Historical Maps Potential on the Assessment of the Hydromorphological Changes in Large Rivers: Towards Sustainable Rivers Management under Altered Flows

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1 Summary

Hydromorphology changes in large rivers result from a long history of human interventions (Poff *et al.*, 2007). In this study, we evaluate the causes and effects of hydromorphological alterations in the Iberian Minho River using a planform change analysis. We performed a temporal comparison using historical maps (nineteen century) and contemporaneous maps. The results revealed a significant alteration in flow regime, active channel geometry and sinuosity indexes, representing an overall degradation of river condition. We also noticed a drastic diminution in the number and total area occupied by lentic habitats causing fish habitat shifts. Changes were less evident in upstream sampling units due to diverse Land Use/Land Cover (LULC) changes combine with some geological constraints. These responses were consistent with reductions in mean of intra and inter annual discharge, flood disturbance decrease, and minimum flow increase during the summer season. This work allows to understand the evolutionary trajectory of large fluvial system over more than 100 years and to implement concrete measures for sustainable river management.

2 Methodology

2.1 Indicators of Hydrological Alteration (IHA)

- 33 IHA and 34 Environmental Flow Components (EFC) by IHA software, Version 7.1, (Richter *et al.*, 1996).

2.2 Maps Processing

- Georeferencing of historical maps through ground control points method (GCP), WGS84 coordinate system (Aguiar *et al.*, 2016; Fernandes *et al.*, 2011), .
- Hydromorphological features extraction
- Land Use/Land Cover (LULC) mapping

2.3 Longitudinal Alteration Index (LAI)

- This index is measured by using (Eq.1).

$$LAI = (L_{ACh} - L_{ACc})\, L_{ACh}^{-1} \quad \text{(Eq.1).}$$

L_{ACh} – Historical active channel length
L_{ACc} – Contemporaneous active channel length

2.4 Active Channel Alteration Index (ACAI)

- This index is measured by using (Eq.2).

$$ACAI = (Ph - P_c)P_h^{-1} \quad \text{(Eq.2).}$$

P_h – Historical Perimeter of active channel
P_c – Contemporaneous Perimeter of active channel

2.5 River Width Alteration index (RWAI)

- This index is measured by using (Eq.3).

$$RWAI = (WA_{Ch} - WA_{Cc})WA_{Ch}^{-1} \quad \text{(Eq.1).}$$

W_{ACh} – Historical active channel width
W_{ACc} – Contemporaneous active channel width

2.6 Sinuosity Index (SI)

- Sinuosity index is compute by (Eq.4).

$$SI = \frac{Channel\ Length}{Valley\ Length}$$

3 Study Area and Sampling Design

Minho River, Portugal (Fig. 1).

Studied river = 62.5 km (Portuguese part)
(25 sampling units with 2.5 km each one)

Several dams along Minho River mainly constructed in **1950 and 1960**.

Flow Data

94 year mean daily flow data were obtained from Portuguese Water Information System (SNIRH) and Spanish Water Information System (SIA).

