants requires a comprehensive review, flexibility and appropriate indicators for the prediction of the required land, distribution and the coordination between different types of land use. One of group decision support tools is a PROMETHEE with fuzzy approach that could increase the reciprocal effect and participation of people in decision-making. This study examined the application of fuzzy PROMETHEE technique in wind power plant site selection process. The technique was designed to use effective spatial criteria on future performance of wind power plants such as technical, economic and environmental data layers. All data layers were obtained from various resources and were analyzed in a GIS environment. GIS was used in combination with fuzzy PROMETHEE method. The results of sensitivity analysis show accuracy and applicability of fuzzy PROMETHEE for land suitability assessment. The application of fuzzy PROMETHEE for Lorestan province shows that the most suitable areas are located west of the Lorestan province. This area represents about 7.38 % of the total area of the province. There is good potential in this location for wind power plants development. Used together with fuzzy PROMETHEE, these tools are used for wind power plant planning while making decisions on the type of use of a wind site as well as provide a possibility for the selection of a suitable wind site. Here, uncertainty and complexity of the real world provides more flexibility to the use of PROMETHEE based on fuzzy AHP. The fuzzy PROMETHEE approach is suggested in future studies to develop models for the site selection of renewable energy plants.

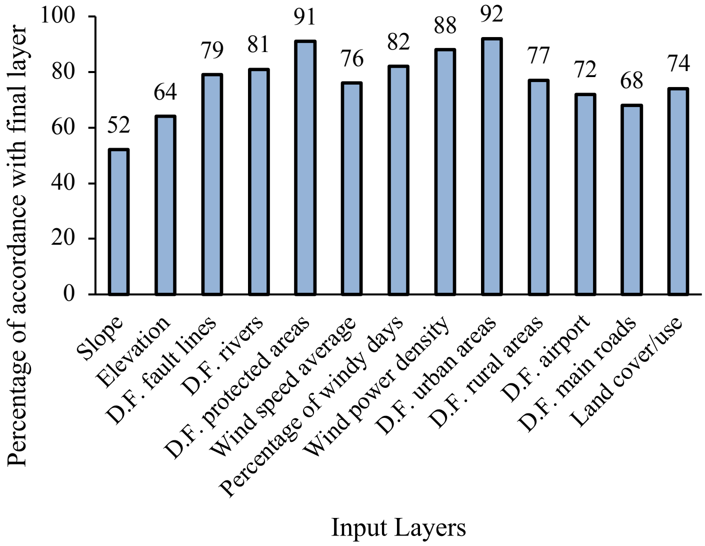

Figure 8. Sensitivity analysis results for fuzzy PROMETHEE

Figure 8 illustrates the results of the sensitivity analysis for the best class of each criterion (Figure 7) and the final map (as suggested by Latinopoulos and Kechagia, 2015, Noorollahi et al., 2016, Fetanat and Khorasaninejad, 2015, Ayodele et al., 2018). Sensitivity analysis is undertaken to examine the reliability of the best option in the fuzzy PROMETHEE model. According to the result of sensitivity analysis, all input layers in the fuzzy PROMETHEE model are coincided well with the final map (+63 %) except for the slop layer. So, the sensitivity analysis of layers showed lower sensitivity for the fuzzy PROMETHEE model. These results show that the fuzzy PROMETHEE model is robustness and reliability for wind power plant site selection. In other words, the results of sensitivity analysis reaffirmed the result of Hanine's study (Hanine et al., 2017) that in general fuzzy PROMETHEE is less sensitive to the criteria changes.

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Reference

Ahmadipari, M.; Hoveidi, H.; Jafari, H.; Pazoki, M. (2018). An integrated environmental management approach to industrial site selection by genetic algorithm and fuzzy analytic hierarchy process in geographical information system. Global J. Environ. Sci. Manage. 4, 339-350 .

Albadvi, A.; Chaharsooghi, S. K.; Esfahanipour, A. (2007). Decision making in stock trading: An application of PROMETHEE. European Journal of Operational Research, 177, 673-683.

Asakereh, A.; Omid, M.; Alimardani, R.; Sarmadian, F. (2014). Developing a GIS-based fuzzy AHP model for selecting solar energy sites in Shodirwan region in Iran. International Journal of Advanced Science and Technology, 68, 37-48.

Aydin, N. Y.; Kentel, E.; Duzgun, H. S. (2013). GIS-based site selection methodology for hybrid renewable energy systems: A case study from western Turkey. Energy Conversion and Management, 70, 90-106.

