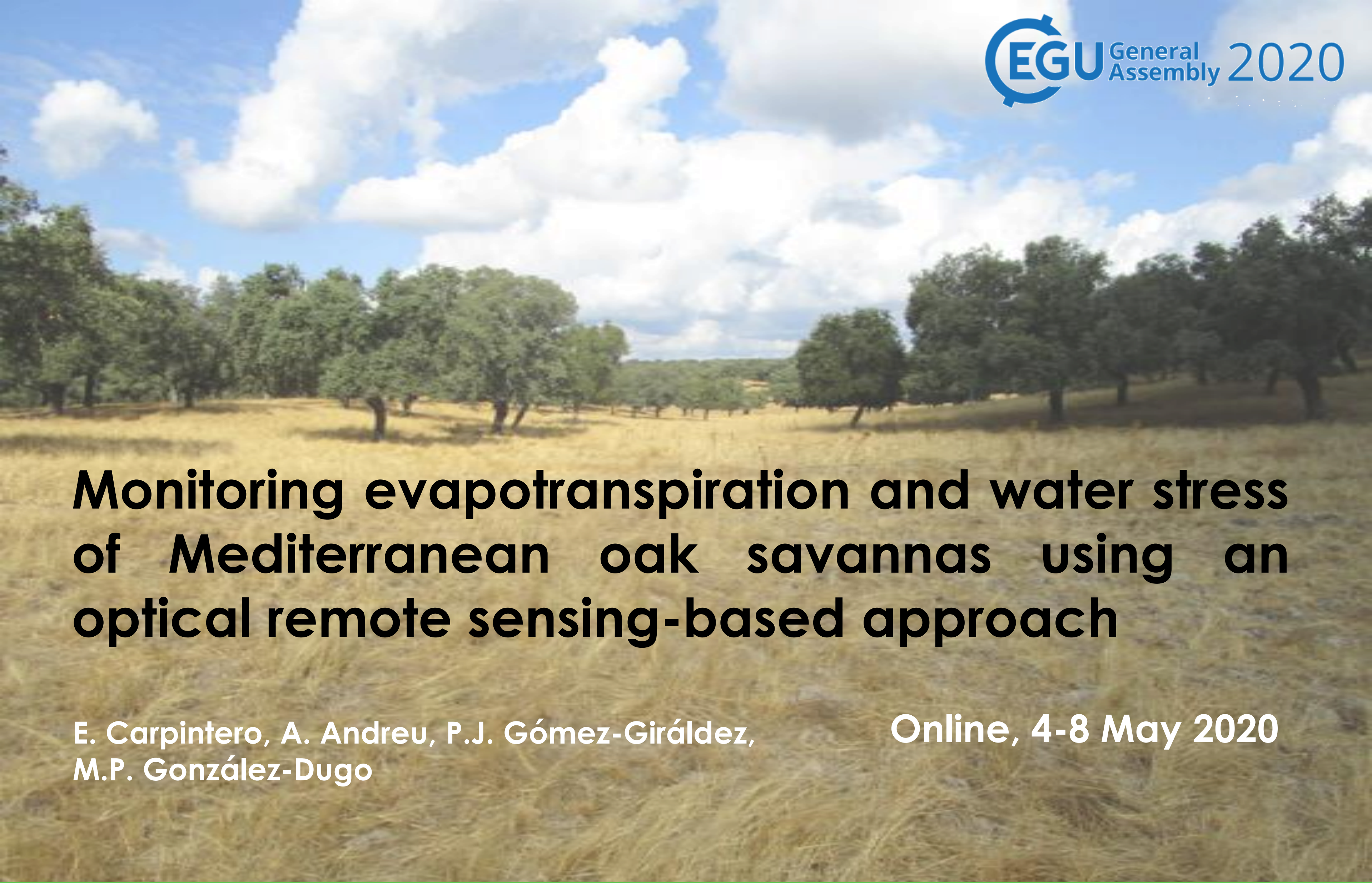

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# Monitoring evapotranspiration and water stress of Mediterranean oak savannas using an optical remote sensing-based approach

