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Meryem Taoufik[1], Meriem Laghlimi[2], Ahmed Fekri[3]

Land suitability analysis for solar farms exploitation using the GIS and Analytic Hierarchy Process (AHP) – a case study of Morocco

Abstract: Given Morocco's geographical position and climatic conditions, solar energy will supply a large portion of the country's energy demand. In this paper, the suitability of Moroccan lands for hosting Solar Power Plants was studied using the combination of the Geographic Information System (GIS) and the Analytical Hierarchy Method (AHP). The multi-criteria decision framework integrates technical, socio-economic and environmental constraints. For this purpose, a GIS database was created using layers from various sources. In addition, since the potential of Global Horizontal Irradiation (GHI) is the most relevant criterion for the selection of solar farms, a high-quality solar satellite map with a spatial resolution of 0.27 km was used, covering a period from 1994 to 2018. Obtained results show a great potential for solar energy development in Morocco, represented by the availability of 90% of areas. In fact, the resulting map was classified into 6 different classes, namely:

✉ Corresponding Author: Meryem Taoufik; e-mail: meryem.taoufik@gmail.com

[1] Laboratory of Applied Geology, Geomatics and Environment, Faculty of Sciences Ben M'Sik, Hassan II University of Casablanca, Casablanca, Morocco; ORCID iD: 0000-0001-8572-3459; e-mail: meryem.taoufik@gmail.com

[2] Laboratory of Applied Geology, Geomatics and Environment, Faculty of Sciences Ben M'Sik, Hassan II University of Casablanca, Casablanca, Morocco; ORCID iD: 0000-0003-0192-075X; e-mail: laghlimi.meriem@gmail.com

[3] Laboratory of Applied Geology, Geomatics and Environment, Faculty of Sciences Ben M'Sik, Hassan II University of Casablanca, Casablanca, Morocco; e-mail: ahmedfekri13@gmail.com

Very high suitability, High suitability, Moderate suitability, Low suitability, Very low suitability and Exclusion areas, which 53.88%, 24.08%, 0.15%, 0%, 0% and 21.89% are respectively the percentages of their area occupation. According to the performed investigations, the most significant criteria that should be considered include: The Global Horizontal Irradiation, Slope, Temperature and Slope orientation. The obtained map was then compared to the existing solar farms, and show that all the existing projects are located within areas classified as highly suitable.

Keywords: Geographic Information Systems, Multi-criteria analysis, Solar energy, Site selection, Africa

Introduction

In the last few years, due to increased use of fossil fuels, high levels of CO_2 in the atmosphere, and irreversible environmental harm, the world is gradually transitioning to clean, environmentally sustainable sources of energy. Renewable energies come from natural sources and can be regenerated, such as wind energy, geothermal energy, solar energy and hydropower.

Morocco has great potential for solar energy, as well as a key geographical location. Two major green energy schemes – Moroccan wind and solar initiatives – have been initiated to achieve the national goal of growing the share of renewable energy sources in the energy mix to 42% by 2020. With an abundance of solar resources, Morocco offers a wide variety of investment opportunities in the solar energy sectors. The average daily solar radiation level in Morocco is equivalent to 5.80 kWh/m^2/day (El Mghouchi et al. 2016).

One of the inherent difficulties of solar power development is the identification of the most suitable site for solar installations due to associated environmental, technical and socioeconomic restrictions. In this view, the solar farm planners are faced with a multi-criteria decision-making issue. Site selection based only on the solar radiation may lead to several problems as regards the environmental and socioeconomic impacts. Therefore, there is a need to explore additional factors to evaluate the suitability degree of different sites.

The objective of this study is to highlight the suitability of Morocco to host PV plants. Maps with high spatial resolution and the combination of the Geographic Information System (GIS) software and the Multi-Criteria Decision Making (MCDM) approach were used.

The integration of GIS software and MCDM techniques has been a popular solution to solving the complex problem of solar plant site selection. Many researchers use this technique to assess the potential of their regions or countries to host renewable power plants. For instance, Alqaderi, Emar et al. 2018 evaluated the suitability of the UAE to host large photovoltaic (PV) farms by using GIS tools and Analytical Hierarchy Process. Ali, Taweekun et al. 2018 used the same technique to assess the potential of Songkhla in Thailand to host solar plants, and 11.42% of the areas were suitable. Another research study was also conducted in Ourique in Portugal, and the rate of suitable areas was 20.90% (Rodrigues et al. 2017).

In this paper, a combination of the AHP and GIS tools to identify the most suitable sites to host PV plants in Morocco was used. The AHP approach is employed to determine the relative weights of the selected criteria. The obtained weights were incorporated into different map layers, each layer representing one of the selected criteria, and then processed in ArcGIS.

