UAS Multi-Sensor Integration with a Two-Source Energy Balance Model for Evapotranspiration Estimations for the Entire Growing Season of Sugar Beet

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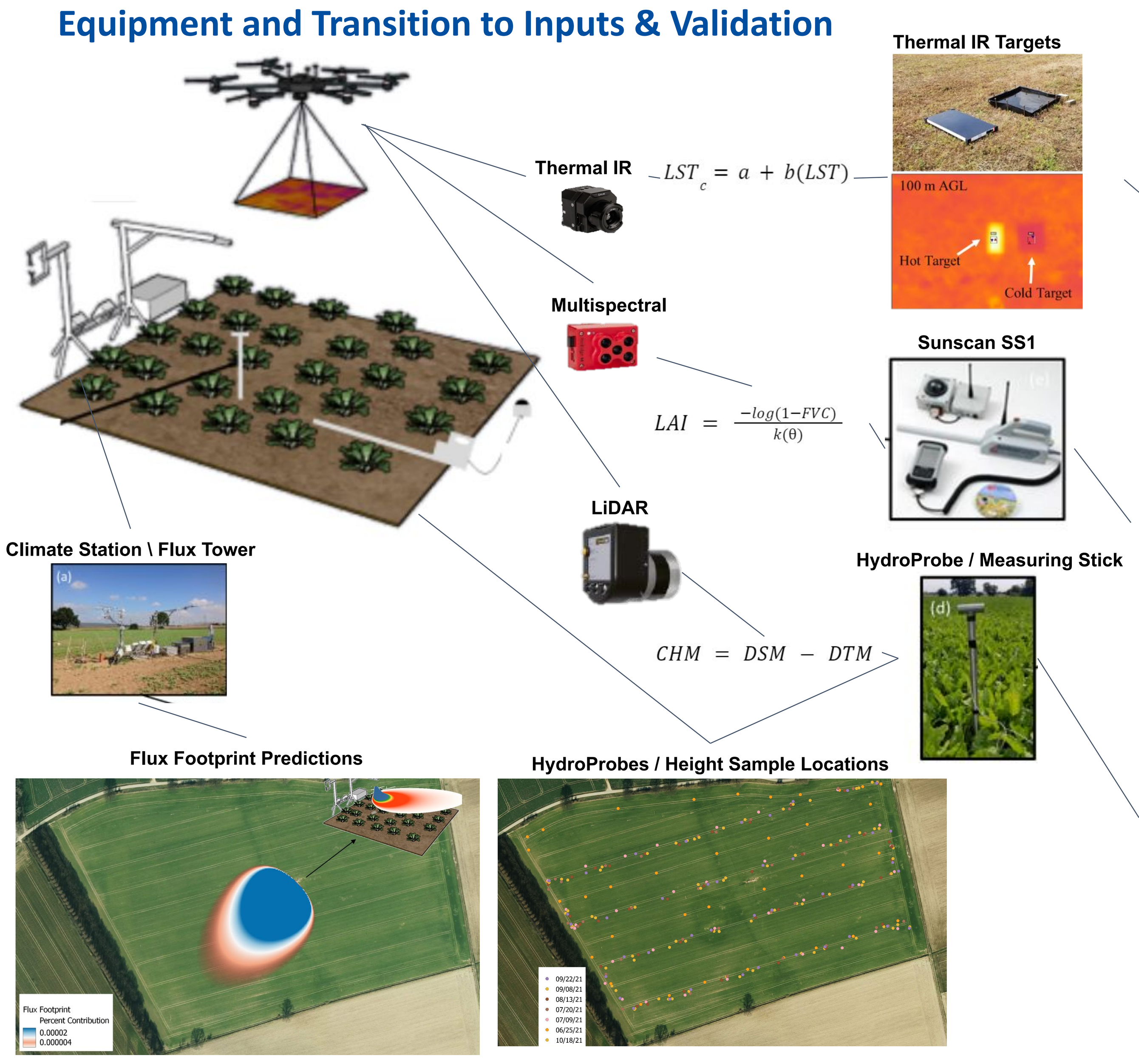
Motivation

