Dynamics of riparian plant communities, a new integrative ecohydrological modelling approach (EGU2015-3202)

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1. INTRODUCTION

Study of vegetation dynamics in riparian areas:

- tight research line of the Ecohydrology

The river hydrodynamics determine the vegetation distribution and its wellbeing:

- Specially in semi-arid Mediterranean riparian areas

Different modelling approaches have arisen during recent past:

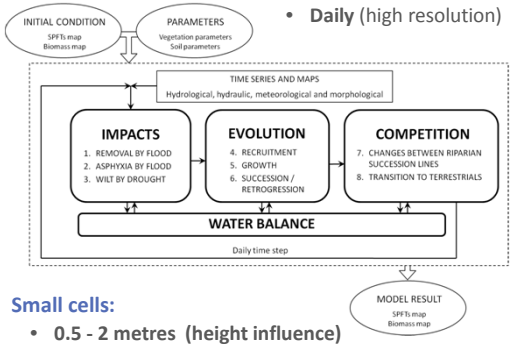
- Hooke *et al.*, 2005; Camporeale and Ridolfi, 2006; Perona *et al.*, 2009; Benjankar *et al.*, 2011; Maddock III *et al.*, 2012; García-Arias *et al.*, 2013; Ye *et al.*, 2013; García-Arias *et al.*, 2014; etc.

RVDM:

- A new model that integrates the knowledge provided by previous tools and that represents an upgrade in the way of understanding the relations between the riparian hydrodynamics and the vegetation dynamics

2. RVDM OVERVIEW

Modular structure:



Time step:

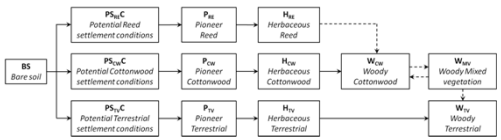
- **Daily** (high resolution)

Small cells:

- **0.5 - 2 metres** (height influence)

Main state variables:

- Successional Plant Functional Types (SPFTs)

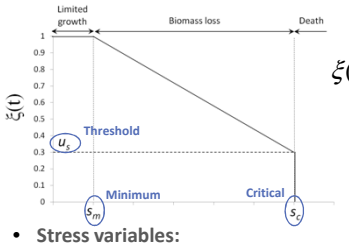


- Biomass estimations

3. IMPACTS MODULE

Effects of hydrological extremes over vegetation

- Biomass remain → **B(t) = B(t-1) · ξ(t)**
- Parameters: **minimum** and **critical** values of the stress variable (*s*) to mark out the impact
- Linear biomass loss functions, ξ(t)



$$\xi(t) = -a\,s(t) + b$$

$$a = \frac{u_s - 1}{s_m - s_c}$$

$$b = 1 + a\,s_m$$

- Stress variables:
  1. Remotion by flood → **shear stress**
  2. Asphyxia by flood → **water table elevation**
  3. Wilt by drought → **soil moisture**

4. EVOLUTION MODULE

Recruitment:

- **Presence of available seeds: BS → PSC** controlled by **seasonal timing** and **floods occurrence**
- **Germination of the seeds: PSC → P** requirements of **temperature**, **oxygen**, **moisture** and **light**
- **Establishment of the seedlings: P → H** limited by **transpiration** and **time since germination**

Growth:

$$B(t) = B(t-1) + \Delta B(t)$$

Logistic component: $\varphi_i(t) = 1 - \frac{LAI(t)}{LAI_{max}}$

Water availability: $ET_{idx}(t) = \frac{T(t)}{cv\,ET_0(t) - E_i(t)}$

$$\frac{dB}{dt} = \left[LUE \cdot APAR(t) \cdot ET_{idx}(t) - \mathrm{Re}(t)\right] \cdot \varphi_{xl}(t-1) - k_a \cdot B(t-1)$$

Succession / Retrogression:

- Affects to each succession line independently
- Each SPFT has associated **age spans** and **minimum biomass**
- **Retrogression** to BS: age span exceeded without reaching the minimum biomass of the next SPFT

5. COMPETITION MODULE

Changes between riparian succession lines:

- On H_{RE} cells → optimum **light conditions** for the **recruitment of the cottonwood** series
  - **potential coexistence**: $H_{RE} - PS_{CW}C$ (germination)
  - **coexistence**: $H_{RE} - P_{CW}$ (establishment)
  - **competition**: $H_{RE} - H_{CW}$ (transpiration capabilities)
- **Succession**: $H_{RE} \rightarrow W_{CW}$ requires $\Sigma T(t)H_{RE} < \Sigma T(t)H_{CW}$ and $B(t) \geq Bmin_{WCW}$

Competition is not considered to limit the biomass growth or loss between competitors

Transition to terrestrials:

- On W_{CW} or W_{MV} cells:

$t_{W_{CW}} > Age_t$ → $\Sigma ET_{idx\,W_{CW}}$ *vs* $\Sigma ET_{idx\,W_{MV}}$ → W_{CW} / W_{MV}

- On W_{MV} cells:

$t_{W_{MV}} > t_{min}TV$ → $\Sigma ET_{idx\,W_{MV}}$ *vs* $\Sigma ET_{idx\,W_{TV}}$ → W_{MV} / W_{TV}

No competition is analyzed in cells occupied by terrestrials (Hydrological disturbances are enough to maintain the riparian dynamics)