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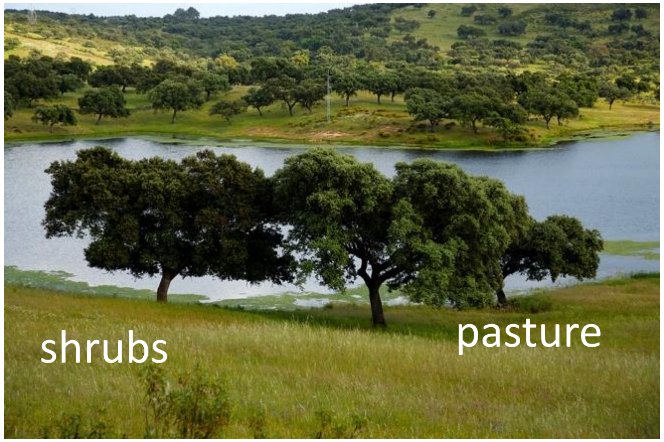
## Mediterranean oak savannas

Known as *dehesas* in Spain





Human induced landscape

Recurrent water scarcity conditions, accentuated by climate change

Threats derived from natural and economic causes

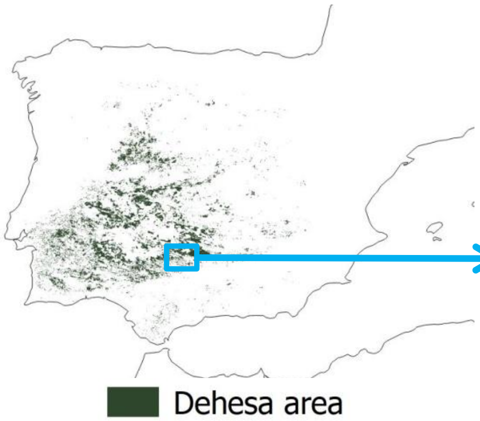
Improved knowledge of hydrologic process dynamics and its impact on vegetation to:

- **Evaluate actual threats**
- **Design water resources management and planning actions**
- **Reduce the economic and environmental vulnerability**

# Objectives

- Quantify evapotranspiration (*ET*) and water stress over a dehesa ecosystem by integrating remotely sensed data into a water balance using the FAO-56 approach ($VI\text{-}ET_o$ model)
- Special attention is paid to the different phenology and contribution to the system's hydrology of the two main canopy layers of the system (tree + grass)

# Study site and validation measurements




*Santa Clotilde dehesa*

- **Strongly seasonal climate**: moderately cold winters alternating with long, hot, and dry summers
- **Gentle slopes and multiple uses** (agriculture, extensive livestock and hunting)

## Eddy covariance systems

**Energy balance components:**

- Turbulent fluxes: Sensible heat (*H*) and latent heat (*LE*)
- Net radiation (*Rn*) and the soil heat flux (*G*)

Open grassland

Combined tree+grassland system

# Remote sensing-based water balance

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***VI-ET$_o$* approach:** combination of FAO56 (Allen et al., 1998; 2005) with vegetation indices (*VIs*) provided by remote sensors to compute more accurately the canopy transpiration

$$ET = (K_{cb}K_s + K_e)ET_o$$

Transpiration ($K_{cb}K_s$) — Evaporation from the soil ($K_e$)

**Daily time step**

| Variable | Procedure | Inputs |
|---|---|---|
| ***ET$_o$***: reference *ET* | Penman-Monteith equation | Meteorological data |
| ***K$_{cb}$***: basal canopy coefficient | Relationship from *VIs* (González-Dugo et al., 2009) | Satellite dataset: Landsat-8 and Sentinel-2 |
| ***K$_s$***: water stress coefficient<br>***K$_e$***: soil evaporation coefficient | Soil root zone water balance<br>Soil surface water balance | ▪ Soil parameters<br>▪ Vegetation parameters (Tabulated, measured and calibrated) |

## *VI-ET$_o$* approach applied over:

1) **Whole *dehesa* ecosystem** (tree + grass) between 2013 and 2017
2) **Open grassland area** between 2015 and 2017