Results show that 53.88% of Moroccan lands are highly suitable to host PV plants, while the unsuitable sites represent 21.89% of the total areas. Such findings could be of considerable concern not only to the Moroccan Agency for Sustainable Energy MASEN or Moroccan decision makers, but also to foreign investors.

1. Methodology

1.1. Study area

Morocco is the most westerly of the North African countries with coastal exposure to both the Atlantic Ocean and the Mediterranean Sea, with land borders with Algeria to the east and Mauritania to the south (Fig. 1). The climate is mostly semiarid with warm to hot, dry summers, occasional droughts, and mild, relatively wet winters (Verner et al. 2018). Over the last decades, Morocco has experienced significant economic and social development within the context of climate change that has impacted several sectors. Consequently, natural resources are being unceasingly depleted, affecting the resilience of the agricultural and forestry sectors (Ministry Delegate of the Minister of Energy, Water and Environment 2016). In addition, Morocco has a population of approximately 36 million, and the population is expected to increase to 40 million by 2040 (Khatib 2018). Thus, energy demand is set to increase significantly in the coming years.

Concerning the geography, a large area in the northern part of Morocco is mountainous. The Moroccan mountains form four distinct massifs, which are surrounded by lowland plains and plateaus (Maher 2002). In the north, the Rif Mountains comprise a rugged arc of mountains that extend from the Mediterranean coastline to the Moulouya River valley near the Moroccan--Algerian frontier. The Middle Atlas chain lies immediately south of the Rif, separated by the Col of Taza and form a broad barrier between Morocco and Algeria. The High Atlas extends from southwest to northeast and form a physical barrier between the northern plains and the pre-Sahara. The Anti-Atlas is the most southerly running parallel to and southward of the central range of the Atlas Mountains. The Moroccan Sahara reliefs are made up of mainly plains and some table lands rarely reaching 400 meters in height.

With its diversified geography and climate, Morocco offers favorable conditions for implementing ambitious renewable energy projects. However, the country is the largest energy importer in North Africa and is still extremely dependent on conventional energies with a recent import rate that reaches 96% (Amegroud 2015). A recent study revealed that Morocco has the lowest

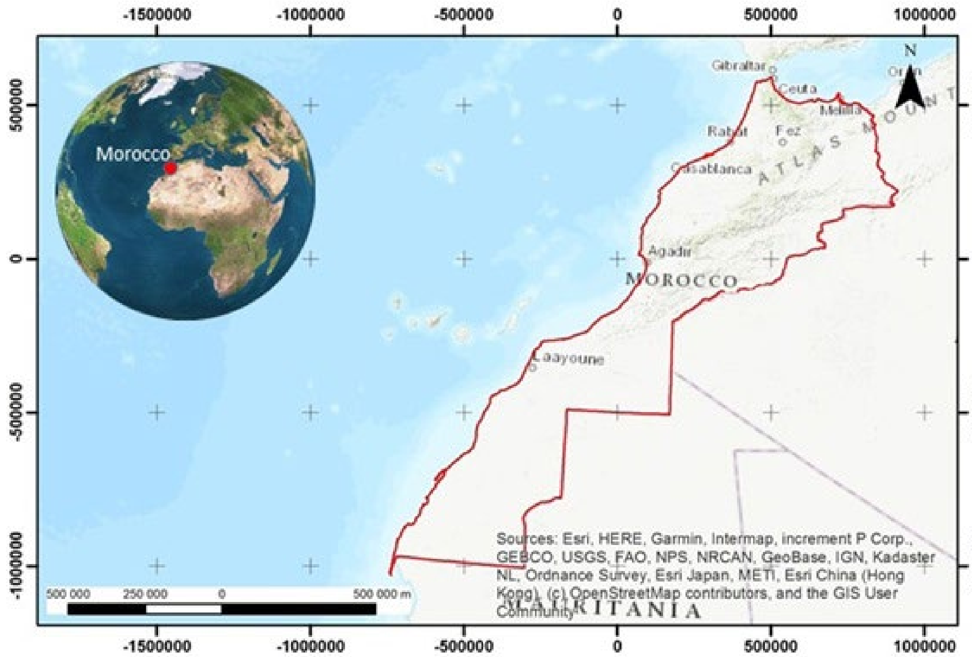

Fig. 1. The study area

Rys. 1. Obszar badań

Energy Security Index (ESI) among the MedRing countries (–0.038) (Chentouf and Allouch 2017). Hence, the restructuring of the energy sector in Morocco may contribute to alleviating this critical situation by reducing its reliance on imported fossil fuels while capitalizing more in the local energy sources.

1.2. Definition of factors and criteria

Before any solar plant project is carried out, a pre-feasibility analysis must be conducted taking a range of different parameters into account. The first step is to identify the factors and criteria. The selected variables are based on research and expert opinions. In this study, the parameters chosen for the solar site selection are: technical, socio-economic and environmental factors. Each factor is divided into a number of criteria. The hierarchical structure of factors and criteria for solar site selection is shown in Figure 2.

