Assessment of transpiration in different almond production systems with two-source energy balance models using high-resolution aerial imagery.

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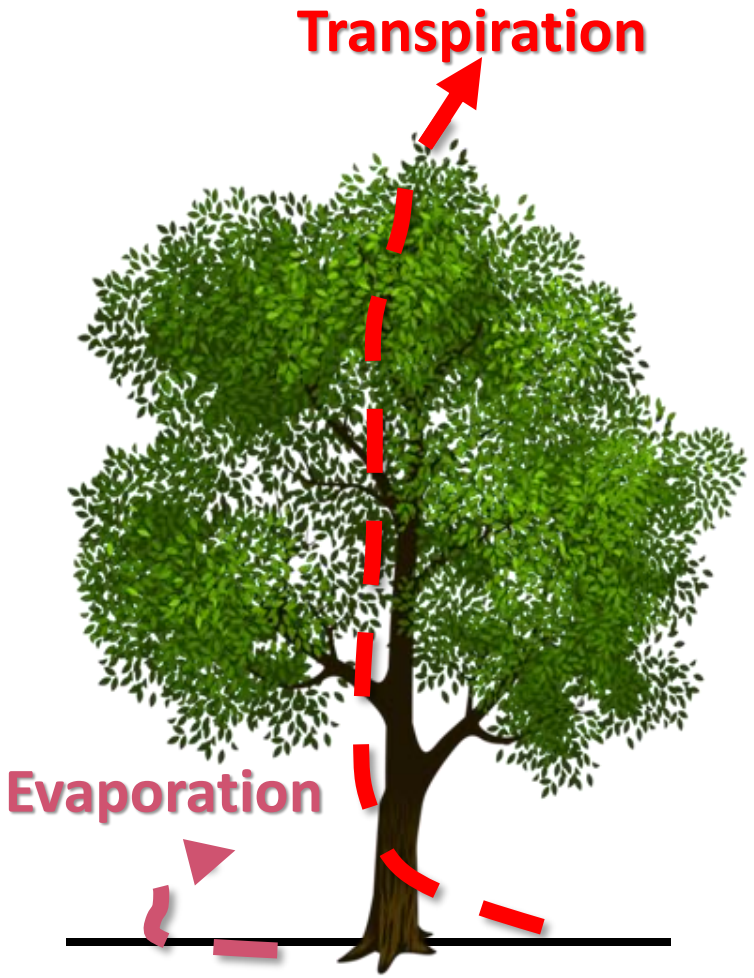
Water scarcity

The amount of water available in Catalonia's reservoirs have reached 27% of their capacity in 2023 while the air temperature has increase in the last 30 years.

Increased irrigation demand

the more intensive orchard has replaced the traditional almond systems and the percentage of irrigated almond surface has increased exponentially



ET monitoring

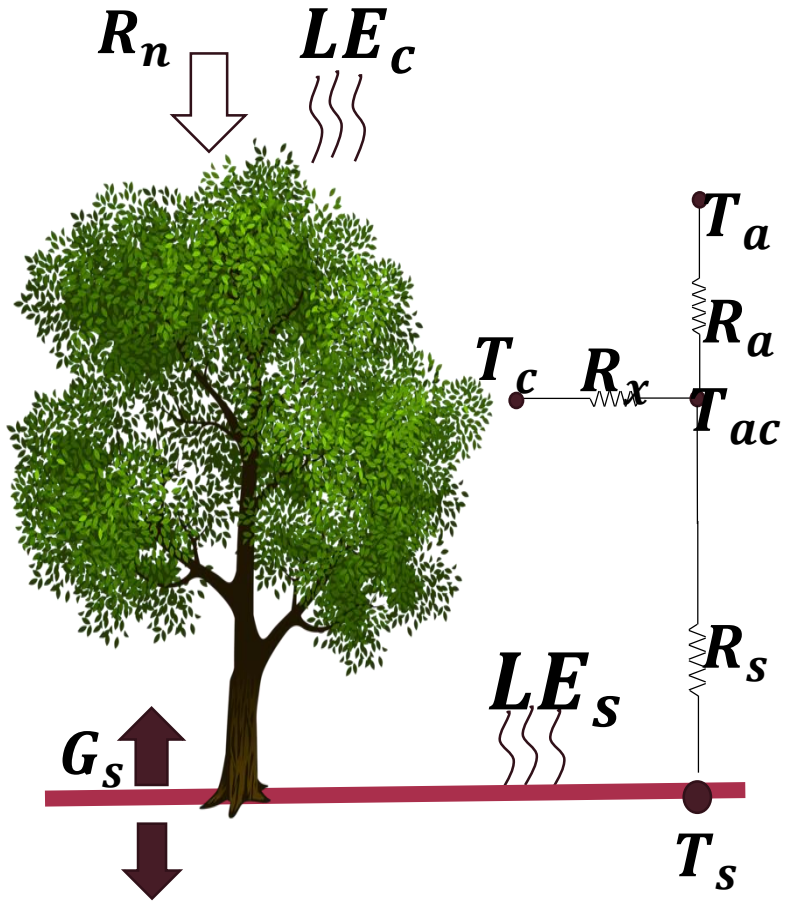
Precision Irrigation

At the right time

In the right place

In optimal quantities

Accurate methods for estimating crop water requirements



Two Source Energy Balance Model (TSEB)

Norman 1995, Norman & Kustas 1999

Estimate the plant Transpiration and evaporation from non-vegetated surfaces separately.

