HydroEco´2015

HydroEco 2015 - 5th International Multidisciplinary Conference on Hydrology and Ecology: Advances in Monitoring, Predicting and Managing Hydroecological Processes

Modelling hydroecological processes to determine riparian vegetation dynamics

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Outline

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- RVDM
  - Water balance module
  - Impacts module
  - Evolution module
  - Competition module
- Model strengths discussion
- Conclusion

Introduction

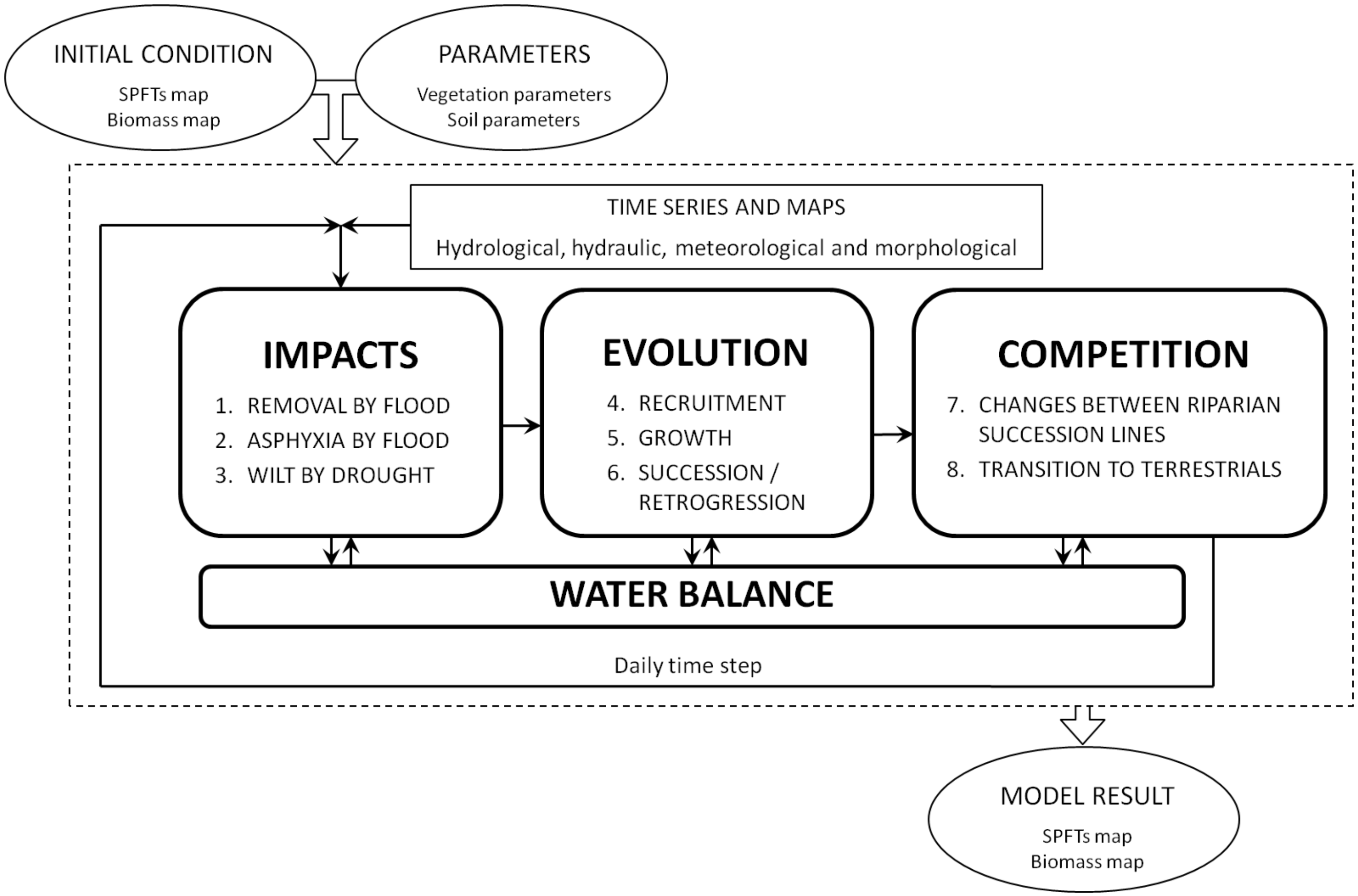
Introduction

- **Ecohydrology → vegetation dynamics in riparian areas**
- **Mediterranean riparian areas (semi-arid)**
  - **The river hydrodynamics determine the vegetation distribution and its wellbeing**
- **Different modelling approaches**
  - 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:**
  - **integrates the knowledge provided by previous tools**
  - **represents an upgrade** → understanding the relations between the riparian hydrodynamics and the vegetation dynamics

