A Robust Machine Learning Framework for Soil Moisture Prediction in 12 Moroccan Regions: Insights for Climate-Resilient Agriculture

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Abstract:

This research proposes a detailed framework for soil moisture prediction across 12 distinct regions in Morocco by employing advanced machine learning models and integrating multi-source remote sensing data. The dataset spans a 12-year period (2011–2023) and combines essential hydrological, meteorological, and geological variables, such as soil moisture, precipitation, temperature, evapotranspiration, and elevation. To account for regional variability, data from five provinces within each region were aggregated, with mean values calculated for most parameters and cumulative precipitation summed to represent overall climatic patterns. Several machine learning models—Random Forest, Decision Tree, KNN, LightGBM, and CatBoost—were assessed based on key performance indicators, including R^2, RMSE, and MAE. CatBoost demonstrated superior predictive performance and robustness across all regions. The findings reveal significant spatial and temporal variations in soil moisture, driven by regional climatic and topographic differences. Furthermore, the study emphasizes the adverse effects of climate change, such as heightened precipitation variability and extended droughts, on soil moisture patterns. These results offer valuable guidance for optimizing irrigation systems, enhancing water resource management, and fostering climate-resilient agricultural practices. By tackling data integration challenges and improving model adaptability, this study advances soil moisture prediction and promotes sustainable management of resources in arid and semi-arid regions.

Keywords:

Soil moisture prediction, Machine learning models, Remote sensing data, Climate-resilient agriculture, Regional variability, CatBoost, Hydrological modeling, Precipitation variability, Irrigation optimization, Sustainable resource management, Arid and semi-arid regions, Spatiotemporal analysis.