The need for improved efficient use of water resources continues to increase as the global population rises and is further complicated by issues of climate change. A better understanding of evapotranspiration (ET) and the water demand throughout an agricultural field will help farmers preserve water. Ground-based sensing methods such as lysimeters and flux towers do not depict the spatial variation of ET needed for variable rate irrigation planning. Manned airborne methods are not economically efficient for high temporal collection and satellites are too coarse for field scale. However, UAS are becoming more easily accessible and provide higher possibilities of increased spatial and temporal resolutions. In this study, the Priestley-Taylor Two-Source Energy Balance (TSEB) model was used, with various inputs from UAS data collection, where ET is estimated per pixel with a grid size of 15 cm. These inputs include thermal infrared for land surface temperature and multispectral and LiDAR data for resistances to heat and momentum transport parameters. Measurements were taken over a sugar beet field, 10 hectares in size, for the entire growing season from May 28th to October 18th, 2021.

Study Area

Methods

Equipment and Transition to Inputs & Validation



UAS Sensor derived data model inputs

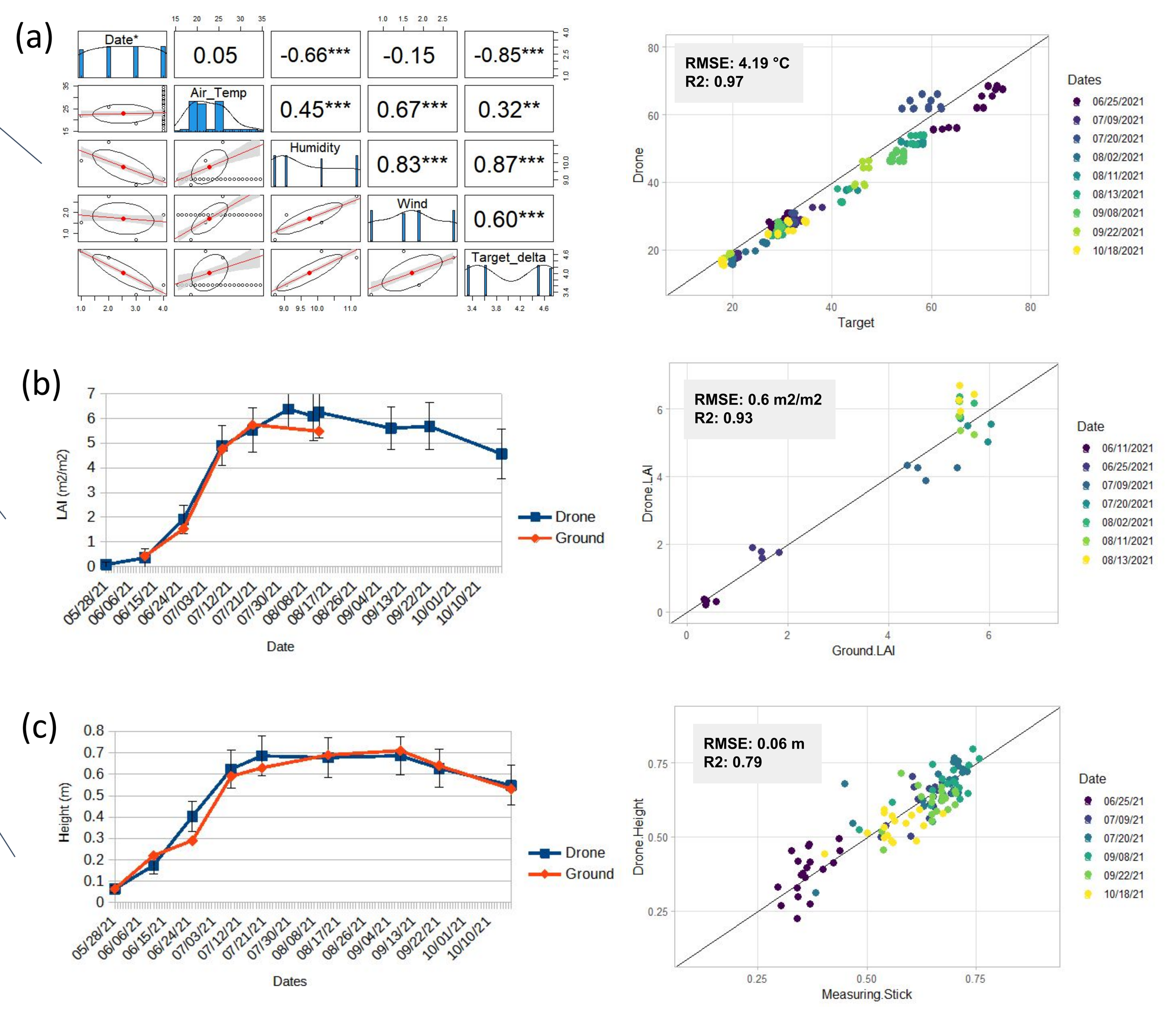


Figure 2. Data collected via drone for inputs and their associated accuracies and temporal trends if relevant with (a) thermal IR data accuracy considerations and comparison to thermal calibration targets (b) LAI accuracy to ground ceptometer measurements (c) LiDAR height to measuring stick

