Proper modelling of the hydrological behaviour of facultative phreatophytes at plot scale using additional in-situ transpiration measurements

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Introduction

- Facultative phreatophytes are characterised by the partial or infrequent use of groundwater resources to survive (Macfarlane et al. 2018)
- In semi-arid conditions groundwater transpiration is a key contribution to total plant transpiration (Barbeta and Peñuelas, 2017)

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- In semi-arid conditions groundwater transpiration is a key contribution to total plant transpiration (Barbeta and Peñuelas, 2017)
- *Quercus ilex* is one of the main Mediterranean evergreen oaks
  - grows in the upper part of catchments
  - in semi-arid conditions becomes a facultative phreatophyte

***Q. ilex* actual evapotranspiration can heavily influence downstream water availability** (Vicente et al. 2018)

↓

Conventional hydrological models do not often consider groundwater transpiration

Introduction

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  - Parameters are representative of the modelling scale (Mertens et al., 2005)
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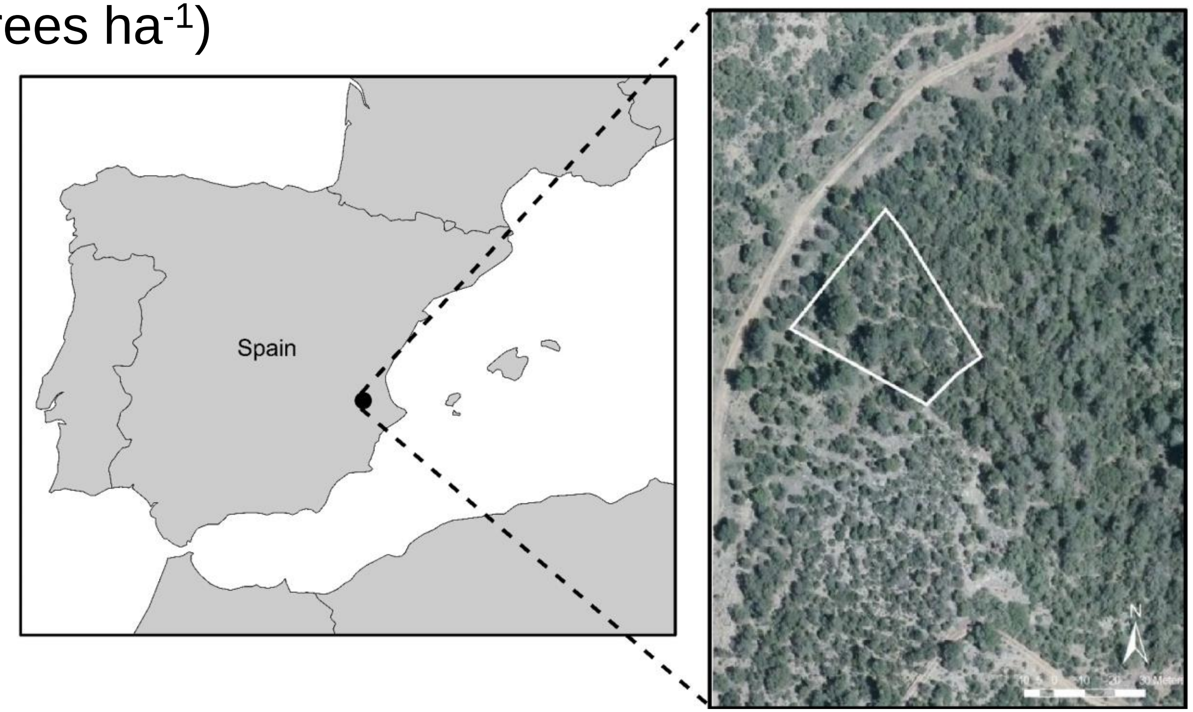
- **This study aims** to better reproduce the hydrological behaviour of facultative phreatophytes by means of:

A multi-variable and multi-objective modelling approach **+** Additional in-situ transpiration measurements

Study area

- Experimental plot
- Area: 1800 m^2
- Forest: high-density stand of *Q. ilex* (1059 trees ha^{-1})
- Semi-arid climate
  - Precipitation: 466 mm yr^{-1}
  - ET_0 : 1200 mm yr^{-1}



