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Evaluation of Sentinel-2 MSI and Sentinel-3 SLSTR data for estimating evapotranspiration in an irrigated olive orchard in Southern Iberian Peninsula

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INTRODUCTION

Olive trees are one of the most important crops in the Mediterranean basin (10.5 Mha), accounting for 97.5% of the world's olive cultivation area with relevant social and economic benefits and ecological consequences. Concretely, it takes up 2.7 Mha in Spain, of which more than 1.6 are in Andalusia. Olive cultivation demands climate-smart management to facilitate crop adaptation to climate scenario and predictable development. A more efficient water use and management optimization is an especially important issue and, therefore, quantifying and modeling evapotranspiration (ET) is essential.

STUDY SITE

It is located at southern iberian peninsula in the province of Jaén in Andalusia (figure 1), at 370 m elevation above sea level. The area has a Mediterranean climate. During the year 2018, a nearby climatic station (343 m elevation above sea level; 37.9427° N, 3.3002° W) registered annual mean values of 67.5% relative humidity; 22.3 (max), 14.4 (mid) and 7.6 (min) °C of averages temperatures; 536 mm of accumulated precipitation; and 918.6 mm of reference ET.

It is composed by an irrigated olive grove (Olea europaea L.) divided into two flat plots, one of them with spontaneous weed canopy and the other, treated with herbicide, weed free. Plots take up 36.5 and 21.17 ha of extension respectively, in which the olive trees are distributed in a plantation frame of 12x12 m, and their crown height is 4 m approximately. Trees are irrigated by drip at rate of 32 L/h for 8 hours at night 3 times a week from February to October. Each plot has an Eddy Covariance (EC) (Dabberdt et al., 2006) tower and sensors that, among others variables, measure Net Radiation (Rn), Soil Heat Flux (G), Sensible Heat (H) and Latent Heat (LE).

METHODS

To get estimations of actual ET, we have evaluated from October-2016 to September-2019, a data fusion methodology (Gao et al., 2012) that combines Sentinel-2 MSI and Sentinel-3 SLSTR images with the two-source energy balance Priestley-Taylor model (TSEB-PT) (Norman et al.,1995) proposed by Guzinski & Nieto (2019) (figure 2). The maximum temporal resolution have been 5-10 days, depending on Sentinel-2 and Sentinel-3 images availability and cloud-free conditions.

Firstly, in order to get high-resolution surface temperature images, has been used the thermal image sharpening method, which takes advantage about relationships between optical bands and thermal data. Subsequently the TSEB-PT model was applied, which takes as the main input the sharpened thermal data and biophysical and structural variables. Process flow is showed in figure 2 (right).

Finally, the modelled values have been validated using ground-based eddy covariance data, depending on its availability at the acquisition time period of each Sentinel-3 SLSTR image. In order to this, have been averaged the eddy covariance data that were collected at the same time of each Sentinel-3 SLSTR image acquisition time period, and have been averaged too the modelled pixel values according to the eddy covariance footprint model described in Schmid (2002) (figure 3).

RESULTS AND DISCUSSION

Figure 4 and table 1 show the modelled results obtained for each variable vs values measured at each Sentinel-3 SLSTR image aqcuisition time period.