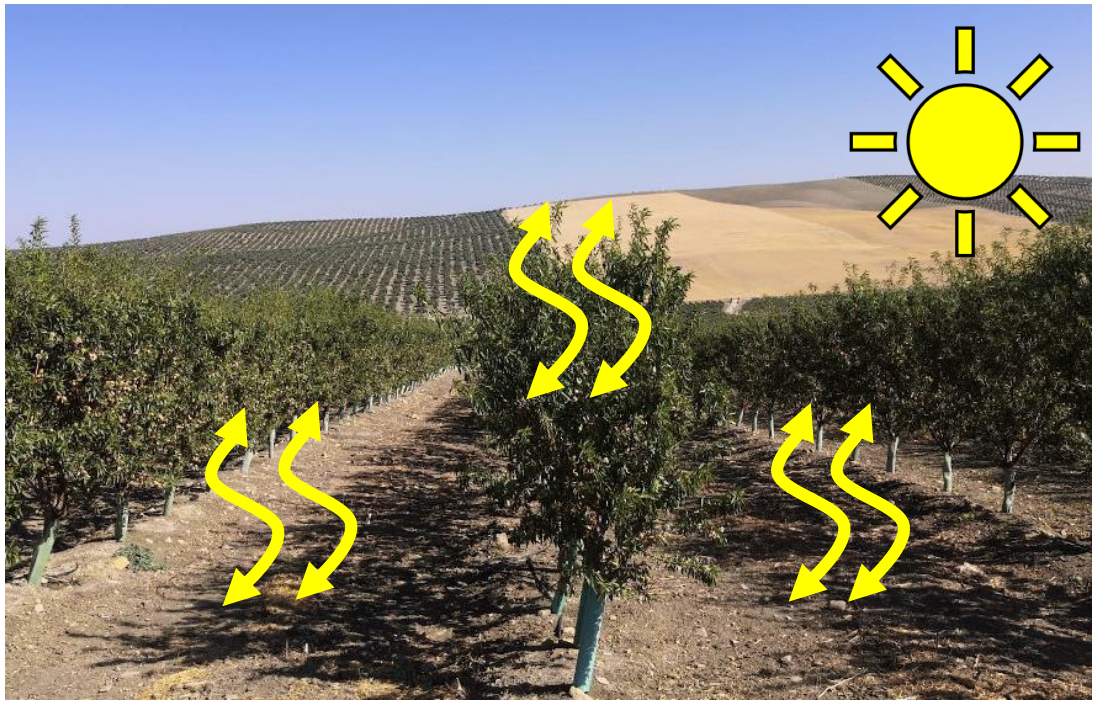
$$LE = H - Rn + G_s + P - R + G_p$$

$$\boxed{LE_c = Rn_c - H_c}$$

$$LE_s = Rn_s - H_s - G_s$$

https://github.com/hectornieto/pyTSEB

Shortwave Transmittance models in Transpiration

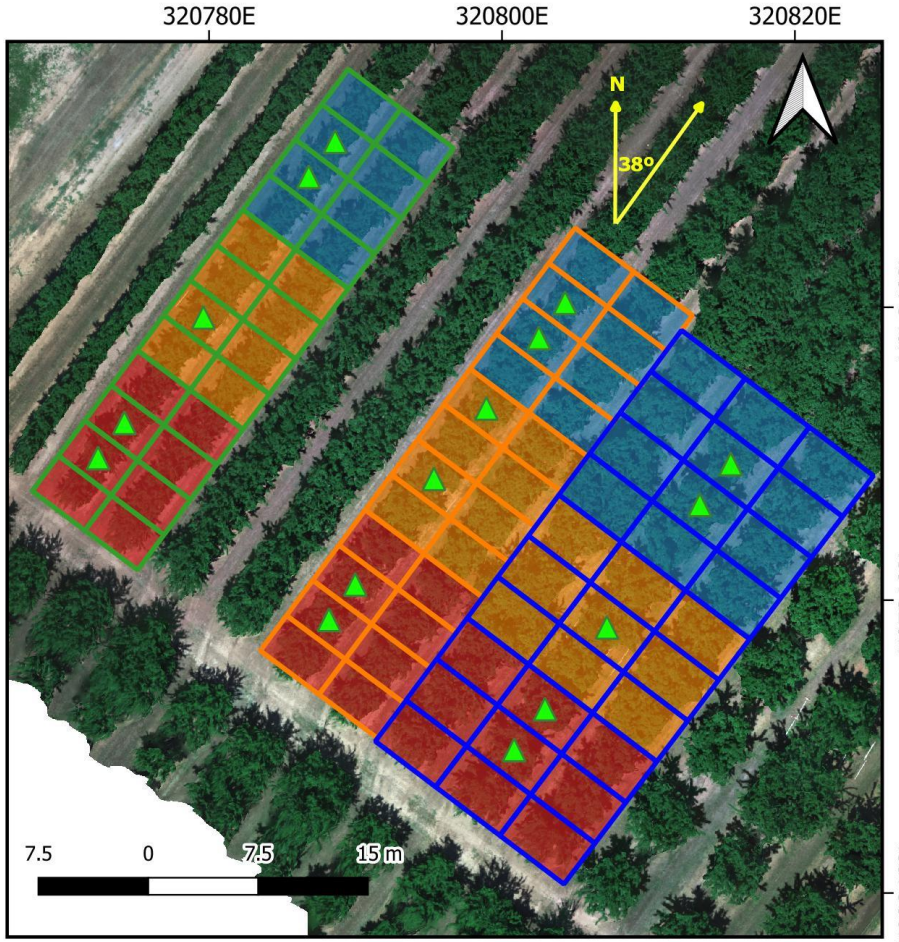


canopy architecture (*fc*, *hc*, LAI, *wc*) → Shortwave transmittance → Divergence of net Radiation → Transpiration rate

Objetives

1. To **validate** the estimation of **transpiration using the TSEB** model in almond trees under three different productivity systems and water regimes using **sap flow measurements**.
2. To **evaluate the effect** of applying the **shortwave transmittance** model C&N-R in the TSEB using the Priestley-Taylor (PT) and contextual (2T) schemes