The data used in this study is comprised of free of charge datasets downloaded mainly from the world data catalogs. Table 1 summarizes the data used in the analysis, in addition to its format and sources.

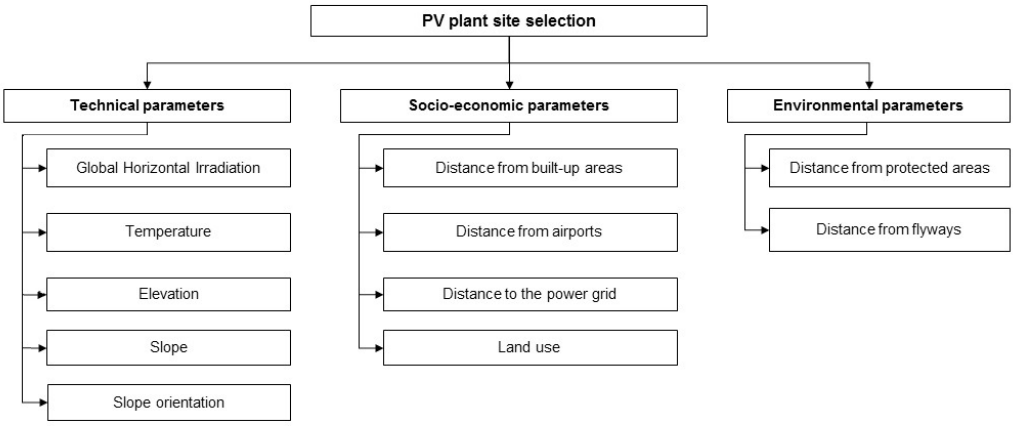

Fig. 2. The hierarchical structure of factors and criteria for solar site selection

Rys. 2. Hierarchiczna struktura czynników i kryteriów wyboru lokalizacji słonecznej

Table 1. Data collection and its sources

Tabela 1. Gromadzenie danych i ich źródła

Data	File Format	Source
Global Horizontal Irradiation GHI	GRID	Global Solar Atlas 2.0
Temperature	GRID	Global Solar Atlas 2.0
Digital Elevation Model (DEM)	GRID	U.S. Geological Survey
Land use	Shapefile	Open Street Map (OSM)
Power Grid	Shapefile	World Bank Data Catalog
Airports	Shapefile	World Bank Data Catalog
Migratory birds routes	Shapefile	Turtle Doves (Eraud et al. 2013) Lesser Black-backed Gulls (Stienen et al. 2016)
Protected areas	Shapefile	World Database on Protected Areas (WDPA)/UN Environment Programme World Conservation Monitoring Centre

1.3. Factors' description

Global Horizontal Irradiation (*GHI*): GHI is a crucial criterion for the construction of solar power projects (Janke 2010; Uyan 2013; Al Garni and Awasthi 2017). The geographical positioning of Morocco is best suited to solar energy, since, on average, the country collects a solar irradiation of 21 MJ/m^2/day (5.80 kWh/m^2/day) (El Mghouchi et al. 2016). In this study, areas receiving GHI of less than 3 kW/m^2/day have been excluded, while areas receiving more than 5 kW/m^2/day are suggested as being highly suitable. The GHI solar map used has a high spatial and temporal resolution (0.27 × 0.27 km/pixel and covering a period from 1994 to 2018).

Temperature: Temperature is an essential criterion since it negatively affects the efficiency of the photovoltaic system whenever it exceeds 25°C. This criterion has been taken into account and was considered in the calculation of the photovoltaic suitability (Carrión et al. 2008; Komoto et al. 2014). In this paper, the lowest average temperatures have been prioritized.

Elevation: High elevation was not suggested for solar projects in a number of studies (Ali et al. 2018). Ruiz et al. (2020) recommend areas below 200 m as being highly suitable for solar energy projects. In fact, high areas suffer from inaccessibility and lack of basic infrastructure. Therein, in order to minimize the high costs arising from construction costs, areas below 500 m are given the highest score.

Slope and Slope orientation: Flat or mild slopes are the most preferable for solar projects, whereas steep slopes lead to a significant increase in the working and maintenance cost of the project. In addition, a south-facing slope is an ideal orientation for PV plants. Therefore, in this study, the most suitable classes are given to flat and south oriented areas. The slope and the slope orientation were derived from the Digital Elevation Model DEM using the spatial analyst extension in ArcGIS.

Distance from built-up areas: In terms of residential and populated areas, a buffer distance should be considered for the solar farm site selection in order to prevent the most direct impacts and resistance of local communities (Tsoutsos et al. 2005; Janke 2010; Turney and Fthenakis 2011). In this research, distance from built-up areas is considered as one of the significant criteria in PV farms' site selection. Solar farms are therefore not to be built at a distance of less than 4000 m from built-up areas. Moreover, regions more than 12 km away from populated areas are considered to be highly suitable for solar farms' establishment.