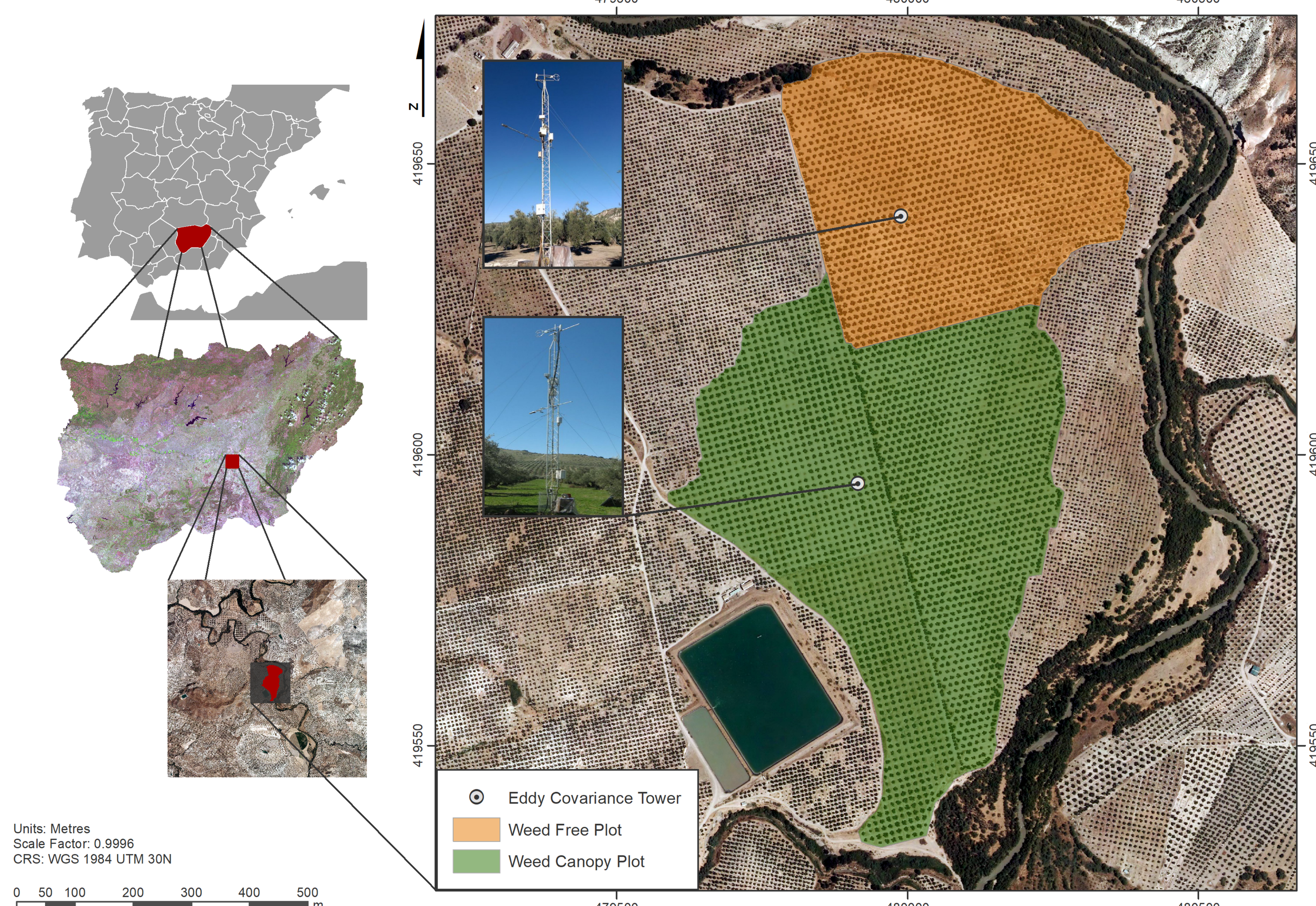

FIGURE 1. Location of study area. Cartographic sources: Base cartography of the CNIG (National Spanish Center for Geographical Information) BCN500; Orthoimage of the PNOA (National Plan of Aerial Orthophotography), study site at 0.5 m of spatial resolution of maximum actuality, acquired from the CNIG; Province of Jaén, Sentinel-2 (https://sentinel.esa.int/web/sentinel/sentinel-data-access - accessed June 2019)