# Performance of the $VI\text{-}ET_o$ model

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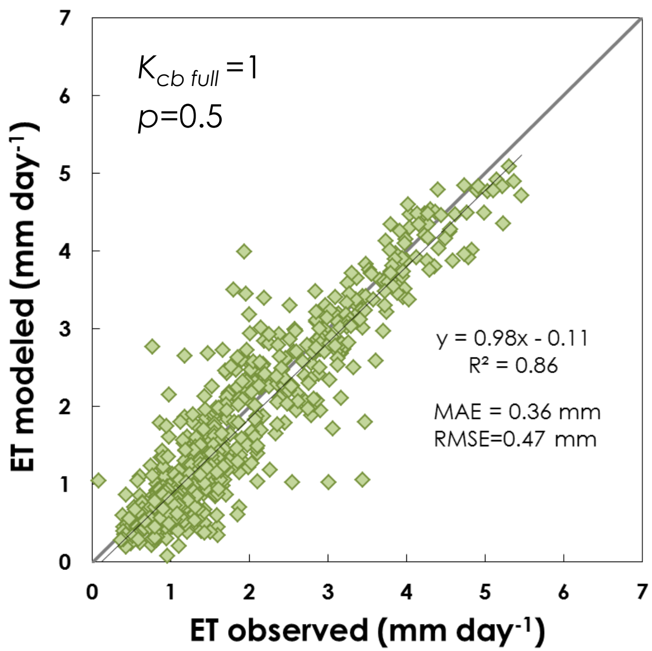
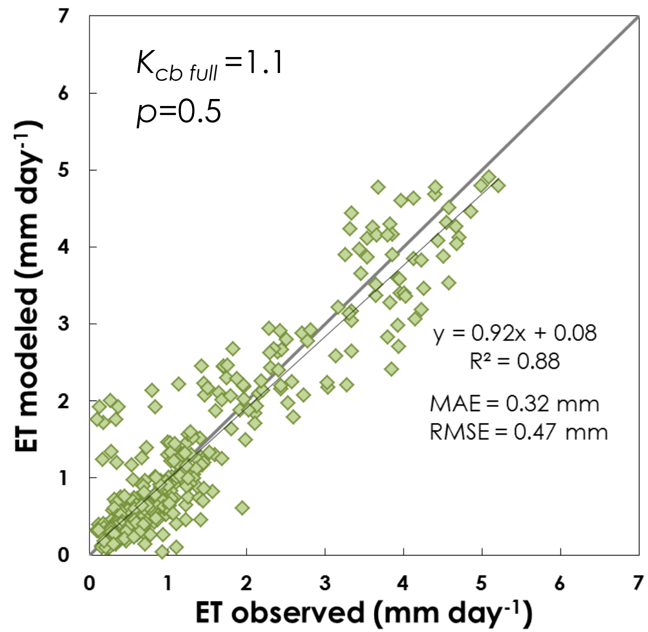
## *Dehesa* ecosystem




## Open grassland




**Parameters calibrated**:

- $K_{cb}$ for full cover vegetation, $K_{cb\ full}$
- Depletion fraction, *p*

- **Reasonable agreement** with the **tower observations (RMSE=0.47 mm day$^{-1}$)**, consistent with that observed with similar approaches in the same ecosystems (Campos et al., 2013, Andreu et al., 2019), for woody semi-arid crops (Consoli et al., 2014)and for field crops (Mateos et al., 2013).
- In *dehesa*, relatively **low bias** of -0.15 mm day$^{-1}$ with slight underestimation of the *ET* rates, while for grass this value was lower (-0.03 mm day$^{-1}$)

