Wind-Solar Site Selection using a GIS-MCDM-based Approach with an Application in Kayseri Province/Turkey

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Abstract— **Renewable and sustainable energy sources such as wind, biomass, geothermal and solar are defined as a less harmfully to environment than other fossil fuels reserves. At the last decade, the demand of energy because of the rising of industrialization and population is increasing in Turkey. Thus, investments on renewable energy sources especially wind and solar energy systems are increasing rapidly because of unlicensed energy production legislation published by Turkish Ministry of Energy and Natural Sources. Although Turkey has high solar and wind capacity, there has not been develop a tool to determine the suitable regions for hybrid energy systems. In this study, geographical information systems (GIS) and Multi-criteria-base method (MCDM) are used to determine the suitable regions for wind-solar hybrid energy systems of Kayseri Province under potential and environmental impacts. The results shows (2.080 km2) %12.3 of Kayseri is suitable for hybrid energy system investment.**

***Keywords*— renewable energy, hybrid energy, geographical information systems, suitable site selection, multi-criteria-decision method, Kayseri**

I. Introduction

Energy is one of the most important need in the daily life due to development of technological devices and rising of world population. Energy has become the basic input in many areas such as factories, workshops, electronic devices in homes, street lighting, railway transportation an even electric vehicles. Thus, the countries have showed the great in renewable energy sources to produce electric energy [1]. Among renewable energy sources solar and wind energy systems became the more preferable than other systems because of high potential and easy application [2,3]. Wind energy systems were the highest installed power systems (excluding hydropower) around the renewable energy systems and also solar energy systems capacity is increased constantly around the world [4].

Turkey has high wind and solar energy capacity because of its geographical position. After published unlicensed energy production legislation in 2011, wind and solar energy investments have gained the momentum. Wind energy capacity had reach to 10 GW with 198 wind power plants and solar energy capacity had reach to 6 GW with 528 solar power plant in 2020 [5,6]. To benefit from high wind and solar energy, hybrid energy systems can be developed in Turkey. The multiple energy systems could be combined to obtain hybrid energy systems. Continuously generating energy was provided by using the solar-wind hybrid energy systems. In the uncertain weather conditions, the high energy production could be provided from the solar-wind hybrid energy systems thanks to low voltage wave [7].

It was examined the wind and solar potential of Igdir by using GIS-AHP method [8]. Liang and Liao [9] created a fuzzy-optimization approach for scheduling with wind and solar energy by calculated energy production. It was determined the suitable regions for wind power plants by using GIS-MCDM in Develi [10]. Experts examined the most suitable regions for solar photovoltaic (PV) power plants in Malatya [11]. Until now, there has not been comprehensive study related to wind-solar hybrid energy systems. In this study, an innovation hybrid energy system was examined under potential and environmental impacts. The suitable regions were determined by using GIS-MCDM approach in Kayseri. Thus, a comprehensive analysis study was put forward by considering the potential, environmental analysis result of wind-solar hybrid energy system. The output of this comprehensive study provides information to policymakers and investors for the wind-solar hybrid energy systems.

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II. MATERAİL AND METHOD

Selected of suitable regions was very important for each energy investments. Suitable site selection of hybrid energy systems was the more important due to presence of two energy sources. Fig 1. shows that the method of our analysis study under 4 steps. Firstly, the necessary restrictions and buffer zones were determined. The requirement dataset obtained different data sources. For the potential analysis, Global wind atlas [12] and Global solar atlas [13] were used preparing proper format to use in GIS. For the environmental impacts, Copernicus land monitoring service [14] provided necessary data. After obtained data, map layers and buffer zones were created in GIS both solar and wind energy power plants. Finally, the suitable map layer was obtained under potential and environmental impacts. Based on this map layer, the size of suitable regions was measured in Kayseri Province.