Distance from airports: Distance to airports has been considered in a number of similar studies (Ali et al. 2018; Spyridonidou et al. 2021). In fact, glint and glare from the PV panels will distract pilots' vision and may also have detrimental effects on radar systems if solar panels are mounted close together (Ali et al. 2018). A buffer of 1000 m between airports and solar farms was therefore considered as a restriction area, while regions more than 5000 m away from airports have been prioritized.

Distance to power grid: Distance to the power grid is directly related to the income and the cost of the PV plant construction. In fact, the closer the PV plants are to gridlines, the lower the cost of constructing new power lines to expand the existing ones to ensure connectivity. Solar farms must be as close as possible to the electricity grid in order to minimize costs related to cabling and avoid electricity loss. For the current analysis, areas located at less than 5 km are classified as the most suitable for solar power projects.

Land use: Land use deserves thoughtful analysis before any investments in solar projects are made. Studies (Mevlut 2013; Spyridonidou et al. 2021) suggest barren land as highly suitable for solar energy projects. Open areas and grassland are considered here as more preferable ones for solar farm siting, as no land use conflict can be created.

Distance from protected areas: One of the environmental considerations integrated into the design process for solar farm projects in site selection, is the distance to protected areas. This criterion was discussed in a number of studies. Al Garni and Awasthi (2017) have classified these areas as a restricting factor. Gašparović and Gašparović (2019) have defined a restricted area of 100 m from the ecologically sensitive area. These areas represent nature, wildlife, archeological and historic sites. Therefore, a buffer distance of 1000 m was set as constraint parameters before using protected areas' layer as input in the MCDM process.

Distance from flyways: A buffer zone of 500 m was considered a restricted area to reduce the potential risk of bird collision on solar panels and to protect rare bird species. In fact, birds may mistake the glare from the solar panels to the surface of lakes, and swoop in for landing which causes deadly results. Therefore, areas more than 2500 m away from flyways are given the highest score.

Figure 3 shows all spatial data used in the research, and Table 2 shows a detailed standardization of the selected criteria using a score from 0 to 5 (the score 0 indicates restriction).

1.4. MCDM using an AHP approach

In the presence of multiple criteria, decision making would be complicated and must be supported by an adequate instrument. MCDM is a modelling tool for solving complex issues as characterized with multiple actors, criteria's, and objectives (Kumar et al. 2017). MCDM problems usually consist of five components, namely: goal, decision maker's preferences, alternatives, criteria's and outcomes (Wang et al. 2009; Kumar et al. 2017). This technique has been widely used in various sectors; environment, health care, economics, transport etc. (Zavadskas and Turskis 2011; Karmakera and Sahab 2015; Taoufik et al. 2016; Emec et al. 2019; Galińska 2019; Czaplicka-Kolarz et al. 2014). In the energy sector, several multi criteria techniques have been applied in renewable energy planning (Beccali et al. 2003; Algarín et al. 2017; Samanlioglu and Ayağ 2017). One of the most important and commonly used MCDM is the Analytic hierarchy process (AHP) (Zohrul Kabir and Shihan 2003; Rumbayan and Nagasaka 2012; Stojanovic 2013; Taha and Daim 2013; Algarín et al. 2017; Budak et al. 2019).

The AHP is a structured technique for helping decision makers deal with complex decisions. This method was first introduced by Thomas L. Saaty (Saaty 1990), and has been considerable improved since then. In AHP, the problem is constructed as a hierarchy breaking down the decision top to bottom. The overall goal is located in the top level and is broken down into elements (De Felice et al. 2016), criteria and sub-criteria are in middle level and the alternatives are at the bottom layer of the hierarchy (Daim et al. 2013). The Application of AHP involves four steps listed as follows:

Step 1: Decomposition of the decision-making problem and description of the main factors or elements (criteria, sub-criteria, alternatives, etc.) of the problem. Then construct a linear hierarchy of problems based on a finite number of levels or components. Each level contains