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- Semi-arid climate
  - Precipitation: 466 mm yr^{-1}
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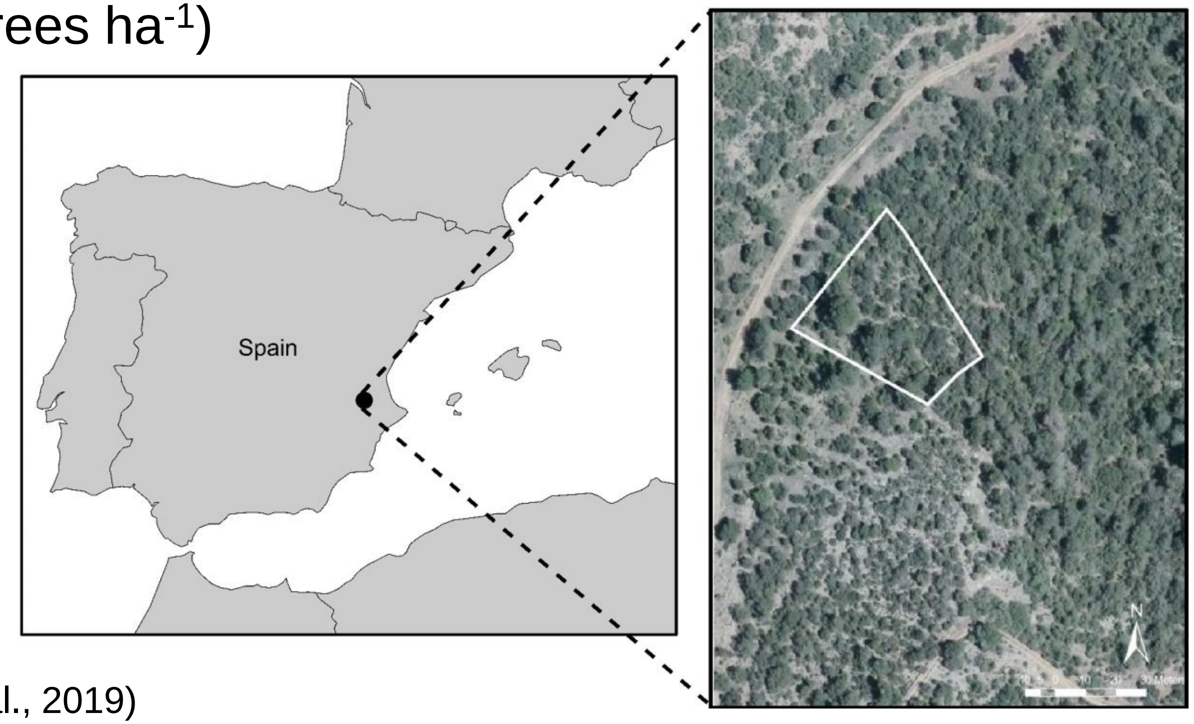
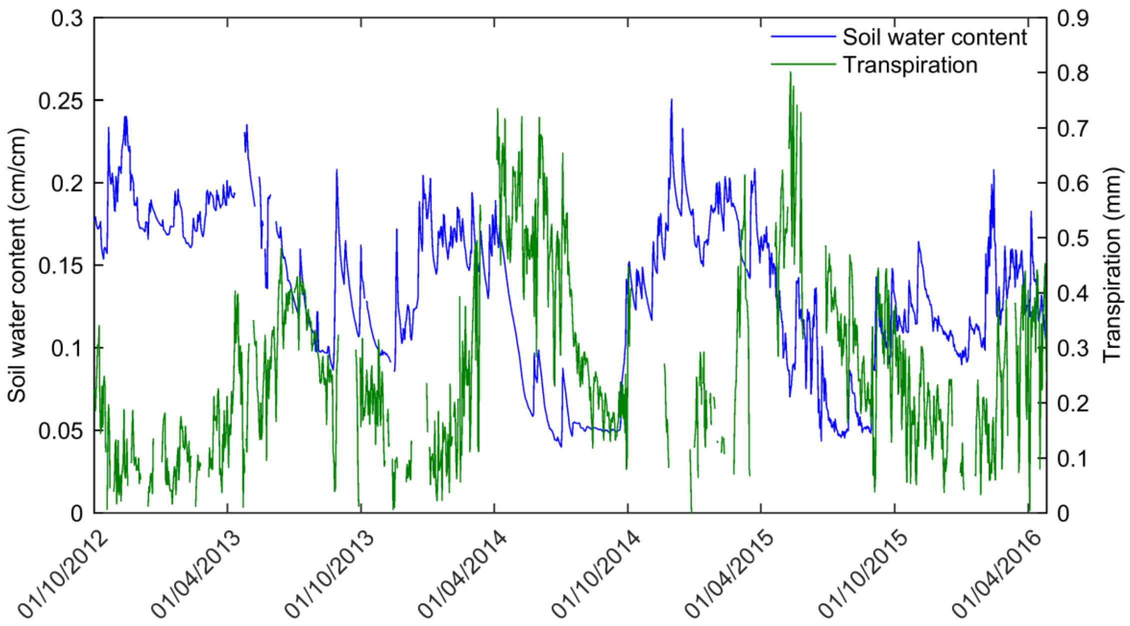
- Soil thickness: 10 - 40 cm
- Karstified Jurassic limestone parent rock
  - Significant storage of deep water (del Campo et al., 2019)



