Integrating Analytical Hierarchical Process with Random Forest for Geospatial Optimization of Renewable Energy Sites

Victor Nnam (Nigeria), Joseph Odumosu (Namibia) and Uche Ikwueze (Nigeria)

SUMMARY

Abstract

This study presents a comprehensive approach for optimizing site selection for renewable energy installations using a combination of Multi-Criteria Decision Analysis (MCDA) and machine learning techniques. The study focuses on installation of hybrid solar-wind systems, with focus on solar PV as the primary energy source due to its high regional potential within the study area. The key factors considered in this study were wind speed, solar potential, slope, elevation, land use, distance to road networks, and distance to transmission lines. The Analytic Hierarchy Process (AHP) was employed to prioritize these criteria based on expert judgment, generating a weighted overlay map that showed potential sites for renewable energy development. To enhance prediction accuracy and validate the AHP results, a machine learning model, specifically the Random Forest classifier, was implemented. Hence, the methodological approach was such that AHP was used to derive weights from expert judgement, GIS was used for the spatial data processing, while RF was used to refine predictions and also validate the AHP outputs. The model achieved high accuracy (96%), demonstrating its effectiveness in refining site suitability analysis. Feature importance analysis revealed that land use, solar potential, and proximity to roads were the most influential factors. Also, the statistical evaluations (ROC-AUC score, confusion matrix, and regression analysis), further validated the model's robustness and predictive capabilities. The findings of the study revealed the potential of combining expert-driven methods with data-driven techniques to identify optimal sites for renewable energy projects. This hybrid approach not only improves the precision of site selection but also provides information about the factors influencing renewable energy development. The study offers a practical framework for policymakers and planners to support sustainable energy initiatives.

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