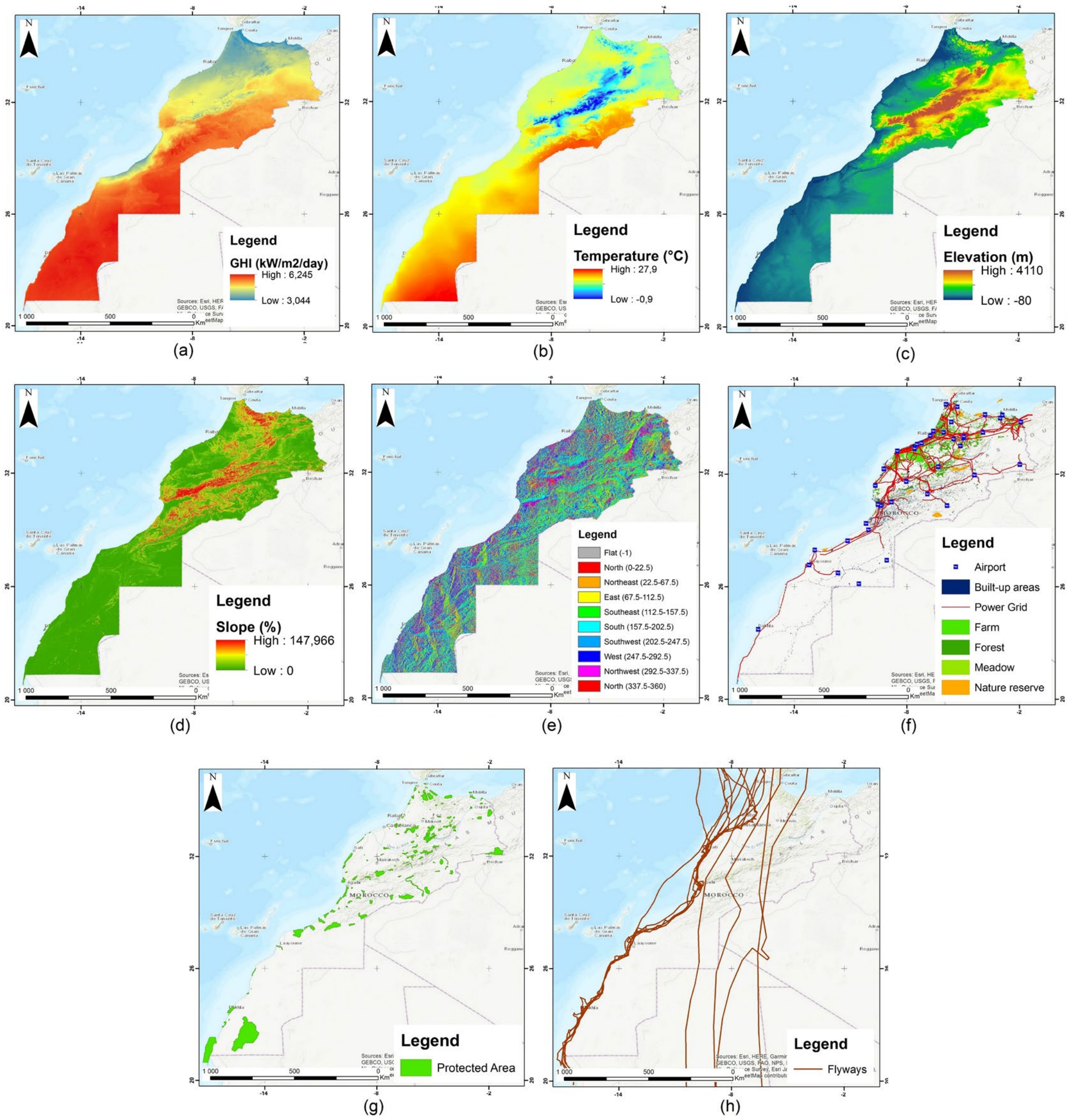

Fig. 3. Layers of the selected criteria: (a) The Global Horizontal Irradiation GHI; (b) Temperature; (c) Elevation; (d) Slope; (e) Slope orientation; (f) Land use and Infrastructure; (g) Protected areas; (h) Flyways

Rys. 3. Warstwy spełniające wybrane kryteriach: (a) globalne nasłonecznienie poziome GHI; (b) temperatura; (c) wysokość; (d) nachylenie; (e) orientacja zbocza; f) użytkowanie gruntów i infrastruktura; (g) obszary chronione; (h) drogi przelotowe

TABLE 2. Suitability scores of the selected criteria

TABELA 2. Oceny adekwatności wybranych kryteriów

Criteria	Sub-criteria	Score					
		0	1	2	3	4	5
Technical	Global Horizontal Irradiation [kW/m^2/day]	< 3	3–3.5	3.5–4	4–4.5	4.5–5	>5
	Temperature [C°]	–	–	>25	–	–	<25
	Elevation [m]	–	>1200	1000–1200	800–1000	500–800	0–500
	Slope [%]	> 11	9–11	7–9	5–7	3–5	<3
	Slope orientation	–	North-West, North	North-East	West	East, South--West	Flat, South, South-East
Socio-economic	Distance from built-up areas [km]	<4	4–6	6–10	8–10	10–12	>12
	Distance from airports	<1000	1000–2000	2000–3000	3000–4000	4000–5000	>5000
	Distance to the power grid [km]	–	>12	10–12	08-oct	5–8	<5
	Land use	Public settlements, Wetlands, Forests, etc.	–	Agricultural land	–	Short vegetation and scrubs	Barren/ /Grassland
Environmental	Distance from protected areas [m]	<1000	–	–	–	–	>1000
	Distance from flyways [m]	<500	500–1000	1000–1500	1500–2000	2000–2500	>2500

a limited number of decision factors. The purpose, or focus, of the problem lies at the first level. The criteria and sub-criteria are typically on the second and third levels, respectively. Lastly, alternative decisions are put at the lowest level of the hierarchy.

