Suitable Sites for Wind Hydrogen Production Based on GIS-MCDM Method in Algeria

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Abstract. Hydrogen production driven by renewable energy sources (RES) represents an attractive energy solution to global warming. This paper deals with site selection problems for wind hydrogen production and aims to propose a structural procedure for determining the suitable sites. The study area is Algeria. The methodology focuses on the combined use of geographic information systems (GIS) and multi-criteria decision making (MCDM), aiming to provide a decision tool for wind hydrogen production sites. The first stage excludes sites that are infeasible for wind hydrogen production, based on land use, water bodies, water ways, roads, railways, power lines, and also their buffer around these zones. The second stage weighting criteria will be chosen according to the objective to be reached, in this case they will be distance to roads, to railways, to power lines, hydrogen demand, wind hydrogen potential, digital elevation models (DEMs), and slope. Through the use of MCDM the criteria mentioned will be weighted in order to evaluate potential sites to produce hydrogen from wind energy. Analysis and calculation of the weights of these criteria will be conducted using SWING weighting method. The overlaid result map showed that 23.59% (561 836 km^2) of the study area is promising and suitable for deploying wind hydrogen farms while the most suitable areas to be in the southwest of the Algeria. It has been found that suitable lands are following the pattern of the wind hydrogen potential. The integration of the GIS with MCDM methods is a powerful tool to deal with a geographical information data and vast area as well as manipulate criteria importance towards introducing the best sites for wind hydrogen production.

Keywords: Hydrogen energy, Geographical Information System (GIS), MCDM method.

1. INTRODUCTION

An increasing need of a human for energy resources has always been the fundamental issues in the life of a human being. The population explosion is the main factor that leading to increase in energy demand in the world. According to BP statistical review, more than 80 percent of today's energy demand is produced using fossil fuels [1]. However, fossil fuel reserves are limited and their usage has significant environmental effects. The burning of fossil fuels such as coal, oil and gas releases greenhouse gases such as carbon dioxide and methane into Earth's atmosphere and oceans. According to the International Energy Agency, the world CO_2 emissions from fuel combustion rose from 15 458 in 1973 to 32 294 *Mt* of CO_2 in 2015 [2].

The transport sector is the fastest growing contributor to climate emissions, which is for approximately 23% of total energy-related CO_2 emissions (6.7 $GtCO_2$) [3]. Almost all (95%) of the world's transportation energy comes from petroleum-based fuels, largely gasoline and diesel. Such problems strongly encourage the research, development and demonstrations of clean energy resources, energy carriers, and in the case of transportation.

In recent study, hydrogen is one of the energy carriers that can replace fossil fuels [4]. Hydrogen may be produced from renewable energy sources through a variety of pathways and methods [5]. Hydrogen as an energy vector, together with electrolyzer and fuel cell technologies can provide a technical solution to this challenge. Moreover, the use of hydrogen for a clean transportation fuel will increase the need of renewable hydrogen producing [6].

Among renewable energy sources, wind power has had a faster growth than other renewable sources, because the use of wind turbine leads distributed generation system to a system with variable production in addition to the environmental and economic capabilities in production of clean and sustainable energy [7].

Algeria has enormous potential of renewable energy namely solar, wind, geothermal and biomass and hoping to increase its renewable energy status by producing as much electricity from green sources as it currently produces from its natural gas power plants by 2020 [8]. The selection of an installation site from other sites is MCDM problem containing many criteria [9].

MCDM offers as set of procedures and techniques for structuring decision problems, and designing, evaluating and prioritizing decision alternatives. GIS are designed to store, manage, analyze and visualize geospatial data required by decision-making processes [10]. In recent years GIS integrated with MCDM have been widely used as a decision support system (DSS) to assist in locating suitable sites for wind farms [11].

Several studies have been done on the wind hydrogen production in Algeria. Aîche-Hamane et al. [12] gave an estimation of hydrogen production from wind power in the south of Algeria. They considered two aspects of the system. Estimation of the wind power produced by three types of wind turbines generators and the energy required for the electrolysis process. Their results indicate that the hydrogen production strongly depends on the wind speed and its frequency distribution. Douak et al. [13] gave a simplified methodology to evaluate the hydrogen production from the wind energy available at each site using different wind turbine. Their results indicated that the hydrogen production strongly depends on the site and the selected wind turbine. Messaoudi et al. [14] developed a methodology for site selection of hydrogen refueling stations with on-site hydrogen production from wind energy sources. The authors examined a case study for the region of Adrar in Algeria and they followed an analytical hierarchy process belonging to the multi-criteria decision making tools in order to identify which of the available petrol stations can be reverted to H_2 refueling stations. Out of 24 conventional petrol stations in total, 15 were investigated and only 4 sites were found suitable for wind powered onsite H_2 stations. The rest 11 however, could be modified as off-site hydrogen stations in the retail refueling market. In this paper, a GIS-based methodology for evaluating alternative locations of wind hydrogen production sites is developed by using MCDM. The main objective is to produce a decision support system which can assist authorities and decision makers to identify priority sites for wind hydrogen production in Algeria.