The Riparian Vegetation Dynamic Model (RVDM)

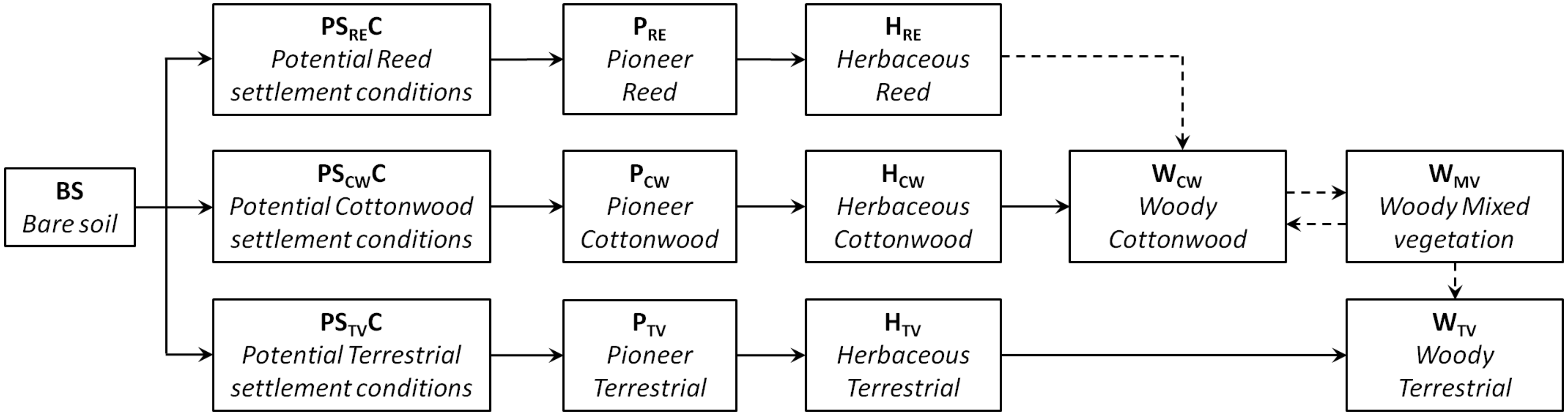
RVDM OVERVIEW

Modular structure



RVDM OVERVIEW

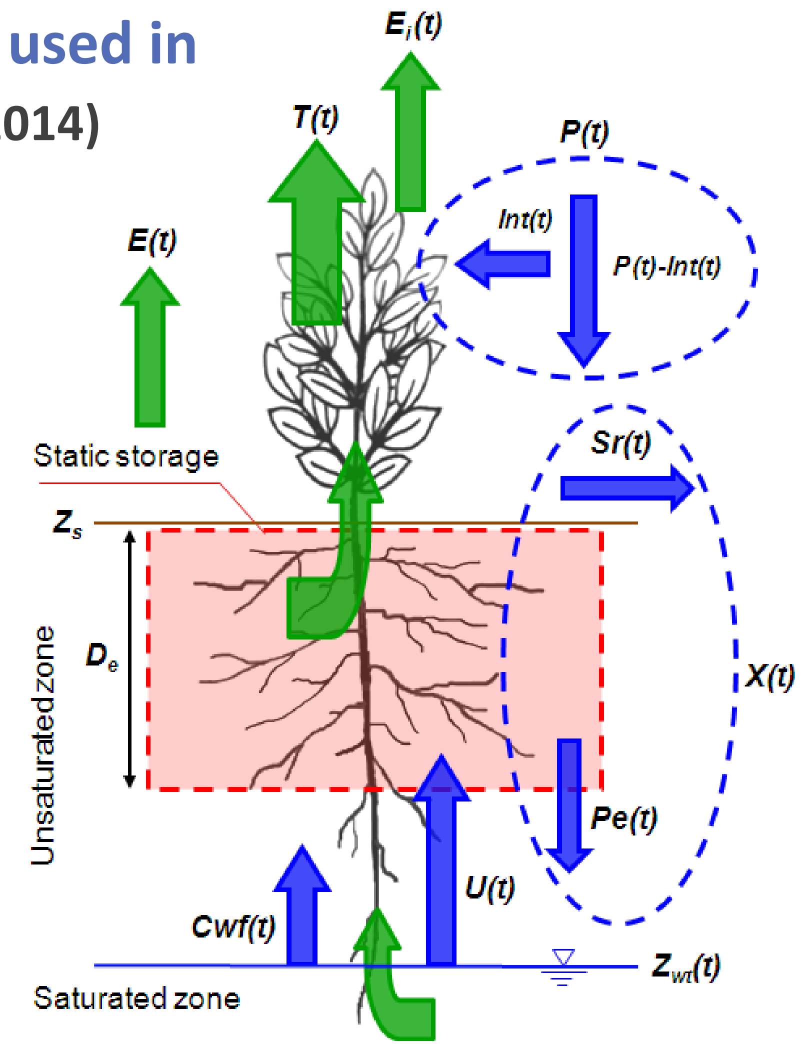
- **Modular structure**
- **Temporal resolution → daily time step**
- **Distributed in small cells → 0.5 - 2 metres (height influence)**
- **State variables:**
  - **Successional Plant Functional Types (SPFTs)**



