TUNING THE MONITORING OF ACTUAL DAILY EVAPOTRANSPIRATION MERGING SATELLITE DATA FUSION AND SURFACE ENERGY BALANCE

David Gómez-Candón [(1)], Álvaro Sánchez-Virosta [(1)], Yeray Pérez [(1)], Juan M. Sánchez [(1)], José González-Piqueras [(1)], Joan M. Galve [(1)]*

[(1)] Remote Sensing and GIS group, Regional Development Institute, University of Castilla-La Mancha, Campus Universitario s/n, 02071 Albacete, Spain (* David.GomezCandon@uclm.es)

ABSTRACT

The estimation of actual daily evapotranspiration (ET) at field scale from satellite imagery poses a challenge for water management due to its high demand for computational resources. This study introduces a methodology that simplifies this process by estimating ET and crop coefficients (Kc) once per week. Intermediate days are gap-filled, from these calibrated Kc and reference daily evapotranspiration (ETo) values. Weekly ET estimates were obtained using recent advances in Sentinel-3, Sentinel-2 and Landsat satellite data fusion as inputs in a Two Source Energy Balance (TSEB) model. This research was carried out in a semiarid region in southeastern Spain. An experiment was conducted in a drip-irrigated almond orchard between June 5 and July 25, 2023. The resulting ET was evaluated using data from an eddy-covariance tower. An overall bias of 1.0 $mm \cdot day^{-1}$ and a root mean square error of 1.5 $mm \cdot day^{-1}$ were revealed. These results underscore the feasibility of the proposed method to monitor almond crop evapotranspiration at the field scale on a daily basis while minimizing computational workload.

***Index Terms*—** TSEB, almond, water requirements, eddy covariance, thermal imagery

1. INTRODUCTION

In recent years, almond cultivation has experienced a significant surge in importance within the agricultural sector. This trend is driven by the increasing global demand for almonds due to their nutritional value and diverse applications in various industries. However, like many other crops, almond cultivation confronts the critical challenge of efficient water management, especially in semi-arid regions. With water resources under strain, monitoring crop water consumption, particularly in irrigated woody crops, has become crucial for a sustainable water management.

Addressing this challenge demands methodologies for precise and timely assessment. Integrating surface energy balance models, notably the Two-Source Energy Balance (TSEB) model using satellite imagery, emerges as a promising approach [1]. TSEB facilitates the estimation of crop water consumption by considering the energy fluxes between the land surface and the atmosphere, and then capturing the actual crop water conditions. In addition, these models require high-resolution land surface temperature data that can be obtained from disaggregation of satellite images [2]. Despite its potential, the application of such models demands extensive computational resources and time, presenting a barrier to accessibility for farmers.

Reducing the computational load and processing time required for satellite data analysis is imperative to enable timely and practical utilization by agricultural stakeholders. Streamlining these processes is pivotal in providing actionable insights to farmers for effective water management and sustainable almond cultivation practices.

This study addresses the challenge of daily ET estimation in large agricultural areas introducing a recent approach that combines satellite data fusion from Sentinel 2 and Sentinel 3 along with the TSEB model. Weekly ET estimation becomes critical for efficient irrigation management, especially in semi-arid regions. Here, ET was estimated from satellite data once a week, a crop coefficient Kc was derived and then applied to estimate ET from ETo Penman Monteith on the remaining days.

2. MATERIAL AND METHOD

2.1. Experimental setup

This study was carried out in a 10.5 ha drip irrigated commercial field (39º15'58"N, 1º56'23"W) planted with almond trees (*Prunus dulcis*), located in the semi-arid province of Albacete (Southeastern Spain, Figure 1). The field was widely monitored during the 2023 growing season, and this work focuses on the results from the period June 5 to July 25. Meteorological data were gathered from the closest agroclimatic weather station, La Gineta.

An eddy covariance station system was installed at the center of the almond orchard, positioned around 150 m away from the field's edge (Figure 1).

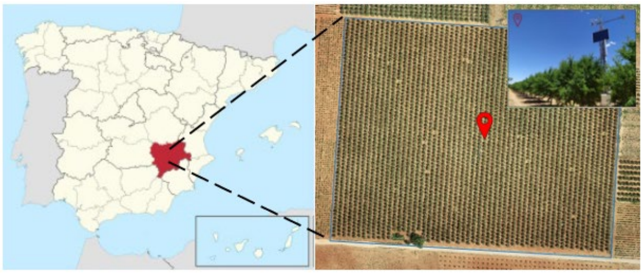

Figure 1. Location of Tarazona de la Mancha (ES-TzM, site details http://www.europe-fluxdata.eu/) experimental site and the eddy covariance tower.