Trial location and design

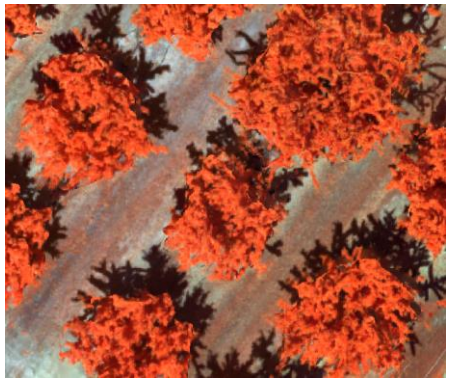


Les Borges Blanques

Production System
- Open vase
- Central axis
- Hedgerows

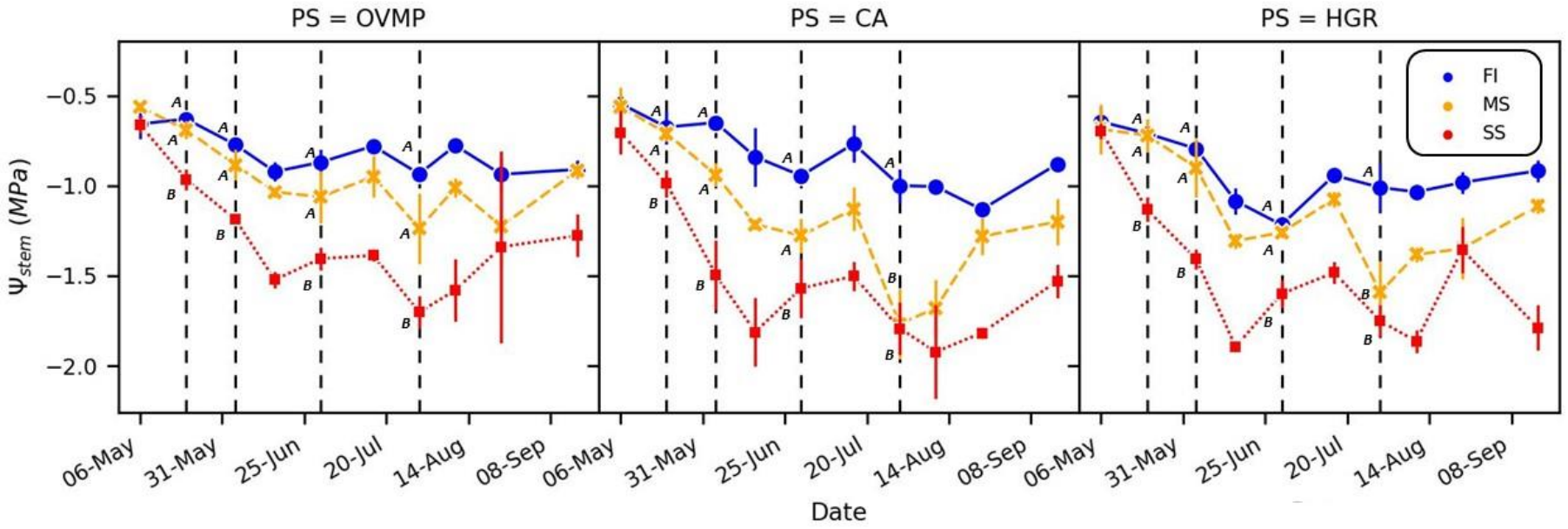
Sap flow

Irrigation Treatment
- Full irrigation
- Mild stress
- SeveresStress



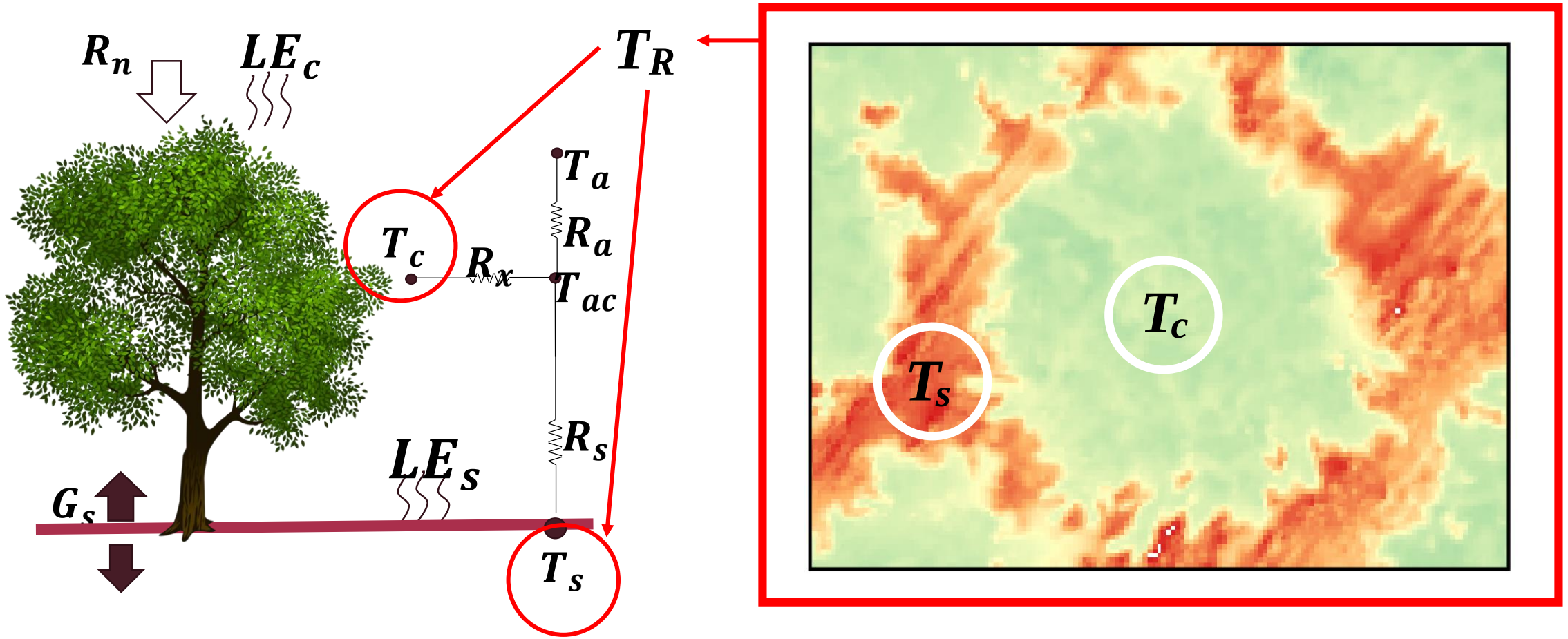
Water regimenes in 2021

Stem water potential

