Integration of Treetalker Sensors, Remote Sensing, and Machine Learning for Predicting Water Consumption in Cherry Orchards under Different Irrigation Regimes

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Abstract

Efficient irrigation management is a critical challenge for cherry production systems in central Chile under increasing water scarcity and climate variability. This study aimed to develop and evaluate machine learning models capable of predicting water consumption in sweet cherry (Prunus avium L.) orchards using integrated eco-physiological, meteorological, and remote sensing data. The experimental design included three irrigation treatments: full irrigation (T0), 20% irrigation reduction (T1), and 40% irrigation reduction (T2). A network of TreeTalker sensors monitored 36 trees and soil conditions at hourly resolution over two years. Additional datasets included Sentinel-2 imagery, and meteorological data from a nearby agrometeorological station.

A comprehensive preprocessing workflow was implemented, including outlier removal, Savitzky–Golay filtering, interpolation of short gaps, and cubic spline smoothing. Sap flow measurements were transformed into hourly water consumption estimates through a radial integration approach considering sapwood depth and flow variability within the trunk. Correlation analyses identified air temperature, relative humidity, solar radiation, wind speed, and potential evapotranspiration as the most relevant predictor variables.

Seven machine learning algorithms were evaluated across different phenological stages: Random Forest (RF), K-Nearest Neighbors (KNN), Support Vector Machine (SVM), Gradient Boosting Machine (GBM), eXtreme Gradient Boosting (XGB), Generalized Additive Models (GAM), and Artificial Neural Networks (ANN). Models were trained using a 70/30 training-test split with cross-validation. Among all algorithms, RF consistently achieved the best predictive performance, with Determination Coefficient (R^2) values reaching 0.81 and Medium Absolut Error (MAE) values as low as 0.16 during periods with leaf presence. Variable importance analyses highlighted air temperature, relative humidity, solar radiation, and evapotranspiration as the dominant drivers of water consumption dynamics.

The results demonstrate the potential of combining proximal sensing, UAV imagery, satellite data, and machine learning to support precision irrigation management in cherry orchards. The proposed framework provides a robust basis for improving irrigation decision-making and optimizing water use efficiency under Mediterranean climatic conditions.

Keywords

Precision agriculture, Machine learning, Irrigation management, TreeTalker sensors, Prunus avium.