## 改善葡萄园水资源管理:整合 SAR 和光学遥感技术进行土壤水分预测

准确估算每日蒸散量对于农业有效水资源管理至关重要,尤其是对于葡萄园等作物,保持精确的水平衡对于葡萄质量至关重要。随着气候变化加剧水资源短缺,优化用水已成为确保农业生产盈利能力和可持续性的关键。因此,有必要加强该领域用水量的监测和量化。

地球观测的空间数据集成,尤其是合成孔径雷达 (SAR),在监测环境变化 (包括农业用水)方面发挥了重要作用。SAR 能够提供有关植被状况、土壤水分水平和用水特征的洞察,这一点已被证明是无价之宝。通过将 SAR 图像与光学图像和地面传感器数据相结合,决策者可以改进灌溉实践并最大限度地减少环境影响。

本研究重点利用葡萄牙北部葡萄园的 SAR (Sentinel-1)、光学 (Sentinel-2)和现场土壤水分数据,通过遥感预测土壤水分值。SAR 数据集包含来自三个采集轨道的 60 个系列干涉宽 (IW) 1 级地面范围检测 (GRD)数据。SAR 后向散射数据以对土壤水分的敏感性而闻名, 经过处理后,基于 Sentinel-1 的各种极化得出合成波段。此外,光学数据还用于计算归一化 差异水指数 (NDWI)、归一化差异红外指数 (NDII)和归一化差异植被指数 (NDVI)等指数。 这些值是使用以每个地理坐标为中心的 3x3 窗口提取的,对应于两个葡萄园中传感器的位 置。

综合 SAR、光学和传感器数据,为 2023 年生成了 174 个样本,每个样本包含 28 个特征。随后,使用重复的 k 倍交叉验证对具有 6 个隐藏层的人工神经网络模型进行训练、测试和评估。采用的性能指标包括均方根误差 (RMSE)、R 平方 (R2) 和平均绝对百分比误差 (MAPE),在评估数据集上得出 R2 为 0.857、MAPE 为 6.199% 和 RMSE 为 1.515。图 1 展示了模型预测与传感器测量结果的图形分析。

未来的研究工作将侧重于扩大各种作物的传感器数据收集、增加样本量、纳入地形特征以及提高模型性能。



图1: 预测的葡萄园土壤湿度水平与传感器测量值的比较。

## 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.