Towards Improved Vineyard Water Management: Integrating SAR and Optical Remote Sensing for Soil Moisture Prediction

The accurate estimation of daily evapotranspiration is pivotal for effective water management in agriculture, particularly in crops like vineyards, where maintaining a precise water balance is imperative for grape quality. With climate change intensifying water scarcity, optimizing water usage has become crucial for ensuring both profitability and sustainability in agricultural production. Thus, there's a need to enhance monitoring and quantification of water usage in this sector.

The integration of spatial data from Earth observation, notably Synthetic Aperture Radar (SAR), has gained prominence in monitoring environmental changes, including agricultural water usage. SAR's capacity to provide insights into vegetation status, soil moisture levels, and water usage characteristics has proven invaluable. By integrating SAR imagery with optical images and ground sensor data, decision-makers can refine irrigation practices and minimize environmental impact.

This study focuses on utilizing SAR (Sentinel-1), optical (Sentinel-2), and in-situ soil moisture data from vineyards in northern Portugal to predict soil moisture values through remote sensing. The SAR dataset comprises 60 series of Interferometric Wide (IW) level-1 Ground Range Detected (GRD) data from three acquisition tracks. SAR backscatter data, known for its sensitivity to soil moisture, were processed to derive synthetic bands based on various polarizations from Sentinel-1. Additionally, optical data were used to compute indices such as the Normalized Difference Water Index (NDWI), Normalized Difference Infrared Index (NDII), and Normalized Difference Vegetation Index (NDVI). These values were extracted using a 3x3 window centered at each geographical coordinate, corresponding to the locations of sensors in two vineyards.

The combined SAR, optical, and sensor data resulted in 174 samples for the year 2023, each containing 28 features. Subsequently, an artificial neural network model with 6 hidden layers was trained, tested, and evaluated using repeated k-Fold cross-validation. Performance metrics including Root Mean Squared Error (RMSE), R-squared (R2), and Mean Absolute Percentage Error (MAPE) were employed, yielding an R2 of 0.857, MAPE of 6.199%, and RMSE of 1.515 on the evaluation dataset. Figure 1 illustrates the graphical analysis of the model's predictions compared to sensor measurements.

Future research endeavors will focus on expanding sensor data collection across various crops, augmenting sample size, incorporating topographic features, and enhancing model performance.

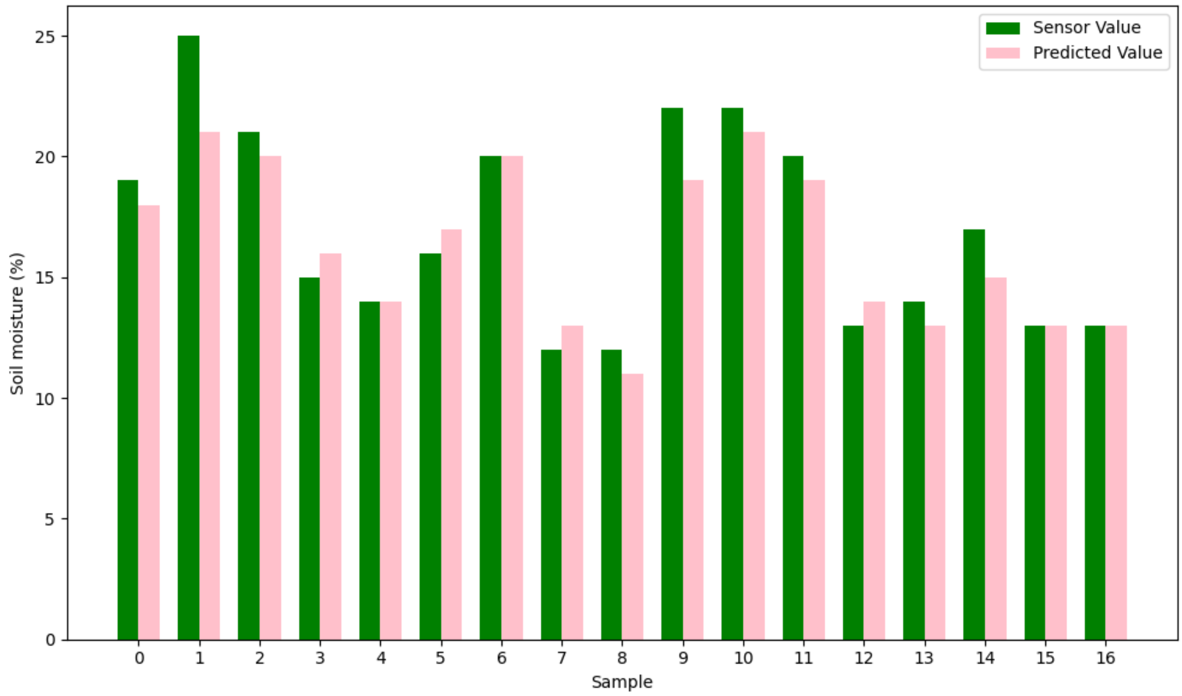

Figure 1: Comparison of Predicted Soil Moisture Levels with Sensor Measurements in Vineyards