IECHo 2025 Conference

The 2nd International Electronic Conference on Horticulturae

27–29 May 2025 | Online

Estimating the water requirements of citrus trees using multispectral and radar imagery

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INTRODUCTION & AIM

The cultivation of citrus fruit, particularly orange trees, is particularly water-intensive and vulnerable to water stress, especially in semi-arid Mediterranean regions. Accurate and efficient irrigation is therefore essential to guarantee crop quality, preserve water resources, and strengthen resilience in the face of climate change.

Traditional methods of estimating water requirements, such as soil moisture measurements or visual observations, are often cumbersome, costly and ill-suited to large-scale management.

Satellite imagery offers a modern, high-performance alternative. In particular, radar imagery (Sentinel-1) enables continuous monitoring whatever the weather conditions, while multispectral imagery (Sentinel-2) provides detailed vegetation indices revealing the hydric and physiological status of crops.

Objectives

Integrate radar (Sentinel-1) and multispectral (Sentinel-2) imagery to estimate the water requirements (ETc) of orange trees.

METHODOLOGY

🗺️ Study area:

Oulad Aissa (Taroudant province, Morocco) - Orange Navel, mature trees at high density.

🌦️ Data:

Radar: Sentinel-1 (VH, VV) - 2019 to 2023Multispectral: Sentinel-2 - 195 images (10 m resolution, <5% clouds)Weather: ETo via Hargreaves-Samani

🛠️ Processing:

Google Earth Engine, Jupyter Notebook, ArcGIS ProWeighted local regressions (LOESS) to smooth radar indices

RESULTS & DISCUSSION

✅ Multispectral (NDVI → Kc)

- Correction applied : -0.3065
- Final RMSE: 0.1938 (nRMSE = 1.94)

✅ Radar (VH-VV, best index)

- Best performance with K = 30
- RMSE = 0.0500, nRMSE = 0.5002
- Less affected by clouds and light

🕒 & 🗺️ 4. Water Requirements (ETc)

🌱 Clear seasonality:

- Summer (Jun-Aug) → peaks > 6 mm/day
- Winter (Dec-Jan) → < 1 mm/day

📍 Spatialization:

- Multispectral: homogeneous, precise distribution.
- Radar: noisier, sensitive to ground roughness

Criterion	Multispectral	Radar
Temporal resolution	Good	Excellent
Spatial resolution	Very good	Less homogeneous
Weather sensitivity	Sensitive to clouds/light	Independent of conditions
Processing complexity	Moderate	High (requires smoothing)

CONCLUSION

In conclusion, the combination of radar and multispectral data provides a complementary and particularly robust method for estimating the water requirements of orange trees. This approach enables continuous monitoring of crop evapotranspiration on both temporal and spatial scales, while reducing dependence on field surveys. Ultimately, it offers a precision irrigation tool capable of maximizing productivity while achieving significant water savings.

FUTURE PROSPECTS AND WORK

Future work

In the next stages, it is planned to integrate thermal data to improve the estimation of actual evapotranspiration. Artificial intelligence models, such as random forests or neural networks, could also be tested to refine prediction accuracy. The methodology will be extended to other Mediterranean fruit crops in order to validate its generalizability. Finally, a long-term analysis will enable us to assess the hydric resilience of orchards in the face of climatic hazards.

🌍 **Agronomic and environmental perspectives**

This approach paves the way for more sustainable irrigation management, by adapting water inputs to actual crop needs. It contributes directly to the preservation of water resources, a major challenge in arid zones. By reducing wastage, it is part of an agro-ecological approach. Ultimately, it could make farming systems more resilient to the effects of climate change.

🚜 **Concrete agricultural applications**

The results obtained can be used to pilot intelligent irrigation systems, such as automated drip irrigation based on satellite data. The method also provides farmers and cooperatives with concrete support for decision-making, thanks to up-to-date maps. It can be integrated into digital farm advisory platforms, enabling early detection of water deficits to optimize yield and fruit quality.