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

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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

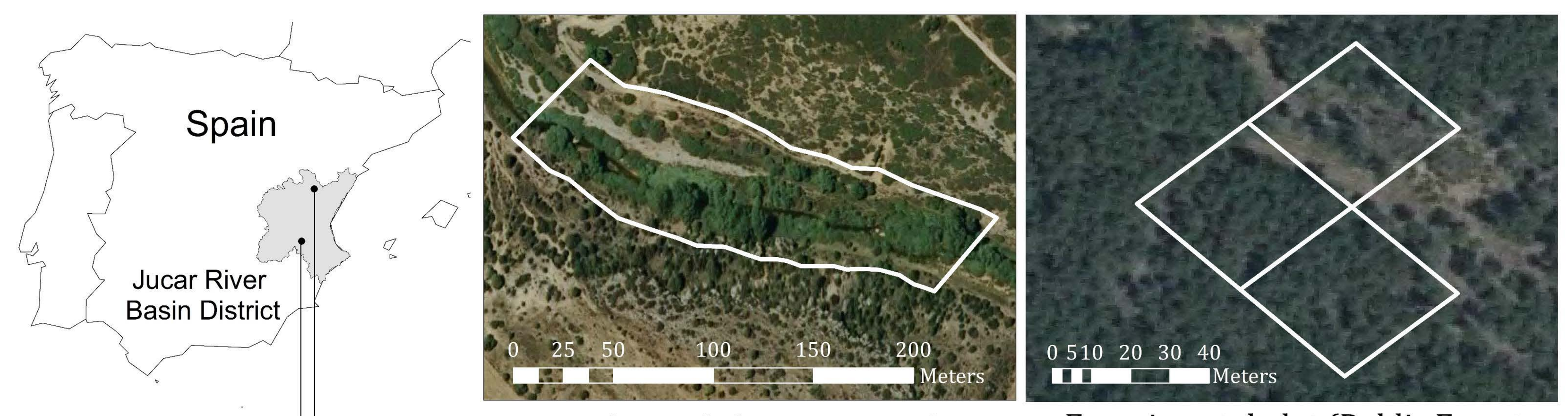
CASE STUDIES

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



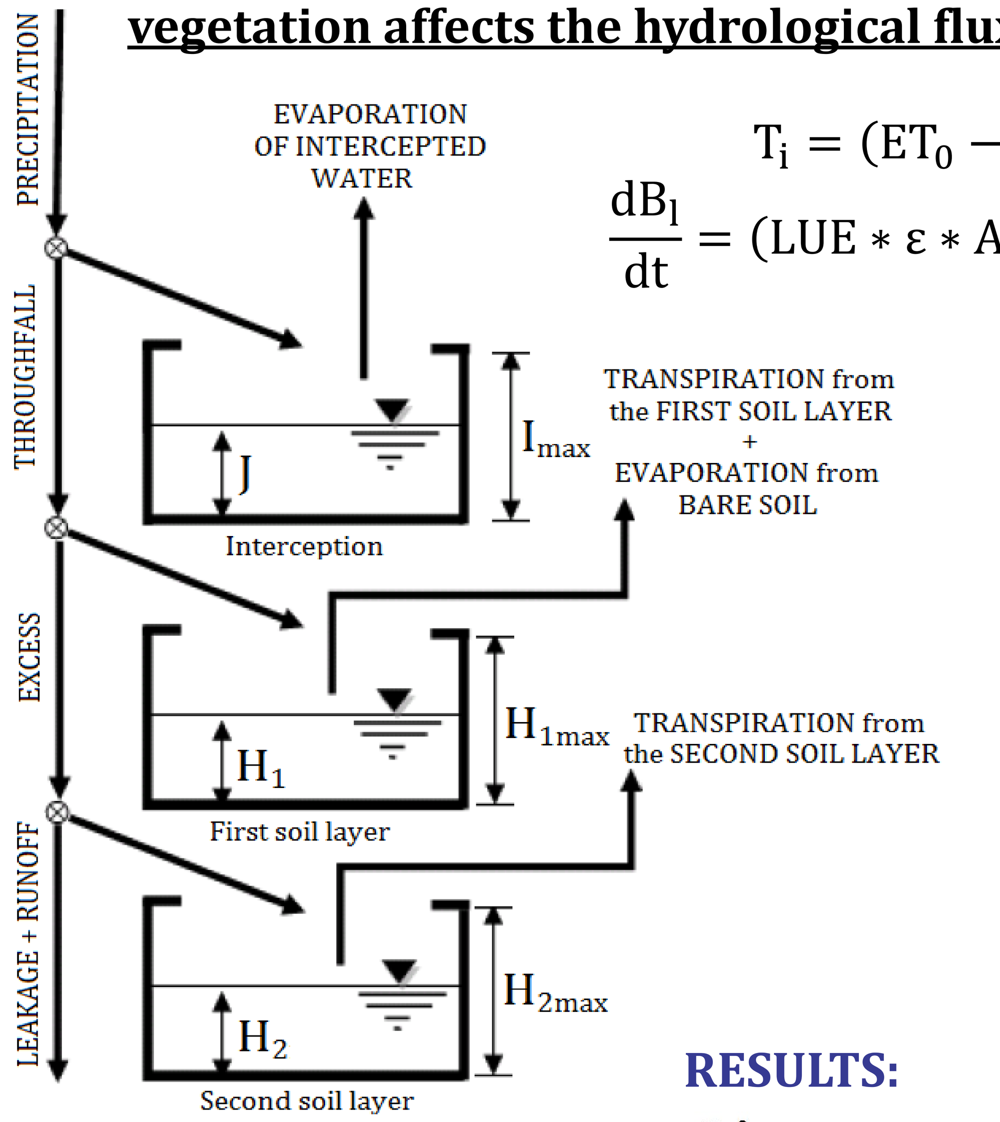
Terde reach (Mijares River)

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**