Observations

- Soil water content
  - 15 probes (5, 15 and 30 cm)
- Transpiration
  - Sap flow velocity
  - 14 trees divided into 4 different diametrical distributions



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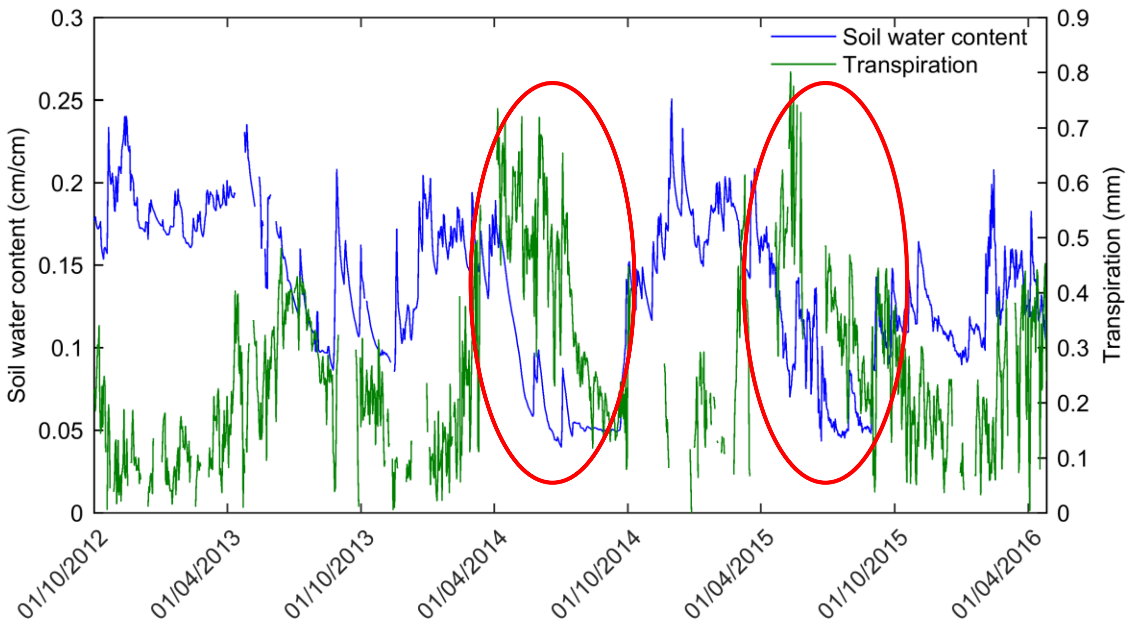

Summer drought periods

Tr > SWC

Additional groundwater transpiration!

Models

- LEACHM (Hutson, 2003)
  - Process-based model
  - User's fixed number of layers
  - 15 + 9·nlayers parameters
  - Richards' equation
  - Interception is not considered
  - Transpiration:
    - Unsaturated hydraulic properties
    - Effective water potential gradient at roots-soil interface
    - Vegetation cover fraction
    - Percentage of roots
- TETIS (Puertes et al., 2019)

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- TETIS (Puertes et al., 2019)
  - Tank type conceptualization
  - Two layers
  - 21 parameters
  - Water moves downwardly as long as the tank outflow capacity is not exceeded
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Groundwater transpiration