- Pre-Impact- 1920-1966
- Post-Impact- 1966-2014

Maps

- Historical maps 1898
- Contemporaneous maps 2016

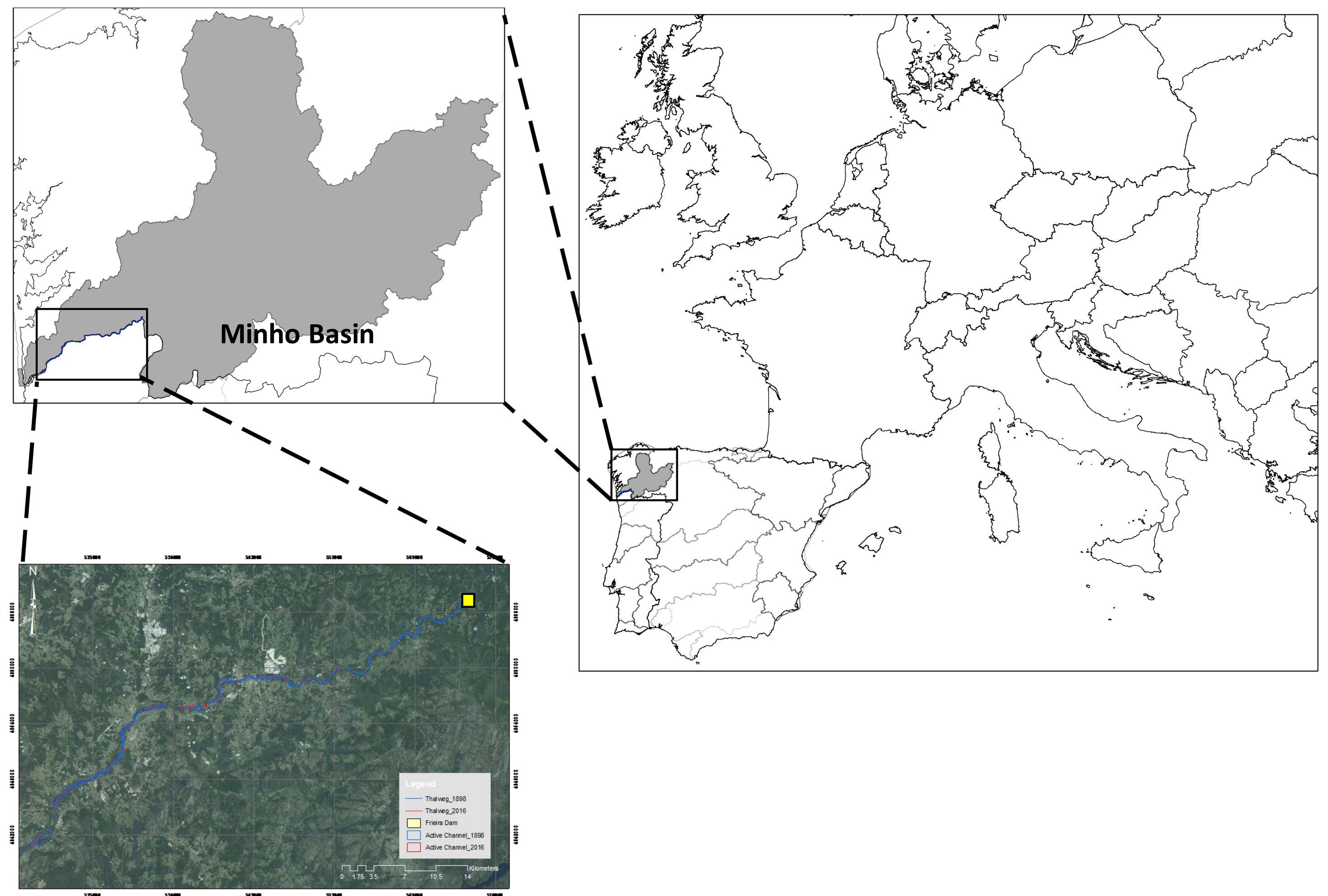

Fig.1 Study area,. Portuguese part of Minho River

4 Results

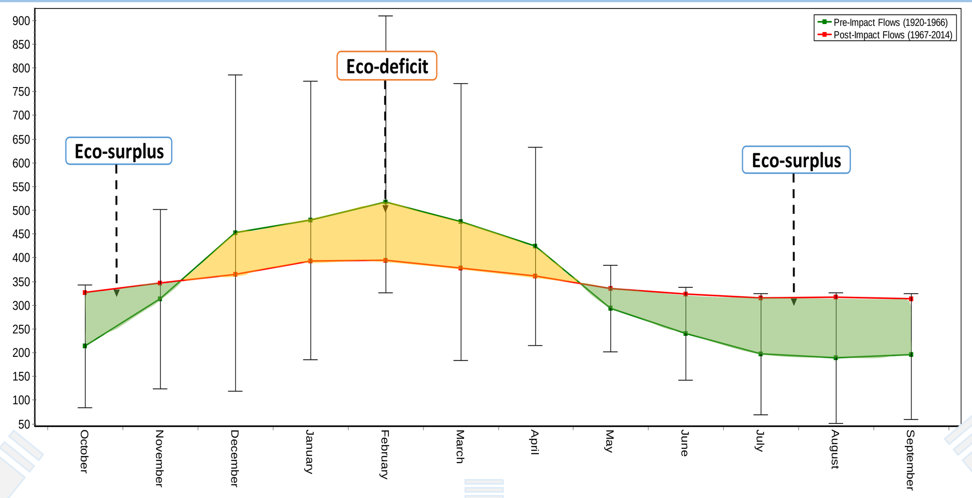

Fig.2 Mean monthly inter-annual flow variability regarding pre and post impact period. Flow alteration is indicated through two metrics, eco-surplus and eco-deficit. Significant eco-surplus is noticed during autumn, spring and summer season while eco-deficit is occurred during the autumn and mainly during winter season. This type of flow alteration is due to dam operation which cause the majority of flow regime alteration.

