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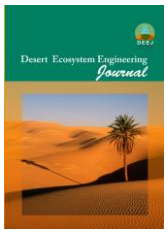

Site Suitability Analysis of Wind Power plants using Fuzzy Hierarchical Analysis (Case Study: Sistan Plain)

Sanaz Tanakian[1], Hossein Piri Sahragard*[۲], Meysam Amiri[3]

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Extended Abstract

Introduction: Energy as a contributor to human well-being plays an important role in the sustainable development of human societies. The growing demand for energy, higher standards of living, global warming, and decreasing fossil fuel resources have focused the global attention on renewable energies (Kaya and Kahraman, 2010). Owing to the rapid development of wind energy extraction technologies, low cost of this type of energy, and easy installation of wind turbines, this kind of energy is considered to be a viable alternative to current energy systems (Yang et al., 2016; Zaim et al., 2014; Tsoutsos et al., 2016). The present study aimed to identify the factors with more weight and more suitable sites for wind power plants in Sistan by considering climatic criteria (wind speed and direction), geographical criteria (elevation and slope), socioeconomic criteria (distance from residential areas, distance from routes, and proximity to electrical grids) and environmental criteria (distance from protected areas and waterways) through fuzzy hierarchical analysis and GIS.

Materials and Methods: The present study applied available 20-year weather statistics including wind speed, wind direction, temperature, and pressure in the Sistan region (Zabol, Zahak, Hirmand, and Hamoun) and the regions around the Sistan plain (Zahedan, Nehbandan, Birjand, Qaen, Shahdad, and Bam) from 1996 to 2016. Initially, expert opinion was used to extract climate measures (including wind velocity and direction), geographical factors (elevation and slope), socio-economic criteria (distance from residential areas, distance from communication pathways and vicinity to energy transport networks), and environmental scales (distance from protected areas and waterways) as significant and effective factors, which were later compared in pairs. Criteria and subcriteria weights were then obtained using fuzzy hierarchical analysis with Fuzzy AHP SolVer software. Maps needed for locating areas for the construction of wind power plants in the study area were prepared using GIS according to the sub-criteria. In the next step, each of the maps was classified using GIS. Based on the paired comparisons, each class was then scored according to the expert opinion, and the weight of each class was thus obtained using Fuzzy AHP SolVer. Finally, a map of suitable sites for the construction of wind power plants was developed, and the final map was provided in the form of a raster map with a precision of 500 square meters.

1. MSc graduated, Range and Watershed department, University of Zabol

2. Assistant Professor, Soil and Water College, Range and Watershed department, University of Zabol (Corresponding author: hopiry@uoz.ac.ir).

3. Academic staff, Hamoun international wetland research institute, University of Zabol

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Results

Determining the weight of criteria: According to the study results, the climatic criterion is of greatest importance among the criteria considered for locating wind power plants, and the environmental criteria was identified as the least important. The most important criteria were found to be wind speed with a weight of 0.57 (among the climate criterion), elevation with a weight of 0.66 (among the geographical criteria), distance from route, and proximity to electrical grids with a weight of 0.42 (among the socioeconomic criteria), and distance from protected areas with a weight of 0.66 (among the environmental criteria).

Final map for the location of wind power plants: The resulting map was classified into four classes (excellent, good, moderate, and poor) according to relative average change in each parameter. The results of the present study showed that an area of 5941 km^2 of the total area of the study area (16208 km^2) (36.6%) includes restricted areas, and the authorized areas for the construction of wind power plants (in the excellent class) are part of the Sistan plain (Nimruz and Hamoon cities) with an area of 7130 km^2 (44%). In terms of land suitability, 611 km^2 (3.7%) of the area was classified in the moderate class and 462.5 km^2 (15.1%) in the good class. In addition, the regions of Bandan and Sefidabeh around the Sistan plain with an area of 62.5 km^2 (0.38%) are among the areas less suitable for construction according to the criteria.

Discussion & conclusion: Wind speed is one of the most important climatic criteria considered for the construction of wind power plants. The higher the wind speed, the greater the power generated by the wind turbines. On the other hand, the more a wind blows in one direction, the higher the wind is scored as it more effectively rotates the turbine blades. Consistent with the findings of the present study, wind speed was reported to be the main climatic criterion for the construction of wind power plants (Azizi et al., 2014). among the geographical criteria, elevation was found to be the most important one for the construction of wind power plants in the studied area. The possibility for building facilities and agricultural activities decreases with higher elevation as a limiting factor (Sabokbar et al., 2010). Therefore, areas with higher elevations must be avoided when locating a suitable site as higher elevations increase the investment cost (Bennui, 2007).

Considering general results of this study, we can conclude that 44 percent of the regions highly suitable for establishment of wind power plants, contributing to 7130 kilometers in area. Resulting regions with high potential for wind power plant establishment, mainly areas in the central plaint of Sistan (Nimruz and Hamoon cities) were selected from regions consistent with the inclusion criteria of this study. According to the study results, the combined use of fuzzy hierarchical analysis and GIS as a decision-making support system can be an effective strategy to identify more potential areas to create the conditions for the regional sustainable development, reduce the costs, and speed up the implementation of development projects and plans aimed at new energies. The study results emphasized the necessity of more serious and effective efforts for proper management and effective solutions to fully exploit the potential of the Sistan region. It is also imperative that part of the investments is spent annually on sustainable development plans for new energies, in particular wind energy in Sistan. The production of electricity as a sustainable energy can play a significant role in economic, social, and cultural development in the region.

Keywords: Sistan, wind power plant, fuzzy hierarchy analysis, geographic information system