2. Study area

Algeria is situated in northern Africa, bordered to the east by Tunisia and Libya, to the southeast by Niger, to the southwest by Mali, and to the West by Mauritania, occidental Sahara, and Morocco as shown in Fig. 1. Algeria is the largest country in Africa with a total surface of 2 381 741 km^2 and a population of 41.2 Millions of inhabitants. The climate is transitional between maritime in the north region and semi-arid to arid middle and south. The mean annual precipitation varies from 500 *mm* in the north to 150 *mm* in the south. The average annual temperature is about 12 *°C* [15]. Algeria has promising wind energy potential of about 35 *TWh/year*. Almost half of the country experience significant wind speed [16].

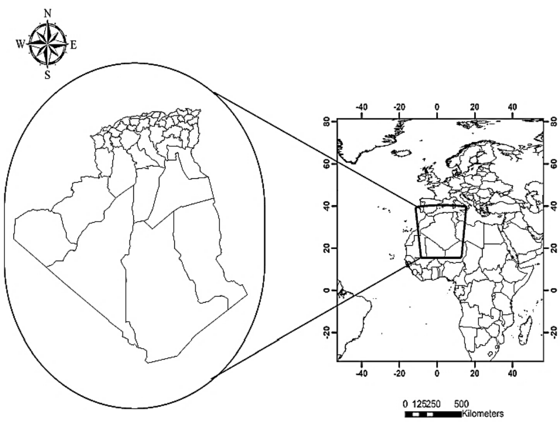

Fig. 1. Location map of the study area.

3. Methodology

Many criteria should be included in site selection for wind hydrogen production. Based on several literatures and case studies concerning wind farm site selection, seven criteria were selected to evaluate the suitability of sites to host wind hydrogen production system in Algeria [11], [17].

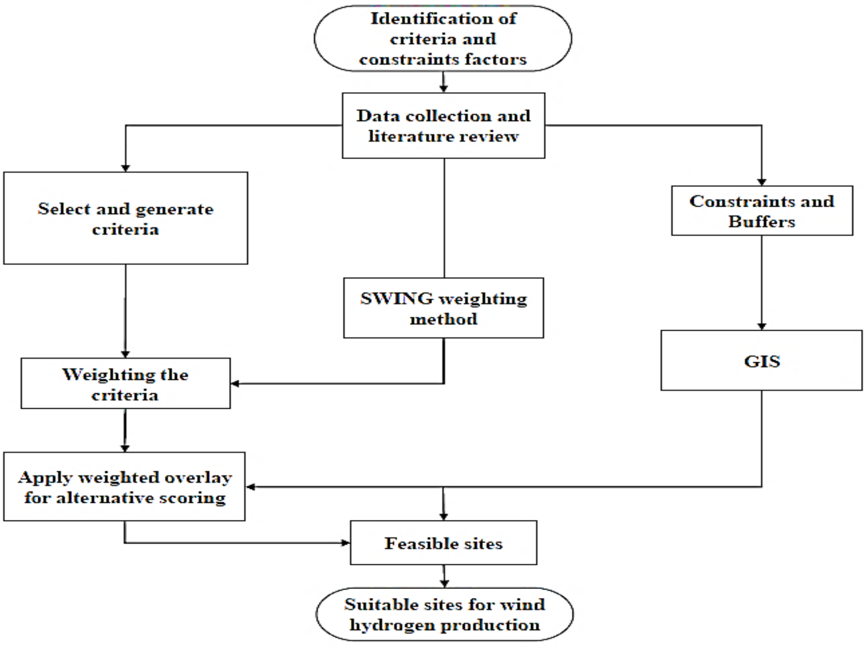

Fig. 2. Flowchart of the methodology.

