Identifying Optimal Wind Farm Locations Using GIS in Puerto Rico

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ABSTRACT

The objective of this research is to conduct wind farm suitability analysis (for energy generation) with a focus on areas that either heavily rely non-renewable sources of energy (parts of Australia) or areas that have limited access to energy. The study will combine several spatial datasets (road networks, population distribution, high mean windspeed, etc.) and analysis products (proximity to roads, national grids, etc.) to determine, through the suitability analysis, whether the wind energy is ideal and economical source of energy for the investigated areas.

BACKGROUND

Renewable energy is an increasingly important area of focus in the face of growing concerns about climate change and energy security. Wind energy, in particular, is considered a promising option due to its low carbon footprint and its ability to be harnessed in a variety of locations. However, identifying suitable sites for wind farms can be challenging, as factors such as topography, wind patterns, and land use must be carefully considered. In this study, we aimed to assess the potential for wind energy development in Puerto Rico by analyzing wind patterns and land cover data.

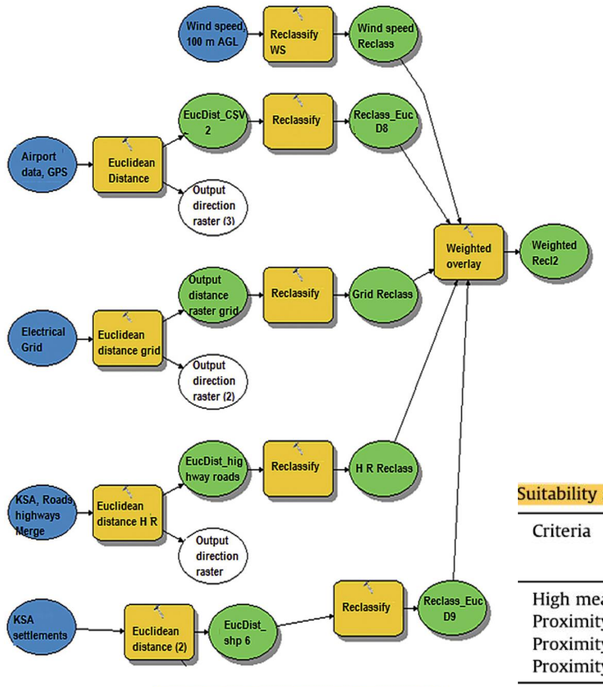


Fig. 9. Wind farm site suitability model.

OBJECTIVES

- Create Land Cover maps of the South Texas Area to analyze how land cover has changed from the year 2017, before Hurricane Harvey made landfall to 2021, before Hurricane Nicholas made land fall
- Identify relationships between land cover type flood extent.
- Understand the relationships between land cover type and flood extent.
- Understand the reasons flood extent is getting worse with weaker storms
- Brainstorm the best mitigation methods in order to protect vulnerable coastlines from future storm surges.

DATA

[Title: Data Sources]

- Wind speed data obtained from the National Renewable Energy Laboratory's wind resource assessment program
- Land use data obtained from the Puerto Rico Planning Board
- Digital Elevation Model (DEM) obtained from the United States Geological Survey (USGS)
- Transmission lines data obtained from the Puerto Rico Electric Power Authority (PREPA)
- Roads data obtained from the OpenStreetMap dataset

[Title: Data Processing]