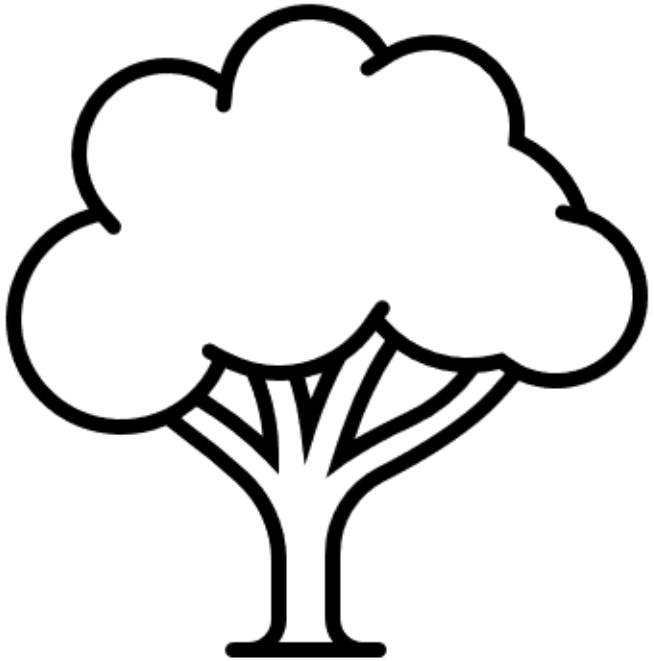


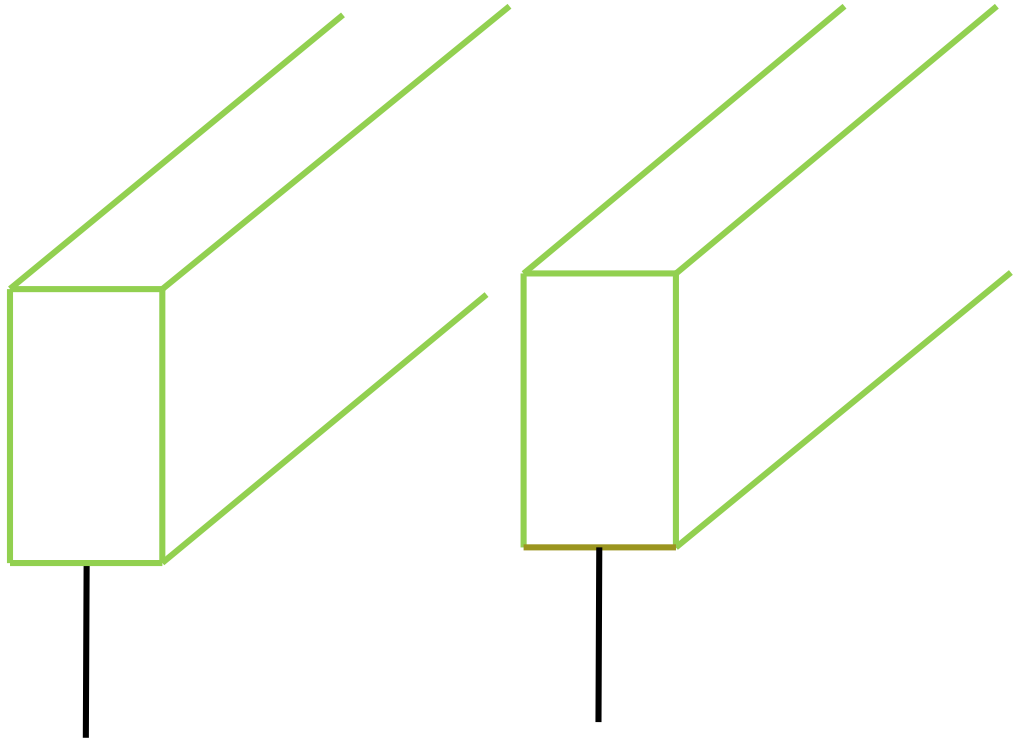
----- Flights

TSEB Prlestley-Taylor (TSEB-PT) and contextual (TSEB-2T) approachs



Shortwave Transmittance (τ_C) models in Transpiration





- **C&N-H**

Campbell and Normal with basic clumping index

- **C&N-R**

Campbell and Normal with hedgerow clumpling index

(Colaizzi et al. 2012; Parry et al. 2018)