  - **Biomass estimations**

WATER BALANCE MODULE

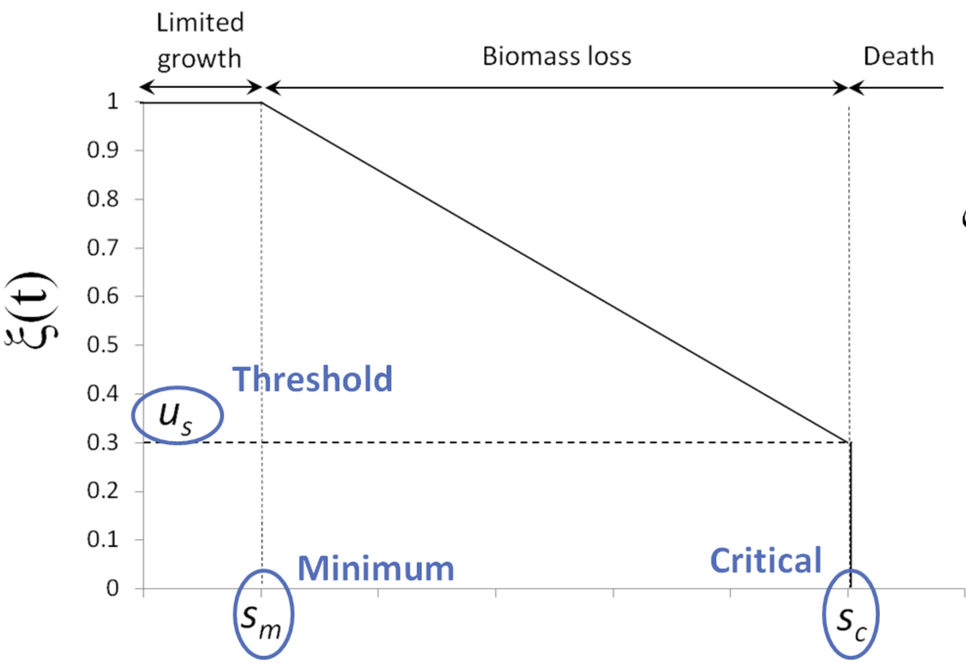
- **balance equations similar to those used in the RibAV model** **(García-Arias *et al.*, 2014)**
- **Estimation of the capillary water in the upper soil (*H*) and the actual transpiration (*T*)**
- **RVDM improves the RibAV approach by considering:**
  - **the interception (*Int*) of a part of rainfall water by the plants**
  - **the evaporation (*E*) from the bare soil**



IMPACTS MODULE

❑ Effects of hydrological extremes over vegetation

- **Biomass remain** → **$B(t) = B(t-1) \cdot \xi(t)$** (linear biomass loss functions)
- **Parameters: minimum and critical values of the stress variable (*s*)** to mark out the impact



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

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

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

IMPACTS MODULE

❑ Effects of hydrological extremes over vegetation

- **Biomass remain** → **B(t) = B(t-1) · ξ(t)** (linear biomass loss functions)
- **Parameters: minimum and critical values of the stress variable (*s*)** to mark out the impact
- **Stress variables:**
  - **Remotion by flood** → **shear stress**
  - **Asphyxia by flood** → **water table elevation**
  - **Wilt by drought** → **soil moisture**