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

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

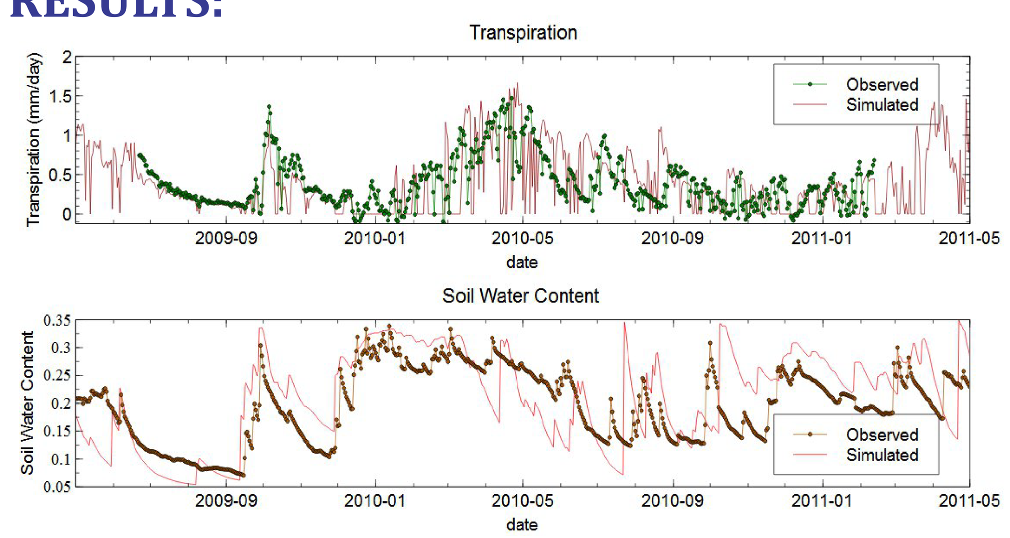
$$LAI = B_l * SLA * f_c$$

(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
φ_l: fractional leaf allocation
k_l: leaf natural decay factor (senescence)
SLA: specific leaf area
f_c: vegetation fractional cover

