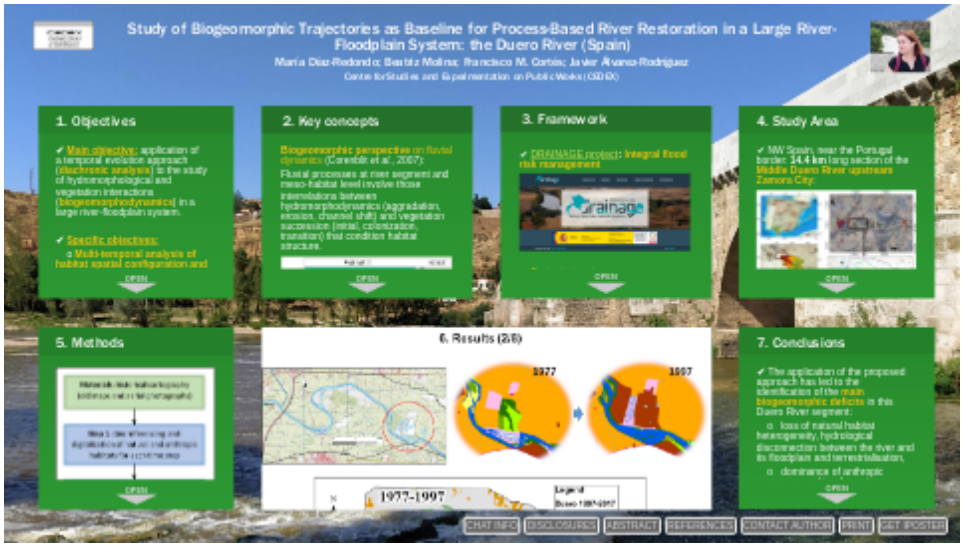
Study of Biogeomorphic Trajectories as Baseline for Process-Based River Restoration in a Large River-Floodplain System: the Duero River (Spain)



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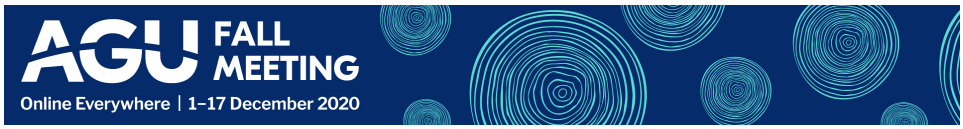


1. OBJECTIVES

✓ **Main objective:** application of a temporal evolution approach (**diachronic analysis**) to the study of hydromorphological and vegetation interactions (**biogeomorphodynamics**) in a large river-floodplain system.

✓ **Specific objectives:**

o **Multi-temporal analysis of habitat spatial configuration and fluvial dynamics** through GIS-based tools on available historical cartography.

o Identification of **biogeomorphic deficits** based on parameters of spatial heterogeneity, hydrological connectivity, balance of natural vs. anthropic habitats, and balance of progression vs. processes.

o Present an **approach largely exportabl**e to different fluvial contexts.

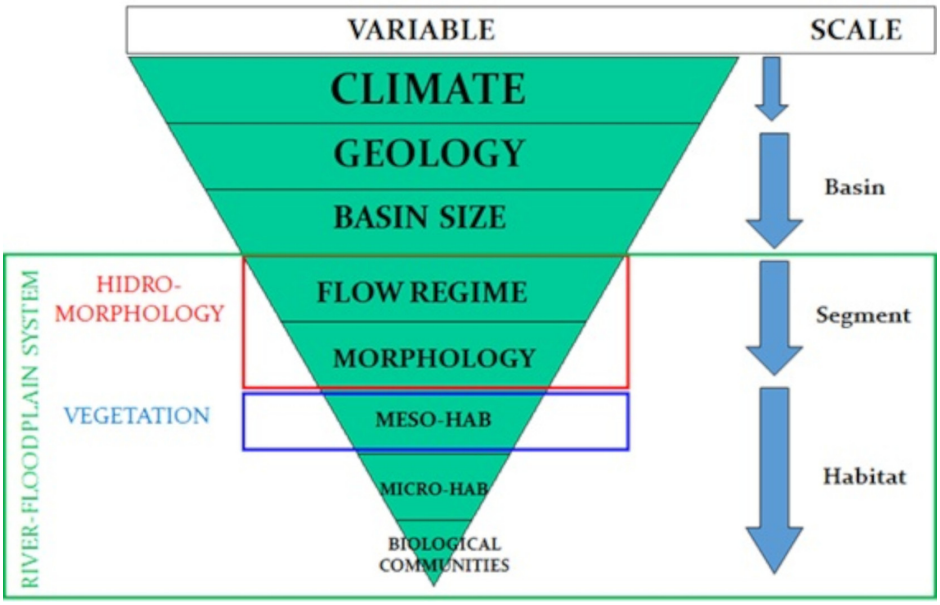
o Highlight the potential of the presented approach as a basis to **guide process-based river restoration** initiatives.

