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Supplement of

Riparian evapotranspiration is essential to simulate streamflow dynamics and water budgets in a Mediterranean catchment

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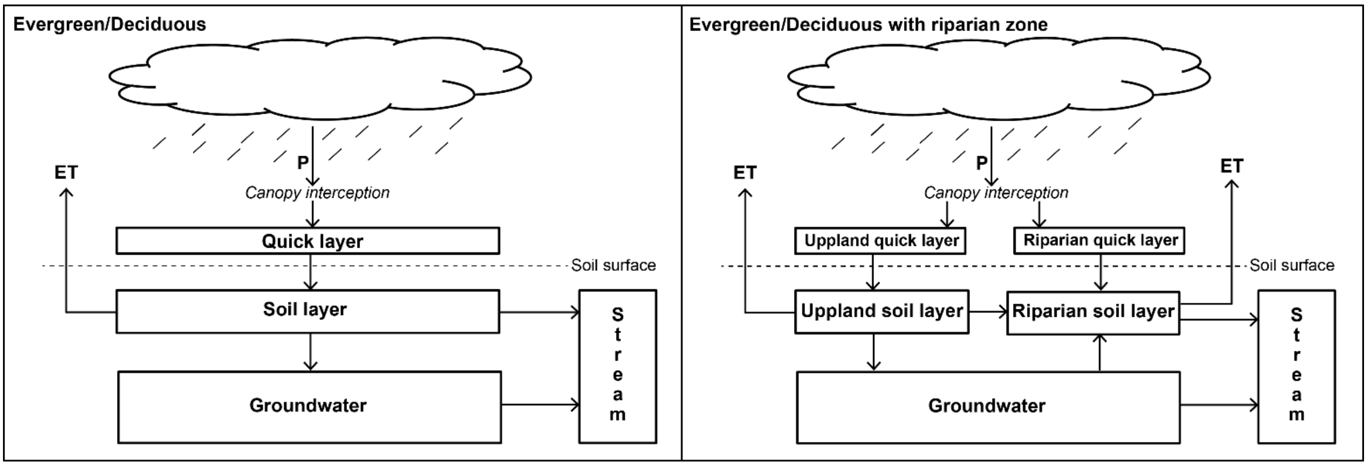
Supplement 1. Model configuration

PERSiST conceptualizes the landscape in four spatial levels. A *catchment* (level 1) is represented as one or more *sub-catchments* or reaches (level 2). Within each sub-catchment, there are one or more hydrologic response *or landscape units* (level 3), namely forest types in the present study. Finally, each landscape unit is made up of one or more *buckets/soil box* (level 4) through which water is routed. In our study, the model configuration presented one *catchment*, three local *sub-catchments* (up-, mid- and downstream), four *landscape units* (evergreen, deciduous, evergreen riparian, and deciduous riparian), and from three to five *buckets/soil boxes* (upland quick layer, upland soil layer, riparian quick layer, riparian soil layer, and groundwater). The three local sub-catchments (level 2) were divided based on the proportion of each landscape unit (level 3) within their local drainage area (Table S1). Moreover, each *landscape unit* was conceptualized with corresponding *buckets*/*soil boxes* (level 4) for both the model configuration excluding (Figure S1, left panel) and including (Figure S1, right panel) the riparian compartment.

Table S1: Proportion of each landscape unit for each local sub-catchment and model configuration.

	Configuration excluding riparian zone				**Configuration including riparian zone**			
Local Sub-catchment	**Evergreen**	**Deciduous**	**Evergreen riparian**	**Deciduous riparian**	**Evergreen**	**Deciduous**	**Evergreen riparian**	**Deciduous riparian**
Upstream	8.2%	91.8%	0%	0%	8.2%	91.8%	0%	0%
Midstream	55%	45%	0%	0%	27.5%	22.5%	27.5%	22.5%
Downstream	62.8%	37.2%	0%	0%	0%	0%	62.8%	37.2%

Figure S1: Conceptual diagram showing the water fluxes within and between landscape units for the model configuration excluding (left panel) and including (right panel) the riparian compartment. Boxes are the different buckets/soil boxes, while arrows represent the water fluxes.



Supplement 2. Data and parameters used for the model calibration

List of PERSiST model inputs, model “hard” calibration data, model outputs and most important parameters for the present study. Note that only stream flow data was at nested sub-catchment level (i.e. integrates the whole upstream area).

Table S2: Description of the PERSiST model inputs, model (“hard”) calibration data, and model outputs.