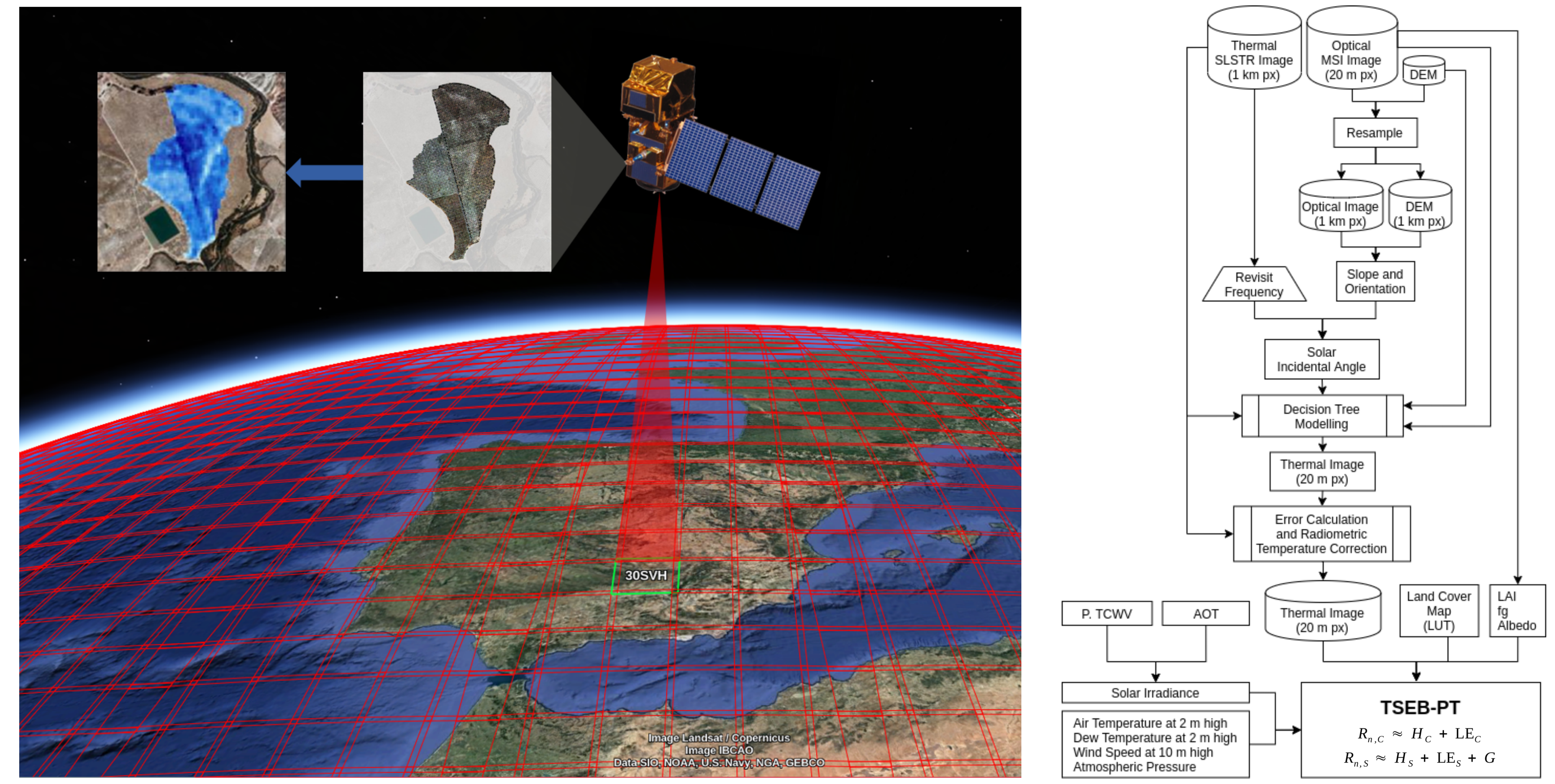

FIGURE 2. Left) Simple illustration of the objective and how to get it. Sources: Image Landsat / Copernicus, Image IBCAO, Data SIO, NOAA, U.S. Navi, NGA, GEBCO; European Space Agency; (https://es.wikipedia.org/wiki/Archivo:Sentinel_2-IMG_5873-white.jpg – accesed April 2020). Right) Process Flow. DEM: Digital Elevation Model; P. TCWV: Pressure of Total Column Water Vapour; AOT: Aerosol Optical Thickness; Land Cover Map (LUT): Look Up Table of Crop Characteristics; LAI: Leaf Area Index; fg: Green vegetation fraction, able to transpire; $R_{n,C}$ & $R_{n,S}$: Canopy & Soil Net Radiation Fractions; H_C & H_S: Canopy & Soil Sensible Heat Fractions; LE_C & LE_S: Canopy & Soil Latent Heat Fractions; G: Soil Heat Flux.

