Mathematical modeling riparian vegetation zonation in semiarid conditions based on a transpiration index

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1. Introduction

River banks are an essential part of riparian ecosystems. They represent the transition between the aquatic and terrestrial environments, receiving influence from both of them. In semiarid climates the vegetation classification is normally done by functional types (*Baird and Maddock, 2005; Horton et al, 2001*), with the aim of analyzing the interaction between biotic and abiotic factors.

Plant survival not only depends in water availability but also in the presence of nutrients , mineral salts, carbon dioxide.... Even so in semiarid and arid climates the latter don't influence a lot, and plant survival mainly depends on soil water availability (*Goodwin and Tarboton, 2001; Rodriguez-Iturbe and Porporato, 2004*). In the river banks the soil moisture and the water table elevation is determined by the river hydrologic regime (*Richards et al, 1996*). Additionally the flood and drought frequency and magnitude is crucial in the plant development (*Tabacchi et al, 1998*).

The actual condition of most floodplain sites in Spain is very deteriorated (Ibero, 1996). There are a lot of factors that have caused this situation (agriculture, urbanization, canalizations …) The modification of river flow and the flood intensity and frequency are the main factors that can enable or disable the natural regeneration of the riparian forests.

Fig.1 River gallery at Lorcha site in Serpis river

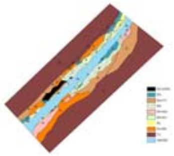

Fig. 2 Vegetation patch maps at the Lorcha site

Fig.3 Aerial photo of the Terde I (River Mijares) study site with its studied transects.

2. Case of Study

For this work seven study sites of the Jucar River Basin District have been selected. The sites are mainly selected in the upper and medium river stretches, where the rivers suffer less alterations. Four of the sites have a natural flow regime and three of them a regulated flow regime.

Fig.4 Location of the 7 study sites of the Jucar River Basin District.

4. Ribav-1D Software

A software package called **Ribav-1D** has been designed to aid with the model usage. The software has been designed in Visual Basic.net and its data inputs are classified in CSV files which are: Hydrometeorology, Rating Curves, Soil Parameters, Vegetation Parameters and Simulation Points.

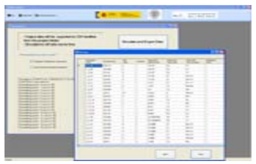

Fig 5 Ribav-1D software during execution

3. Ribav Model Conceptualization

In this model the studied soil section is represented as a water tank filled with porous material *(Morales and Frances 2009)*. The vertical water of the tank will has a daily variation depending on the soil moisture fluxes.

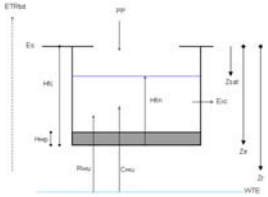

Fig. 6 Conceptual scheme of Ribav model

•The vertical **limits** of the tank are determined by the following equivalent water quantities:
- (Hfc) Equivalent soil moisture height at field capacity [mm].
- (Hwp) Equivalent soil moisture height at permanent wilting point [mm].

•Depending on the plant functional type there are different actives root fractions:
- (Ri) Active root fraction or transpiration efficiency on the unsaturated soil zone
- (Rj) Active root fraction or transpiration efficiency on the saturated soil zone

•The model requires the following **elevations and depths**:
- (Wte) Daily Water table elevation [m].
- (Zr) Maximum Root Depth [m].
- (Ze) Effective Root Depth [m].
- (Zsat) Water depth at extinction for saturation [m].
- (Es) Soil Surface Elevation [m].

•The tank has the following **input fluxes**: :
- (PP) Daily Precipitation [mm/day].
- (Rwu) Root Water Rise [mm/day].
- (Cwu) Capillary Water Rise [mm/day].

•The tank has also the following **output fluxes**:
- (Exc) Water excess when the tank is full [mm/day].
- (ETRtot) Actual evapotranspiration of the vegetation [mm/day].