Calibration process

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  - Multiobjective Shuffled Complex Evolution Metropolis (Vrugt et al., 2003)
    - Based on the concept of Pareto-optimal solutions
  - Goodness-of-fit indices:
    - Soil water content and transpiration → Nash and Sutcliffe (EI)
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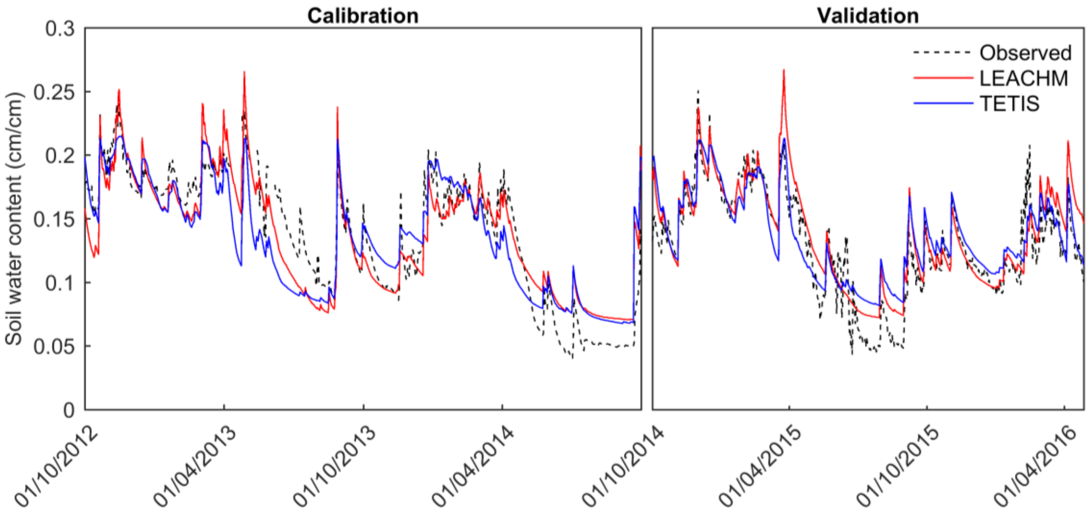
  - Calibration approaches:
    - Single-variable and single-objective calibration by using soil water content
    - Single-variable and single-objective calibration by using transpiration
    - Multi-variable and multi-objective calibration by using both soil water content, transpiration and accumulated interception only with TETIS
      - Minimum Euclidean distance