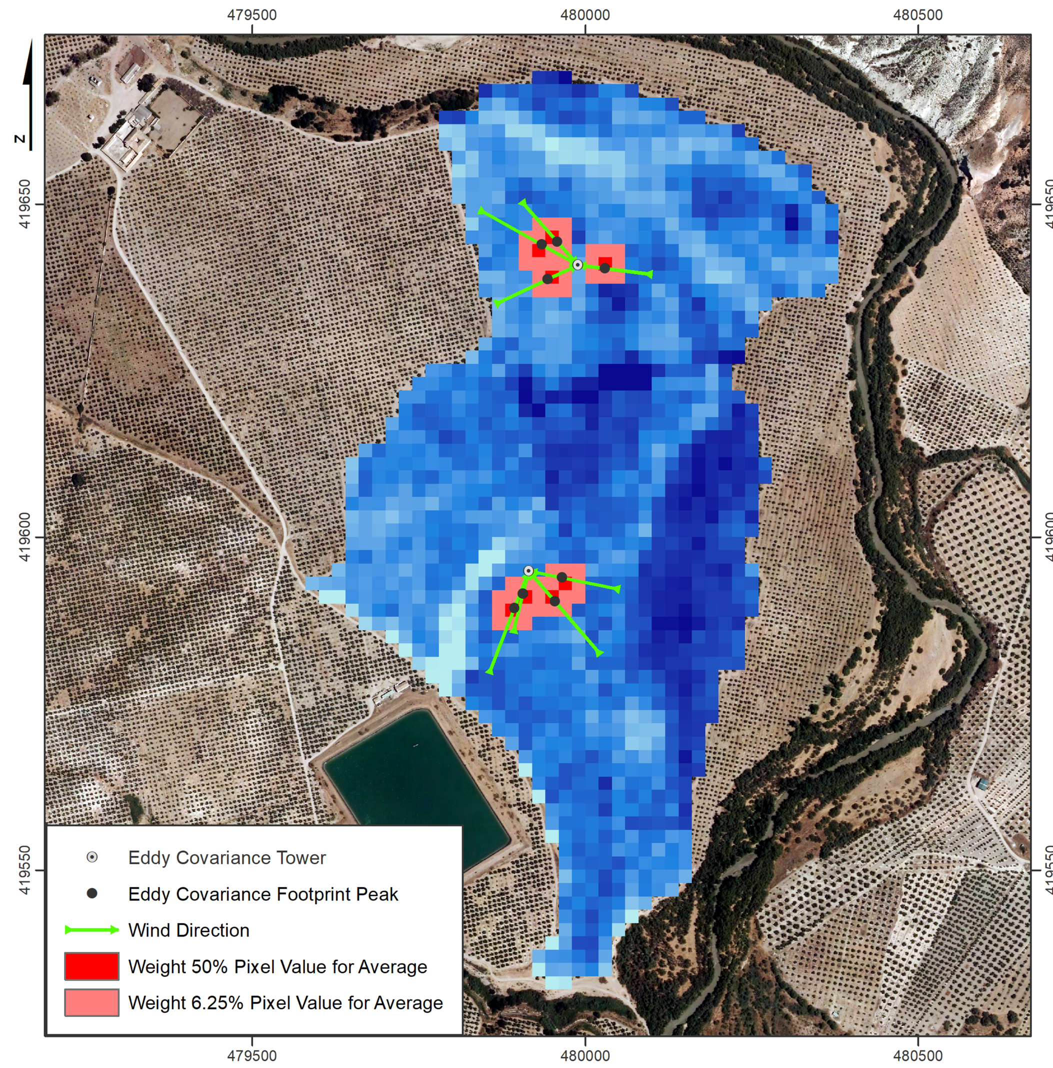

FIGURE 3. Output of model for 2019-08-25, averaged pixels and weight used according to the eddy covariance footprint model, example of validation for each data image modelled vs the eddy covariance data averaged that were collected at the same time of each Sentinel-3 SLSTR image acquisition time period.