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

EVOLUTION MODULE

- **Recruitment**
- **Growth**

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

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

Logistic component

$$\varphi_l(t) = 1 - \frac{LAI(t)}{LAI_{\max}}$$

Water availability

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

$$APAR(t) = 0.95 \left(- e^{-l_e LAI(t-1)} \right) \cdot PAR(t)$$

$$LAI(t) = \mathrm{SLA}\; B(t)\, cv$$

$$\mathrm{Re}(t) = \left(\frac{rr\; B(t-1)\; 2.2}{29} \right) \cdot e^{308.56\left[\left(\frac{1}{56.02} - \frac{1}{T_{med}+46.02}\right)\right]}$$

EVOLUTION MODULE

- Recruitment
- Growth
- 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

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} → **W_{CW}** requires **$\Sigma T(t)H_{RE} < \Sigma T(t)H_{CW}$** and **$B(t) \geq Bmin_{WCW}$**

COMPETITION MODULE

- Changes between riparian succession lines
- Transition to terrestrials
  - On W_{CW} or W_{MV} cells:

$$t_{W_{CW}} > Age_t \rightarrow \Sigma ET_{idx\ W_{CW}} \ vs \ \Sigma ET_{idx\ W_{MV}} \rightarrow W_{CW},\ W_{MV}$$

  - On W_{MV} cells:

$$t_{W_{MV}} > t_{min}TV \rightarrow \Sigma ET_{idx\ W_{MV}} \ vs \ \Sigma ET_{idx\ W_{TV}} \rightarrow W_{MV},\ W_{TV}$$

- No competition is analyzed in cells occupied by terrestrials
  - Hydrological disturbances maintain the riparian dynamics

Model strengths discussion

CASE STUDY

- **Terde reach** (UTM30-ETRS89: 689183, 4448735 m; Mijares River, Spain)
- **Mediterranean semi-arid natural conditions**
- **Substrate dominated by gravels, cobbles and scattered boulders**
- **Good representation of the three succession lines**

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)