Ayodele, T.; Ogunjuyigbe, A.; Odigie, O.; Munda, J. (2018). A multi-criteria GIS based model for wind farm site selection using interval type-2 fuzzy analytic hierarchy process: The case study of Nigeria. Applied Energy, 228, 1853-1869.

Baban, S. M.; Parry, T. (2001). Developing and applying a GIS-assisted approach to locating wind farms in the UK. Renewable energy, 24, 59-71.

Bili, A.;Vagiona, D. G. (2018). Use of multicriteria analysis and GIS for selecting sites for onshore wind farms: the case of Andros Island (Greece). European Journal of Environmental Sciences, 8, 5-13.

Brans, J. (1982). Lingenierie de la decision. Elaborationdinstrumentsdaide a la decision. Methode PROMETHEE. In R. Nadeau & M. Landry (Eds.), Laide a la Decision: Nature, Instrument s et Perspectives Davenir. Presses de Universite Laval, 1, 183-214.

Cashmore, M.; Rudolph, D.; Larsen, S. V.; Nielsen, H. (2018). International experiences with opposition to wind energy siting decisions: lessons for environmental and social appraisal. Journal of Environmental Planning and Management, 11, 1-24.

Elevli, B.; Demirci, A. (2004). Multicriteria choice of ore transport system for an underground mine: Application of PROMETHEE methods. Journal-South African Institute of mining and metallurgy, 104, 251-256.

Fetanat, A.; Khorasaninejad, E. (2015). A novel hybrid MCDM approach for offshore wind farm site selection: A case study of Iran. Ocean & Coastal Management, 109, 17-28.

Ghadirian, O.; Hemami, M.; Soffianian, A.; Pourmanaphi, S.; Malekian, M.; Tarkesh, M. (2017). Probabilistic prediction of forest decline in Lorestan province using a combined modeling approach. Iranian Journal of Forest and Range Protection Research, 15, 131-145 .

Ghobadi, M.; Jafari, H. R.; Nabi Bidhendi, G.; Yavari, A. R. (2015). Environmental impact assessment of petrochemical industry using fuzzy rapid impact assessment matrix. Petroleum and environmental biotechnology, 6, 1-7.

Gigović, L.; Pamučar, D.; Božanić, D.; Ljubojević, S. (2017). Application of the GIS-DANP-MABAC multi-criteria model for selecting the location of wind farms: A case study of Vojvodina, Serbia. Renewable Energy., 103, 501-521 .

Gorsevski, P. V.; Cathcart, S. C.; Mirzaei, G.; Jamali, M. M.; Ye, X.; Gomezdelcampo, E. (2013). A group-based spatial decision support system for wind farm site selection in Northwest Ohio. Energy Policy, 55, 374-385.

Govindan, K.; Kadziński, M.; Sivakumar, R. (2017). Application of a novel PROMETHEE-based method for construction of a group compromise ranking to prioritization of green suppliers in food supply chain. Omega., 71, 129-145.

Gul, M.; Guneri, A.; Baskan, M. (2018). An occupational risk assessment approach for construction and operation period of wind turbines. Global J. Environ. Sci. Manage., 4, 281-298 .

Hanine, M.; Boutkhoum, O.; Agouti, T.; Tikniouine, A. (2017). A new integrated methodology using modified Delphi-fuzzy AHP-PROMETHEE for Geospatial Business Intelligence selection. Information Systems and e-Business Management, 15, 897-925.

Hansen, H. S. (2005). GIS-based multi-criteria analysis of wind farm development. Proceedings of the 10th Scandinavian research conference on geographical information science. Citeseer. 2: 75-78 .

Hatami, E.; Abbaspour, A.; Dorostkar, V. (2018). Phytoremediation of a petroleum-polluted soil by native plant species in Lorestan Province, Iran. Environmental Science and Pollution Research, 22, 1-8.

Juan, Y.-K.; Roper, K. O.; Castro-Lacouture, D.; Ha Kim, J. (2010). Optimal decision making on urban renewal projects. Management Decision, 48, 207-224.

Latinopoulos, D.; Kechagia, K. (2015). A GIS-based multi-criteria evaluation for wind farm site selection. A regional scale application in Greece. Renewable Energy, 78, 550-560.

Mahdy, M.; Bahaj, A. S. (2018). Multi criteria decision analysis for offshore wind energy potential in Egypt. Renewable Energy, 118, 278-289.