TSEB-PT Model

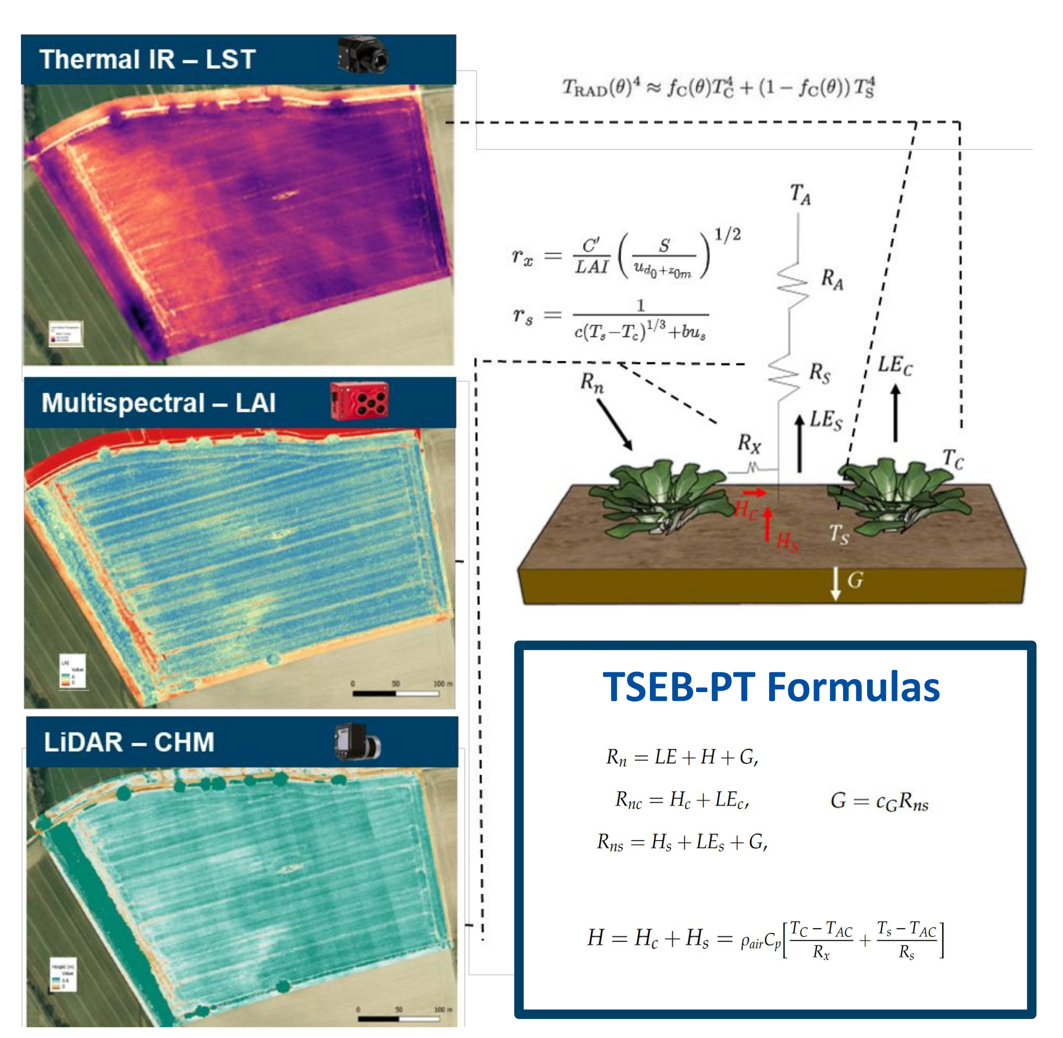


Figure 3. Schematic representation of TSEB with $\mathbf{T_A}$: Air Temperature, $\mathbf{R_A}$: aerodynamic resistance (soil/canopy system), $\mathbf{R_S}$: aerodynamic resistance (boundary layer), $\mathbf{R_X}$: boundary layer resistance of canopy leaves, $\mathbf{T_{AC}}$: temperature of canopy – air space, $\mathbf{T_C}$: canopy temperature, $\mathbf{T_s}$: soil temperature, $\mathbf{LE_s}$: latern heat flux (soil), $\mathbf{LE_c}$: latent heat flux (canopy), $\mathbf{H_s}$: sensible heat flux (soil), $\mathbf{H_c}$: sensible heat flux (canopy), $\mathbf{G}$: soil heat flux