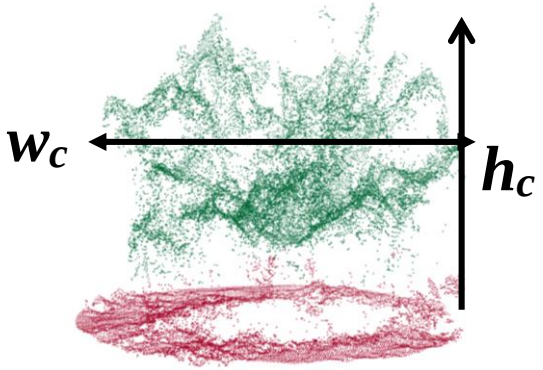
Image Acquisition

Temperature and biophysical traits and Transpiration estimate using UAVs

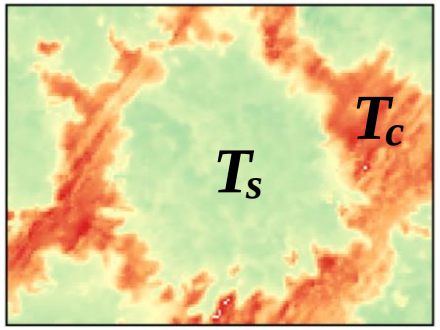
Multispectral

LAI

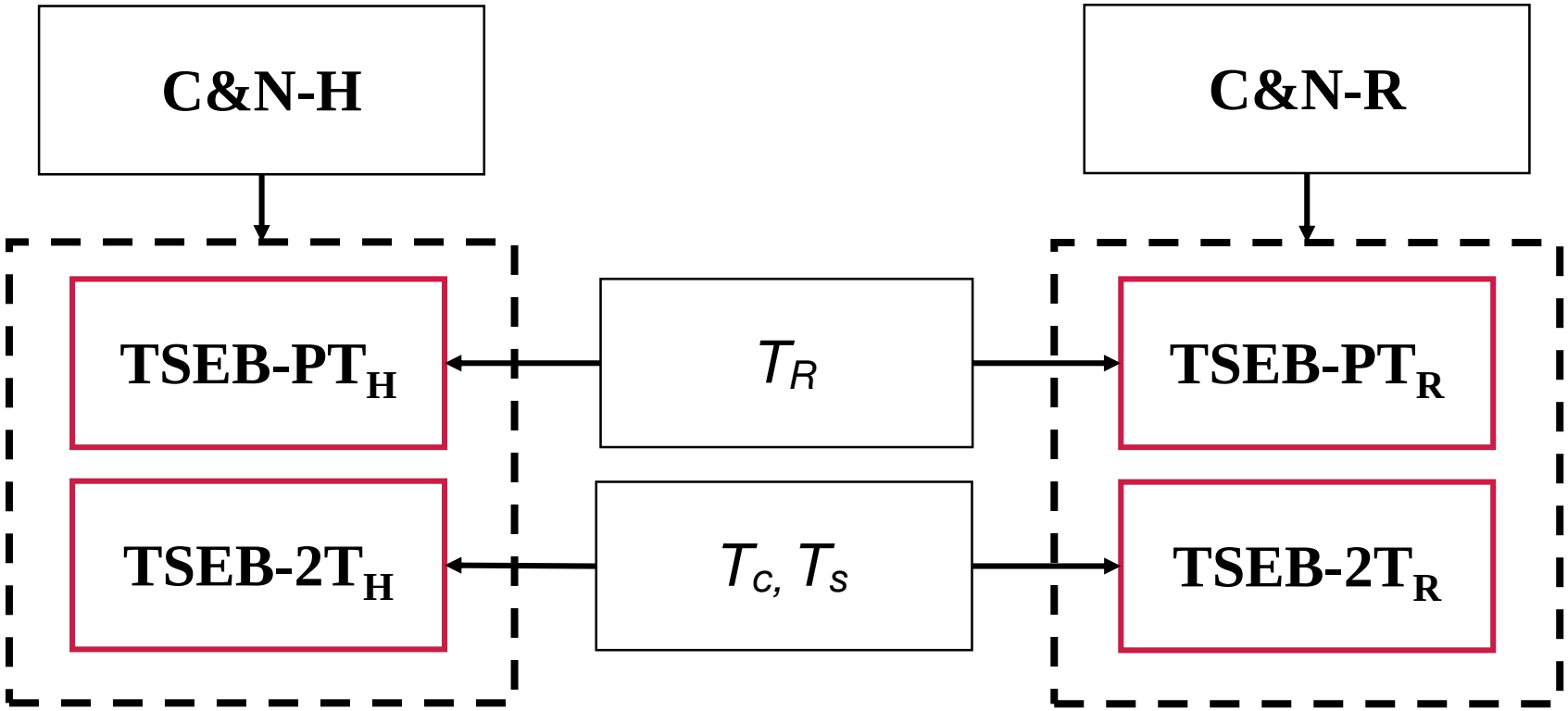