The SWING methodology has been accepted by the international scientific community as a robust and flexible MCDM tool to deal with complex decision problems. The decision maker starts by rank ordering criteria in terms of their related value ranges. First of all, the person who answers questions in a survey is asked to select the criteria that he would most prefer to change from its worst to its best level and to assign 100 points to this most important criteria. Then the same person is continued to choose the criteria change from the worst to the best level which he considers to be the second most desirable improvement and to assign points less than 100 to that criteria change. The decision maker ranks all criteria and gives relative importance points to their value ranges. Finally, the given points are normalized to sum up to one to get the criteria weights. The SWING method is an algebraic, decomposed, direct procedure [11], [18].

4. Results and discussion

The weights of the criteria are carried out in excel spread sheet. Table 1 presents the weight of criteria with respect to the goal obtained by SWING weighting method. The wind hydrogen potential is the important criteria with a value of 20.51% and the less important criteria is distance to railways with 8.25%.

Table 1. Criteria weights.

Criteria	Distance to Roads	Distance to Rail-ways	Distance to Power lines	Hydrogen Demand	Wind Hydrogen Potential	DEMs	Slope
Weight (%)	16.87	8.25	16.38	10.92	20.51	14.74	14.32

The Fig. 3 illustrates the suitable sites were defined by overlaying the results of the constraints and the results of different weighted criteria. The final results are classified the study area into a scale between 0 and 8.063 where the pixel that have a high value corresponds to the most suitable area for wind renewable hydrogen production.

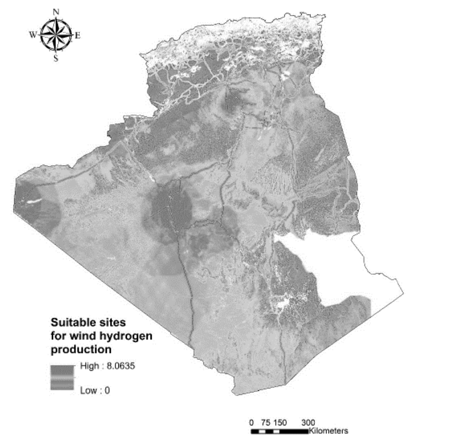

Fig. 3. The most suitable sites for wind hydrogen production.

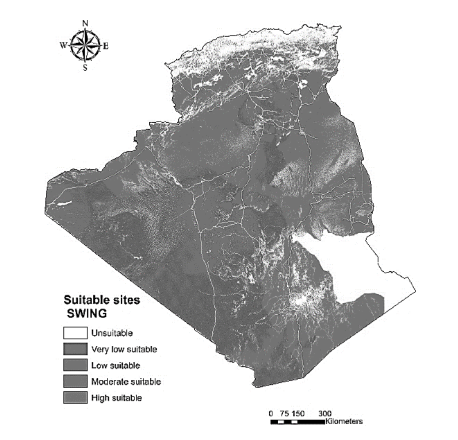

Fig. 4. The sites suitability map for the wind hydrogen production.

Table 2 presents the final suitability results were divided into four discrete categories: very low suitable areas, low suitable areas, moderate suitable areas, and high suitable areas which is used to define the degree to which site is suitable for wind hydrogen production according to the associated criteria and excluding all restrictions.

Table 2. Suitability index

Suitability	Unsuita-ble	Very Low Suitable	Low Suita-ble	Moderate Suitable	High Suitable
Value score	0	0-2	2.01-4	4.01-6	6.01-8.063

According to the land suitability index (LSI) analysis (Table 2), it is observed that 0.11%, of the study area has very low suitability, 54.51% has low suitability, 23.53% has moderate suitability and 0.06% has high suitability for a wind renewable hydrogen production. The other 21.79% of the study area is not suitable for wind hydrogen production.

The final suitable locations map (Fig. 4) showed that many of the highly suitable locations are located in the southwest region. The low suitable areas are located Southeast to High Plains, mainly due to lower wind energy in that regions.

5. Conclusion

This paper presents an application of combining MCDM with GIS for sites selection of wind renewable hydrogen production in Algeria. The objective of the study was to find suitable sites for wind hydrogen production taking into account a number of different criteria. SWING weighting method was utilized to assign the relative weights of the evaluation criteria, while GIS established the spatial dimension of constraints and evaluation criteria and elaborated them in order to produce the overall suitability map. The final result map showed that 23.59% (561 836 km^2) of the study area is promising and suitable for deploying wind hydrogen farms while the most suitable areas to be in the southwest of the Algeria. The MCDM methodology integrated with GIS is a powerful tool for the effective evaluation of the wind hydrogen production site selection.

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