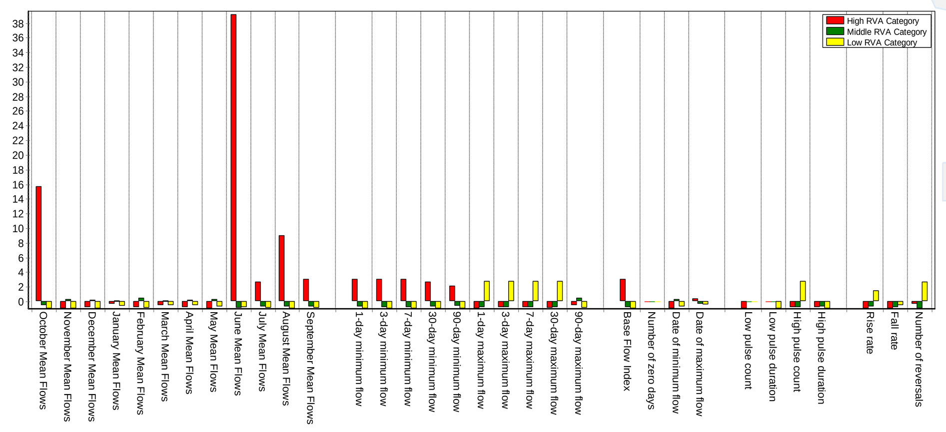

Fig.3 All hydrologic alteration indicators are characterised by relatively high range of variability approach (RVA) specially during October , June, August, September and minimum flow (i.e., 1-day, 3-day, 7-day, 30-day and 90-day). The rest of indicators in generally reveals moderate to low RVA.

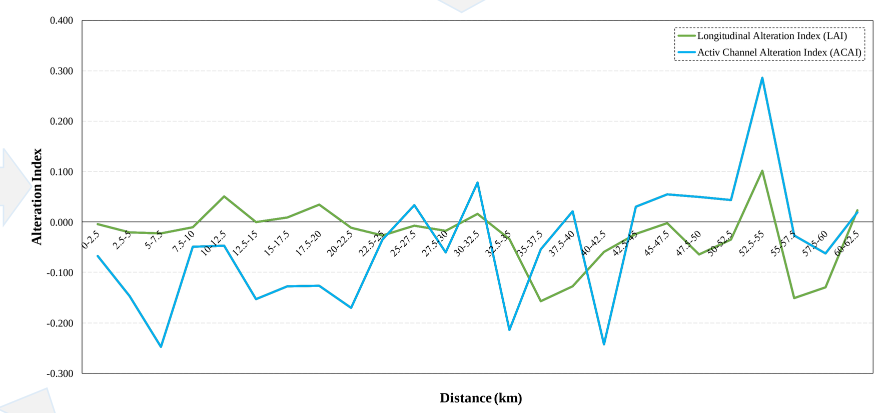

Fig.7 Longitudinal (green line) and active channel (blue line) alteration along the river, from upstream to downstream. Active channel reveals high alteration along the whole river, while longitudinal alteration is more evident at the downstream part.

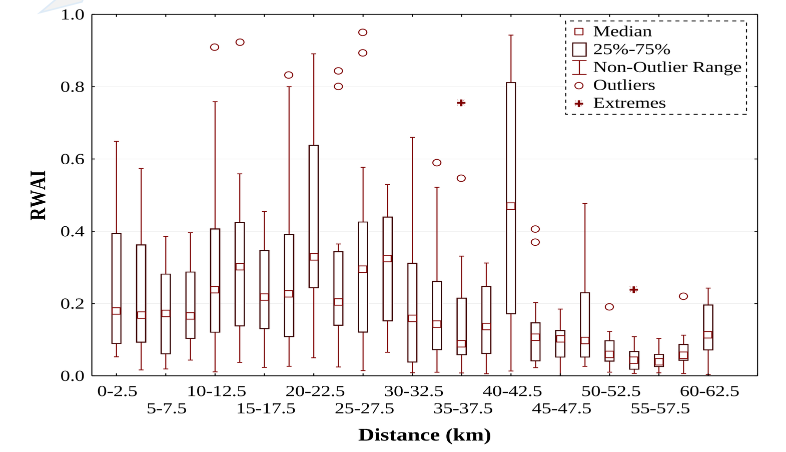

Fig.5 River width alteration index (RWAI). The highest variability of WAI were mainly observed in middle course sections. Geological constrains and anthropogenic interventions (i.e., dikes, groins) explain the low variability of WAI in the upper and lower sections of Minho River, respectively.

