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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.

Contents

1. Introduction . . . 1
   1.1. Renewable energy . . . 2
   1.2. Renewable energy in Iran . . . 2
2. Material and methods . . . 3
   2.1. Case studies . . . 3
   2.2. Definition of criteria and factors . . . 3
   2.3. Data analysis . . . 4
      2.3.1. Preparation and valuation of layers by using fuzzy method . . . 5
      2.3.2. Weighting criteria process . . . 5
      2.3.3. Final combination of criteria . . . 6
      2.3.4. Extracting the restrictive layer . . . 8
3. Result . . . 9
4. Conclusion . . . 10
Reference . . . 10
Reference . . . 10

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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.

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