Mohammadizadeh, M.; Karbassi, A.; Nabi Bidhendi, G. R.; Abbaspour, M. (2016). Integrated environmental management model of air pollution control by hybrid model of DPSIR and FAHP. Global J. Environ. Sci. Manage., 2, 381-388 .

Nassereddine, M.; Eskandari, H. (2017). An integrated MCDM approach to evaluate public transportation systems in Tehran. Transportation Research Part A: Policy and Practice, 106, 427-439.

Noorollahi, Y.; Yousefi, H.; Mohammadi, M. (2016). Multi-criteria decision support system for wind farm site selection using GIS. Sustainable Energy Technologies and Assessments., 13, 38-50.

Oberschmidt, J.; Geldermann, J.; Ludwig, J.; Schmehl, M. (2010). Modified PROMETHEE approach for assessing energy technologies. International Journal of Energy Sector Management, 4, 183-212.

Ogrodnik, K. (2017). The application of the promethee method in evaluation of sustainable development of the selected cities in Poland. Ekonomia i Środowisko, 3, 19-36 .

Panwar, N.; Kaushik, S.; Kothari, S. (2011). Role of renewable energy sources in environmental protection: a review. Renewable and Sustainable Energy Reviews, 15, 1513-1524 .

Peko, I.; Gjeldum, N.; Bilić, B. (2018). Application of AHP, Fuzzy AHP and PROMETHEE Method in Solving Additive Manufacturing Process Selection Problem. Tehnički vjesnik, 25, 453-461.

Pirdashti, M.; Behzadian, M. (2009). Selection of the best module design for ultrafiltration (UF) membrane in dairy industry: an application of AHP and PROMETHEE. International Journal of Engineering, 3, 426-442.

Rezaee, M. A.; Aidin, P.; Kamran, A.; Hadi, M. M. (2018). The influence of rural road development on forest extent changes over the three time periods: A case study of Chegeni region, Lorestan province. Journal of Forest Science, 64, 313-318.

Sánchez-Lozano, J.; García-Cascales, M.; Lamata, M. (2016). GIS-based onshore wind farm site selection using Fuzzy Multi-Criteria Decision Making methods. Evaluating the case of Southeastern Spain. Applied energy, 171, 86-102 .

Schallenberg-Rodríguez, J.; Montesdeoca, N. G. (2018). Spatial planning to estimate the offshore wind energy potential in coastal regions and islands. Practical case: The Canary Islands. Energy, 143, 91-103 .

Sen, D. K.; Datta, S.; Patel, S. K.; Mahapatra, S. S. (2015). Multi-criteria decision making towards selection of industrial robot: exploration of PROMETHEE II method. Benchmarking: An International Journal, 22, 465-487.

Simao, A.; Densham, P. J.; Haklay, M. M. (2009). Web-based GIS for collaborative planning and public participation: An application to the strategic planning of wind farm sites. Journal of environmental management, 90, 2027-2040 .

Solangi, Y. A.; Tan, Q.; Khan, M. W. A.; Mirjat, N. H.; Ahmed, I. (2018). The Selection of Wind Power Project Location in the Southeastern Corridor of Pakistan: A Factor Analysis, AHP, and Fuzzy-TOPSIS Application. Energies., 11, 1-26.

Tabaraee, E.; Ebrahimnejad, S.; Bamdad, S. (2017). Evaluation of power plants to prioritise the investment projects using fuzzy PROMETHEE method. International Journal of Sustainable Energy, 12, 1-15.

Talinli, I.; Topuz, E.; Aydin, E.; Kabakc, S. (2011). A holistic approach for wind farm site selection by using FAHP. Wind Farm-Technical Regulations, Potential Estimation and Siting Assessment. InTech, 14, 213-234 .

Van Haaren, R.; Fthenakis, V. (2011). GIS-based wind farm site selection using spatial multi-criteria analysis (SMCA): Evaluating the case for New York State. Renewable and Sustainable Energy Reviews, 15, 3332-3340.

Villacreses, G.; Gaona, G.; Martínez-Gómez, J.; Jijón, D. J. (2017). Wind farms suitability location using geographical information system (GIS), based on multi-criteria decision making (MCDM) methods: The case of continental Ecuador. Renewable Energy, 109, 275-286.

Vincke, J.; Brans, P. (1985). A preference ranking organization method. The PROMETHEE method for MCDM. Management Science, 31, 647-656.

Watson, J. J.; Hudson, M. D. (2015). Regional Scale wind farm and solar farm suitability assessment using GIS-assisted multi-criteria evaluation. Landscape and Urban Planning, 138, 20-31.