# Monitoring of *ET* and water stress

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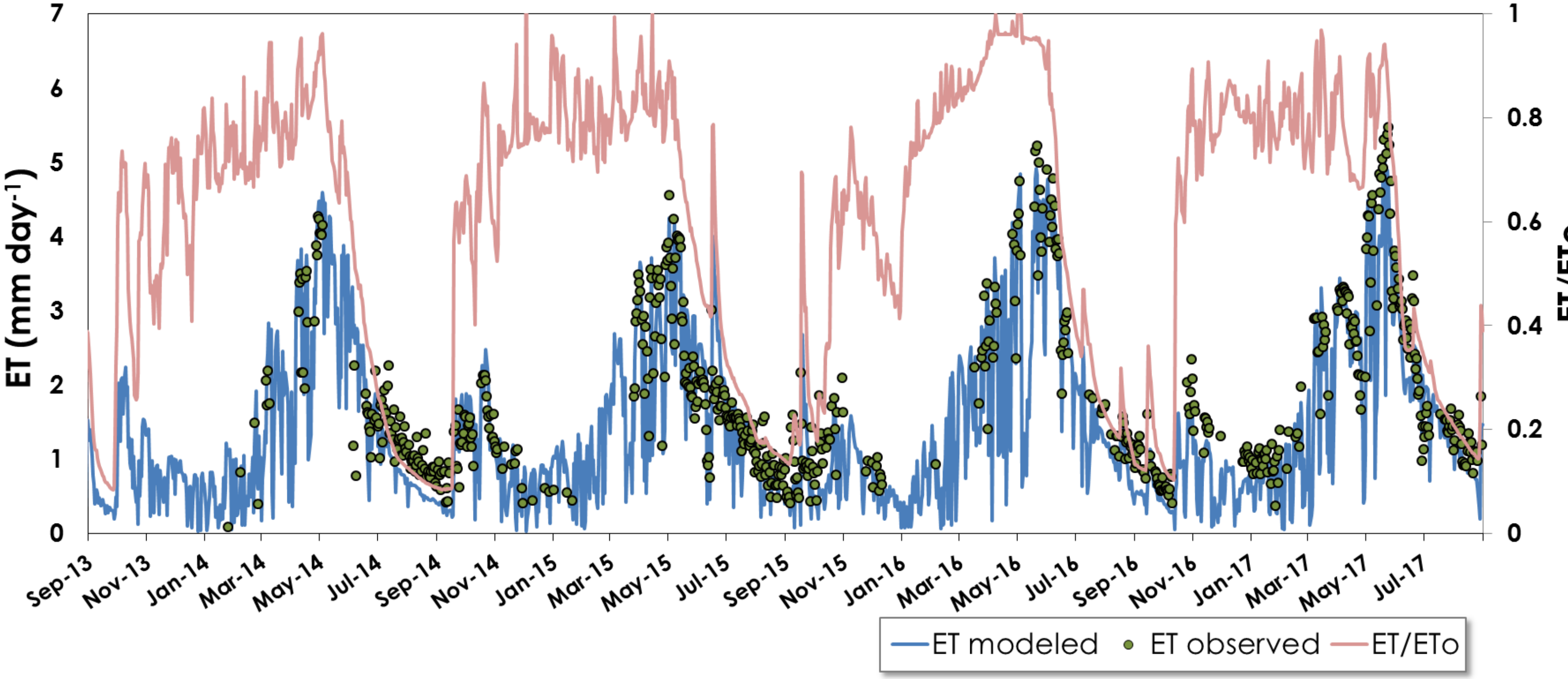
## *Dehesa* ecosystem




- **Annual bimodal behavior** of *ET* rates, linked to the rainfall distribution
- Modeled *ET* accurately reproduced the flux tower measurements
- Oak trees maintained transpiration rates of **0.5-0.6 mm day$^{-1}$** during dry season
- **Ratio *ET/ETo***: useful tool for assessing anomalous dry periods