The Duero River at Zamora City

2. KEY CONCEPTS

Biogeomorphic perspective on fluvial dynamics (Corenblit *et al*., 2007):

Fluvial processes at river segment and meso-habitat level involve those interrelations between hydromorphodynamics (aggradation, erosion, channel shift) and vegetation succession (initial, colonization, transition) that condition habitat structure.



Spatial scope of the study

Trajectories of habitat change as indicators of biogeomorphodynamics (Díaz-Redondo *et al.*, 2016):

- **Changeless**: areas that show no change
- **Progression**: habitat development and vegetation succession towards forests
- **Regression:** re-setting of floodplain habitats
- **Anthropization:** exclusively human-induced changes

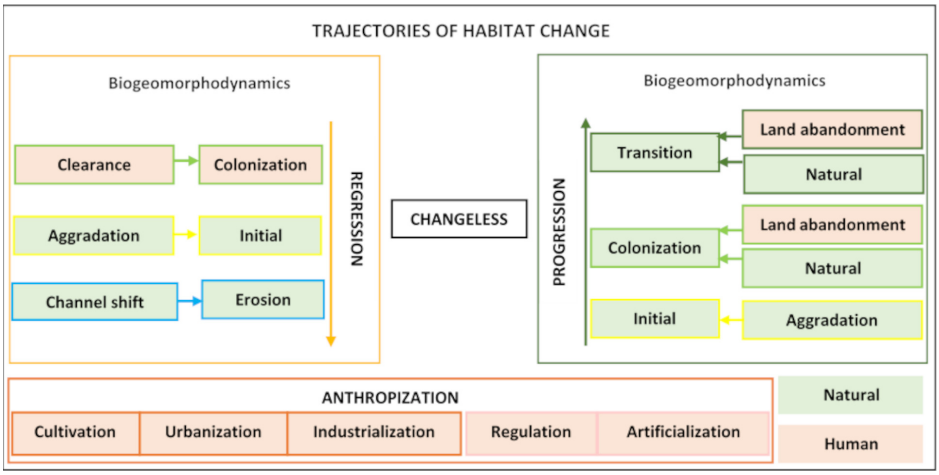


Diagram with the main trajectories and biogeomorphodynamics

The **balance between progression and regression forces** is characteristic of natural riverine ecosystems and leads to a continuous spatial re-organization of habitats among several developmental stages (Stanford *et al.*, 2005).

3. FRAMEWORK

✓ **DRAINAGE project (http://drainage.cedex.es/): Integral flood risk management**

(http://drainage.cedex.es/)

✓ **Project structure:**

o Subproject UCLM (http://www.uclm.es/): Design of a methodology to foster social and environmental resilience to flooding.

o Subproject CEDEX (http://www.cedex.es/): Analysis of advanced methodologies for enhancing flood resilience and eco-hydromorphological quality of water bodies.

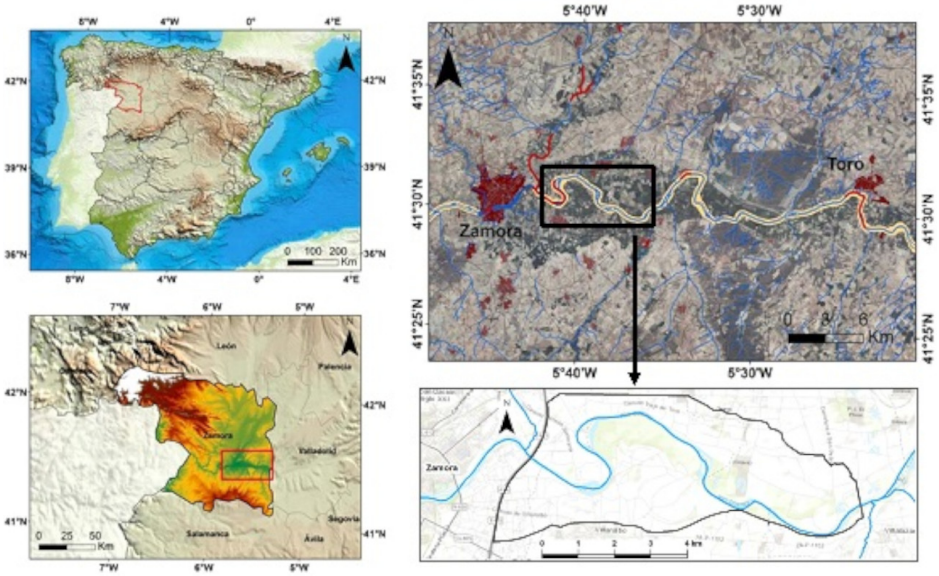
o Subproject IGME (http://www.igme.es/): Advanced methodologies for flood risk scientific-technical analysis to promote resilience and risk reduction.