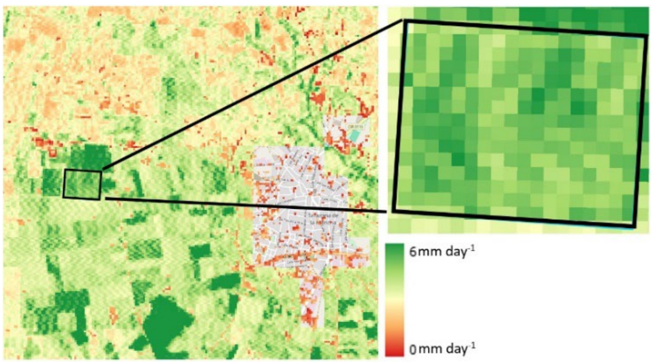

Figure 2. Map of estimated ET in the ES-TzM parcel. Example corresponding to July 10.

2.2. ET estimations

ET was estimated for each image acquisition date using the two-source energy balance (TSEB) model [3, 4]. Due to the computational demands, ET from satellite images (ET-Sat) was estimated once a week. Sentinel-2 20m resolution imagery were used to disaggregate Sentinel-3 1000m thermal data to 20m following the methodology described in Guzinski et al. [5]. Crop biophysical parameters derived from Sentinel-2 multispectral data and disaggregated Sentinel-3 thermal data were used as inputs of the TSEB model.
Subsequent to each ET-Sat estimation, a crop coefficient (Kc) was calculated as the ratio Kc=ET-Sat/ETo.
Reference evapotranspiration (ETo) was calculated applying the Penman-Monteith equation as described in the FAO-56 manual [6]. In this work, ETo data from the nearest agroclimatic weather station (La Gineta) were used.
For interim days between ET-Sat estimations, daily ET was modelled as ET-mod=Kc·ETo.

2.3. Field assessment

Observed data from the in-situ eddy covariance tower were processed to derive actual ET values, subsequently used to validate the modelled ET estimates.

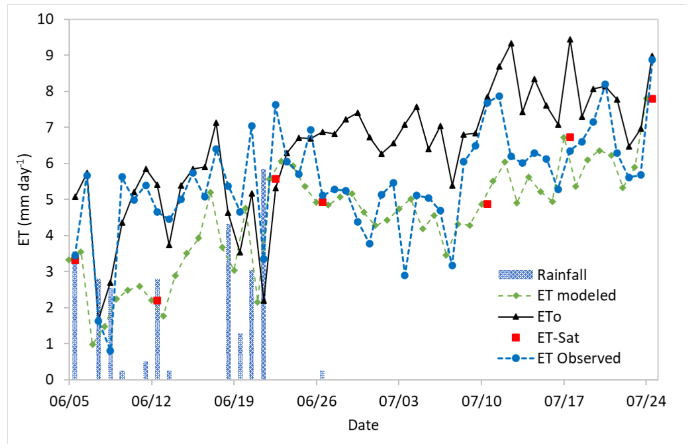

Figure 3. Evolution of modelled and observed ET over the study period. ETo values are also superposed. Modelled values correspond to the average value within the plot.

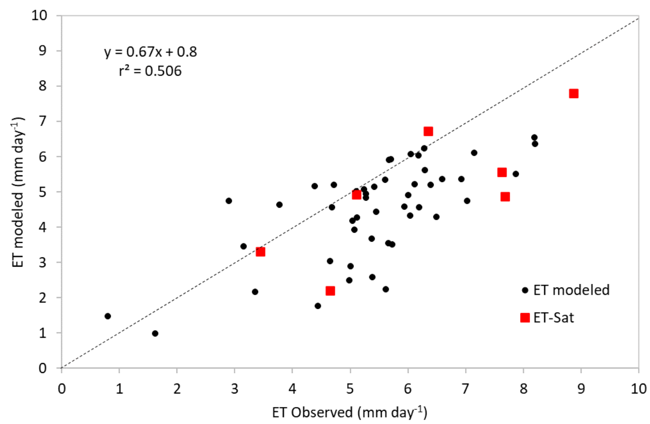

Figure 4. Linear regression between modelled and observed ET.