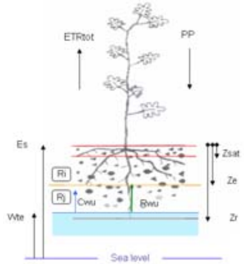

Fig.7 Fluxes and parameters which relevant to the vegetation in the Ribav model

•The **transpiration index** is:
- (ETP) Potential Evapotranspiration [mm/day]
- (Cov) Plant Cover

$$ET_{index} = \frac{ETR_{tot}}{ETP \cdot Cov}$$

5. Sensitivity Analysis

The **sensitivity analysis** was made for**:** 4 vegetation functional types, 7 different elevations, natural and regulated flow regimes, and several soil types. The results have shown that the most sensible parameters are the ones that deal with root depths (Ze and Zr) and root fractions (Ri and Rj).

Vegetation:	TV (Terrestrial Vegetation)								
Soil:	[illegible] (Sand with Gravel)								
Flow Regime:	Regulated								
Elevation (m.a.s.l.)	Elevation over the river level (m)	Standard Values for the Evapotranspiration Index	Evapotranspiration Index Variation according to the Modified Parameter						Most Sensible Parameter
			Zr	Ze	Zsat	Ri	Rj	CRT	
[illegible]	0.314	0.481	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Zr
[illegible]	1.339	0.504	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Ze
[illegible]	1.806	0.482	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Ze
[illegible]	2.661	0.444	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Ri
[illegible]	3.24	0.440	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Ri
[illegible]	3.466	0.440	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Ri
[illegible]	4.401	0.440	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Ri

Table 1 : Results of the sensitivity analysis for several simulation points with different elevations for a terrestrial vegetation functional type and a sandy-gravel soil in a regulated flow regime.

6. Calibration and Validation

•The calibration was made for the most sensitive vegetation parameters from all the vegetation functional types, giving the following results:

CALIBRATED VEGETATION PARAMETERS		VEGETATION FUNCTIONAL TYPES			
		Riparian Herbs	Riparian Juveniles ans small Schrubs	Riparian adult Trees and Schrubs	Terrestrial Vegetation
		RH	RJ	RA	TV
Effective Root Depth	Zr	0.8	1.25	3.5	2
Maximum Root Depth	Ze	0.7	0.9	0.9	1.9
Extinction at Saturation Depth	Zsat	-0.75	-0.1	-0.3	0.3
Root Efficiency in Saturated Zone	Ri	0.8	0.9	0.9	1
Root Efficiency in Unsaturated Zone	Rj	0.6	0.35	0.35	0

Table 2: Calibrated vegetation parameters for each vegetation functional type

•After calibrating, the model was validated for six other river study sites of the Jucar Basin. For the calibration/validation process a **confusion matrix** was used, which also takes into account mixed vegetation functional types.

		SIMULATED								
		Riparian			Terrestrial	Mixed				Total
		RH	RJ	RA	TV	RH+RJ	RH+RA	RJ+RA	RA+TV	
OBSERVED	RH	25	3	39	3	-	-	-	-	70
	RJ	0	2	1	2	-	-	-	-	5
	RA	0	0	17	1	-	-	-	-	18
	TV	0	0	15	110	-	-	-	-	125
	RH+RJ	3	5	5	7	8	-	-	-	20
	RH+RA	0	1	12	4	-	12	-	-	17
	RJ+RA	2	2	29	51	-	-	31	-	84
	RA+TV	0	0	51	41	-	-	-	92	92
	Total	30	13	169	219					431

Table 3: Confusion Matrix for the validation of the Lorcha study site.

7. Conclusions

As the confusion matrix shows, the model simulates very well the transition between observed Terrestrial (TV) and Riparian Adults (RA) vegetation. Unfortunately it doesn't simulate very satisfactorily the presence/absence of Riparian Herbs (RH), possibly because the current Ribav model does not contemplate other fluvial processes as shear stress. For that reason this model is going to merge with a dynamic model which involves additional processes, which greatly affect this vegetation type.

8. Acknowledgments

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