Step 2: Construct the pairwise comparison matrices of all criteria and making the judgment matrix. The pairwise comparison is structured into a matrix for criteria as follow:

$$C = [C_{kp}]_{n \cdot x} = \begin{bmatrix} C_{11} & C_{12} & C_{1J} & \cdots & C_{1n} \\ C_{21} & C_{22} & C_{2J} & \cdots & C_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ C_{k1} & C_{k2} & C_{kp} & \ddots & C_{kn} \\ C_{n1} & C_{n2} & \cdots & \cdots & \tilde{a}_{nn} \end{bmatrix} \tag{1}$$

C_{kp} is the pairwise comparison rating for the k^{th} and the p^{th} criteria. The matrix C is reciprocal; that is, ${C_{kp}}^{-1}$, and all its diagonal elements are unity; that is, $C_{kp} = 1$ for $k = p$. The entries C_{kp} are normally taken from the (1/9–9) ratio-scale (Saaty 1980). The semantic interpretation of the matrix elements is provided in Table 3.

TABLE 3. Saaty's comparison scale

TABELA 3. Skala porównawcza Saaty'ego

Rating scale	Definition	Explanation
1	Equal importance	Two requirements are of equal value
3	Moderate importance of one over another	Experience slightly favors one requirement over another
5	Essential of strong importance	Experience strongly favors one requirement over another
7	Very strong importance	A requirement is strongly favored and its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgement	When compromise is needed

Once the pairwise comparison obtained, a vector of weights can be computed. First, the sum of each value of the p^{th} column is calculated by:

$$S_p = \sum_{k=1}^{n} C_{kp} \tag{2}$$

Secondly, a n × n normalized comparison matrix ${C_{kp}}^*$ is created where each C_{kp} in the matrix C is divided by the sum of its p^{th} column as expressed in:

$$C_{kp}^* = \frac{C_{kp}}{S_p} \tag{3}$$

The k^{th} criterion weights are then computed as follows:

$$w_k = \frac{\sum_{p=1}^{n} C_{kp}}{n} \quad \text{for all } k = 1,2,3, ..., n \tag{4}$$

Step 3: Individual weights of the criteria are determined from the pairwise comparison matrices obtained by using the eigenvalue method.

The eigenvalue λ_{max} is obtained by multiplying each value of the column by the criteria weight as follows:

$$C_k = \left[\prod_{k=1}^{n} w_k C_{kp}\right]_{n \cdot n} = [d_{kp}]_{n \cdot n} \tag{5}$$

Then, calculating the weighted sum value S_w by getting the sum of each value in the row of the previous matrix C_k using the following equation:

$$S_{wk} = \sum_{p=1}^{n} d_{kp} \tag{6}$$

Thirdly, calculating the ratio of weighted sum value S_w and the criteria of weight for each row as follows:

$$Ratio_k = \frac{S_{wk}}{w_k} \tag{7}$$

The largest eigenvalue λ_{max} is obtained by calculating the average of $Ratio_k$.

Step 4: Calculating the Consistency Ratio (CR). This ratio is a test of acceptance of the resulting criteria weights. This step allows for the identification of any inconsistencies in the comparison matrix.

CR is calculated as follows:

$$CR = \frac{CI}{RI} \tag{8}$$

where

$CI = \frac{\lambda_{max} - n}{(n-1)}$ – the consistency index and RI a random index.

RI is a value that depends on the size of the matrix. The table 4 shows the calculating RI value for matrices of different sizes.

Table 4. Random Consistency Index (RI)

Tabela 4. Random Consistency Index (RI)

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

The CR must be less than 10% to conclude that the pairwise comparison judgments are consistent. If not, the matrix must be adjusted and the values of the elements must be reviewed.

2. Results and discussion

The aim of this study was to conduct a suitability analysis to evaluate the most appropriate locations for solar farm development projects in Morocco by following a methodological approach that combines both GIS and AHP tools. The suggested methodology consists of finding a compromise solution in a multi-criteria problem incorporating technical, socio-economic and environmental factors. The results highlight the most decisive criteria in solar farm development. It is evident that the Global Horizontal Irradiation is the main contributor of solar power with the highest relative weight of 26% (Table 5). However, Slope, Temperature and Slope orientation also indicate an important influence with relative weights of 19%, 12% and 12%, respectively, while Distance from flyways, Distance from airports and Distance from built-up areas show the lowest relative weights of 2%, 2% and 3% respectively. Yet, despite their low weights, these criteria must be considered in every solar farm project to avoid and minimize potential adverse impacts.