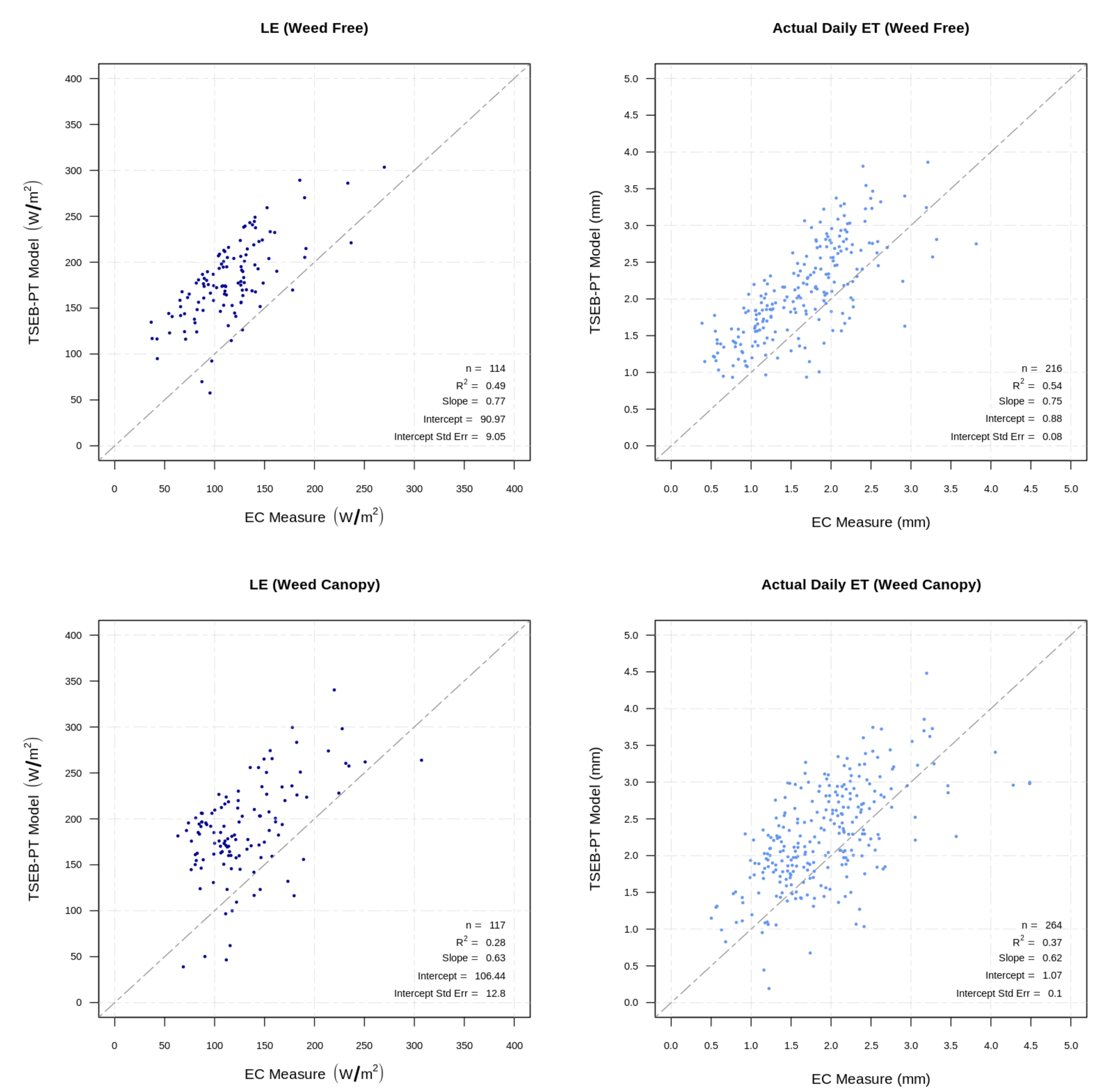

FIGURE 4. Latent Heat (left) and Actual Daily Evapotranspiration (right) for Weed Free Plot (top) and Weed Canopy Plot (down).

Table 1
Sample size (n), root mean square error differences (RMSE) and Pearson correlation (r) between modelled TSEB-PT values and EC measurements for net radiation (Rn), soil heat flux (G), sensible heat (H), latent heat (LE) and actual daily ET (ETd).

Weed Free Plot

Variable	n	RMSE (W/m^2)	r (100x)	Slope
Rn	90	116	88.66	0.76
G	261	43	77.96	0.67
H	291	49	64.46	0.63
LE	114	73	69.92	0.77
		RMSE (mm)		
ETd	216	0.75	73.32	0.75

Weed Canopy Plot

Variable	n	RMSE (W/m^2)	r (100x)	Slope
Rn	229	39	93.67	0.90
G	175	25	81.86	0.74
H	252	48	80.87	0.84
LE	117	74	52.87	0.63
		RMSE (mm)		
ETd	264	0.78	60.59	0.62

It is observed overestimations on latent heat and something lower on actual daily ET. Despite of this, root mean square error for actual daily ET, latent heat and sensible heat, are very similar in both plots. On the other hand, the biggest differences between plots are observed on net radiation and soil heat flux. These results, depending on kind of ecosystems and treatment on olive crop plot, are similar to sharpening and TSEB carried on Guzinski & Nieto (2019) with MODIS and Landsat images.

CONCLUSIONS

Process and model has worked in very similar way on both plots. Alghough it has produced overestimations, errors are overall at the same order of magnitud that those observed in other studies.

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