	Variable	**Units**	**Time resolution**	**Spatial level**
Inputs	Temperature	°C	Daily	Catchment
	Precipitation	mm	Daily	Catchment
Calibration	Stream flow	$m^3 s^{-1}$	Daily	Nested sub-catchment
Outputs	Stream flow	$m^3 s^{-1}$	Daily	Nested sub-catchment
	Evapotranspiration	mm	Daily	Soil box

Table S3: Description of the most important model parameters used for the present study. All parameters were adjusted to simulate realistic values of evapotranspiration (ET), especially the “degree day ET”, the “growing degree threshold”, the “ET adjustment” and the “retained water depth”. The parameters used for the sensitivity analyses can be found in Supplement 3.

Parameter	**Units**	**Description**	**Spatial level**
a (flow velocity multiplier)	m^{-2}	Determines flow velocity as: $v = a \cdot Q^b$	Local sub-catchment
b (flow velocity exponent)	-	Determines flow velocity as: $v = a \cdot Q^b$	Local sub-catchment
Rain multiplier	-	Adjustment factor relating observations at the meteorological station (input rainfall) to depth of rain actually falling on the landscape unit	Landscape unit
Degree day ET	mm $°C^{-1}$ day^{-1}	Maximum (i.e. potential) temperature-dependent rate at which evapotranspiration occurs	Landscape unit
Growing degree threshold	°C	Temperature threshold above which evapotranspiration can occur	Landscape unit
Canopy interception	mm day^{-1}	Fixed amount of precipitation (as snow or rain) intercepted by canopy	Landscape unit
Drought runoff fraction	-	Fraction of incoming precipitation contributing to runoff when depth of water is below an specified “Retained water depth” at the soil box	Soil box
Time constant	days	Residence time of water in a soil box as a proxy of hydrological conductivity	Soil box
ET adjustment	-	Exponent for limiting evapotranspiration when water is below a specified “Retained water depth” at the soil box	Soil box
Retained water depth	mm	Depth of water within a soil box below which water cannot longer drain (but can be lost by evapotranspiration at a rate limited by the “Evapotranspiration adjustment”)	Soil box

Supplement 3. Sensitivity analyses

To test the sensitivity of the stream flow model performance to the parameters related to evapotranspiration (ET), we compared model efficiencies (i.e. log(NS)) obtained from two sets of Monte Carlo (MC) analyses. In the first set, all model parameters potentially influencing stream flow were allowed to vary ± 25% with respect to the best performing parameter set from manual calibration (non-fixed ET analysis, Table S4). In the second set, ET-related parameters (i.e. degree day rates, threshold temperatures, and ET adjustments) were kept constant, while the other parameters were allowed to vary ± 25% (fixed ET analysis, Table S4). Fixed ET-related parameters were set to the mean optimal values obtained for each landscape unit after the manual calibration. The MC analyses consisted in 100 iterations of 1000 runs each. The best parameter set (in terms of model efficiency) from each of the 100 iterations was retained for further analyses. We used Tukey HSD test to compare the model efficiencies between fixed and non-fixed ET analyses. We interpreted a decrease in the goodness of fit (i.e. lower values of log(NS)) for the fixed ET analysis as an indication that the outputs of the model were sensitive to ET. The comparison between these two MC analyses was made for the downstream sub-catchment for the whole calibration period as well as for the vegetative and dormant periods separately.

The sensitivity analysis showed no differences in log(NS) values between the analysis with fixed and non-fixed ET parameters for the whole calibration period (Figure 4, main manuscript). The same occurred when comparing fixed and non-fixed ET simulations for the dormant period. For the vegetative period, the simulation of stream flow worsen when the ET parameters were fixed as indicated by the decrease in log(NS) efficiencies Figure 4, main manuscript), indicating that the model was sensitive to the ET parameters. Similar results were obtained for the NS metric (not shown).

Table S4: Description of the model parameters that were allowed to vary during Monte Carlo simulations. For ET-related parameters, the mean of the best values obtained for the three landscape units were used as fixed values.

Parameter	Units	Best	Min	Max	ET sensitivity analysis
a (flow velocity multiplier) at *upstream site*	m^{-2}	0.10	0.075	0.13	
a (flow velocity multiplier) at *midstream site*	m^{-2}	0.10	0.075	0.13	
a (flow velocity multiplier) at *downstream site*	m^{-2}	0.10	0.075	0.13	
b (flow velocity exponent) at *upstream site*	-	0.70	0.525	0.875	
b (flow velocity exponent) at *midstream site*	-	0.70	0.525	0.875	
b (flow velocity exponent) at *downstream site*	-	0.70	0.525	0.875	
Rain multiplier for *Upland Evergreen*	-	0.80	0.60	1.00	
Rain multiplier for *Upland Deciduous*	-	1.10	0.825	1.375	
Rain multiplier for *Riparian Evergreen*	-	0.80	0.60	1.00	
Rain multiplier for *Riparian Deciduous*	-	1.10	0.825	1.375	

