Performance evaluation of a two-source surface energy balance model by exploiting remote sensing and reanalysis data

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1 Intruduction

Knowledge of vegetation latent heat flux can be used to derive Crop Water Requirements (CWRs), which is crucial for optimizing water resource management in agriculture [1]. To monitor CWRs, various data sources are required, such as: *in situ* meteorological measurements, reanalysis database, and remote sensing images. This data could be employed as input for Surface Energy Balance (SEB) models. Within this research, *in situ* or reanalysis meteorological data and satellite remotely sensed images are integrated in a SEB model with the aim of proposing an operational tool in the context of future Thermal InfraRed (TIR) missions.

2 Materials and methods

2.1 Experimental Site

The experimental field is a 0.5 ha irrigated Mediterranean citrus orchard (*Citrus reticulata Blanco*, cv. Mandarino Tardivo di Ciaculli) located near Palermo, Italy (38◦ 4' 53.4" N, 13◦ 25' 8.2" E). Irrigation season starts in the middle of May and ends in late September, during a period with scarce or absent precipitations. In the inter-row area, weeds occasionally grow according to rainfall events or surface irrigation. The site is equipped with a standard weather station and an Eddy Covariance (EC) flux tower; this latter capable of retrieving the four main components of the energy balance.

2.2 Soil Plant Atmosphere and Remote Sensing Evapotranspiration (SPARSE)

The Soil Plant Atmosphere and Remote Sensing Evapotranspiration (SPARSE) is a two-source SEB model, which was implemented using a parallel soil-plant resistance network scheme [2]. SPARSE requires meteorological data, Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), albedo ( ) and Leaf Area Index (LAI). The model allows the estimation of instantaneous soil and vegetation energy fluxes. The model evaluation was carried out using three input combinations: C1) using *in situ* meteorological data, LST, and and Sentinel-2 derived NDVI (S2-NDVI) and LAI (S2-LAI); C2) by replacing S2-NDVI, LST and with Landsat-8/9 data; C3) by replacing *in situ* data with ERA5-Land reanalysis while maintaining Landsat8/9 inputs and S2-LAI. The SPARSE model was applied in the citrus orchard during irrigation seasons from 2019 to 2024.

3 Results and discussion

The performance was evaluated considering data from all the irrigation seasons together (**Figure 1**) and considering only data acquired contextually to satellite observations.

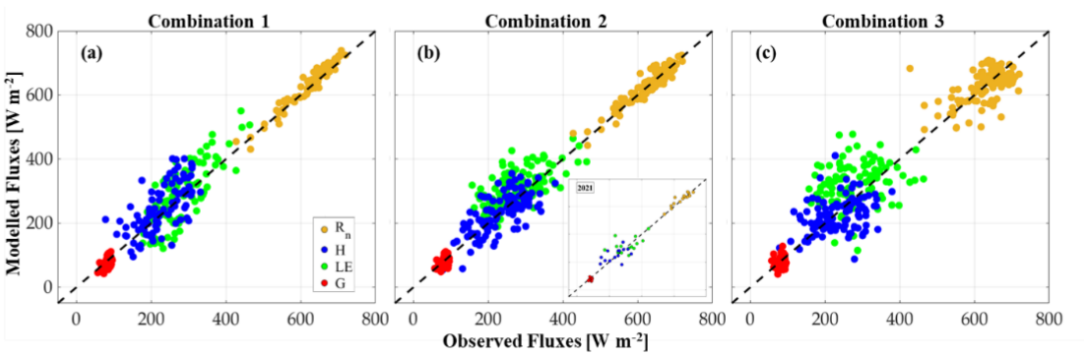

Figure 1. Scatterplots of *in situ* vs. SPARSE modelled energy fluxes for 2019-2024 irrigation seasons: (a) combination-C1, (b) combinationC2 and (c) combination-C3; the insert scatterplot in (b) shows the *in situ* vs. SPARSE modelled energy fluxes only for 2021 irrigation season; the dashed black lines are the 1:1 lines (perfect match)

Combination-C1 results – As expected, the best performance of the model was achieved for all the four flux components. Noticeably that LE were assessed with very low RMSE equal to 53 W m^{-2} (**Figure 1a**).

Combination-C2 results – The model provided the worst RMSE for LE which was ~60 W m^{-2} (R^2 ~0.41); whereas the best RMSE for R_n and G_o, with values of ~20 W m^{-2} (R^2 ~0.88) and ~15 W m^{-2} (R^2 ~0.06), respectively. Also, metrics for H are slightly better than that achieved for LE (~50 W m^{-2} and R^2 ~0.47) (**Figure 1b**). Noticeably that, even by replacing *in situ* data with remote sensing ones, the overall scatterplot is characterized by very limited dispersion around the 1:1 line; thus, suggesting that the model could provide encouragingly accurate estimates even at large scale.

Combination-C3 results – As expected, the statistical metrics considerably decreased (*i.e.*, LE RMSE ~90 W m^{-2}) (**Figure 1c**) as the consequence of the poorer estimation of R_n (RMSE ~30 W m^{-2}), which represents the driving energy for processes.

These results are consistent with those obtained by Boulet et al. [3], where SPARSE was evaluated over both irrigated and rainfed wheat (homogeneous crop). Moreover, these results agree with other studies in which TSEB model is applied [4,5,6,7].

Results suggest that the model can also be effectively applied to estimate instantaneous energy fluxes in orchards (sparse crop). Finally, the model can capture the contribution of weeds; as supported by the low dispersions in the 2021 scatterplots (*e.g.*, **Figure 1b** - inserted plot), characterized by weeds presence due to lack of maintenance from the farmer.

4 Conclusions

Results of the SPARSE model demonstrate that the use of satellite data for the instantaneous estimation of energy balance components is both feasible and reliable, providing spatially distributed LE. Particularly, SEB models combined with remote sensing technologies represent more scalable and cost-effective approaches to support irrigation management, improving the sustainability of agricultural practices.

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