Results

UAS TSEB-PT Model Map Results

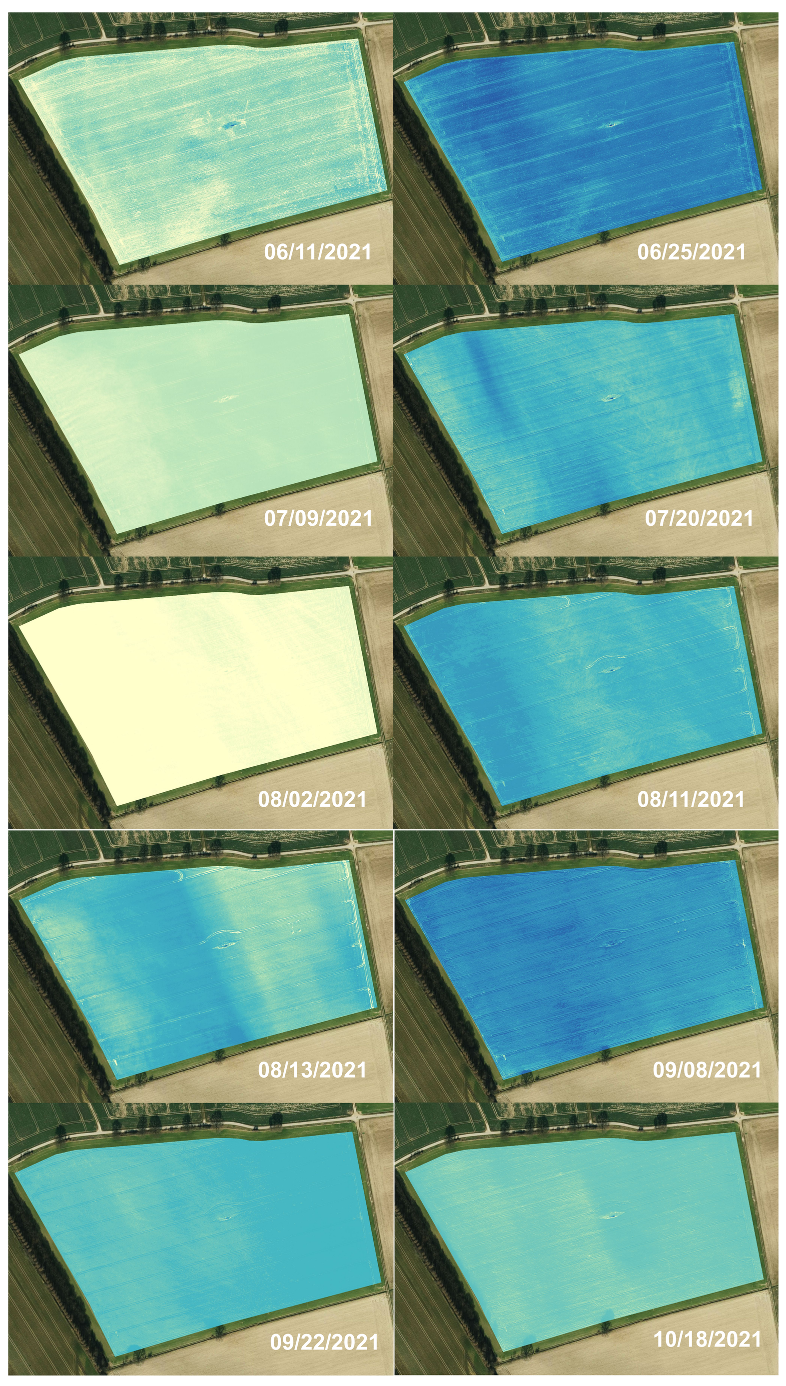


Figure 3. (a) Evapotranspiration (ET) maps produced from TSEB model for each date