Point Clouds



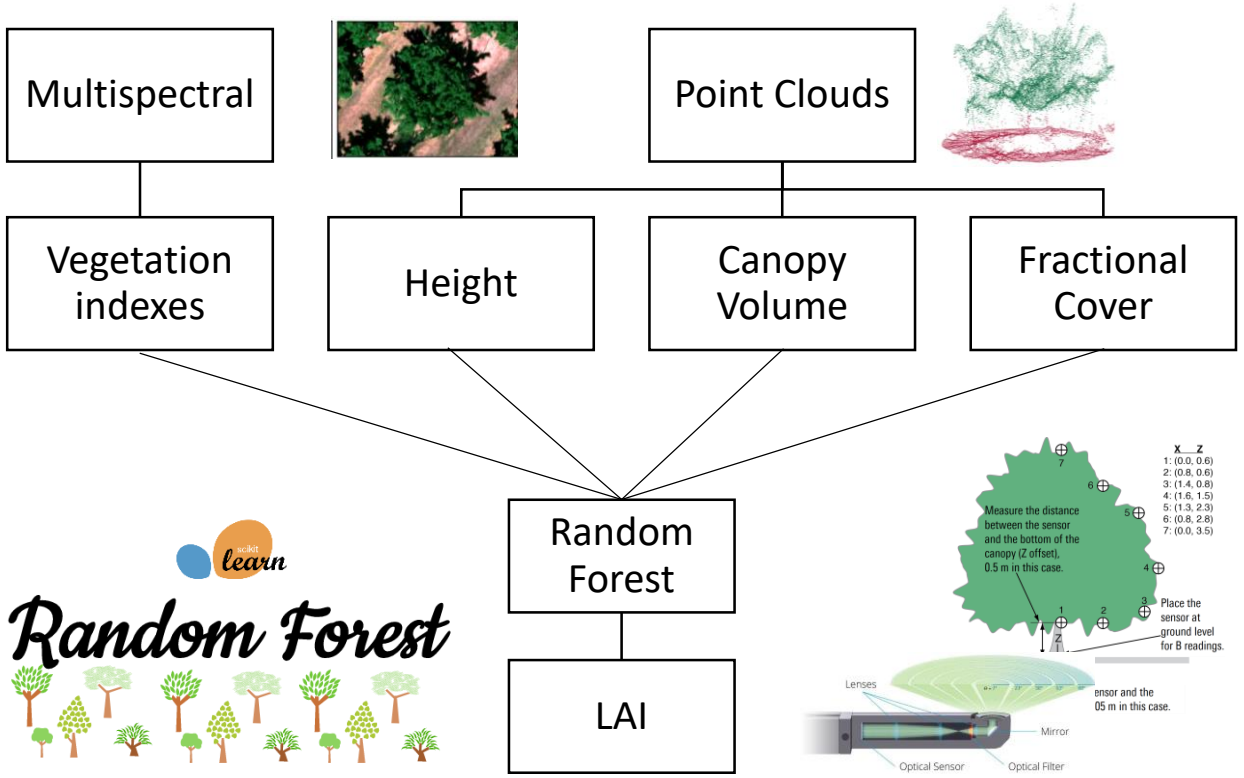
Thermal



T_R

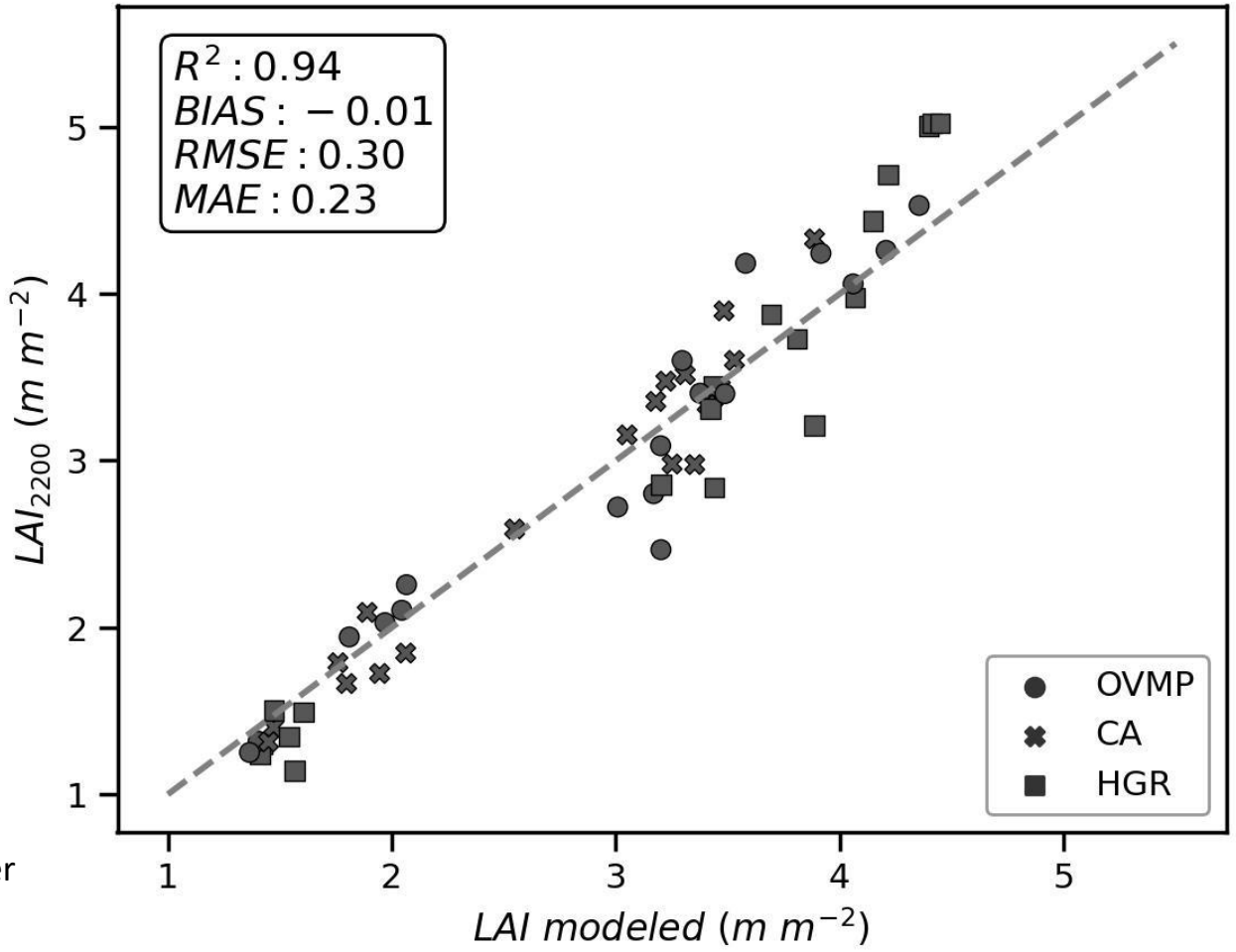


Random forest model to estimate leaf area index (LAI)



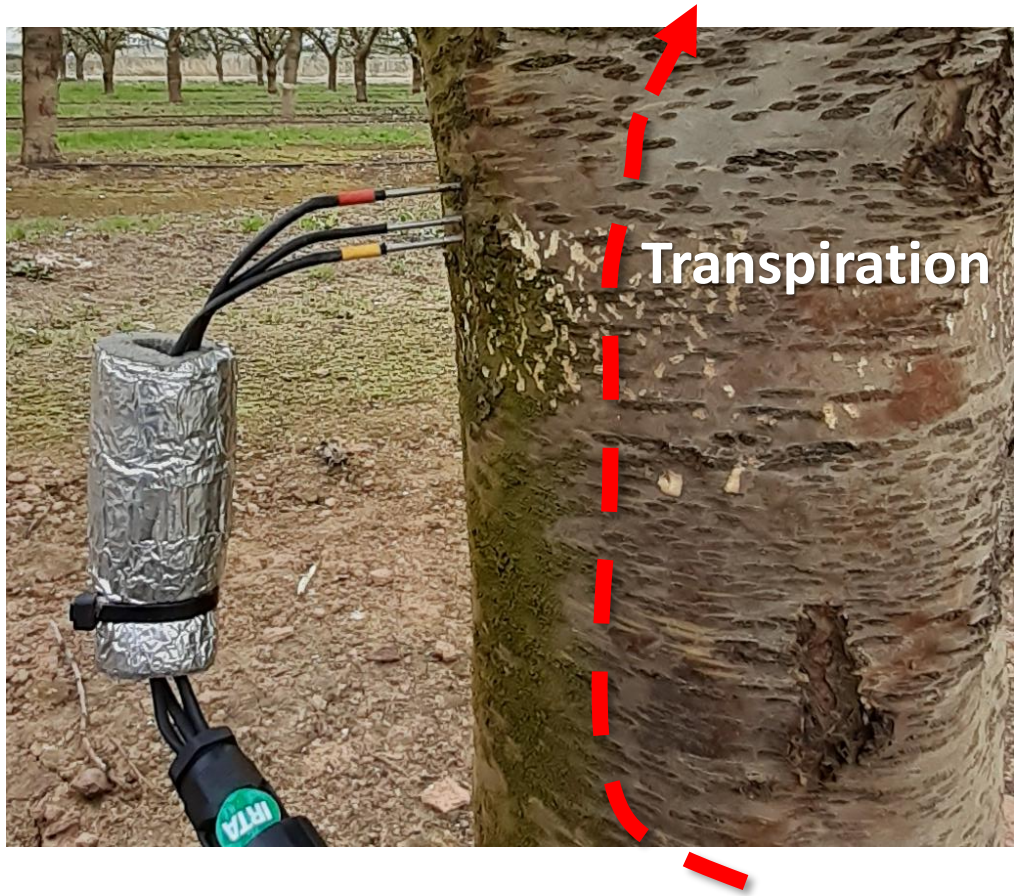
(Gao et al. 2022)

