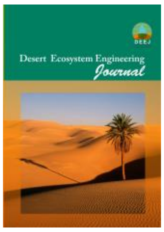
DEEJ (2024) 13 (3) 1-2

University of Kashan

Desert Ecosystem Engineering Journal

Journal homepage: http://deej.kashanu.ac.ir



Machine Learning-Based Decision Support System for Sustainable Wind Erosion Management

Javad momeni damaneh,[1] Hadi Memarian[2*]

Received: 19/01/2025 Accepted: 17/03/2025

Extended abstract

Introduction: Soil erosion, a critical environmental issue, endangers ecosystems, agriculture, and food security. This study aims to develop a precise and comprehensive method for assessing soil vulnerability to erosion by exploring various advanced statistical and machine learning models. Combining spatial modeling and machine learning, this research seeks to create a model capable of accurately simulating complex soil erosion processes and identifying erosion-prone areas with high precision. Our findings reveal that machine learning models like Random Forest and Artificial Neural Networks excel at predicting soil vulnerability. This breakthrough can significantly aid in management planning to mitigate soil erosion and conserve natural resources.

Materials and methods: To comprehensively assess wind erosion in the study area, a multi-stage approach was employed. Initially, a robust foundation for subsequent analyses was established by gathering diverse data, including high-resolution topographic maps, vegetation cover, and soil and geology data, all integrated using GIS. Subsequently, high-quality aerial imagery and extensive field visits were utilized to precisely locate wind erosion points. This step was crucial for ensuring the accuracy and reliability of modeling input data. During field visits, a GPS device was used to record the exact locations of various wind erosion types, such as ripples, dunes of varying density, ridges with different grain sizes and densities, surface erosion in the form of ridges, signs of erosion and transport, and sand plains. Following data collection, we proceeded to identify and select environmental variables that significantly influence wind erosion. From the 25 identified environmental variables, suitable variables for modeling were selected using statistical analysis and the Variance Inflation Factor (VIF) criterion, ensuring a value less than 10. This step aimed to reduce multicollinearity among variables and enhance model accuracy. To model the spatial distribution of wind erosion, a wide range of machine learning algorithms were employed. These algorithms included GLM, GBM, CTA, ANN, SRE, FDA, MARS, RF, and MaxEnt, along with a powerful ensemble model (ESMs) developed in R software. The selection of these algorithms was based on the complex nature of wind erosion and the superior ability of these algorithms to model nonlinear relationships. The data was divided into training and validation sets with a 70:30 ratio and repeated five times for model robustness. To evaluate the accuracy of the developed models, common statistical indices such as ROC, TSS, and Kappa were used. These indices represent the model's ability to discriminate between erosion and non-erosion points, overall model accuracy, and agreement between the model and observed data, respectively. By comparing these indices for different models, the optimal model for predicting wind erosion distribution was selected.

Results: Finally, the generated maps were classified into four classes based on erosion sensitivity: low, moderate, high, and very high. These maps graphically illustrate areas with a high potential for erosion and can be used as a management tool for planning and implementing erosion control measures. Among the 25 environmental variables examined, 23 variables with a Variance Inflation Factor (VIF) of less than 10 were

1. Department of Natural Resources Engineering, Agriculture and Natural Resources Faculty, Hormozgan University, Bandarabbas, Iran. Email: j.momenidamaneh.phd@hormozgan.ac.ir
2. Associate Professor, Department of Watershed Management, Faculty of Natural Resources and Environment, University of Birjand, Birjand, Iran. Email: hadi_memarian@birjand.ac.ir

DOI: 10.22052/DEEJ.2025.256228.1093

selected for the final model to minimize multicollinearity. This careful selection of variables significantly improved model accuracy and reduced errors in the results. Based on the stability results, the ensemble models (ESMs) demonstrated the best overall performance in predicting all forms of wind erosion, including ergs, low-density small dunes, high-density small dunes, high-density coarse-grained ridges, medium-density medium-grained ridges, medium-density fine-grained ridges, surface erosion in the form of ridges, removal and transport traces, and sandy areas, with respective accuracies of 0.982, 0.968, 0.921, 0.984, 0.992, 0.814, 0.816, 0.893, and 0.821. These models achieved very high accuracy in all three evaluation criteria. By combining multiple machine learning algorithms, this model has high generalizability and can be applied to various environmental conditions. Some of the most important environmental variables affecting the potential of wind erosion include drainage density, hydrological groups, frequency of rocks and pebbles, percentage of bare soil, slope, average air temperature, and vegetation cover. These variables indicate that various natural and human factors influence the wind erosion process. Modeling results indicated that nebkas and ergs were primarily distributed in the central part of the basin, while surface erosion was more prevalent in the northwestern and western regions. These spatial patterns highlight the influence of various topographic, vegetation, and climatic factors on wind erosion distribution within the basin.

Conclusion: The significance of this research lies in its ability to empower natural resource planners and managers to accurately identify critical areas susceptible to erosion. By utilizing this information, targeted management practices, such as afforestation, windbreak establishment, mulching, and proper rangeland management, can be strategically implemented in vulnerable areas. These measures not only mitigate wind erosion and conserve soil but also contribute to improved air quality, enhanced biodiversity, and ecosystem sustainability. Machine learning models offer numerous advantages for wind erosion assessment. These models provide a powerful tool for accurate and generalizable prediction and monitoring of soil erosion. Furthermore, they enable the evaluation of the impact of climate change and land use changes on wind erosion, facilitating long-term strategic planning for sustainable water and soil resource management. Additionally, these models can optimize the costs of implementing management measures and enhance their effectiveness. In conclusion, this study demonstrates the significant potential of machine learning models in assessing and managing wind erosion. By employing these models, a deeper understanding of complex wind erosion processes can be achieved, enabling the design and implementation of effective and adaptive management strategies to conserve natural resources and protect the environment.

Keyword: Erosion susceptibility, Risk assessment, Remote sensing data, Spatial data, Ensemble model, Natural resource management.