6. MODEL STRENGTHS DISCUSSION

Case study

- **Terde reach** (UTM30-ETRS89: 689183, 4448735 m; Mijares River, Spain)
- **Mediterranean semi-arid** conditions, no canalization or flow regulation
- Varied substrate dominated by **gravels, cobbles** and **scattered boulders**
- Good representation of the three **succession lines analyzed by RVDM**

Models implementation:

Calibration period:
01/07/**2000** – 31/08/**2006**

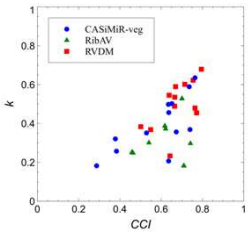
Validation periods:
01/07/**2000** – 31/12/**2009**
31/08/**2006** – 31/12/**2009**

Reference models:

CASiMiR-veg (Benjankar *et al.*, 2011)

RibAV (García-Arias *et al.*, 2014)

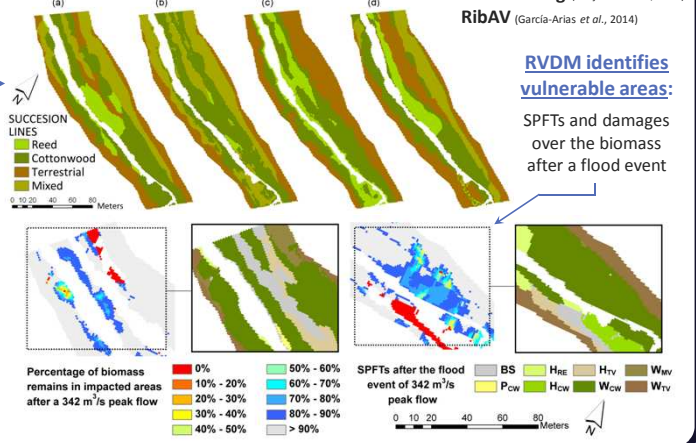
RVDM performs better than other models:



Objective functions for all periods and plant cassifications

Succession lines distribution observed in 2006 (a) compared to the predicted by CASiMiR-veg (b), RibAV (c) and RVDM (d)

Period: 2000-2006				
Plant classification	O.F.	CASiMiR-veg	RibAV	RVDM
MODEL	*CCI*	0.378	0.541	0.670
(Phases/PFTs/SPFTs)	*k*	0.321	0.301	0.589
Phases	*CCI*	0.673	0.742	0.764
	k	0.356	0.297	0.479
Lines	*CCI*	0.652	0.464	0.715
	k	0.502	0.248	0.601
RI-TV-MIX	*CCI*	0.764	0.622	0.795
	k	0.635	0.372	0.679



RVDM identifies vulnerable areas:

SPFTs and damages over the biomass after a flood event

7. CONCLUSIONS

RVDM represents a major improvement :

- higher temporal resolution than previous similar models
- new SPFTs classification useful for research and management
- easy implementation with excellent results
- better representation of the main processes that determine the vegetation dynamics in riparian areas

8. REFERENCES

Benjankar R, Egger G, Jorde K, Goodwin P, Glenn NF. 2011. Dynamic floodplain vegetation model development for the Kootenai River, USA. *Journal of Environmental Management* 92(2011):3058–3070. doi: 10.1016/j.jenvman.2011.07.017

Camporeale C, Ridolfi L. 2006. Riparian vegetation distribution induced by river flow variability: A stochastic approach, *Water Resources Research* 42: W10415, doi:10.1029/2006WR004933.

García-Arias A., Francés F., Ferreira T., Egger G., Martínez-Capel F., Garófano-Gómez V., Andrés-Doménech I., Politti E., Rivaes R., Rodríguez-González P. M. 2013. Implementing a dynamic riparian vegetation model in three European river systems. Ecohydrology. 6(4):635-651. doi: 10.1002/eco.1331

García-Arias A, Francés F, Morales-de la Cruz M, Real J, Vallés-Morán F, Garófano-Gómez V & Martínez-Capel F, 2014. Riparian evapotranspiration modelling: model description and implementation for predicting vegetation spatial distribution in semi-arid environments. *Ecohydrology*, 7:659-677. doi: 10.1002/eco.1387

Hooke JM, Brookes CJ, Duane W, Mant JM. 2005. A simulation model of morphological, vegetation and sediment changes in ephemeral streams. *Earth Surface Processes and Landforms* 30(7): 845–866. DOI: 10.1002/esp.1195

Maddock III T, Baird KJ, Hanson RT, Schmid W, Hoori A. 2012. RIP-ET: A riparian evapotranspiration package for MODFLOW-2005. U.S. *Geological Survey Techniques and Methods* 6-A39, 76 p.

Perona P, Camporeale C, Perucca E, Savina M, Molnar P, Burlando P, Ridolfi L. 2009. Modelling river and riparian vegetation interactions and related importance for sustainable ecosystem management. *Aquatic Sciences* 71: 266–278. DOI 10.1007/s00027-009-9215-1

Ye, F, Chen Q, Blanckaert K, Ma J. 2013. Riparian vegetation dynamics: insight provided by a process-based model, a statistical model and field data. *Ecohydrology* 6: 567–585. DOI: 10.1002/eco.1348

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