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A geospatial multi-criteria analysis for wind turbines and photovoltaic modules optimal siting on the island of Kos

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Abstract: The need to increase the share of renewable energy sources (RES) by 2030 raises the issue of determining the optimal sites for various RES units. Especially for wind turbines (WTs), there is a relevant legislative framework that requires the evaluation of distances from buffer zones. Using a combined model of Geographic Information Systems (GIS) and Multi-Criteria Decision Making (MCDM) in the present study, the results identify the optimal sites for both WTs and photovoltaic modules (PVs) on the island of Kos. Criteria are selected, their weights are estimated using the Analytic Hierarchy Process (AHP), buffer zones are extracted and the final results are classified into three zones, based on the legislation criteria, as well as, on the altitudes and on the maximum wind or solar potential. According to the results, Zone C, for the WT scenario, occupies 6 km^2, while the same area for the PV scenario is 13 km^2.

Keywords: GIS-MCDM model, AHP method, RES penetration, RES optimal site selection

1. Introduction

The rising demand for RES has led to the rapid growth of wind and solar power installations, with WTs and PVs playing key roles in the shift to sustainable energy. However, determining suitable locations for these systems is complex, as it depends on various factors like terrain, weather, energy output, and proximity to urban areas (Abo-Zahhad et al., 2024). Both wind and solar projects face similar challenges in site selection, and poor choices can lead to higher costs, lower performance, and increased environmental or social issues (Demir and Ulusoy, 2024). This highlights the importance of using reliable, systematic methods for selecting appropriate sites.

2. Methodology

The study area is Kos Island, which belongs to the Greek Dodecanese complex in the South Aegean. The island faces serious issues with the supply of fresh water and the use of RES could contribute to meeting the energy needs for seawater desalination. For the optimal site sitting of both WTs and PVs the evaluation criteria based on the Greek legislation are selected. In Table 1 the criteria used in this study are presented. Based on the criteria, geospatial data are collected and processed. Buffer zones are assessed and the standardization of criteria scores is executed. After that criteria are hierarchized by the designers, using the following equations.

$$x_i = \frac{(FV_i - FV_{min}}{(FV_{max} - FV_{min})} \cdot SR$$

$$x_i = 1 - \frac{(FV_i - FV_{min}}{(FV_{max} - FV_{min})} \cdot SR$$

where FV_{min} and FV_{max} are the minimum and maximum criterion values, FV_i is the value of each raster cell standardized to x_i and SR stands for the standardized range.

Table 1. Criteria used for the WTs and PVs site selection

Criteria	
Wind speed	Holy monasteries
Solar potential	Mobile antennas
Altitude	Airport
Settlements	Natura
Swimming coasts	Wildlife sanctuaries
Archeological sites	Road network

An essential part of the decision-making process is assigning weights to criteria based on their importance. The Analytic Hierarchy Process (AHP) is used as it offers a structured method for prioritizing criteria through pairwise comparisons. By organizing the decision into a hierarchy, AHP promotes clarity and consistency, using a comparison scale developed by Saaty (1997). The weighted criteria are integrated using the Weighted Linear Combination (WLC) method within a GIS environment to generate suitability maps, which visually highlight the best locations for development. As noted by Drobne and Lisec (2009), decision-makers select how to combine and weigh the criteria to evaluate different options. This approach is particularly useful for identifying suitable sites for wind turbines and solar panel installations.

3. Results

Figures 1 and 2 present the maps of suitability for WTs and PV locations. The first of the four zones, known as the buffer zone, is off-limits to wind turbine installations. Based on the final score (FS) value, which varies from 0 to 1, the last three zones have been extracted. The better the installation location, the closer the number is to 1. In Figure 1 the suitability map for the WT scenario is presented. The minimum final score value is 0.398, while the maximum is 0.7. The buffer zone occupies 246 km^2 and its final score values are zero. Zone A occupies an area of 21 km^2 and has an FS from 0 to 0.398. Zone B occupies an area of 16 km^2 and has an FS from 0.398 to 0.48. Finally, Zone C occupies an area of 6 km^2 and has an FS from 0.48 to 0.7. The final suitability map with the FS values for the siting of PVs on the island of Kos is shown in Figure 2. The exclusion zone occupies 245 km^2. Zone A occupies an area of 9 km^2 and has an FS from 0 to 0.54. Zone B occupies an area of 21 km^2 and has an FS from 0.54 to 0.62. Finally, Zone C occupies an area of 13 km^2 and has an FS from 0.62 to 0.87.

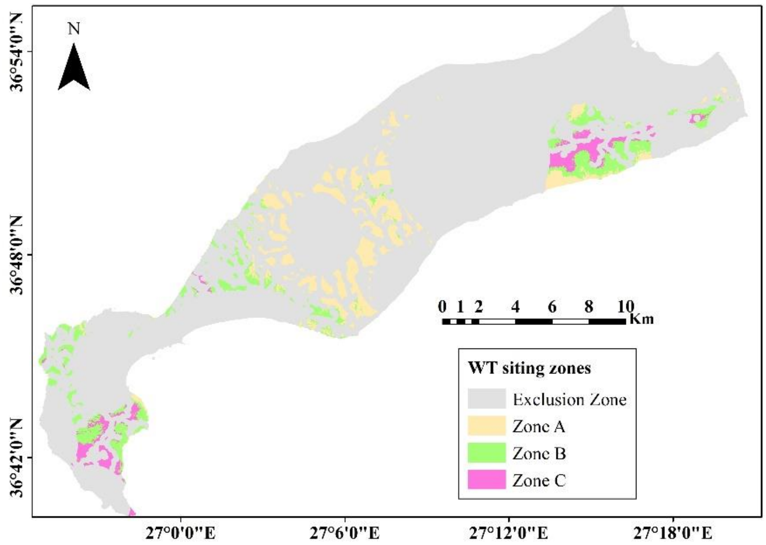

Figure 1. Map of suitability for WT locations

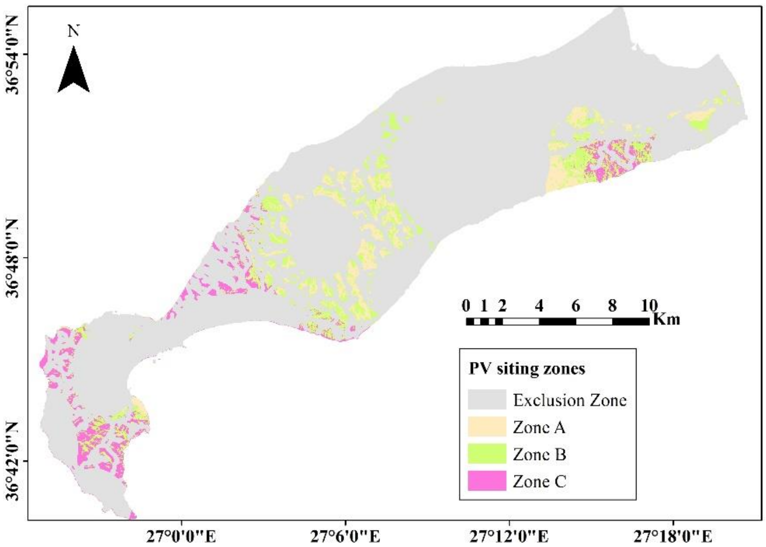

Figure 2. Map of suitability for PV locations

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