Riparian landscapes downstream dams: effects of historical land-use change and altered flows

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The main goal of this study is to quantify and understand the riparian vegetation changes, in hydropower rivers, after dam construction.
Study area

3 dam-regulated rivers
- Lima river (Touvedo)
- Homem river (Vilarinho das Furnas)
- Alva river (Fronhas)

2 types of dams
- run-of-river dam – Touvedo
- 2 storage dams – Vilarinho, Fronhas
<table>
<thead>
<tr>
<th>Case study (dam)</th>
<th>Construction dates</th>
<th>Dam purposes</th>
<th>Qmod Natural (m³/s)</th>
<th>Qmod Modified (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Touvedo</td>
<td>1987-1993</td>
<td>Energy / Irrigation / Flood defense</td>
<td>49,65</td>
<td>43,94</td>
</tr>
<tr>
<td>Vilarinho das Furnas</td>
<td>1966-1972</td>
<td>Energy / Transfer</td>
<td>5,43</td>
<td>0,34</td>
</tr>
<tr>
<td>Fronhas</td>
<td>1985</td>
<td>Transfer / Energy</td>
<td>16,27</td>
<td>3,33</td>
</tr>
</tbody>
</table>

Values of the Indicators of Hydological Alteration (IHA) for each hydrological group

<table>
<thead>
<tr>
<th>Group IHA</th>
<th>Touvedo</th>
<th>Vilarinho</th>
<th>Fronhas</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>✔️ 0,785</td>
<td>✖️ 0,220</td>
<td>✖️ 0,045</td>
</tr>
<tr>
<td>G2</td>
<td>✔️ 0,524</td>
<td>✖️ 0,226</td>
<td>✖️ 0,206</td>
</tr>
<tr>
<td>G3</td>
<td>✔️ 0,575</td>
<td>✔️ 0,358</td>
<td>✔️ 0,353</td>
</tr>
<tr>
<td>G4</td>
<td>✔️ 0,858</td>
<td>✖️ 0,092</td>
<td>✖️ 0,213</td>
</tr>
<tr>
<td>G5</td>
<td>✔️ 0,955</td>
<td>✖️ 0,097</td>
<td>✖️ 0,101</td>
</tr>
</tbody>
</table>

- ✔️ Low alteration: $m_{RA} > 0.67$
- 🟡 Moderate alteration: $0.33 > m_{RA} > 0.67$
- ✖️ High alteration: $m_{RA} < 0.33$
Adapted from: Cardoso JSLL. 2013. Application of indicators of hydrological alteration in Portuguese rivers impacted by dams. Master of Science Thesis in Civil Engineering. Instituto Superior Técnico, University of Lisbon. 53pp annexes.
**Hypothesis 1**: hydrological alterations will induce differences in area occupied by riparian woodlands (increase or decrease)

**Hypothesis 2**: diverse types of dams (storage dams and run-of-river dams) will induce diverse magnitudes and types of vegetation changes

**Hypothesis 3**: Effect of land-use is relevant to understand vegetation changes
Methods
Temporal analysis (pre vs pos-dam comparison)

1965 (pre-dam)

2013 (pos-dam)

Image processing (ArcGIS 10.1):
- Georeferencing (old images)
- Image degradation (recent images)

Touvedo case study
Common spatial resolution
Methods

1. Delimitation of riparian patches

Sampling Units of 250 m long river stretches downstream dams

Touvedo N= 77, Fronhas N= 88, Vilarinho das Furnas N= 94
Methods

1. Delimitation of riparian patches

Classes

- Tree - trees and “tall” shrubs
- Other - herbaceous vegetation, bare soil

River locations

- Riverbank - riparian zone
- Banks - inside the channel, connection with riverbanks
- Islands - inside the channel, no connection with riverbank
Methods

2. Landscape metrics

**CATEGORY**

**AREA/ DENSITY**

- Weighted Class Area (WCA)
- Mean Patch Size (MPS)
- Patch Size Coefficient of Variation (PSCov)

**SHAPE/ EDGE**

- Area Weighted Mean Patch Fractal Dimension (AWMPFD)
- Edge Density (ED)

**Riparian structural attributes**

- Area, size and structural heterogeneity
- Spatial complexity and lateral connectivity

*Patch Analyst (vector format) for ArcGIS 10.1*
Methods

3. Delimitation of land-use patches (both river margins; 200 m buffer)

*Land use classes:*

<table>
<thead>
<tr>
<th>Scrubland</th>
<th>Forest</th>
<th>Agriculture</th>
<th>Impervious</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unmanaged</td>
<td>Managed</td>
<td>intensive</td>
<td>extensive</td>
</tr>
<tr>
<td>scrublands, fallow ground</td>
<td>semi-natural or planted woodlands, usually mixed forests with deciduous quercus</td>
<td>crops, orchards, rice fields</td>
<td>urban and industrial areas, includes mines, roads</td>
</tr>
<tr>
<td>with shrubs</td>
<td>Eucalyptus and pine forests</td>
<td>pastures, recent abandoned lands</td>
<td></td>
</tr>
</tbody>
</table>
Methods

4. Statistical analysis

Hypothesis test (t-test)

Test for differences between post (New) and pre (Old) dam periods, for riparian landscape metrics and for percentages of land-uses

**Paired t-test**
- Landscape metrics (MPS, WCA, ED)
- Percentages of land-uses

**Independent t-test**
- Landscape metrics (AWMPFD, PSCov)
  (inability to match sampling units – absence is not a “0” value)

Matrix of spatial overlapping between sampling units

Corrects the spatial offset between historical and current imagery
  (river morphology + georeferencing )
Results – Riparian vegetation changes

H1: Riparian woody vegetation show different patterns (area, shape size and complexity) after the dam construction, in all river locations, (riverbank, bank, islands) and for all case studies, although with different magnitudes.
Total area occupied by riparian woodlands **increased** (WCA) and riparian patches are **larger** (MPS) in the pos-dam period.
Reduced shape complexity (AWMPFD) in the pos-dam period
Major changes: **Vilarinho das Furnas**

Total riparian area ➡️ Shape complexity ➝

Low shape complexity ≈ Riparian degradation  (Fernandes *et al.*, 2011)

Floristic composition change ??????

**Results** – Riparian vegetation changes

**H2:** Diverse types of dams (storage dams and run-of-river dams) induce different patterns of vegetation changes
The influence of the dam operation type was only observed in the riparian vegetation located inside the channel.
Touvedo: Run-of-river

Riverbanks - ❌ High alteration:
Banks and islands - ✅ Low alteration:
Touvedo: Run-of-river

Riverbanks - ✗ High alteration:
Banks and islands - ✔ Low alteration:
Touvedo: Run-of-river

Riverbanks - ❌ | High alteration:
Banks and islands - ✔️ | Low alteration:
Fronhas: Storage dam

Riverbanks -  ❌ High alteration:
Banks and islands -  ❌ High alteration:
Fronhas: Storage dam

Riverbanks - High alteration:
Banks and islands - High alteration:
Riverbanks -  ⚠️ High alteration:
Banks and islands -  ⚠️ High alteration:
Fronhas: Storage dam
Results – Land use changes

Relevant decrease in the agriculture intensive and increase of the impervious area
Work still continues....

**Hypothesis 3**: Assessing the combined effect of hydrological/land-use effects in the riparian vegetation changes....
Acknowledgements

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http://www.isa.ulisboa.pt/proj/oasis/