Degree day evapotranspiration for *Upland Evergreen*	mm °C^{-1} day^{-1}	0.35	0.263	0.437	Fixed to 0.375
Degree day evapotranspiration for *Upland Deciduous*	mm °C^{-1} day^{-1}	0.40	0.3	0.5	Fixed to 0.375
Degree day evapotranspiration for *Riparian Evergreen*	mm °C^{-1} day^{-1}	0.35	0.263	0.437	Fixed to 0.375
Degree day evapotranspiration for *Riparian Deciduous*	mm °C^{-1} day^{-1}	0.40	0.3	0.5	Fixed to 0.375
Growing degree threshold for *Upland Evergreen*	°C	3	2.25	3.75	Fixed to 4
Growing degree threshold for *Upland Deciduous*	°C	5	3.75	6.25	Fixed to 4
Growing degree threshold for *Riparian Evergreen*	°C	3	2.25	3.75	Fixed to 4
Growing degree threshold for *Riparian Deciduous*	°C	5	3.75	6.25	Fixed to 4
Canopy interception for *Upland Evergreen*	mm day^{-1}	0.75	0.562	0.937	
Canopy interception for *Upland Deciduous*	mm day^{-1}	1	0.75	1.25	
Canopy interception for *Riparian Evergreen*	mm day^{-1}	0.75	0.562	0.937	
Canopy interception for *Riparian Deciduous*	mm day^{-1}	1	0.75	1.25	
Drought runoff fraction for *Upland Evergreen, Soil layer*	-	0.1	0.075	0.125	
Drought runoff fraction for *Upland Deciduous, Soil layer*	-	0.2	0.15	0.25	
Time constant for *Upland Evergreen, Quick layer*	days	1.3	0.975	1.625	
Time constant for *Upland Deciduous, Quick layer*	days	1.7	1.275	2.125	
Time constant for *Riparian Evergreen, Quick layer*	days	1.3	0.975	1.625	
Time constant for *Riparian Deciduous, Quick layer*	days	1.7	1.275	2.125	
Time constant for *Upland Evergreen, Soil layer*	days	2.5	1.875	3.125	
Time constant for *Upland Deciduous, Soil layer*	days	2.5	1.875	3.125	
Time constant for *Riparian Evergreen, Soil layer*	days	5	3.75	6.25	
Time constant for *Riparian Deciduous, Soil layer*	days	5	3.75	6.25	
Time constant for *Evergreen, Groundwater layer*	days	70	52.5	87.5	
Time constant for *Deciduous, Groundwater layer*	days	100	75	125	
Evapotranspiration adjustment for *Upland Evergreen, Soil layer*	-	0.75	0.562	0.937	Fixed to 0.625
Evapotranspiration adjustment for *Upland Deciduous, Soil layer*	-	0.5	0.375	0.625	Fixed to 0.625
Evapotranspiration adjustment for *Riparian Evergreen, Soil layer*	-	0.75	0.562	0.937	Fixed to 0.625
Evapotranspiration adjustment for *Riparian Deciduous, Soil layer*	-	0.5	0.375	0.625	Fixed to 0.625

Supplement 4. **Present and future climate at Font del Regàs**

Temperature and precipitation for the reference period (1981–2000) and the future period (2081–2100) at Font del Regàs (FR) were inferred by using daily meteorological data for the period 1981–2000 from Turó de l'Home (TH) (Meteocat, www.meteocat.cat), a meteorological station located < 10 km from the study site (Figure S2). We assumed that the occurrence of days with $P = 0$ was equal between TH and FR. When $P > 0$ at TH, daily P at FR was estimated by dividing the intercept of the model equation by the number of days with $P > 0$ in that month, and applying the linear regression as in Figure S2a (i.e. P at FR = $3.48/n + 0.72*P_{TH}$, being n the number of rainy days in a given month). Daily P and T at FR for the future period (2081–2100) were constructed from the estimated values at the reference period using the IPCC scenarios as described in the main manuscript.