Results

Single-variable and single-objective calibration by using soil water content



	SWC	
	Cal.	**Val.**
LEACHM	0.825	0.773
TETIS	0.757	0.764

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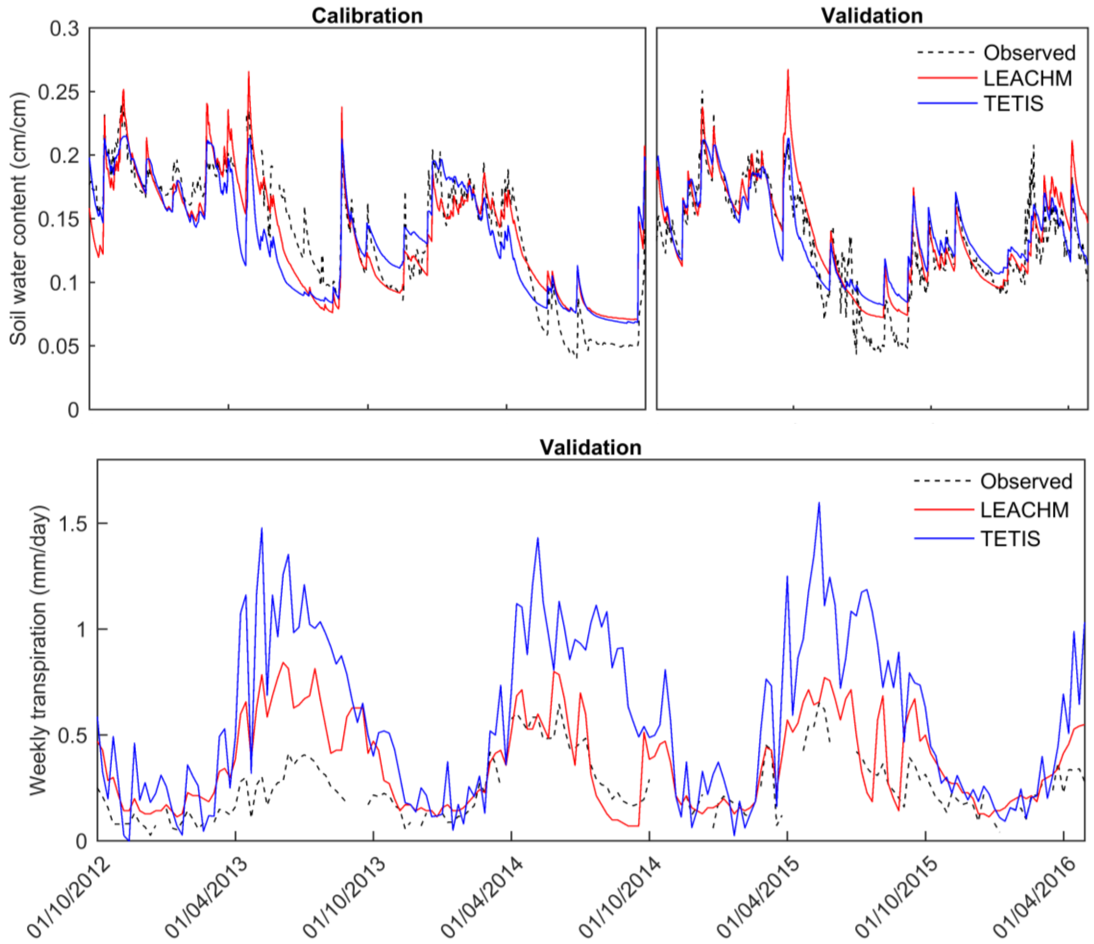
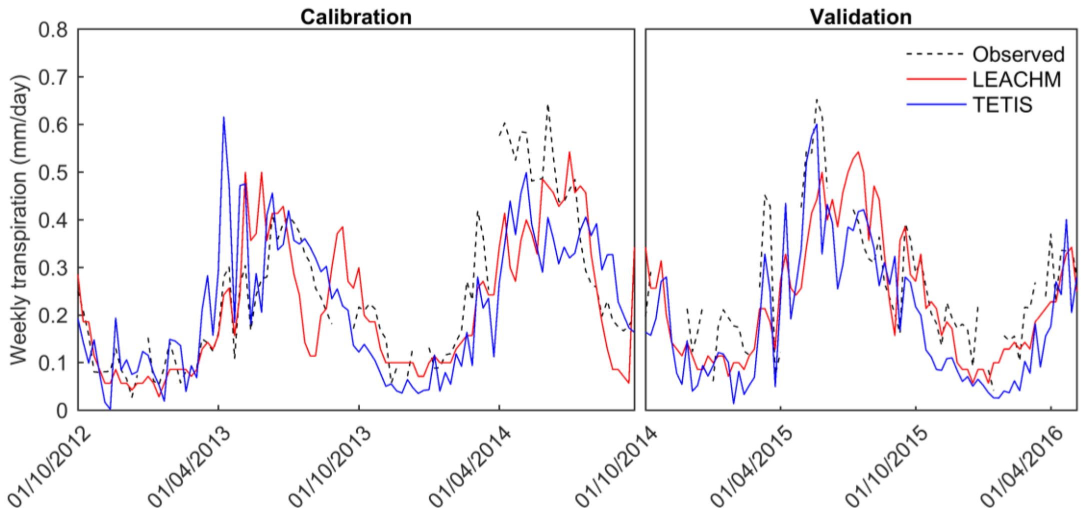


	SWC		TR
	Cal.	**Val.**	**Val.**
LEACHM	0.825	0.773	-0.218
TETIS	0.757	0.764	-6.735

