Chapter 7
Machine Learning and Remote Sensing for Soil Moisture Prediction:
A Smart Agriculture Approach in Morocco

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ABSTRACT

Artificial intelligence (AI) plays a crucial role in soil moisture prediction, essential for sustainable agriculture in arid regions where water scarcity and climate variability threaten crop yields. This study introduces an AI-driven framework to forecast soil

DOI: 10.4018/979-8-3373-6608-1.ch007

moisture across five sites in Morocco's Draa Valley (Agdz, Tagounite, Tamegroute, Tansikht, Zagora). A dataset (2003–2024) was built by integrating historical climate records with remote sensing indicators using Google Earth Engine (GEE). Six models Random Forest (RF), XGBoost, CatBoost, k-Nearest Neighbors (KNN), Long Short-Term Memory (LSTM), and Temporal Convolutional Networks (TCN) were assessed with RMSE, NSE, MSE, and MAPE. Results showed that tree-based models clearly outperformed deep learning, with RF, XGBoost, and CatBoost achieving RMSE of 2.89%–9.11% and NSE > 0.965. Findings highlight the potential of AI-based soil moisture prediction to enhance irrigation scheduling, optimize water allocation, and support climate-resilient farming, offering a scalable solution for precision agriculture.

INTRODUCTION

Machine learning (ML) has revolutionized various fields, including agriculture, by enabling data-driven decision-making for sustainable water resource management and precision irrigation (Padhiary et al. 2024). In arid and semi-arid regions, where water scarcity, unpredictable rainfall, and soil moisture fluctuations threaten agricultural productivity, ML models offer innovative solutions for optimizing irrigation schedules, reducing water waste, and improving crop yields (Parra-López et al. 2025). By combining multi-source datasets, including meteorological records, in-situ soil moisture measurements, and remote sensing data, ML models can generate accurate soil moisture predictions, allowing farmers to adapt their irrigation strategies to changing environmental conditions (Li et al. 2025). Studies have demonstrated the effectiveness of models such as Long Short-Term Memory, Random Forest, and XGBoost, achieving RMSE values as low as 0.012 cm^3/cm^3 in soil moisture forecasting (Zhang, Hu, and Xu 2023). These advancements are particularly relevant in regions like the Draa Valley in southern Morocco, where erratic precipitation patterns and frequent droughts pose significant challenges to agricultural sustainability (Karmaoui and Moumane 2016).

The Draa Valley is emblematic of the agricultural struggles faced in semi-arid regions, characterized by annual rainfall rarely exceeding 140 mm (Schulz, Busche, and Benbouziane 2009) and a heavy reliance on groundwater for irrigation-intensive crops, such as date palms (Heidecke 2009). Traditional irrigation methods, often guided by empirical knowledge rather than data-driven insights, fail to account for the complex interactions between climate, soil properties, and crop water demands, leading to inefficiencies and excessive water consumption (A. Moumane et al. 2021). Given the increasing climate variability and depletion of groundwater resources,

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