✓ **Coordinated by:** Universidad de Castilla-la Mancha-UCLM (http://www.uclm.es/)

✓ **Funded by** the **Spanish Ministry of Science and Innovation (https://www.ciencia.gob.es/)** through the State R + D + i Program oriented to the challenges of society 2017.

4. STUDY AREA

✓ NW Spain, near the Portugal border: **14.4 km** long section of the **Middle Duero River upstream Zamora City**:



→ corresponding Fluvial Territory (*sensu* Ollero *et al*., 2014): 2,860 ha

→ meandering segment: 1.56 sinuosity index

→ average width of the active channel: 165 m

→ permanent rainfall Mediterranean flow regime

→ catchment area: 46,283.6 km^2

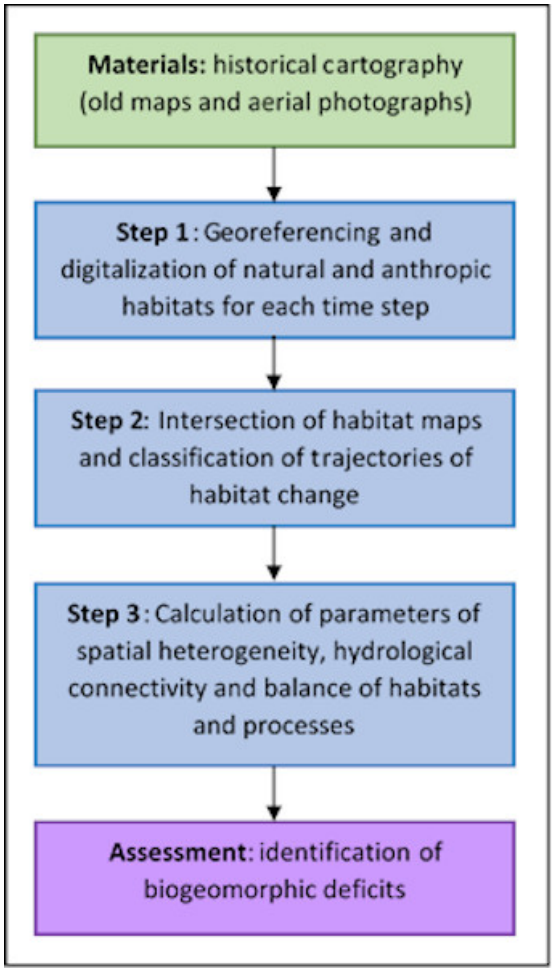
→ mean annual flow: 111.3 m^3/s

→ average annual contribution: 4,525 hm^3

→ upstream reservoir storage capacity (40 reservoirs): 1,000 hm^3

→ right and left bank channels for a current total irrigable area of 11,000 ha approx.

5. METHODS



Work flow of the proposed approach

Selected **historical cartography** for the study (aerial photographs): 1945, 1956, 1977, 1997 and 2017 → **72 years**

Aerial photograph 1956

Source of aerial photographs and other cartographic information for this study: ***Spanish National Center for Geographic Information (Instituto Geográfico Nacional-IGN (https://www.ign.es/web/ign/portal/cbg-area-cartografia))***

Calculated parameters:

· Island area (temporal, semi-stable and stable) as indicator of habitat heterogeneity (Belletti *et al.*, 2013).

· Hydrological connectivity in terms of area covered by the different types of surface water connection (eupotamon, parapotamon and plesiopotamon; Ward and Stanford, 1995).

· Area percentages of natural versus anthropic habitats.