The eleven criteria used in this study are input to the weighted overlay extension (ArcGIS) which calculates the suitability index for each pixel in the map based on the reclassified maps of each criterion. Figure 4 shows the calculation results of the land suitability index. This final map is distributed into six classes, namely: “Very high suitability”, “High suitability”, “Moderate suitability”, “Low suitability”, “Very low suitability” and “Unsuitable”, covering an area of 53.88%, 24.08%, 0.15%, 0%, 0% and 21.89%, respectively. The percentage calculation is based on the number of pixels for each class. These results show that most of Moroccan land is suitable for solar farms’ development and concern about 77.96% of the total area. It can be seen that areas located in the south part of the country received relatively high value scores. This is clearly due to the pattern of the GHI distribution over Morocco. However, areas in the northern part received low values due to the low GHI but also the existence of protected areas and the north oriented slope. Generally, as GHI is rated as the most important, areas with lowest overall value scores in the suitability map are likely to be those with lower scores in the GHI criterion.

For the sake of validating the obtained results, existing solar farms were compared to the suitability map derived from the AHP model. Figure 4 shows that all the existing sites are located within areas deemed suitable. This indicates results reliability and the accuracy of the proposed framework.

In summary, it was found that only 22.04% of the total area is considered unavailable for solar farm development in Morocco, when 53.88% are rated very suitable for solar power facilities projects. These findings could be used to assist in the efficient management of solar energy planning in Morocco, which ensures the sustainable development of the renewable energy in Morocco, especially in areas suffering from energy shortages.

Table 5. Pairwise comparison matrix and relevant weights of evaluation criteria

Tabela 5. Macierz porównań parami i odpowiednie wagi kryteriów oceny

Criteria	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	Weight
Global Horizontal Irradiation (1)	1	3	5	2	3	8	9	4	7	8	9	26%
Temperature (2)	1/3	1	3	1/2	1	6	7	2	4	5	7	13%
Elevation (3)	1/5	1/3	1	1/4	1/3	3	5	1/2	2	3	5	6%
Slope (4)	1/2	2	4	1	3	6	7	3	6	6	7	19%
Slope orientation (5)	1/3	1	3	1/3	1	5	7	3	4	5	7	13%
Distance from built-up areas (6)	1/8	1/6	1/3	1/6	1/5	1	3	1/6	1/2	1	3	3%
Distance from airports (7)	1/9	1/7	1/5	1/7	1/7	1/3	1	1/5	1/4	1/3	1	2%
Distance to the power grid (8)	1/4	1/2	2	1/3	1/3	6	5	1	3	6	5	9%
Land use (9)	1/7	1/4	1/2	1/6	1/4	2	4	1/3	1	2	4	4%
Distance from protected areas (10)	1/8	1/5	1/3	1/6	1/5	1	2	1/6	1/6	1	2	3%
Distance from flyways (11)	1/9	1/7	1/5	1/7	1/7	1/3	1	1/5	1/5	1/3	1	2%
λ_{max} = 8.34	CI = 0.05			CR = 0.035								

Conclusion

This paper is based on the combination of a Geographic Information System and Multi--Criteria Decision-Making methods in order to obtain the evaluation of the optimal placement of solar farms in Morocco. Analytical Hierarchy Process techniques were employed to solve decision-making issues through the assessment of the weights of criteria determining suitability of the solar farm location.

The overlay layer results show that the majority of Moroccan land is highly suitable for solar power plants. Three criteria groups have been used: technical, socio-economic and environmental. It was concluded that the Global Horizontal Irradiation is the most important factors for solar farm site selection. In order to confirm the results obtained, the suitability map was overlaid on existing sites and shows that all the operating solar farms are within areas deemed as very suitable. This comparison attests to the effectiveness of the applied method.

The present investigation can be further extended by including more decisive criteria such as land price and electricity demand. These, as well as other factors can be considered in the spatial data processing model if required. At the end, the use of a different multi-criteria decision

