Modelling hydroecological processes to determine riparian vegetation dynamics

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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)
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Modelling hydroecological processes to determine riparian vegetation dynamics

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

RVDM OVERVIEW

- Biomass estimations
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 ($\text{Int}$) of a part of rainfall water by the plants
- the evaporation ($E$) from the bare soil
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

\[ \xi(t) = -a \cdot s(t) + b \]

\[ a = \frac{u_s - 1}{s_m - s_c} \]

\[ b = 1 + a \cdot s_m \]
Effects of hydrological extremes over vegetation

• Biomass remain $\rightarrow B(t) = B(t-1) \cdot \xi(t)$ (linear biomass loss functions)
• Parameters: minimum and critical values of the stress variable ($s$) to mark out the impact
• Stress variables:
  • Remotion by flood $\rightarrow$ shear stress
  • Asphyxia by flood $\rightarrow$ water table elevation
  • Wilt by drought $\rightarrow$ soil moisture
Recruitment

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

Growth

\[ B(t) = B(t - 1) + \Delta B(t) \]

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

Logistic component

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

Water availability

\[ ET_{idx}(t) = \frac{T(t)}{cv \cdot ET_0(t) - E_i(t)} \]

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

\[ LAI(t) = \text{SLA} \cdot B(t) \cdot cv \]

\[ Re(t) = \left( \frac{rr \cdot B(t-1) \cdot 2.2}{29} \right) \cdot e^{308.56 \left[ \left( \frac{1}{56.02} - \frac{1}{T_{med} + 46.02} \right) \right]} \]
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
Changes between riparian succession lines

- On $H_{RE}$ cells $\rightarrow$ 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 $B(t) \geq B_{min_{WCW}}$
Changes between riparian succession lines

Transition to terrestrials

- On $W_{cw}$ or $W_{mv}$ cells:
  \[
  t_{W_{cw}} > Age_t 
  \]
  \[
  \Sigma E T_{idx \ W_{cw}} \ vs \ \Sigma E T_{idx \ W_{mv}} 
  \]

- On $W_{mv}$ cells:
  \[
  t_{W_{mv}} > t_{min \ TV} 
  \]
  \[
  \Sigma E T_{idx \ W_{mv}} \ vs \ \Sigma E T_{idx \ W_{tv}} 
  \]

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

**Reference models:**
CASiMiR-veg (Benjankar et al., 2011)
RibAV (García-Arias et al., 2014)
**RVDM performs better than other models**

<table>
<thead>
<tr>
<th>Plant classification</th>
<th>O.F.</th>
<th>CASiMiR-veg</th>
<th>RibAV</th>
<th>RVDM</th>
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<tbody>
<tr>
<td><strong>MODEL</strong> (Phases/PFTs/SPFTs)</td>
<td>$CCI$</td>
<td>0.378</td>
<td>0.541</td>
<td>0.670</td>
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<td>$k$</td>
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<td>0.301</td>
<td>0.589</td>
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<td><strong>Phases</strong></td>
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<td>0.297</td>
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<td><strong>Lines</strong></td>
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<td></td>
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<td>0.601</td>
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<td><strong>RI-TV-MIX</strong></td>
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<td></td>
<td>$k$</td>
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<td>0.372</td>
<td>0.679</td>
</tr>
</tbody>
</table>
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)
- **RVDM performs better than other models**
- **RVDM identifies vulnerable areas**

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**DISCUSSION**

SPFTs and damages over the biomass after a flood event
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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