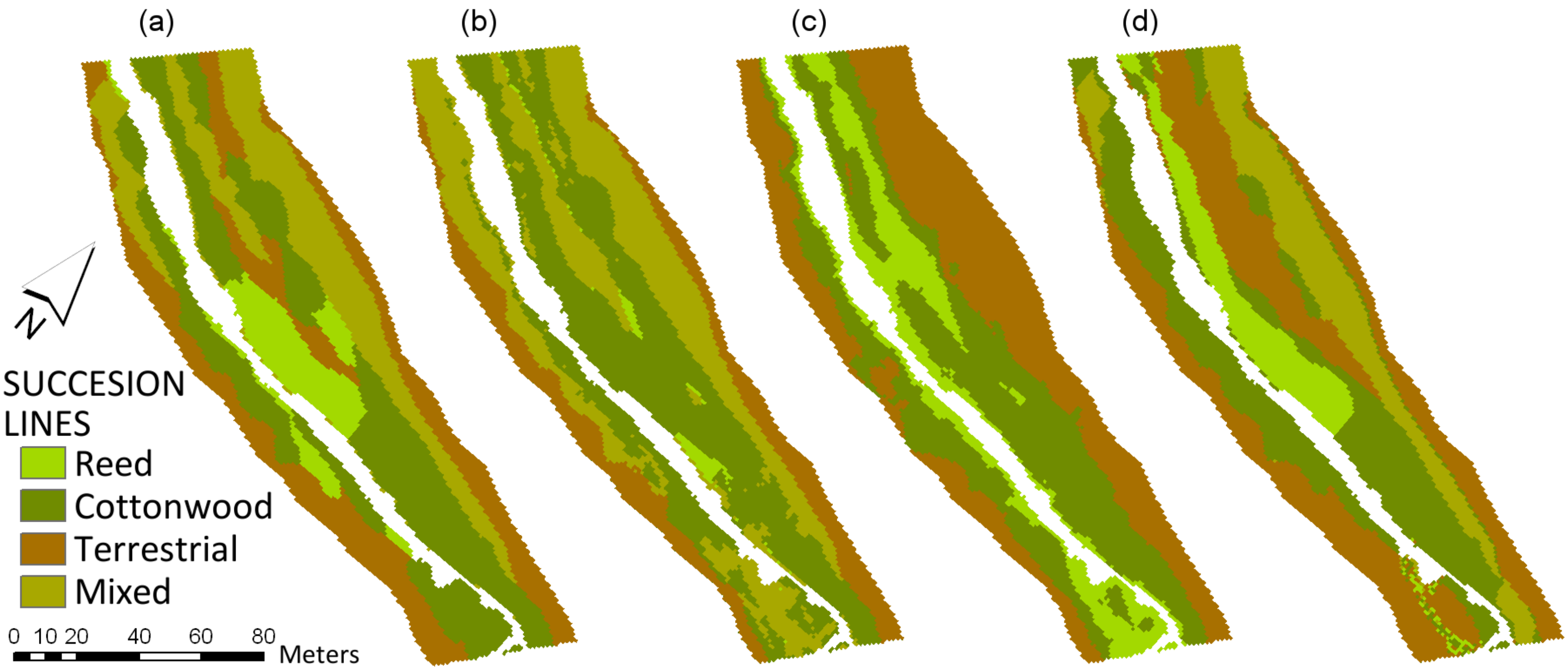
DISCUSSION

- RVDM performs better than other models

Period: 2000-2006				
Plant classification	O.F.	CASiMiR-veg	RibAV	RVDM
MODEL (Phases/PFTs/SPFTs)	*CCI*	0.378	0.541	0.670
	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

DISCUSSION

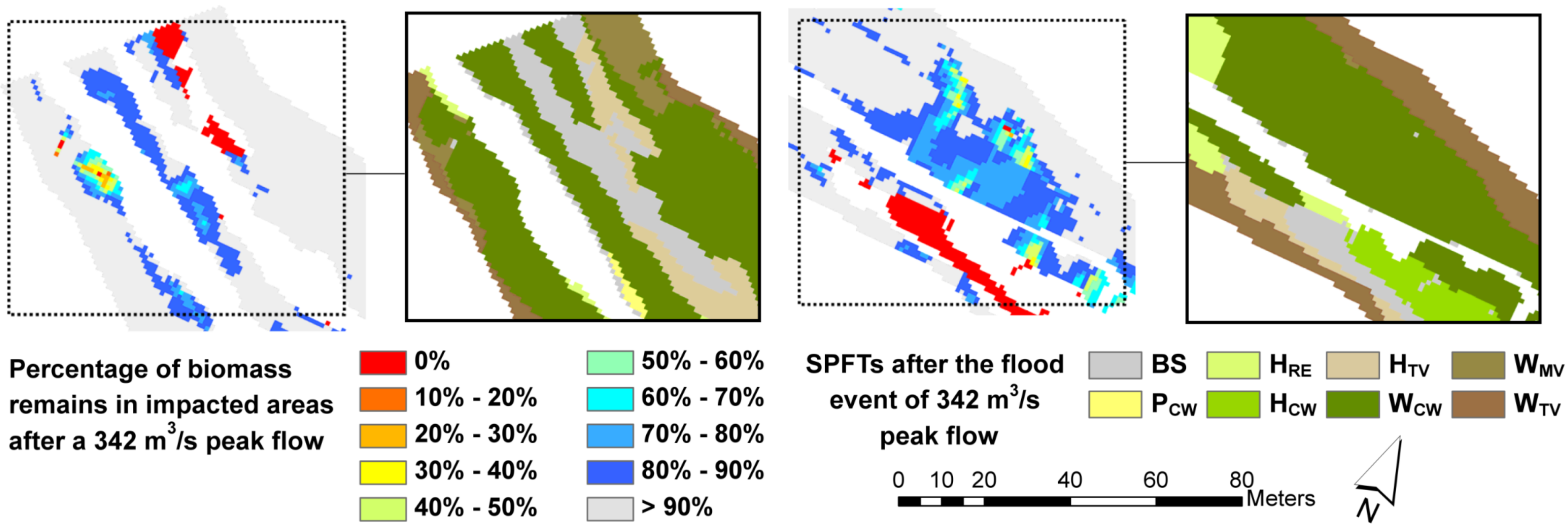
- **RVDM performs better than other models**



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

DISCUSSION

- RVDM performs better than other models
- RVDM identifies vulnerable areas



SPFTs and damages over the biomass after a flood event

Conclusion

CONCLUSION

- **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**

THANK YOU FOR YOUR ATTENTION

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