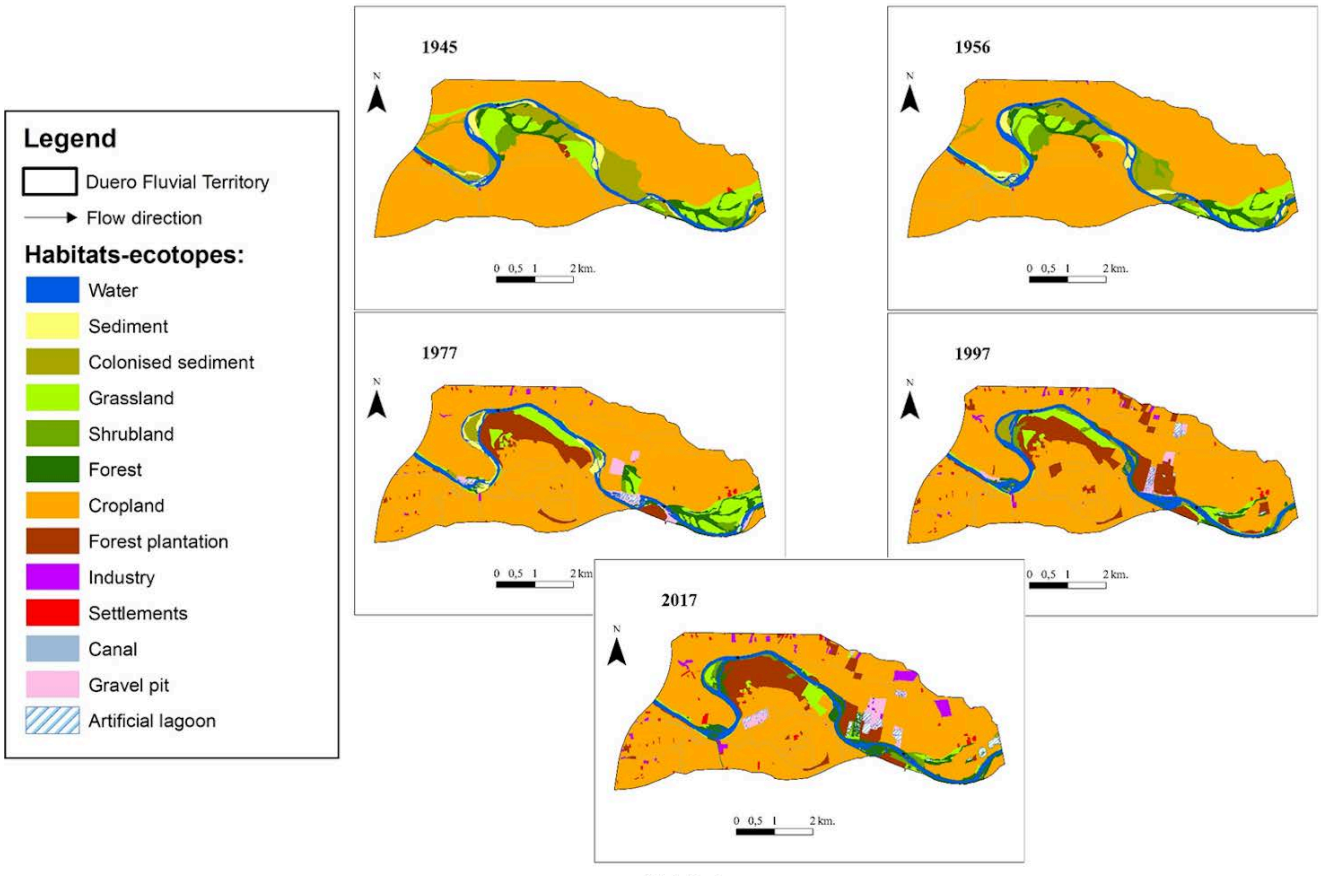
· Active channel area.

· Area percentages of natural versus anthropic processes.

· Area percentages of changeless, anthropization, progression and regression.

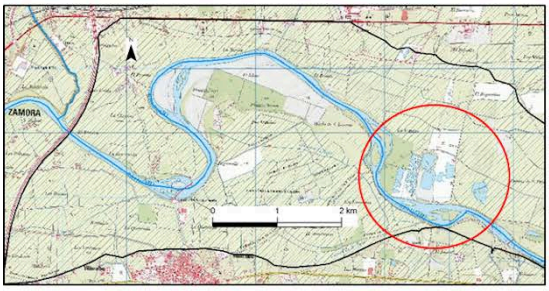
· Progression/regression index to show the relative weight of progression versus regression.

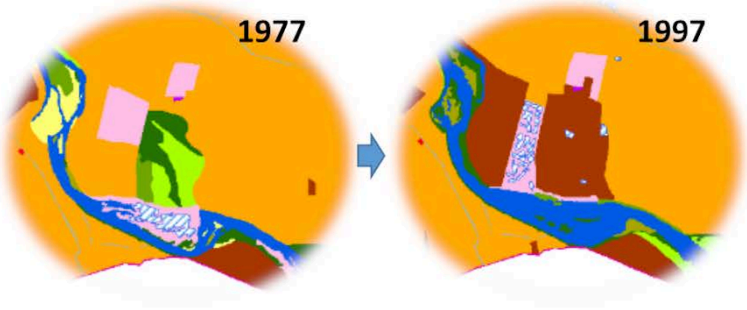
6. Results (1/8)