TSEB-PT vs EC Flux Results

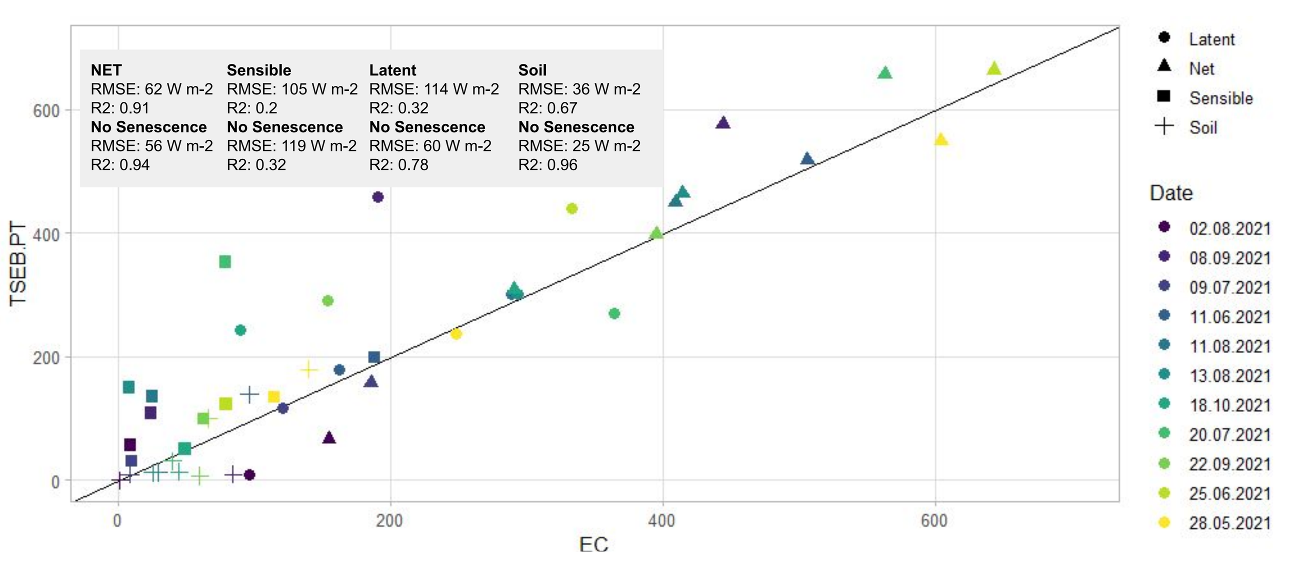


Figure 4. TSEB-PT flux estimations compared to EC fluxes

Flu Footprint Boundaries vs Entire Field (15cm GSD)