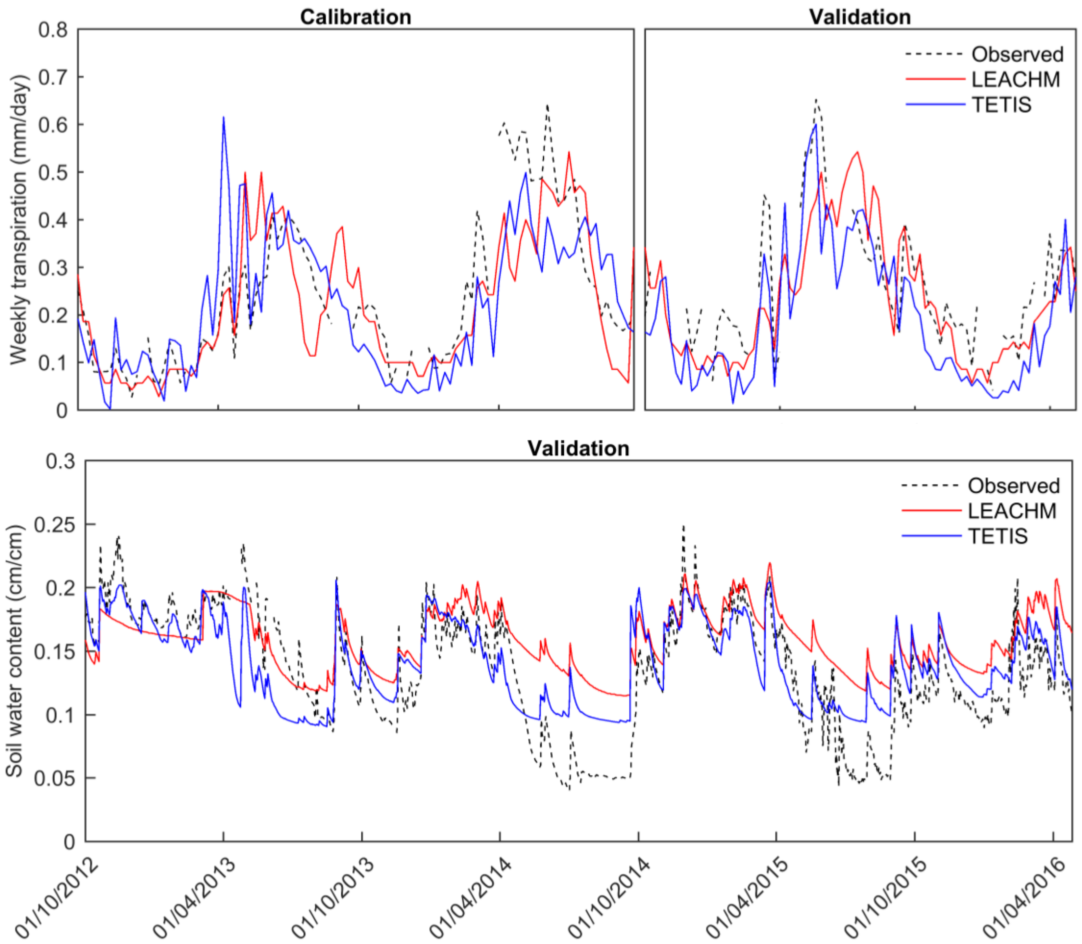
Flows (mm)	Observed	LEACHM	TETIS
Precipitation	426.2	-	426.2
Interception	129.2	-	86.7
Net precipitation	297.1	297.1	339.6
Soil evaporation	-	48.2	114.7
Soil transpiration	-	101.0	70.5
Groundwater transpiration	-	37.3	156.6
Total transpiration	101.6	138.3	227.1
Runoff	4.6	0.0	0.0
Percolation	-	151.1	160.2
Net percolation	-	113.9	3.6