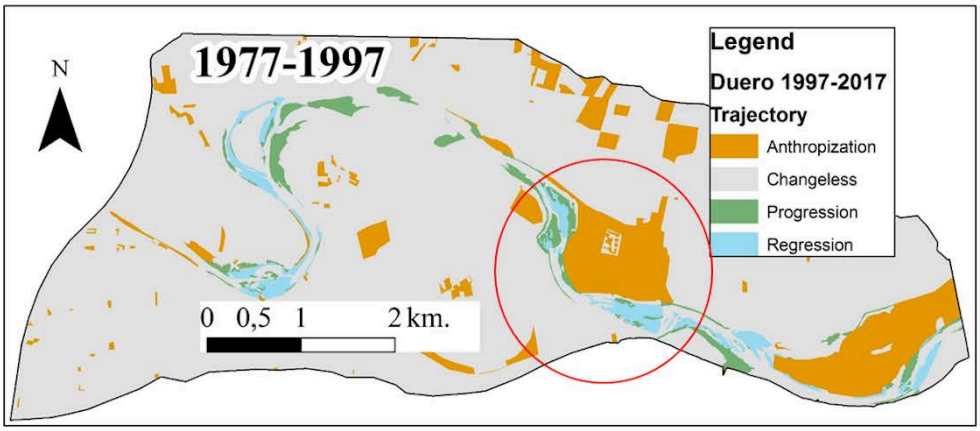


Habitat maps

6. Results (2/8)

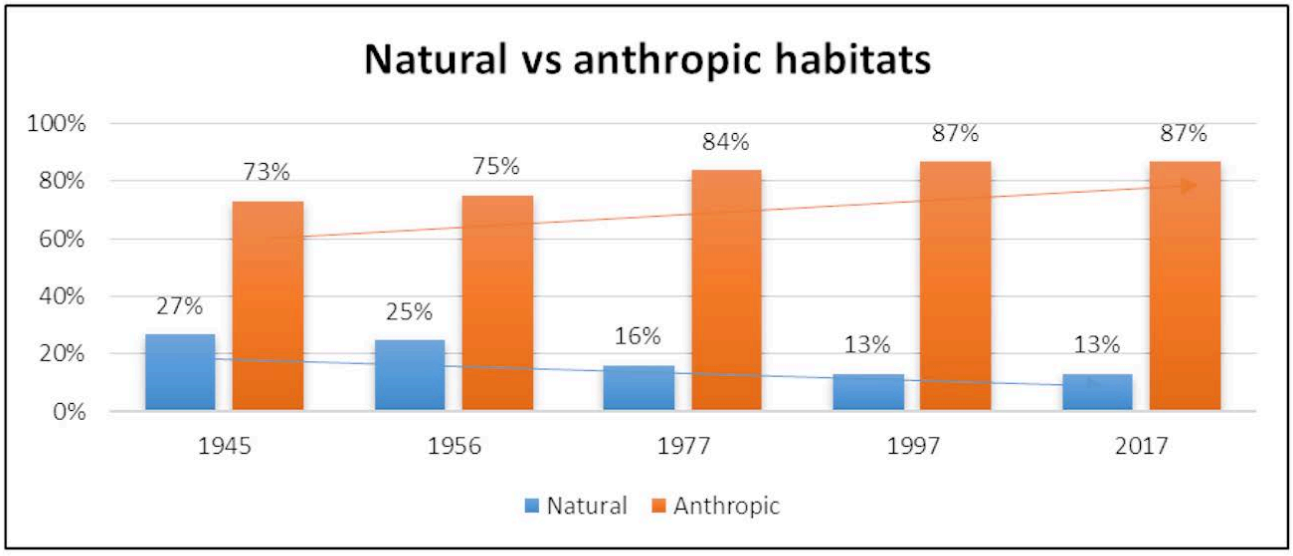






Intersected maps: trajectories of change

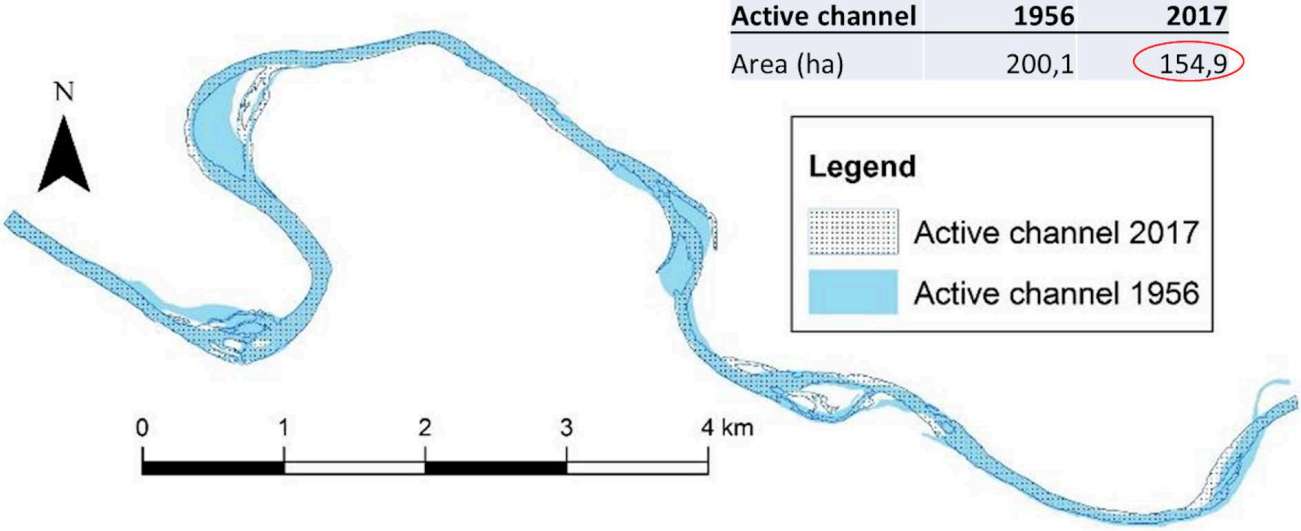
6. Results (3/8)



Loss of natural habitats

6. Results (4/8)

Active channel	1956	2017
Area (ha)	200,1	154,9

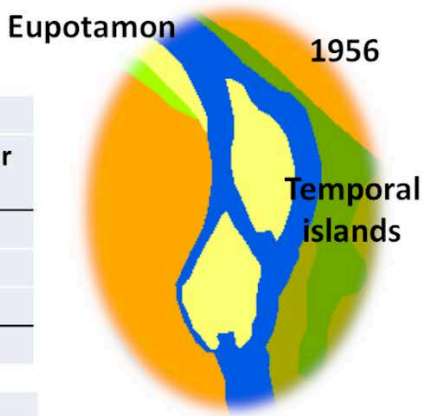


