# Importance of ecohydrological modelling approaches in the prediction of plant behaviour and water balance at different scales

Alicia García-Arias (algarar2@upv.es), Guiomar Ruiz-Pérez, Félix Francés

## INTRODUCTION

- VEGETATION → main role in the water balance of **hydrological systems**
- Science gap: **hydrological modelling** → effect of the **interception** and **evapotranspiration**
  - **ECOHYDROLOGICAL APPROACHES** vs traditional strategies
- Objectives:
  - To demonstrate the **pivotal role of the vegetation** in ecohydrological **models**
  - To achieve a better understanding of the **hydrological systems** by considering the appropriate **ecohydrological processes related to plants**
- Main conclusion of this research: the **capabilities to predict plant behaviour and water balance increase** when **interception** and **evapotranspiration** are taken into account in the soil water balance

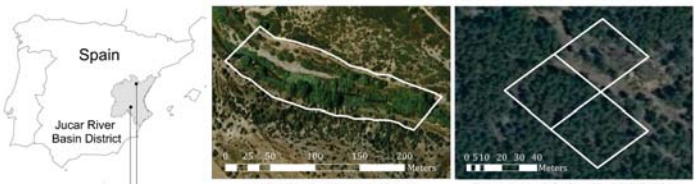
## CASE STUDIES

Main role of vegetation in the water balance → **TETIS-VEG** model (Pasquato et al., 2015; Ruiz-Pérez et al., 2016) → key ecological processes in terrestrial areas determine the hydrological fluxes at plot scale

- Implementation → **Aleppo pine experimental plot of 30X30m** sited in the Public Forest ***Monte de La Hunde y La Palomera***, province of Valencia, East part of Spain

Main role of the water cycle into vegetation dynamics → **RVDM** model (García-Arias and Francés, 2016) → key hydrological processes in riparian areas determine the vegetation dynamics at river reach scale

- Implementation → **river reach of 230 m length** located in the area called ***Terde, Mijares River***, province of Teruel, East part of Spain

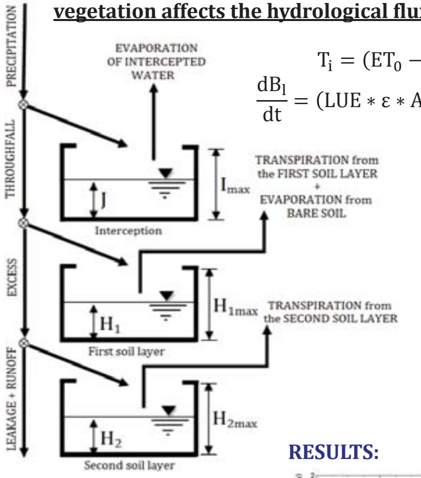



Terde reach (Mijares River) — Experimental plot (Public Forest Monte de La Hunde y La Palomera)

## PLOT SCALE – TERRESTRIAL VEGETATION

**MODELLING APPROACH** → hydrological sub-model: **TETIS** (Francés *et al.*, 2007) → tank-based + dynamic vegetation **LUE model** → **TETIS-VEG**

- each tank: different **storages in the soil water column**
- water intercepted by canopy → max. **interception capacity** ∝ **LAI simulated**. Water extraction = *f* (evaporation) (Pasquato *et al.*, 2015)
- effective root zone: divided, two superimposed layers similar to Scanlon and Albertson (2003) → **transpiration** (both layers) based on FAO recommendations (Allen *et al.*,1998): ***f* (LAI simulated)** → **state of vegetation affects the hydrological fluxes and the water storage**




$$T_i = (ET_0 - EI) * \boxed{\mathbf{min(1, LAI)}} * \zeta * Z_i$$

$$\frac{dB_l}{dt} = (LUE * \varepsilon * APAR - Re) * \varphi_l - k_l * B_l$$

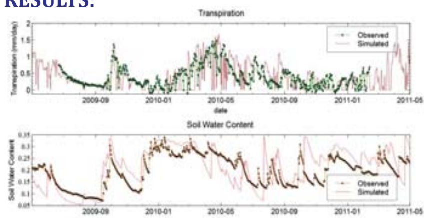
$$LAI = B_l * SLA * f_c$$

(William and Albertson, 2005)

$T_i$ :transpiration from the i soil layer
**EI**: evaporation of the intercepted water
$Z_i$: % roots in the i soil layer
**min(1,LAI)**: replaces the crop factor
**ζ** : water stress factor
**APAR**: absorbed photosynthetically active radiation
**LUE**: light use efficiency
**ε**: reduction in LUE due to stress
**Re**: respiration
$\varphi_l$: fractional leaf allocation
$k_l$: leaf natural decay factor (senescence)
**SLA**: specific leaf area
$f_c$: vegetation fractional cover

| | Flows | Dry year (2005) | | Wet year (2010) | |
|---|---|---|---|---|---|
| | | mm | % | mm | % |
| TETIS-VEG | PPT | 188.00 | | 739.00 | |
| | ET (EI+T+Es) | 165.18 | 91.0 | 431.87 | 56.9 |
| | Excedence | 16.34 | 9.0 | 326.93 | 43.1 |
| | **Blue/Green** | **0.098** | | **0.757** | |
| TETIS | PPT | 188.00 | 0.8 | 739.00 | |
| | ET (EI+T+Es) | 147.00 | 0.3 | 385.37 | 50.9 |
| | Excedence | 33.47 | 2.5 | 370.99 | 49.1 |
| | **Blue/Green** | **0.227** | | **0.963** | |