RESULTS:

	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**	



↑ 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** ($H_{rel} \to Z_{rel}$)

$$T_s = \mathrm{Min} \left| \begin{matrix} f_c (ET_0 - EI) - T_u \\ r_s f_c (ET_0 - EI) Z_{rel} \end{matrix} \right.$$

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)

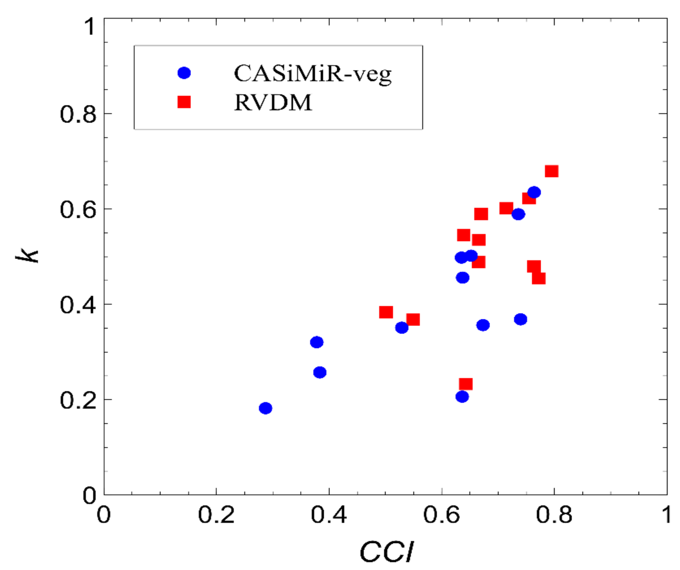
$$\frac{dB_l}{dt} = (LUE * \boxed{ET_{idx\,l}} * APAR - Re) * \varphi_l - k_l * \varepsilon * B_l$$

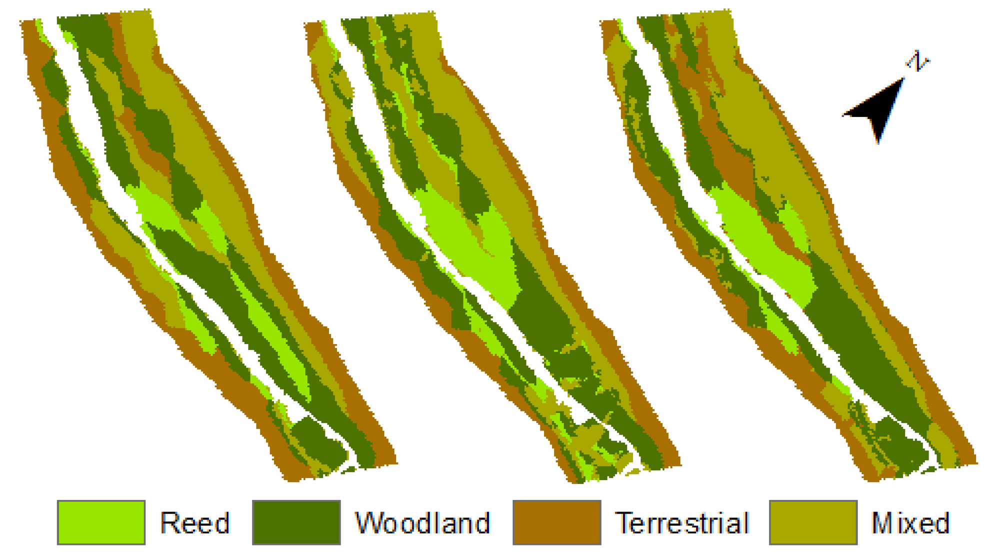
ε: stress factor that consider hydrological extremes

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

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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