# Monitoring of *ET* and water stress

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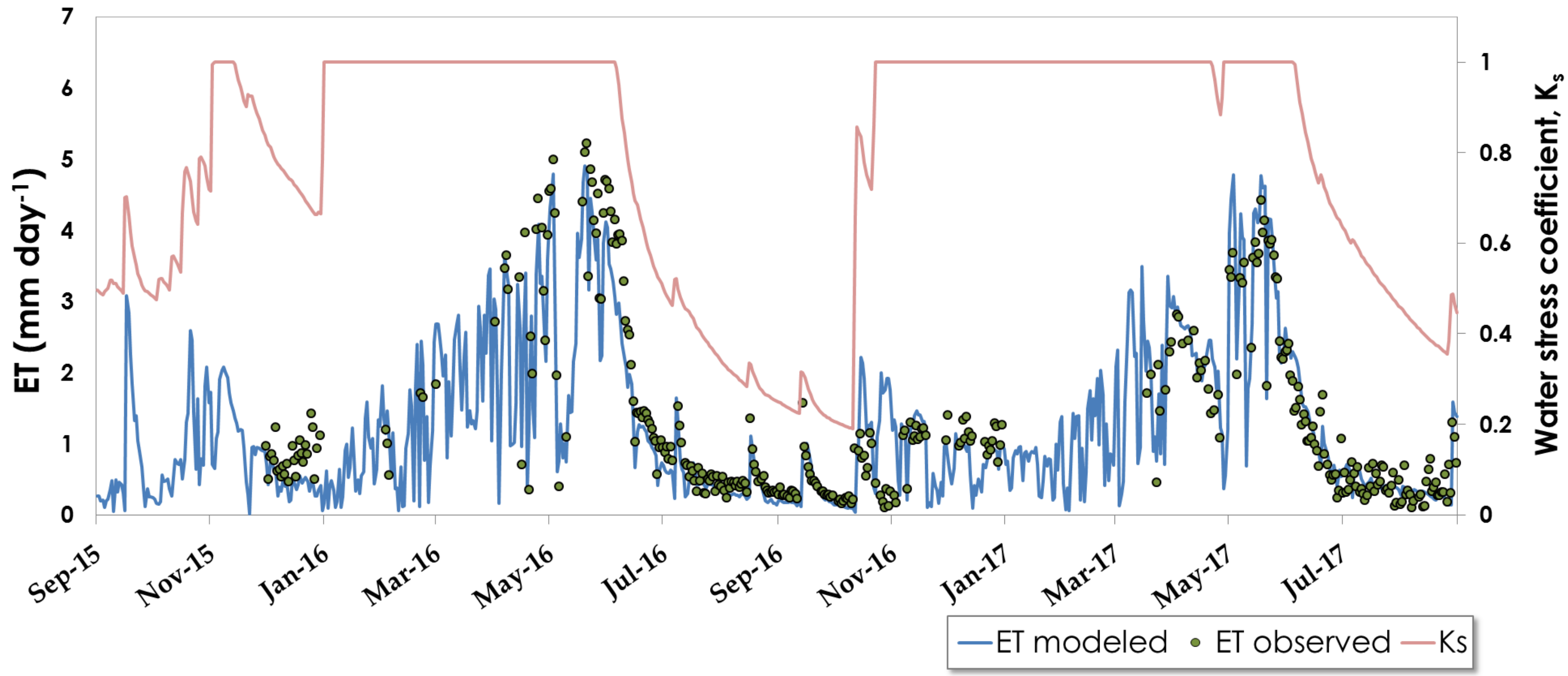
## Open grassland




- Maximum *ET* values were reached during spring (~ **5 mm day$^{-1}$**), sharply decreasing with the drying of the grass, which is consistent with the evolution of water stress coefficient, $K_s$.
- ***ET* basal rates (0.3-0.4 mm day$^{-1}$**) during the summer. It could be due to the presence of morning dew and humidity condensing in the dry grass pockets and the metabolism of heterotrophs and dead grass.

# Conclusions

- The ***VI-ET$_o$* model**, an optical remote sensing-based approach, has proven to be robust to monitor the vegetation water use of this complex ecosystem with RMSE of **0.47 mm day$^{-1}$** and **low biases** for both, the **whole system** and the **grass layer**, when compared with flux tower measurements.

- This work has provided **effective parameters** for applying a remote sensing-based water balance over an oak-grass savanna, in addition to analyzing each of its components.

- The ***ET/ET$_o$* ratio** helped to identify periods of water stress, which can be used to developed management actions leading to maintaining the ecosystem's stability, both environmentally and economically.

- The **Sentinel-2 temporal resolution** was key in the monitoring of grass vegetation layer, where the drying process usually occurs in a few days, therefore being suitable for management and conservation purposes.

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**This work has been submitted to:**

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