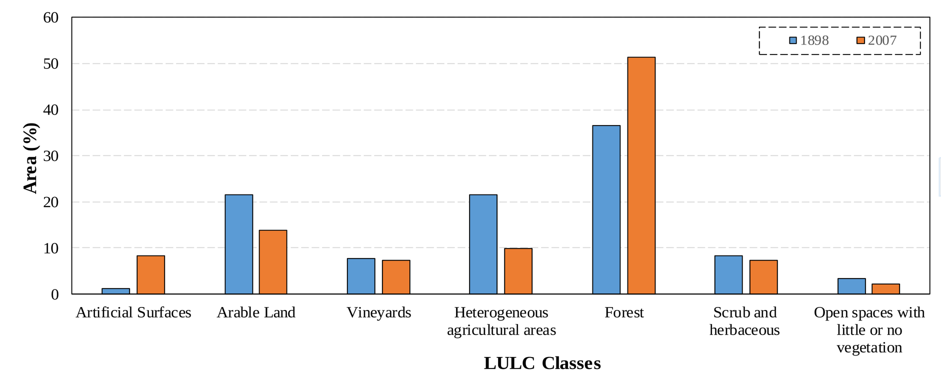

Fig.4 Percentage of the study area occupied by each LULC class in 1898 and 2007, considering 25 sample unit only Portuguese part. LULC is a approximated, extracted in a buffer of 500m surrounding river channel. Significant increase in the forest and artificial land uses and decrease of arable and agriculture areas for the contemporaneous period.

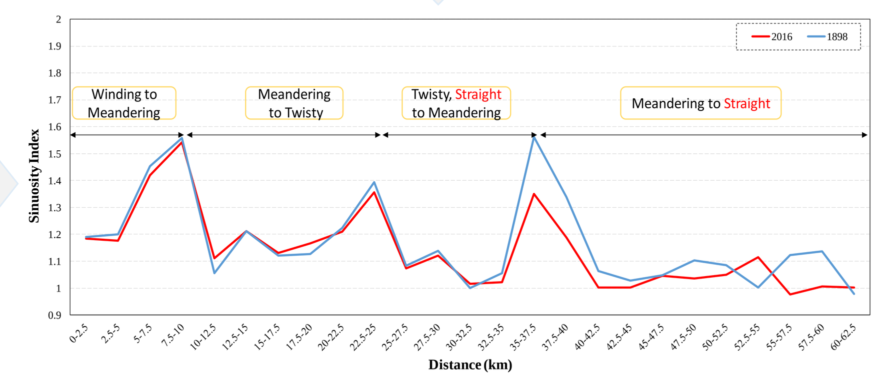

Fig.8 Sinuosity index (SI) for the historical period (blue line) and for the contemporaneous period (red line). Significant decrease of SI (especially in downstream sampling units)

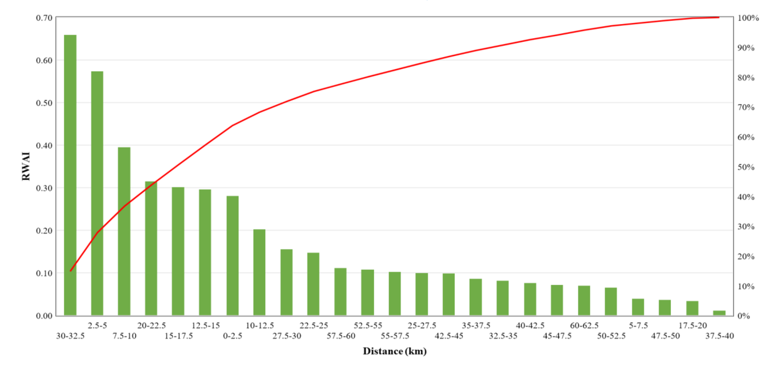

Fig.6 River width alteration index (RWAI) frequency occurrence (left axis) and the cumulative percentage (right axis) of the total number of occurrences.

5 Conclusions

- **Flow Alteration –High** reduction of floods and increase of low flows------ **Main drivers of ecosystem integrity!**
- **Longitudinal Alteration Index (LAI) – Low** for the upstream sections, **High** for the lower sections
- **Active Channel Alteration Index (ACAI) -Along the whole river** with a significant increase in the lower sections
- **Sinuosity Index (SI) -Decrease of SI**, critical situation at the lower part where river morphology tends to changes into a straight type.
- **LULC – Significant** changes for the forest an artificial land uses

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