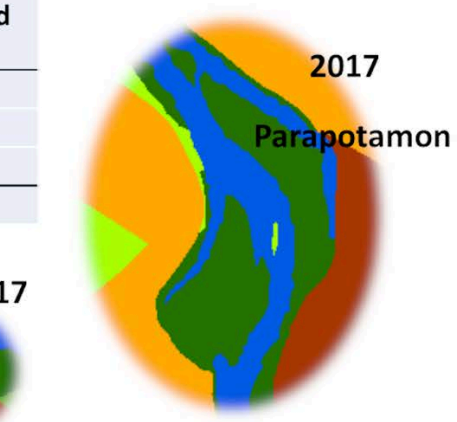
Reduction of active channel area

6. Results (5/8)

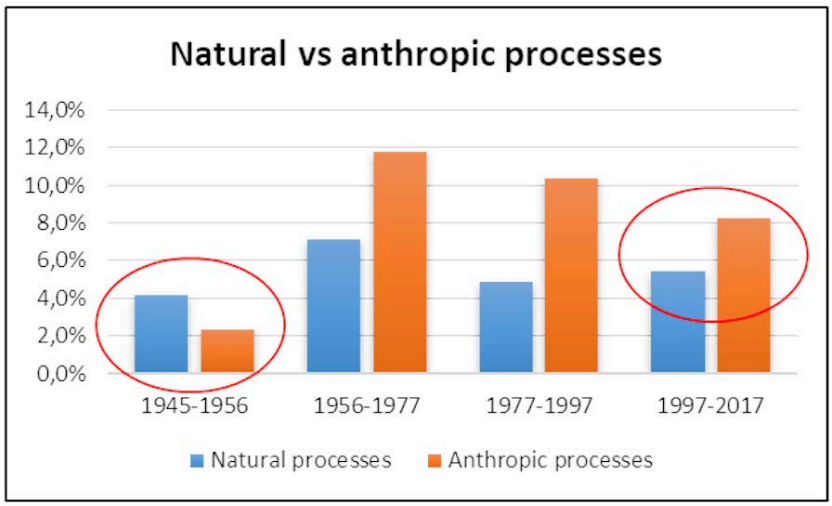
	1956		2017	
Hydro connectivity	Area (ha)	% total water area	Area (ha)	% total water area
Eupotamon	149,9	99%	143,8	95%
Parapotamon	1,1	1%	6,9	5%
Plesiopotamon	0,0	0%	0,8	1%
Total water area	151,0	100%	151,5	100%