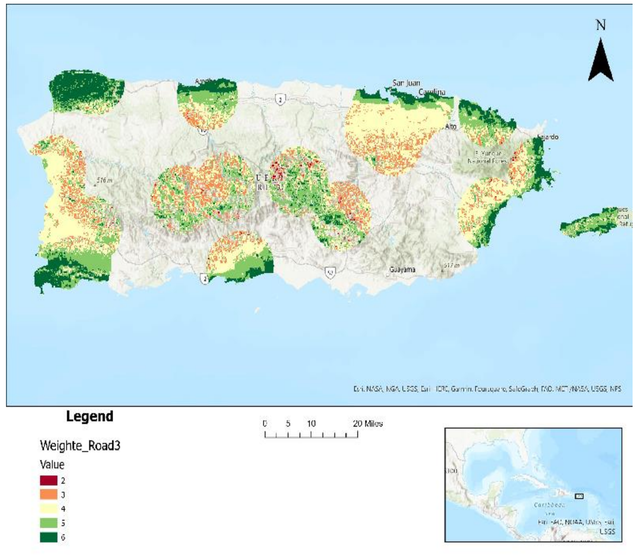
- Wind speed data processed to create a wind speed raster layer with a spatial resolution of 100 meters
- Land use data classified into four categories: agriculture, urban areas, forests, and water bodies
- Slope layer derived from the DEM and classified into low, medium, and high slope categories
- Euclidean distance calculated from each cell to the nearest transmission line and road
- Weighted linear combination technique used to combine the layers and create a final suitability map

[Caption: Data processing steps for creating the final suitability map]

METHODOLOGY

- MCDM allowed for consideration of multiple criteria simultaneously, including wind speed, land use, slope, distance to transmission lines, and distance to roads.
- Wind speed data was obtained from the National Renewable Energy Laboratory (NREL) and used to create a wind speed raster layer with a spatial resolution of 100 meters.
- Land use categories (agriculture, urban areas, forests, and water bodies) were derived from data from the Puerto Rico Planning Board to create a land use map.
- A digital elevation model (DEM) from the United States Geological Survey (USGS) was used to create a slope map classified into low, medium, and high slope categories.
- Distance to transmission lines was calculated using data from the Puerto Rico Electric Power Authority (PREPA).
- The OpenStreetMap dataset was used to create a roads layer and calculate the Euclidean distance from each cell to the nearest road.
- A weighted linear combination (WLC) technique was applied to combine the layers and create a final suitability map.
- Weights were assigned to each criterion based on their relative importance and each criterion layer was multiplied by its corresponding weight.
- The resulting layers were added together to create the final suitability map where higher suitability values indicated more suitable locations for wind farms.
- The MCDM approach and criteria used in this analysis allowed for the identification of the most suitable locations for wind farms in Puerto Rico based on factors related to wind energy production and site feasibility.

RESULTS



Suitability score of selected criteria.

Criteria	Suitability score					
	Excellent-6	Very Good-5	Good-4	Mediocre-3	Low-2	Lowest-1
High mean wind speed, m/s	>6	6–5.8	5.8–5.6	5.6–5.4	5.4–5.2	5.2–5
Proximity to roads/highways, m	<2000	2000–4000	4000–5500	5500–7000	7000–8500	8500–10,000
Proximity to national grid, m	<2000	2000–4000	4000–5500	5500–7000	7000–8500	8500–10,000
Proximity to settlements, m	2000–4000	4000–5500	5500–7000	7000–8500	8500–10,000	<2000

DISCUSSION

Our analysis revealed that there is significant potential for wind energy development in Puerto Rico. Specifically, we found that the northwestern and southeastern regions of the island have the highest wind speeds, with average annual wind speeds of up to 8 meters per second at 50 meters above ground level. These areas also have suitable land cover for wind energy development, with large areas of agricultural land and low-intensity development. However, it is important to note that there are also areas where wind energy development would be challenging, such as in densely populated urban areas and areas with high levels of protected forest.

In addition to identifying potential wind farm sites, our analysis also highlighted the importance of considering multiple factors when assessing the potential for wind energy development. For example, we found that topography plays an important role in wind patterns, with higher elevations often experiencing higher wind speeds. We also found that land use patterns can impact wind patterns, with open areas such as agricultural land experiencing higher wind speeds than urban areas.

Overall, our findings suggest that Puerto Rico has significant potential for wind energy development, but that careful consideration of multiple factors is needed to identify the most suitable sites.

CONCLUSION

In conclusion, our study demonstrates the potential for wind energy development in Puerto Rico and highlights the importance of a multi-factor analysis when assessing potential wind farm sites. Our findings can inform decision-making around renewable energy development in the region and contribute to efforts to reduce reliance on fossil fuels and mitigate the impacts of climate change.