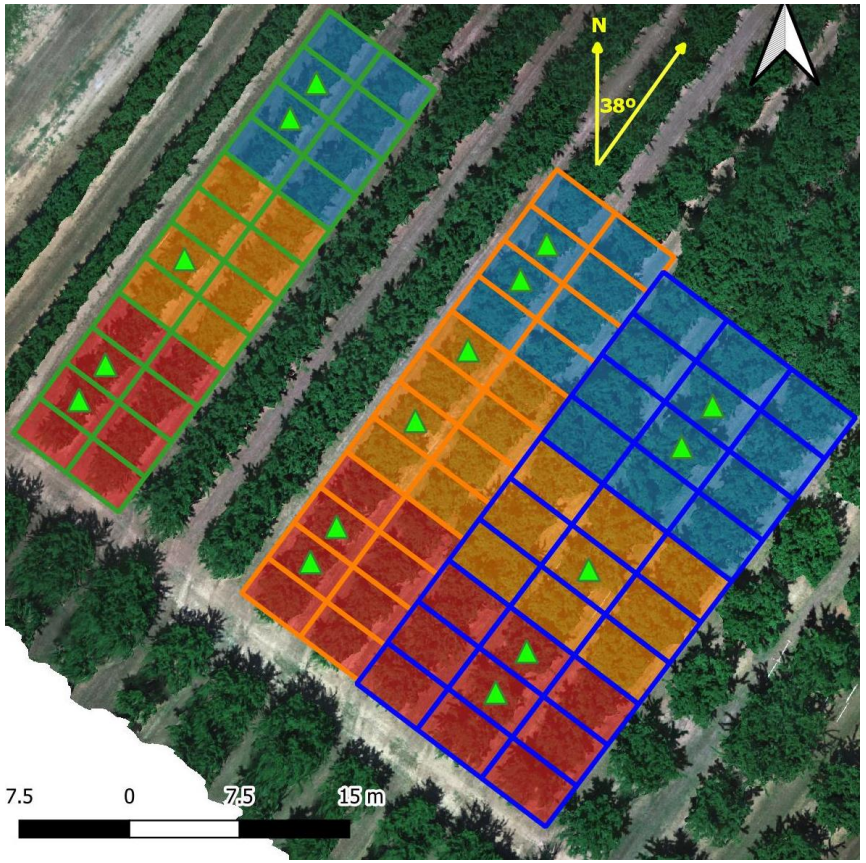
LAI-2200 Plant Canopy Analyzer
LI-COR Inc., Lincoln, NE, USA