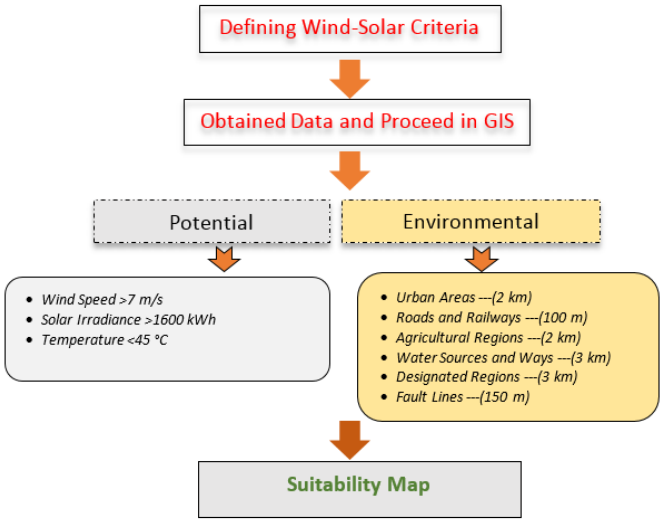

Fig. 1. The method of study

III. SELECTED OF SUITABLE REGIONS DEPENDENCE ON POTENTIAL AND ENVIRONMENTAL IMPACTS

A. Study Area

Kayseri is located in the middle of Turkey. The solar irradiance and wind speed values of Kayseri are suitable for hybrid energy systems [15-17]. Kayseri has Erciyes Mountain and the dominant wind direction is from Erciyes Mountain to other city center. Fig 2. shows that the location of study area.

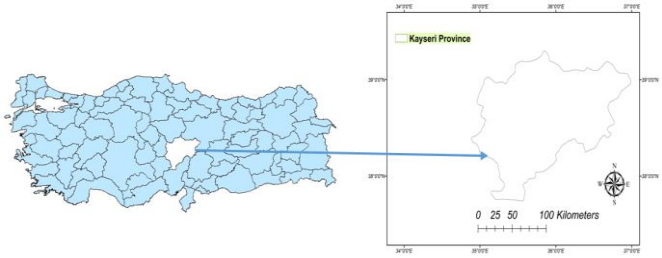

Fig. 2. Study area, Kayseri, Turkey

B. Affecting factors for Suitable Regions

Data are among the most basic requirements in the study of site selection for wind energy power plants. Data must taken from correct and actual sources in order to make complete and accurate analysis [18,19]. In this section, potential and environment impacts were separately examined in sub-steps.

1) Potential impacts

Wind speed of study area is generally below 10 m/s for most of the year. But, stronger winds exceeding 20 m/s in the winter. For the accurate wind power plant investment, the wind speed exceeding 7 m/sec for high level of power generation and indicating good potentiality for feasible wind farms [20]. The average wind speed at 100 m elevation is between 7-9.5 m/s in the study area as shown in Fig 3 (a). The solar irradiance value of study area is between 1500-1650 kWh/m^2*year as shown in Fig 3 (b). This value is assumed in suitable for investments.

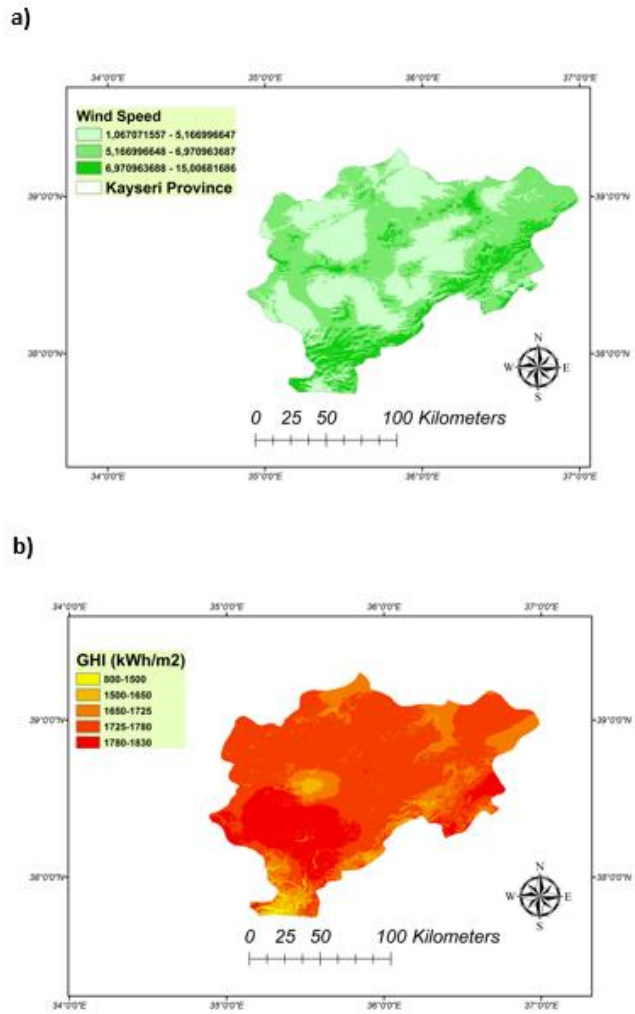

Fig. 3. a) Wind speed distribution, b) global horizontal irradiance

2) Environmental impacts

The environment impacts are very important to determine the suitable site selection for energy power plants. In this study,

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the environment impacts was analyzed for suitable regions in terms of potential suitability. As shown in Fig 4, used environmental restrictions was described following:

Urban Areas: For the energy power plants, urban and residential areas are very restrictions because of buffer zone effect. Urban areas include fabric regions, construction sites, continuous urban fabric, dump sites, green urban areas, industrial and commercial units, sports and leisure facilities. Buffer zone of urban areas was assumed in 2 km [21] and presented in Fig 4.