	1956		2017	
Islands	Area (ha)	% total island area	Area (ha)	% total island area
Temporal	12,0	49%	0,0	0%
Semi-stable	5,8	24%	9,4	30%
Stable	6,6	27%	22,1	70%
Total island area	24,4	100%	31,5	100%



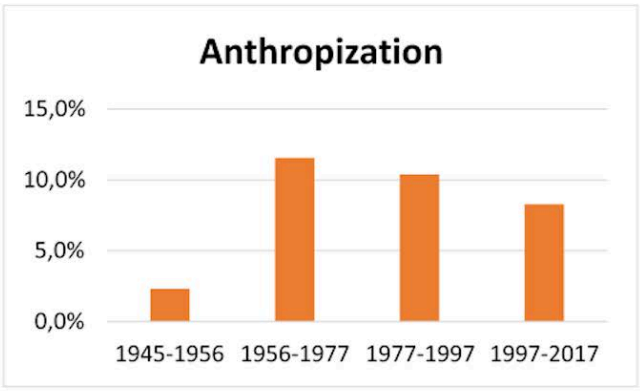


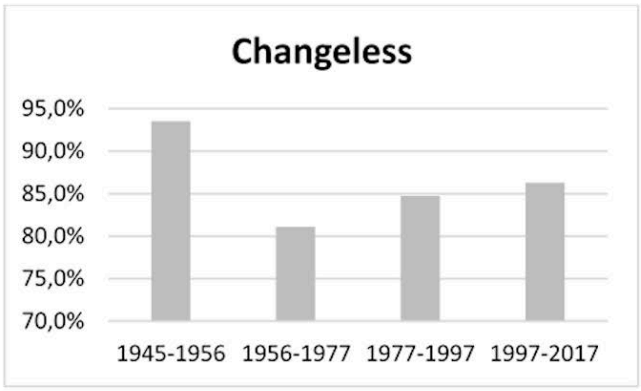
6. Results (6/8)