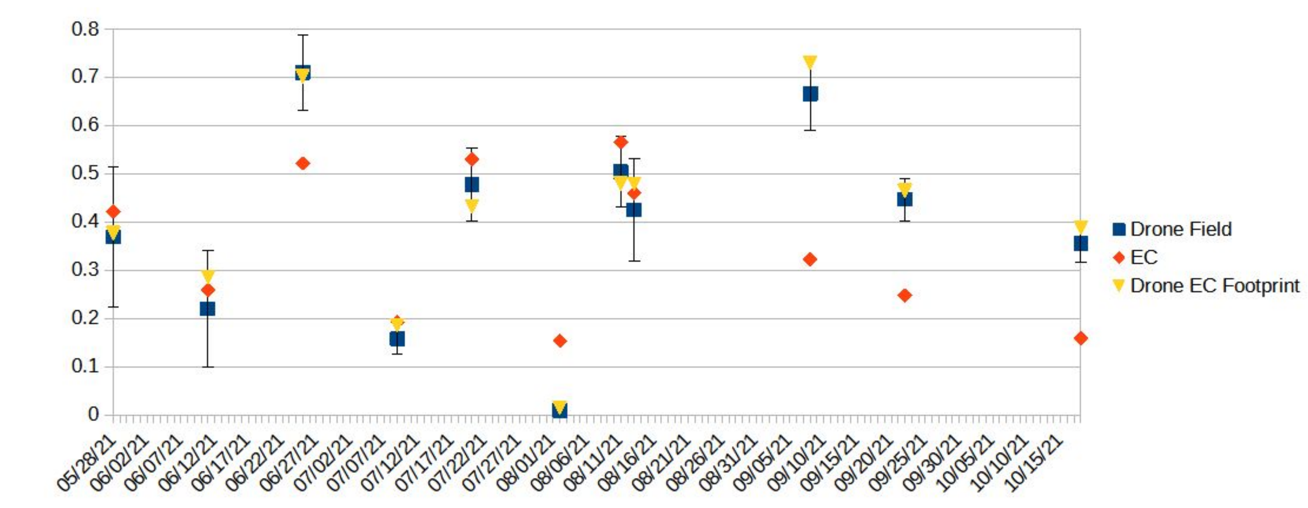


Figure 5. The mean ET of the drone TSEB raster, drone TSEB weighted ET average within flux footprint, and EC ET average within flux footprint

TSEB-PT vs EC ET (calibrated & non-calibrated thermal IR)