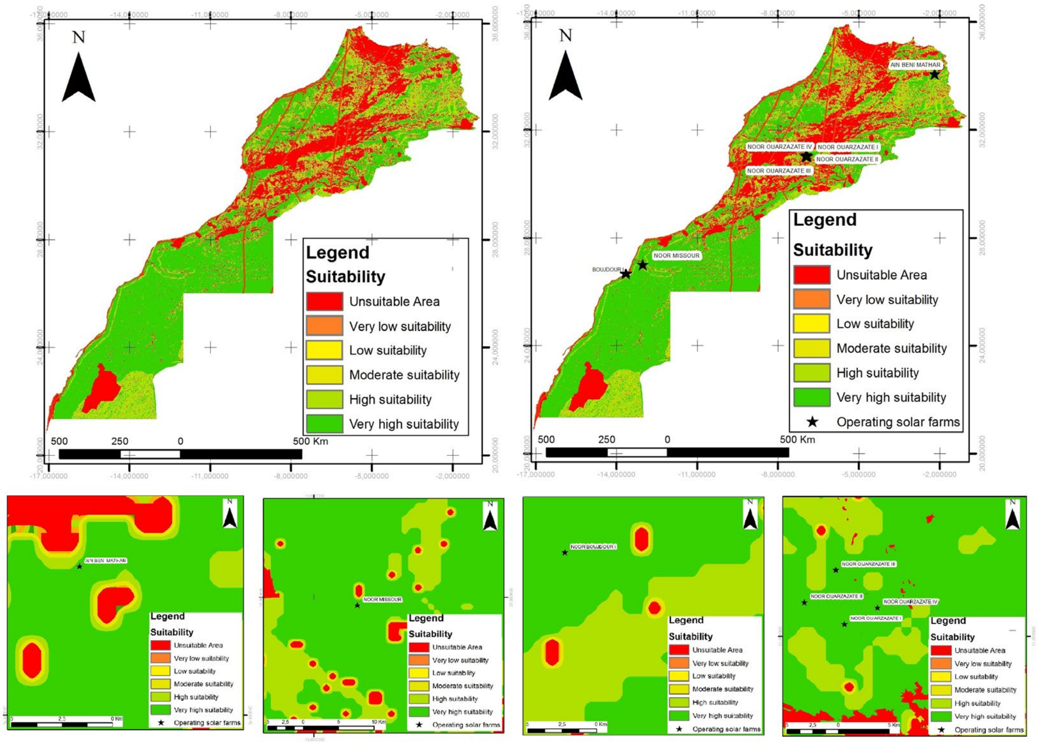

Fig. 4. Suitability Map and the existing solar farms

Rys. 4. Mapa przydatności i istniejące farmy słoneczne

making approach instead of AHP for assessing the decision alternatives might be a subject for future research.

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The protected area data layer used in this research is a product of the World Database on Protected Areas (WDPA): UNEP-WCMC (2020). Protected areas map of the world, September 2020 Available at: www.protectedplanet.net

Data is obtained from the “Global Solar Atlas 2.0”, a free, web-based application is developed and operated by Solargis s.r.o. on behalf of the World Bank Group, utilizing Solargis data, with funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalsolaratlas.info

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Meryem Taoufik, Meriem Laghlimi, Ahmed Fekri

Analiza przydatności gruntów do eksploatacji farm słonecznych z wykorzystaniem Systemu Informacji Geograficznej (GIS) i Analitycznego Procesu Hierarchicznego (AHP) – studium przypadku Maroka

Streszczenie

Biorąc pod uwagę położenie geograficzne i warunki klimatyczne Maroka, energia słoneczna pokryje dużą część zapotrzebowania na energię w tym kraju. W artykule zbadano przydatność terenów marokańskich do lokalizacji elektrowni słonecznych za pomocą połączenia Systemu Informacji Geograficznej (GIS) i metody Analitycznego Procesu Hierarchicznego (AHP). Wielokryterialne ramy decyzyjne uwzględniają ograniczenia techniczne, społeczno-ekonomiczne i środowiskowe. W tym celu utworzono bazę danych GIS przy użyciu danych z różnych źródeł. Ponadto, ponieważ potencjał globalnego nasłonecznienia poziomego (GHI) jest najważniejszym kryterium wyboru farm słonecznych, zastosowano wysokiej jakości słoneczną mapę satelitarną o rozdzielczości przestrzennej 0,27 km, obejmującą okres od 1994 do 2018 roku. Uzyskane wyniki wskazują na duży potencjał rozwoju energii słonecznej w Maroku na 90% obszaru kraju. W rzeczywistości otrzymana mapa została podzielona na 6 różnych klas, a mianowicie: bardzo wysoka przydatność, wysoka przydatność, umiarkowana przydatność, niska przydatność, bardzo niska przydatność i obszary wykluczenia, które stanowią odpowiednio: 53,88; 24,08; 0,15; 0; 0; i 21,89 procent zajmowanej powierzchni. Zgodnie z przeprowadzonymi badaniami, do najważniejszych kryteriów, które należy wziąć pod uwagę, należą: globalne nasłonecznienie poziome, nachylenie, temperatura i orientacja nachylenia. Uzyskana mapa została następnie porównana z istniejącymi farmami fotowoltaicznymi i wykazała, że wszystkie istniejące projekty znajdują się na obszarach o wysokiej przydatności.

Słowa kluczowe: Systemy Informacji Geograficznej, analiza wielokryterialna, energia słoneczna, wybór lokalizacji, Afryka