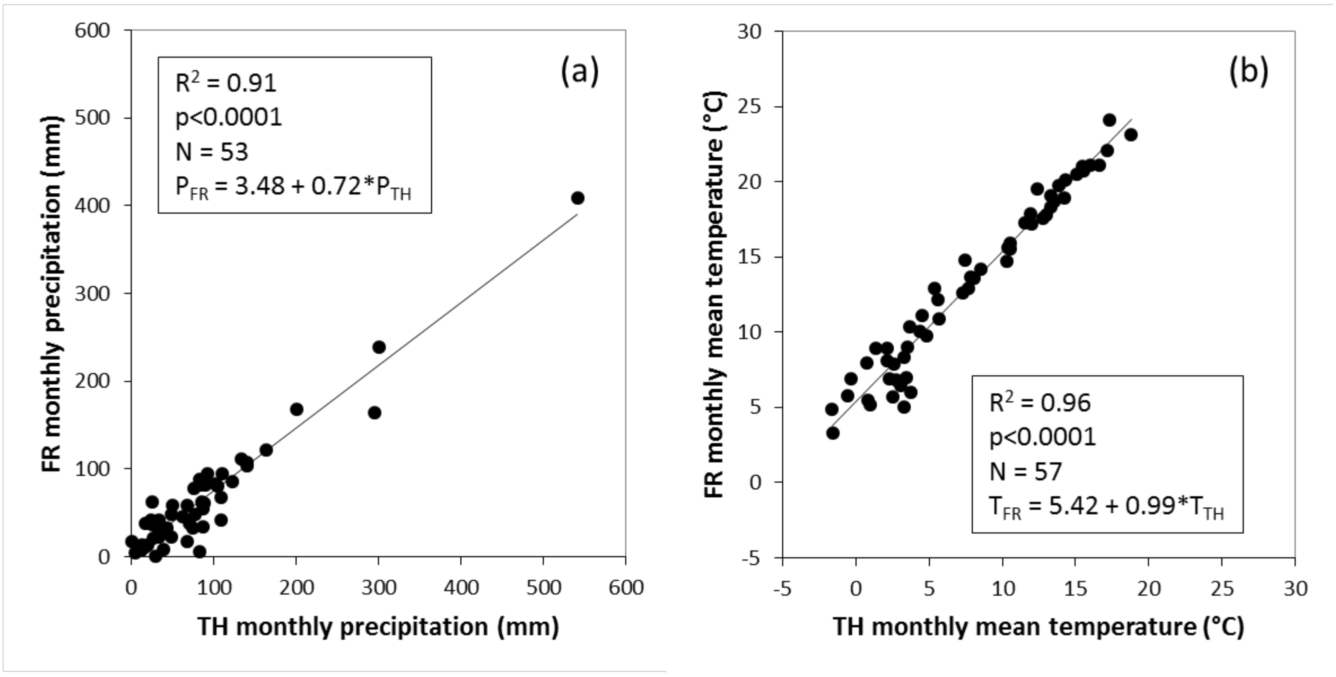


Figure S2: Linear regression of (a) monthly precipitation and (b) monthly mean temperature between Font del Regàs (FR) and Turó de l'Home (TH) for the period 2010-2014.

Supplement 5. Simulated ET (model output)

The PERSIST model simulated not only daily stream flow dynamics at Font del Regàs but also the daily pattern of the different hydrological fluxes contributing to catchment water budgets such as tree evapotranspiration for each catchment unit (Figure S3).

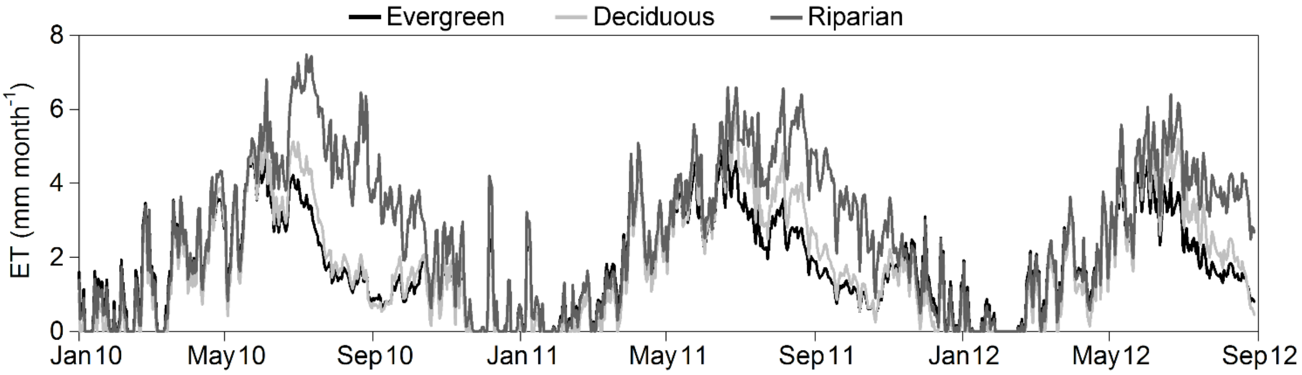


Figure S3: Daily values of simulated evapotranspiration (ET) in the evergreen (black), deciduous (grey) and riparian (dark grey) forests during the period January 2010 – August 2012.