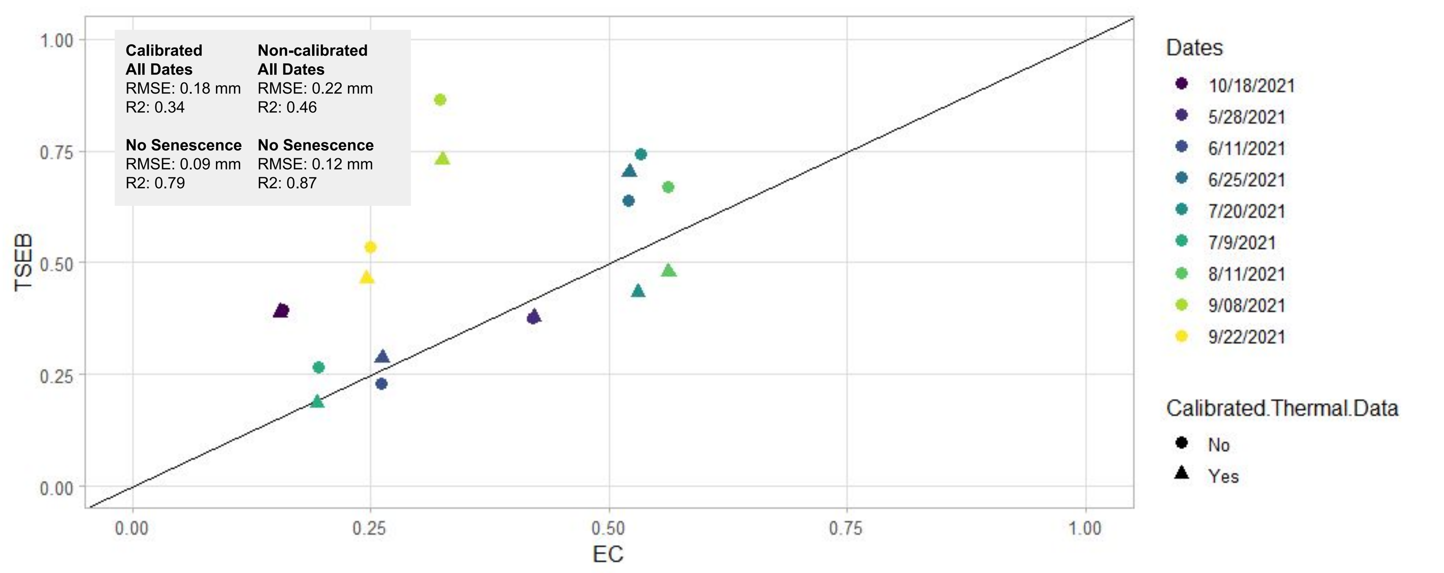


Figure 6. UAS and eddy covariance ET comparisons with all dates and then senescence dates removed with drone thermal data calibrated with thermal targets

HydroProbe Soil Moisture Sampling vs ET Spacial Variability

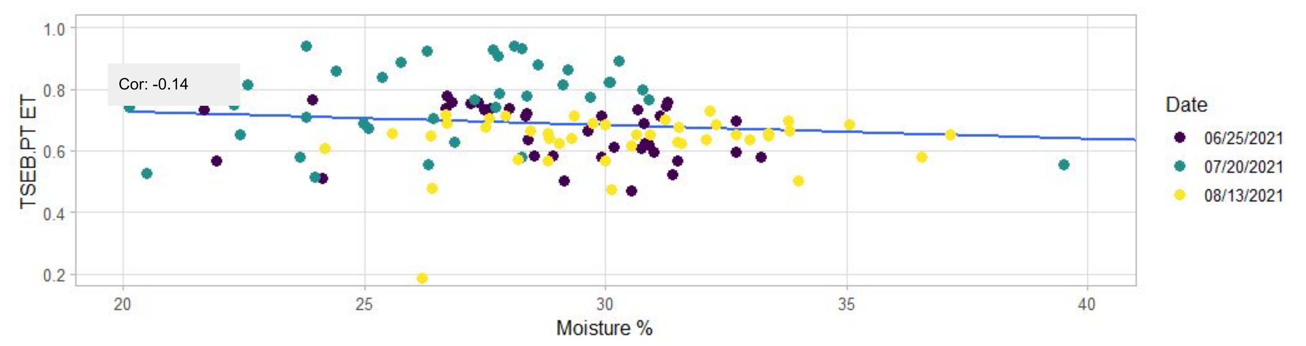


Figure 7. HydraProbe moisture data compared to TSEB ET for validation of the spatial variation depicted in the ET rasters

Contribution of Work

The results showed that TSEB using UAS data in comparison to EC for an hourly time stamp produced an RMSE of 0.18 mm and R2 of 0.34 for all dates and RMSE of 0.09 and R2 of 0.79 when excluding the senescence dates. The results of the study show promise in accurate ET estimations from UAS solutions while doing so with better resolution and depiction of variability.

[1] Norman, J.M.; Kustas, W.P.; Humes, K.S. Source approach for estimating soil and vegetation energy fluxes in observations of directional radiometric surface temperature. Therm. Remote Sens. Energy Water Balance Veg. 1995, 77, 263–293.

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