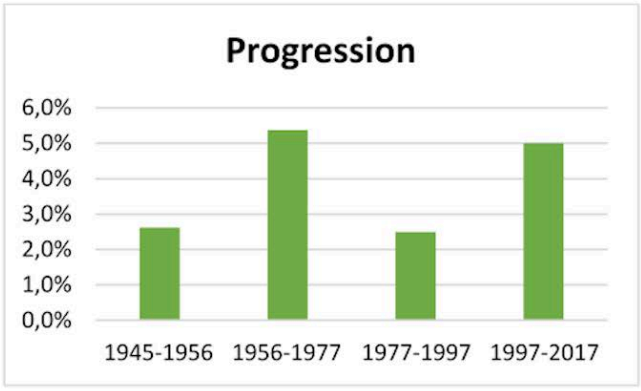


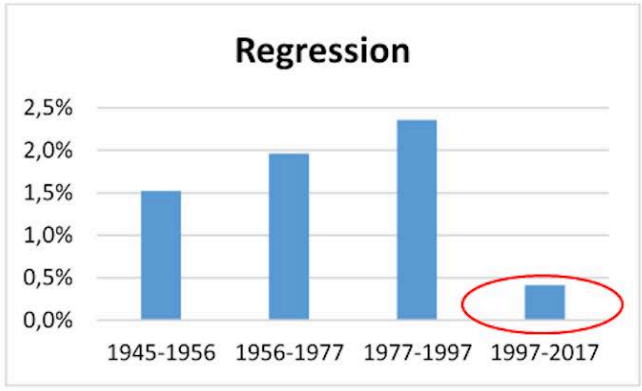
Dominance of anthropic processes

6. Results (7/8)



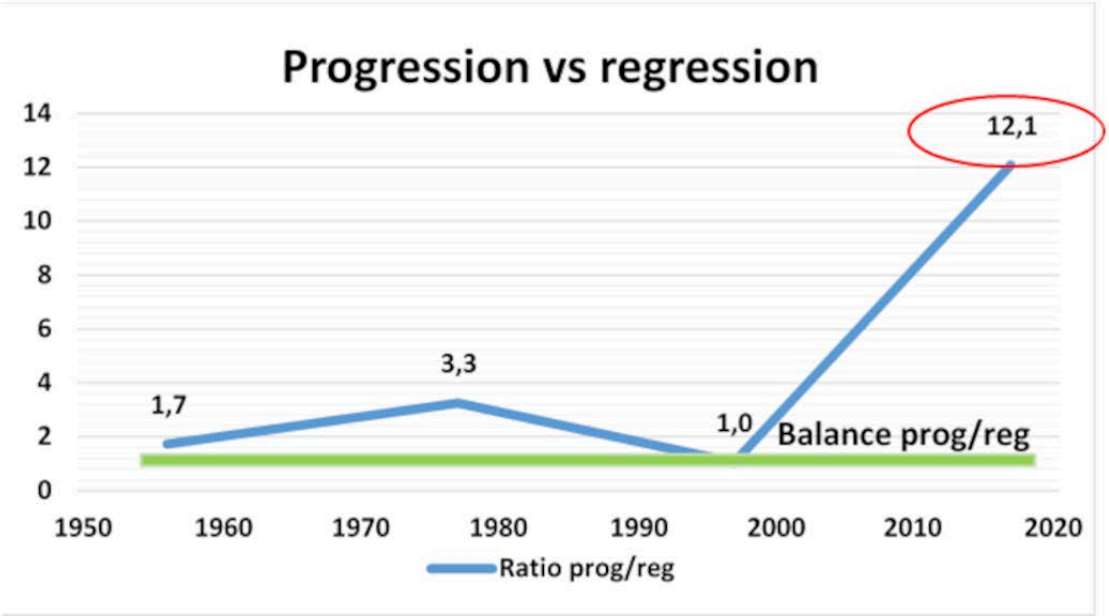






Loss of regression processes

6. Results (8/8)



Imbalance of progression vs. regression processes

7. CONCLUSIONS

✓ The application of the proposed approach has led to the identification of the **main biogeomorphic deficits** in this Duero River segment:

- loss of natural habitat heterogeneity, hydrological disconnection between the river and its floodplain and terrestrialisation,

- dominance of anthropic processes and tendency to progression but, more importantly, **imbalance of progression versus regression dynamics.**

✓ The results obtained in the present study are coherent with **previous research** in other large rivers (Díaz-Redondo *et al.*, 2016; Díaz-Redondo *et al.*, 2018) showing a **decreasing tendency in the river-floodplain rejuvenation capacity.**

✓ **Overall, it is necessary to highlight that t**he recovery of regression processes (e.g. channel shift, erosion and vegetation rejuvenation) should be the focus of future **process-based restoration** initiatives. This perspective is especially relevant within the DRAINAGE project, since:

- the promotion of rejuvenation processes can lead to an **increase in floodplain water retention capacity**, balancing nature conservation goals with flood damage prevention,

- the riverine ecosystem can recover its self-adjustment capacity and **become more resilient** to current and future perturbations associated to climate change, such as floods and droughts.

DISCLOSURES

This study is framed within the **DRAINAGE project for the integral management of flood risk** (http://drainage.cedex.es/), funded by the **Spanish Ministry of Science and Innovation** through the **State R + D + i Program oriented to the challenges of society 2017 (Programa Estatal de I+D+i Orientada a los Retos de la Sociedad 2017 del Ministerio de Ciencia e Innovación de España (https://www.ciencia.gob.es/portal/site/MICINN/menuitem.dbc68b34d11ccbd5d52ffeb801432ea0/?vgnextoid=3ba6fbd0ce7f4710VgnVCM1000001d04140aRCRD&vgnextchannel=b24e067c468a4610VgnVCM1000001d04**

Acknowledgements:

ABSTRACT

When planning river restoration measures, the crucial starting point is investigating how a river-floodplain system deviates from a reference condition or benchmark. Since most large riverslack comparative pristine reaches nowadays, historical analyses of the studied river system canproduce valuable reference data for reconstructing the character of the riverine system prior tomajor alterations; particularly, the time-based perspective of river-floodplain processes is key inunderstanding its evolution until its present situation.

Therefore, this study follows a methodology based on a temporal evolution approach(diachronic analysis) of hydromorphological and vegetation dynamics in a large river system.Habitat maps of a 14.4 km long section of the Duero River upstream Zamora (Spain) wereintersected with GIS-based tools. Patches showing trajectories of anthropization, changeless,progression and regression allowed for the identification of natural and human-inducedprocesses over the time period between 1945 and 2017. Results show that this Duero Riversection is a good example of the situation of many large rivers, where natural rejuvenationprocesses, which involve the re-setting of floodplain habitats (e.g. channel shift, erosion andvegetation rejuvenation), are now highly impaired and whose recovery should be the objectiveof future process-based restoration measures.

This study is framed within the DRAINAGE project for the integral management of flood risk(http://drainage.cedex.es/), funded by the Spanish Ministry of Science and Innovation throughthe State R + D + i Program oriented to the challenges of society 2017 (Programa Estatal deI+D+i Orientada a los Retos de la Sociedad 2017 del Ministerio de Ciencia e Innovación deEspaña). This process-based restoration perspective is especially relevant in promoting theresilience of the river system in the current context of climate change. Specifically, within theDRAINAGE project, with the recovery of natural biogeomorphic processes, an increase in thehydraulic retention capacity of the floodplain is also pursued, balancing objectives of natureconservation and prevention of flood control.

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