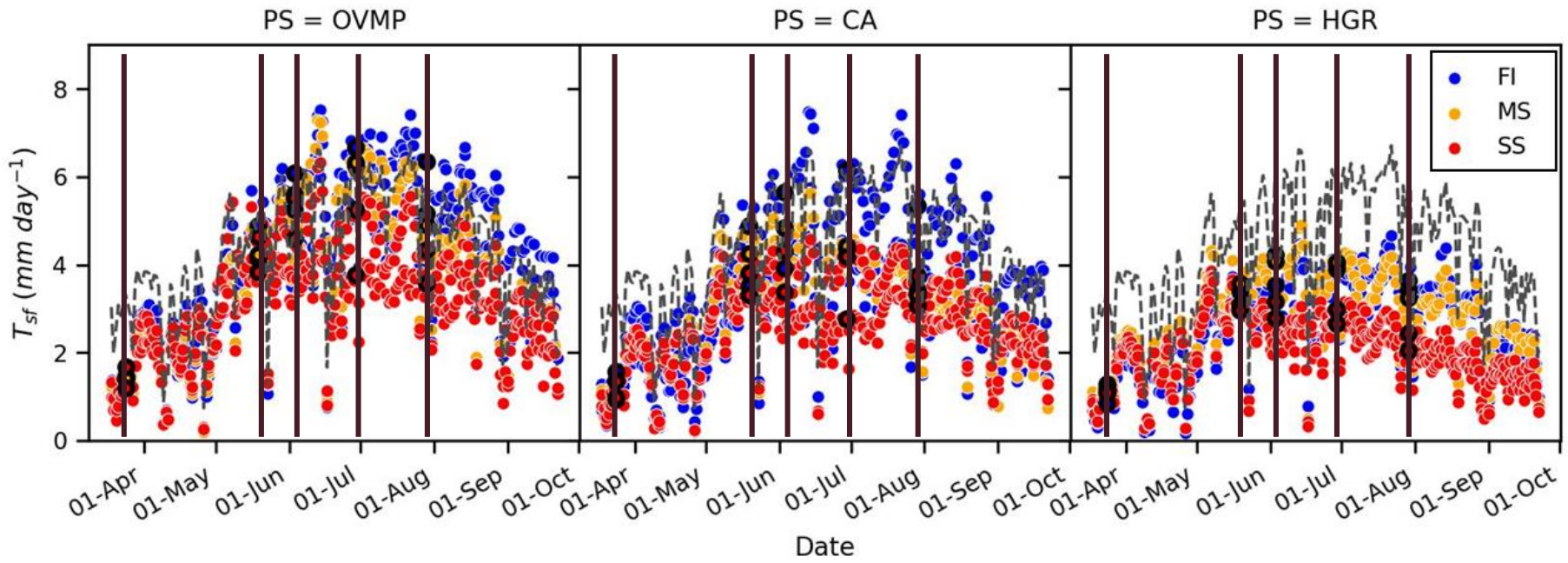
Sap flow measurements

Direct estimation of transpiration

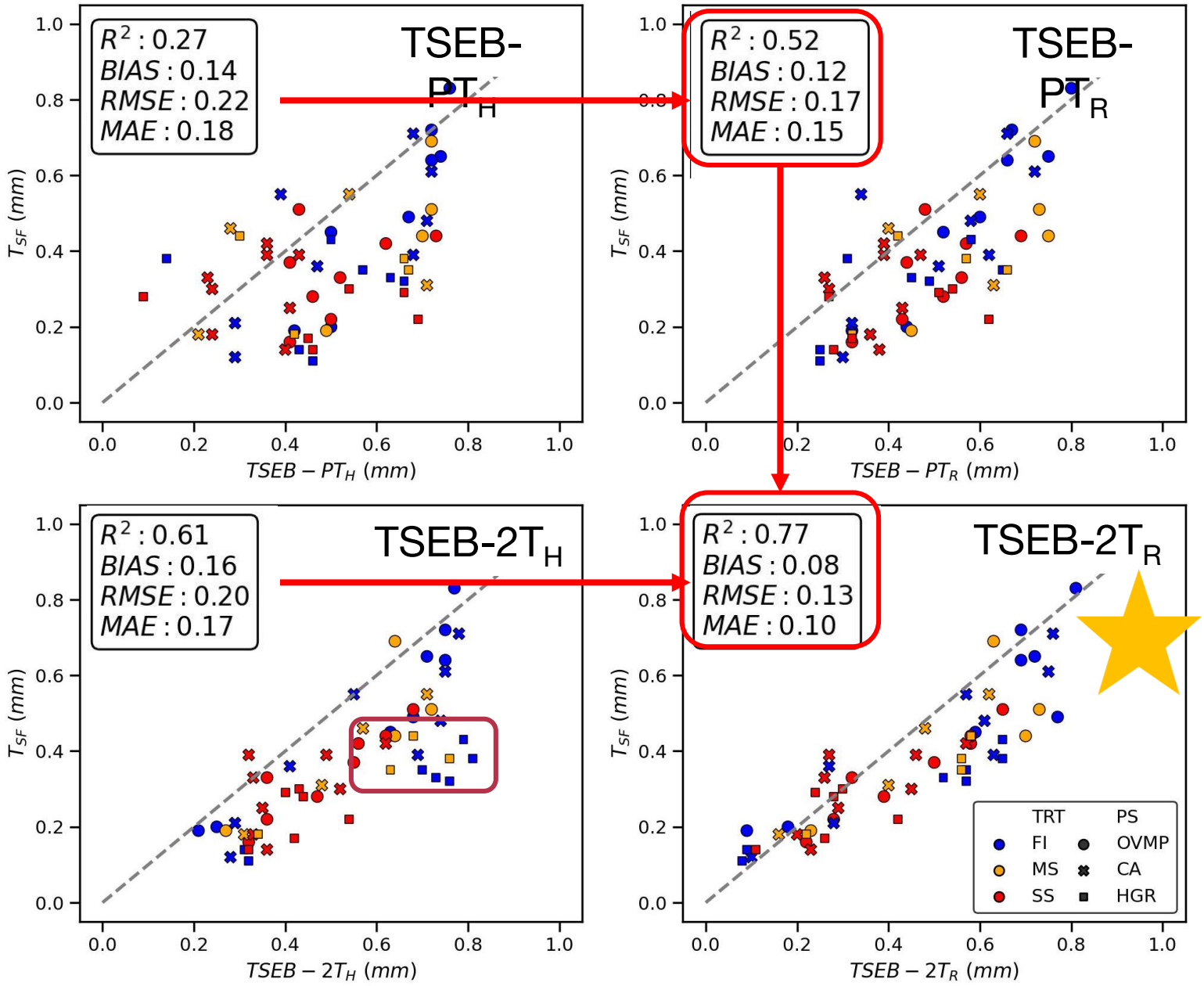




Seasonal trends of daily sap flow transpiration measurement in 2021



Significant differences were found between production systems, irrigation treatments and flight dates ($p<.0001$).



- The use of **C&N-R** transmittance model improved the estimates of transpiration in both the TSEB-PT and TSEB-2T
- **TSEB-2T$_R$** model had the best performance to estimate almond's transpiration
- **Accurately estimate canopy transmittance** is relevant in productive systems such as **Hedgerow,** with high LAI values but with low levels of fIPAR
- It is possible that the error in transmittance models will be more exacerbated in superintensive production systems.

Difference in T
irrigation treat

treatments.

Main conclusions

1. **For the first time**, this study evaluated differences in transpiration estimates in three **different production systems** and water regimes and validated it with **sap flow** data
2. The best performance of **TSEB-2TR** (TSEB + C&N-R) confirms that the availability of **high-resolution UAV** imagery allowed a more detailed characterization of the different input parameters needed in the TSEB scheme (fc, wc, hc/wc, *Tc* and *Ts*).
3. It is key to apply models capable of **accurately estimate canopy transmittance** to estimate the **transpiration**.
4. One source of error may be an inconsistent estimation of **clumping index** in the **different almond production systems.**
5. It is possible that the error in transmittance models will be more **exacerbated** in **superintensive production** systems with narrower planting distances.

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