3. RESULTS AND DISCUSSION

The proposed method was implemented to generate daily modelled ET maps throughout the study period. Figure 2 shows an example of the spatial distribution of ET-Sat estimates for the study site on July 10. Note the potential of the methodology based on the high spatial resolution capacity of Sentinel-2 to capture the intra-plot variability.
In terms of daily evolution, modelled ET values ranged between 1-6 mm day^{-1} for the plot average (Figure 3), aligning with expectations for an almond plantation during the study period.
Comparing the modelled ET estimates from June 5 to July 25 with values obtained from the eddy covariance tower yielded an r^2 coefficient of 0.506 (Figure 4). This assessment resulted in an overall bias of 1.0 mm·day^{-1} and a root mean square error of 1.5 mm·day^{-1}. Although the observed accuracy is slightly lower compared to previous studies [5], the results remain sufficiently accurate for estimating the water status and irrigation needs of almond orchards.

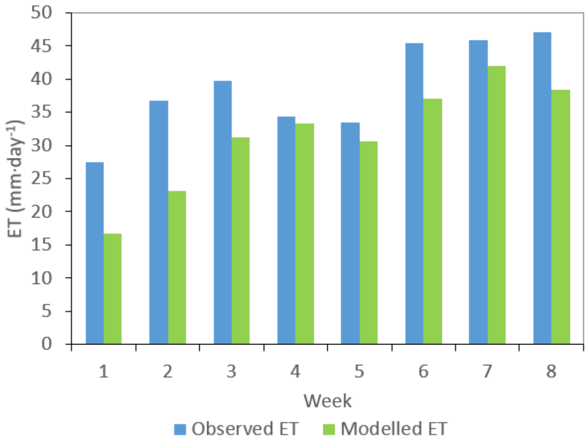

Figure 5. Modelled and observed weekly cumulative values of ET.

In terms of weekly cumulative values, the systematic underestimation in the modeled ET values versus those measured from the eddy covariance tower remains (Figure 5). This deviation should be further explored to avoid underestimation in crop water requirements that can lead to unforced water stress conditions.

Regarding processing costs, handling each Sentinel granule required a minimum of 20 Gb of RAM and the process took at least 3 hours. While modern workstations can manage this process, it remains inaccessible to stakeholders lacking appropriate equipment, demanding more computing time. Employing weekly interpolations significantly simplifies the process, thereby reducing work time.

4. CONCLUSIONS

This study demonstrates the feasibility of daily ET estimation through a combined approach utilizing Sentinel-2, Sentinel-3 and Landsat data fused with the TSEB model. Assessment against ground-based measurements indicates moderate accuracy.

Despite the resource-intensive nature of satellite-based estimation, weekly estimations complemented by Kc coefficients derived from the ETo data for the remaining days help mitigating challenges. Further research will explore the optimization of the introduced methodology to account for the effects of the rainfall, and full seasonal ET values will be accumulated for water accounting purposes.

5. ACKNOWLEDGEMENTS

This research was funded by the Spanish Ministry of Science and Innovation, MICIN/AEI (projects TED2021-130405B-I00 and PID2020-113498RB-C21) and the Education, Culture and Sports Council, JCCM, Spain (SBPLY/21/180501/000070) together with FEDER and Next Generation EU/PRTR funds. The authors express their gratitude to Héctor Nieto for the assistance with the code.

6. REFERENCES

[1] J.M. Sánchez, Ll. Simón, J. González-Piqueras, F. Montoya, R. López-Urrea, "Monitoring Crop Evapotranspiration and Transpiration/Evaporation Partitioning in a Drip-Irrigated Young Almond Orchard Applying a Two-Source Surface Energy Balance Model", *Water*, 13(15), 2073, 2021.

[2] J. M. Sánchez, J. M. Galve, H. Nieto and R. Guzinski, "Assessment of High-Resolution LST Derived From the Synergy of Sentinel-2 and Sentinel-3 in Agricultural Areas," *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 17, pp. 916-928, 2024.

[3] J.M. Norman, W.P. Kustas, K.S. Humes. "Source approach for estimating soil and vegetation energy fluxes in observations of directional radiometric surface temperature". *Agricultural and Forest Meteorology*, 77(3-4), 263-293. 1995.

[4] W. Kustas, M. Anderson. "Advances in thermal infrared remote sensing for land surface modelling". *Agricultural and Forest Meteorology*, 149(12), 2071-2081. 2009.

[5] R. Guzinski, H. Nieto, R.R. Sánchez, J.M. Sánchez, I. Jomaa, R. Zitouna-Chebbi, O. Roupsard, R. López-Urrea. "Improving field-scale crop actual evapotranspiration monitoring with Sentinel-3, Sentinel-2, and Landsat data fusion". *International Journal of Applied Earth Observation and Geoinformation*, 125, 103587. 2023.

[6] R.G. Allen, D. Raes, M. Smith, Crop Evapotranspiration: Guidelines for Computing Crop Requirements, Irrig. Drain. Pap. No. 56, FAO, Rome, Italy. 1998.