Roads and Railways: Transportation and maintenance-operations of the components of energy power plants are important economic impacts. Energy power plants would be accessibility and must be far away maximum 500 meters from roads and railways [10].

Agricultural and Designated Regions: Kayseri is a marvelous agricultural country for a long time. Although Kayseri is expressed as a trade center in Turkey, there are many agricultural region in Kayseri. Thus, the use of effectively farm lands for different purposes is not suitable. Designated regions are protected by some institutions and council. The energy power plant must be far away 3 km from designated regions [10].

Water Sources and Fault Lines: Because of the global warming is constantly increasing, the world is heating therefore the man is need to water. Thus, the water sources cannot used for different targets. Also, there are some active fault lines in Kayseri border. The analysis of fault lines for the wind power plants could be important.

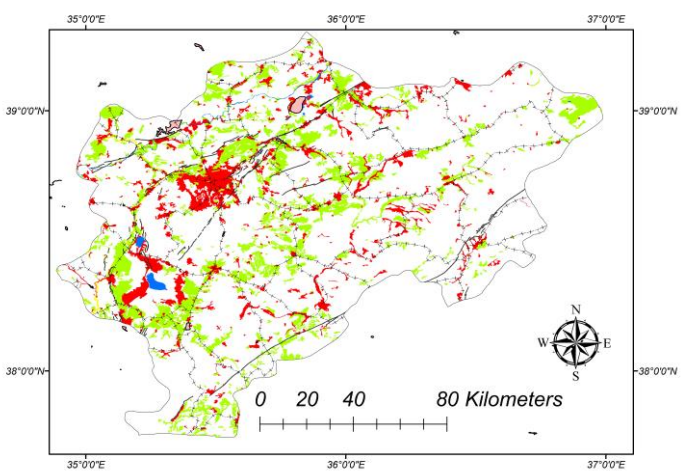

Fig. 4. Environment suitability map

IV. RESULT

Regarding suitable site selection of wind-solar hybrid energy systems for Kayseri Province, necessary data and restrictions were determined. The dataset in terms of potential and environment was proceed in GIS with buffer zones. After obtained environment and potential suitability map, all map layers was combined in the final suitability map. Based on Fig 5, suitable regions for hybrid energy power plants was determined intensively in the part extending from southeast to northeast. The total suitable regions were measured as 2.080 km^2 (%12.3 of study area). According to these results, there are a lot of suitable regions for wind-solar energy power plants in Kayseri based on potential and environment impacts.

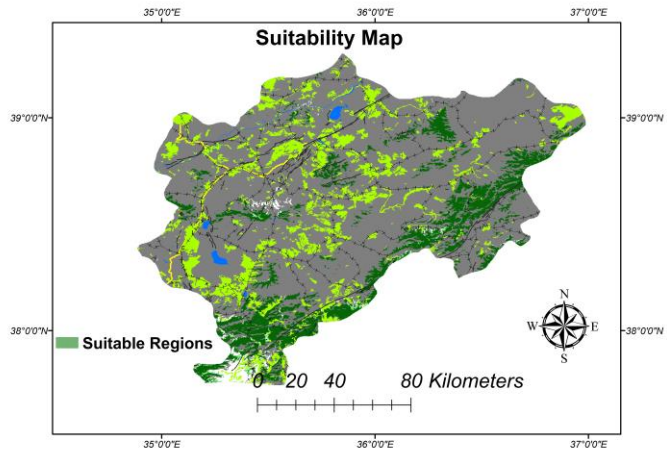

Fig. 5. Suitability map

V. CONCLUSIONS

This comprehensive study investigated the suitability of Kayseri with regards to wind-solar hybrid energy investments. In this study, wind speed, global horizontal irradiance values were described in potential impacts, urban areas, designated agricultural regions, road and railways, fault lines and water sources were described in environment impacts. Based on dataset, the map layers were obtained and reclassified. Finally, suitability map were obtained and determined suitable regions for wind-solar power plant investments. With development of hybrid energy technologies, the importance of this systems were thought to increase day by day. The methodology of this study can gave information to investors, policymakers and energy planners also can easily adopted to different areas and other energy systems.

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