Single-variable and single-objective calibration by using transpiration



	TR	
	Cal.	**Val.**
LEACHM	0.655	0.616
TETIS	0.639	0.624

Single-variable and single-objective calibration by using transpiration

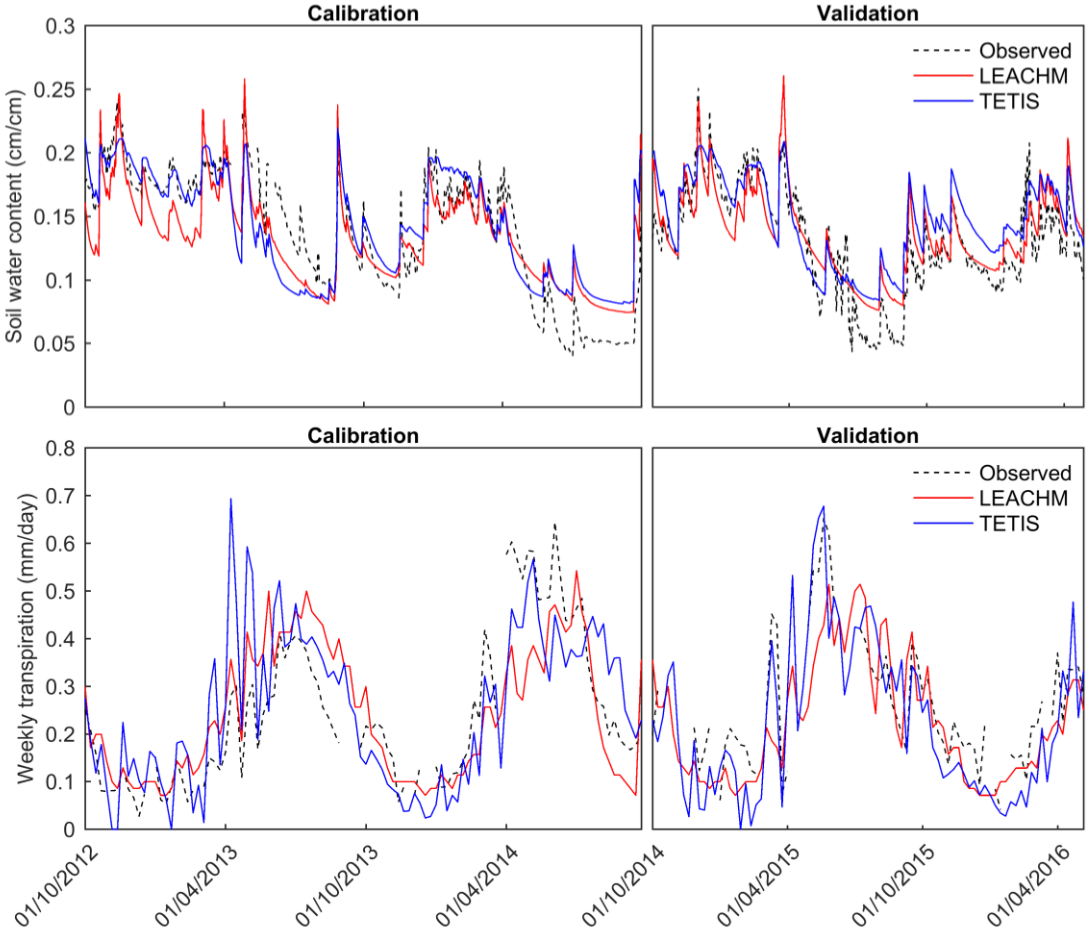


	TR		SWC
	Cal.	**Val.**	**Val.**
LEACHM	0.655	0.616	0.286
TETIS	0.639	0.624	0.636

Flows (mm)	Observed	LEACHM	TETIS
Precipitation	426.2	-	426.2
Interception	129.2	-	72.9
Net precipitation	297.1	297.1	353.4
Soil evaporation	-	44.9	123.2
Soil transpiration	-	55.1	42.1
Groundwater transpiration	-	29.9	40.1
Total transpiration	101.6	85.0	82.2
Runoff	4.6	173.2	0.0
Percolation	-	26.4	193.0
Net percolation	-	-3.5	152.9

Results

Multi-variable and multi-objective calibration

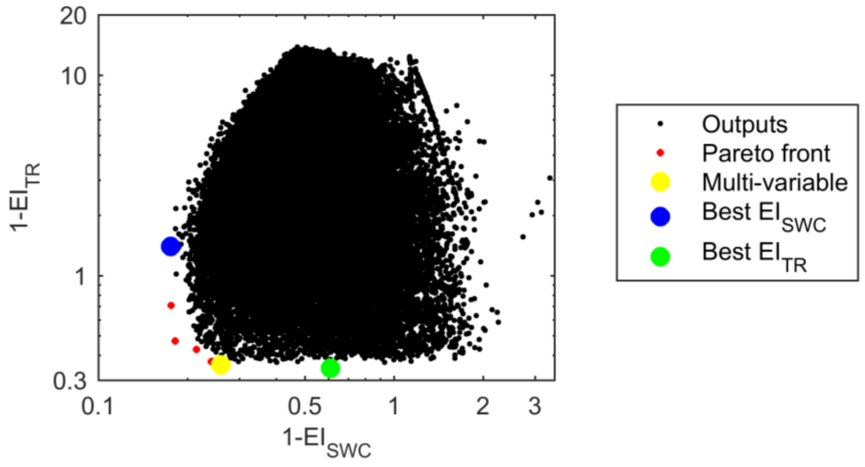


	SWC		TR	
	Cal.	**Val.**	**Cal.**	**Val.**
LEACHM	0.741	0.737	0.641	0.625
TETIS	0.700	0.595	0.619	0.721