**RESULTS:**




↑ Observed precipitation (**PPT**), evapotranspiration (**ET**) as sum of evaporation of the interception (**EI**), transpiration (**T**) and evaporation from the bare soil (**Es**), and the remaining of water or excedence (mm) and as a percentage of the precipitation simulated by the **TETIS-VEG** and the **TETIS** models respectively. In red, the **Blue/Green** water ratio

## REACH SCALE – RIPARIAN VEGETATION

**MODELLING APPROACH** → riparian hydrodynamics + vegetation dynamics

- **CASiMiR-veg** (Benjankar *et al.*, 2011) **flood impacts** approach + **RibAV** (García-Arias *et al.*, 2014) **water balance** approach + other **impacts-evolution-competition processes** modelling → **RVDM** (García-Arias and Francés, 2016)
- Transpiration from **different water sources** → **unsaturated** soil layer and **saturated** soil layer (two main fluxes from the saturated zone: the hydraulic lift and the upward capillary water flow)
- water intercepted by canopy → max. **interception capacity** ∝ **fc**
- **Transpiration** is only allowed under **no asphyxia conditions**
  ***f* (water content, water table relative position to the roots effective and max. depths)**
- Vegetation evolution: ***f* (LAI simulated, $ET_{idx}$)** → **state of vegetation affects the hydrological fluxes, water storage and hydrological fluctuations affect the vegetation development and wellbeing**

$$T_u = r_u f_c (ET_0 - EI) H_{rel}$$

Particular case: **effective root depth connected to the water table → $T_u$ at maximum rate** ($H_{rel} \rightarrow Z_{rel}$)

$$T_s = \mathrm{Min}\begin{vmatrix} f_c (ET_0 - EI) - T_u \\ r_s f_c (ET_0 - EI) Z_{rel} \end{vmatrix}$$

$T_u$: transpiration from the unsaturated zone
$T_s$: transpiration from the saturated zone
$H_{rel}$: relative water content, *f*(water content, optimum threshold and wilting point limit)
$Z_{rel}$: relative depth of the saturated zone, *f*(water table position relative to the asphyxia, effective and maximum root depths)

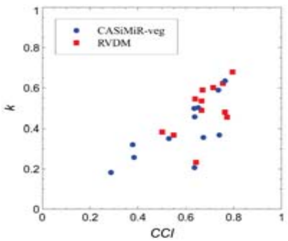
$$\frac{dB_l}{dt} = (LUE * \boxed{\mathbf{ET_{idx\,l}}} * APAR - Re) * \varphi_l - k_l * \varepsilon * B_l$$

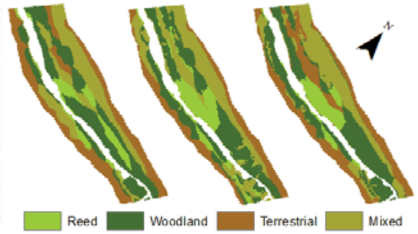
**ε**: stress factor that consider hydrological extremes

$$ET_{idx\,l} = \frac{T_u + Ts}{f_c\, ET_0 - EI}$$

Evapotranspiration index (García-Arias *et al.*, 2014)

**RESULTS:** both models performed satisfactorily (objective functions: *correctly classified instances, CCI,* and *kappa, k*; succession lines classification: reed, woodland, terrestrial and mixed lines )




## CONCLUSIONS

1. In arid and semi-arid areas, the **ET** may account **> 90% annual P** → **key flux of the water cycle**, should not be neglected or poorly modelled
2. The **ecohydrological approaches** usually result in more **complex models**. This increase in the number of parameters should be only accepted in the cases in which the models result in a **substantial better response (e.g. TETIS-VEG)** or when they can **provide more information (e.g. RVDM)** considered relevant to the decision making (e. g. **knowledge of ecohydrological processes**)
3. At plot scale, **TETIS-VEG** was able to **reproduce the soil water content as well as the transpiration** by using **simple equations** and a **limited amount of parameters**. Overestimations of the B/G ratio (i.e. overestimation of the actual available water) where observed when neglecting vegetation dynamics. This pointed out the **key role played by plants in the water balance**
4. At reach scale, **RVDM** improved the **riparian vegetation prediction** by taken into account **daily soil moisture** and detailed **ecohydrological processes** related to the interaction between the vegetation dynamics and the water balance. This is a **more complex modelling approach** → convenience on the choice shall be evaluated in each case of study before neglecting less complex models as **CASiMiR-veg**
5. As main conclusion → **water cycle key processes** and their **evolution** in time and space are both cause and consequence of **vegetation dynamics**

## ACKNOWLEDGEMENTS AND REFERENCES

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