Modelling hydroecological processes to determine riparian vegetation dynamics

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Introduction

RVDM
- Water balance module
- Impacts module
- Evolution module
- Competition module

Model strengths discussion

Conclusion
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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Modular structure

INITIAL CONDITION
- SPFTs map
- Biomass map

PARAMETERS
- Vegetation parameters
- Soil parameters

TIME SERIES AND MAPS
- Hydrological, hydraulic, meteorological and morphological

IMPACTS
1. REMOVAL BY FLOOD
2. ASPHYXIA BY FLOOD
3. WILT BY DROUGHT

EVOLUTION
4. RECRUITMENT
5. GROWTH
6. SUCCESSION / RETROGRESSION

COMPETITION
7. CHANGES BETWEEN RIPARIAN SUCCESSION LINES
8. TRANSITION TO TERRESTRIALS

WATER BALANCE
Daily time step

MODEL RESULT
- SPFTs map
- Biomass map

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**
- 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
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

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

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

\[ b = 1 + a \ s_m \]
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
- Stress variables:
  - Remotion by flood → shear stress
  - Asphyxia by flood → water table elevation
  - Wilt by drought → 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
Recruitment

Growth

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

\[ \frac{dB}{dt} = \sum U \cdot A \cdot P \cdot A R(t) \cdot E T_{idx}(t) - R(t) \cdot \phi_x l(t - 1) - k_a \cdot B(t - 1) \]

Logistic component

\[ \phi_l(t) = 1 - \frac{L A I(t)}{L A I_{max}} \]

Water availability

\[ E T_{idx}(t) = \frac{T(t)}{c v \cdot E T_0(t) - E_i(t)} \]

\[ A P A R(t) = 0.95 \left( - e^{-l_e L A I(t-1)} \right) \cdot P A R(t) \]

\[ L A I(t) = S L A \cdot B(t) \cdot c v \]

\[ R e (t) = \left( \frac{r r \cdot B(t - 1) \cdot 2.2}{29} \right) \cdot e^{308.56 \left[ \left( \frac{1}{56.02} - \frac{1}{T_{med} + 46.02} \right) \right]} \]
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- 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 → optimum light conditions for the recruitment of the cottonwood series
  - potential coexistence: $H_{RE} - P_{CW}C$ (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 $B(t) \geq B_{min_{CW}}$
- Changes between riparian succession lines
- Transition to terrestrials
  - On $W_{CW}$ or $W_{MV}$ cells:
    $t_{W_{CW}} > \text{Age}_t \rightarrow \Sigma ET_{idx \, W_{CW}} \, vs \, \Sigma ET_{idx \, W_{MV}}$
  - On $W_{MV}$ cells:
    $t_{W_{MV}} > t_{\text{min \, TV}} \rightarrow \Sigma ET_{idx \, W_{MV}} \, vs \, \Sigma ET_{idx \, W_{TV}}$
- No competition is analyzed in cells occupied by terrestrials
  - Hydrological disturbances maintain the riparian dynamics
Model strengths discussion
- **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

**CASE STUDY**

**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

<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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<td>MODEL (Phases/PFTs/SPFTs)</td>
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</table>
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 performs better than other models
- RVDM identifies vulnerable areas

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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