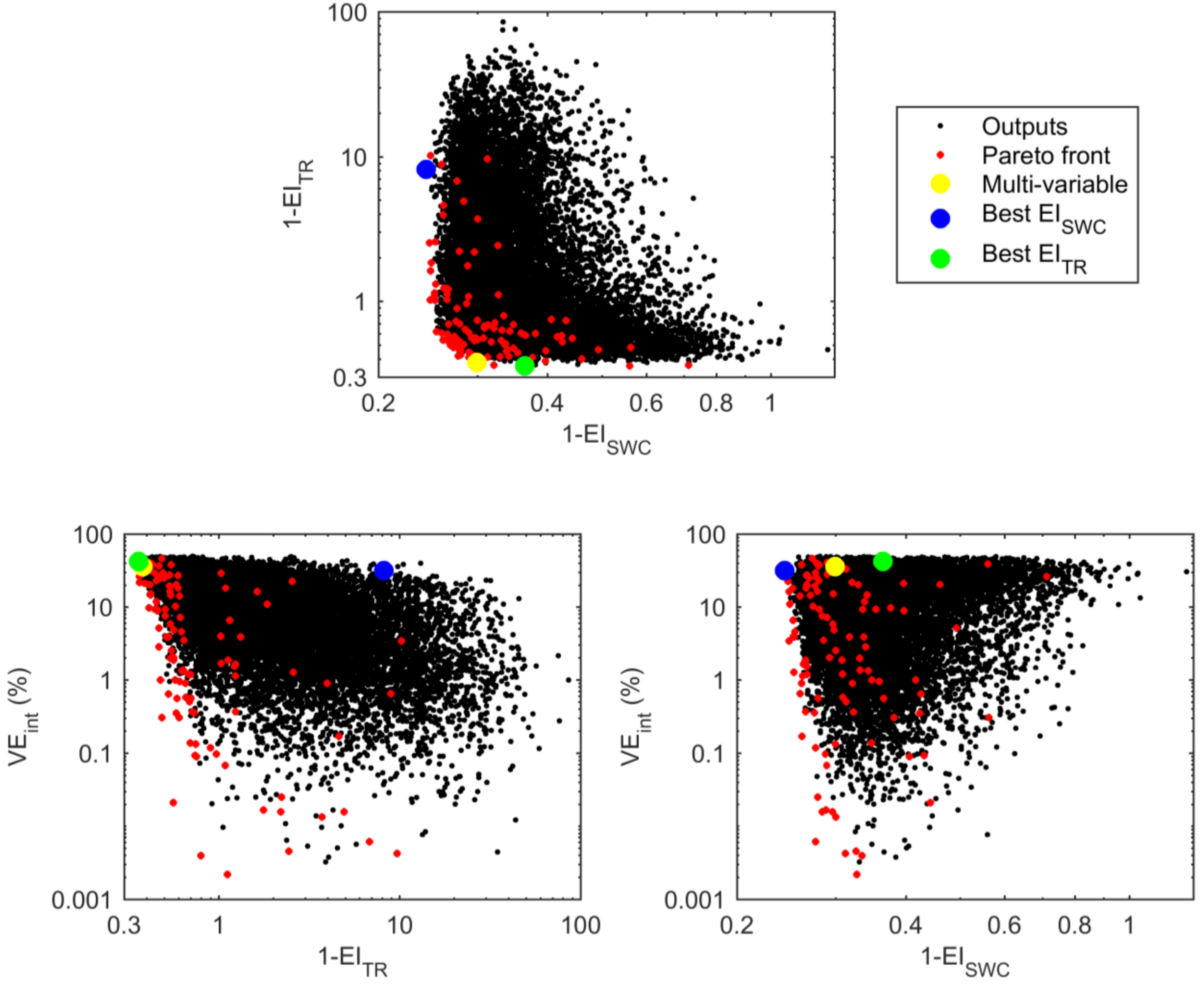
Flows (mm)	**Observed**	**LEACHM**	**TETIS**
Precipitation	426.2	-	426.2
Interception	129.2	-	81.4
Net precipitation	297.1	297.1	344.8
Soil evaporation	-	64.4	118.7
Soil transpiration	-	68.9	49.6
Groundwater transpiration	-	21.0	44.2
Total transpiration	101.6	89.9	93.7
Runoff	4.6	3.0	0.0
Percolation	-	161.8	181.6
Net percolation	-	140.8	137.5

Results

LEACHM



TETIS



Information transfer from the observed transpiration to the model parameters related to soil water content

Conclusions

- Traditional single-variable and single-objective calibration
  - Poorly representation of the non-calibrated state variable
  - Unreal water balances
- Multi-variable and multi-objective calibration
  - Good option to reproduce facultative phreatophytes water dynamics
  - General information transfer from observed state variables to model parameters of related processes
  - Similarity of the results obtained by both models, despite their different conceptualisations

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- Traditional single-variable and single-objective calibration
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  - Unreal water balances
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  - Good option to reproduce facultative phreatophytes water dynamics
  - General information transfer from observed state variables to model parameters of related processes
  - Similarity of the results obtained by both models, despite their different conceptualisations
- *Q. ilex* strongly depends on groundwater resources in semi-arid environments
- Eco-hydrological models should include the groundwater transpiration mechanism
- Both models proved an acceptable tool
  - Application of TETIS (parsimonious) at catchment scale by using remote sensing ET measurements and a multi-variable and multi-objective approach

Thanks for your attention

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This work was supported by the Spanish Ministry of Science and Innovation through the research projects: TETISMED (CGL2014-58127-C3-3-R), SILWAMED (CGL2014-58127-C3-2-R) and TETISCHANGE, and by the project LIFE17 CCA/ES/000063 RESILIENTFORESTS.