A diachronic analysis of trajectories of change in the Duero River reveals imbalances in past and current fluvial dynamics

L'analyse des trajectoires de changement du fleuve Duero (Espagne) révèle des déséquilibres dans la dynamique fluviale passée et actuelle

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RÉSUMÉ

Pour la présente étude, une analyse diachronique des trajectoires de changement a été réalisé dans une section d'étude du fleuve Duero entre Toro et Zamora (Espagne), dans le cadre du projet DRAINAGE pour la gestion intégrale du risque d'inondation. Les images aériennes disponibles pour la période 1945-2017 ont été utilisées pour créer des cartes d'habitat qui ont ensuite été recoupées avec des outils SIG. Des trajectoires de changement naturelles et induites par l'homme (anthropisation, sans changement, progression et régression) ont été identifiées, et un indice de trajectoire naturelle (NTI) a été calculé pour montrer le poids relatif de la progression (croissance vers le développement des forêts de plaine inondable) par rapport à la régression (remise en place des habitats de la plaine inondable). Les résultats de l'analyse diachronique ont conclu que la trajectoire de progression est devenue dominante au cours des dernières décennies. La perte des processus de rajeunissement naturel (par exemple, déplacement de canaux, érosion et rajeunissement de la végétation) est un symptôme que le système rivière-plaine inondable est de moins en moins résilient. Cette étude vise à être la base d'une restauration basée sur les processus dans une perspective d'adaptation des systèmes fluviaux au changement climatique.

ABSTRACT

For the present study, a diachronic analysis of trajectories of change has been undertaken in a study section of the Duero River between Toro and Zamora (Spain), within the framework of the DRAINAGE project for the integral management of flood risk. Available aerial imagery for the period 1945-2017 was used to create habitat maps that were subsequently intersected with GIS-based tools. Natural and human-induced trajectories of change (anthropization, changeless, progression and regression) were identified, and a Natural Trajectory Index (NTI) was calculated to show the relative weight of progression (growth towards the development of floodplain forests) versus regression (re-setting of floodplain habitats). Results from the diachronic analysis concluded that the progression trajectory has become dominant in the last decades. The loss of natural rejuvenation processes (e.g. channel shift, erosion and vegetation rejuvenation) stands as a symptom that the river-floodplain system is becoming less resilient. This study seeks to be the basis for process-based restoration with a view in the adaptation of riverine systems to climate change.

KEYWORDS

Diachronic analysis, Duero River, eco-hydromorphology, Natural Trajectory index, process-based river restoration, resilience, trajectories of change

1 INTRODUCTION

River-floodplain systems are potentially highly diversified environments and the source of multiple ecosystem services, but human impairments have led to different degrees of disconnection between the river and its original floodplain. Consequently, the natural interactive processes that structure the riverine landscape are now greatly affected.

In order to guide process-based restoration approaches (Beechie *et al.,* 2010), historical or diachronic analyses can provide a valuable baseline for identifying major alterations of key processes that have to be addressed (Díaz-Redondo *et al.*, 2018).

In the present study, a Duero River section has been selected for the application of an approach on the identification and assessment of spatio-temporal channel-floodplain dynamics, as a basis to guide process-based restoration. Objectives of the study include (i) identifying natural and human-induced processes through trajectories of change over the time period between 1945 and 2017, (ii) proposing and applying an index that assesses progression versus regression (Natural Trajectory index), and (iii) discuss potential implications for process-based river restoration practice.

2 METHODS

2.1 Study site

This case study is located within the Duero River basin in northwest Spain, near the Portuguese border. Upstream Zamora city, the river section is 14.4 km long (Fig. 1) and it is characterized by a meandering behavior (the sinuosity index is 1.56) and a wide alluvial floodplain. The study area (2,800 ha; 2.3 km average width) corresponds to the Fluvial Territory (*sensu* Ollero *et al.*, 2014), and it partially comprises the European Natura 2000 Special Area of Conservation (SAC) "Riberas del río Duero y afluentes" (ES4170083).

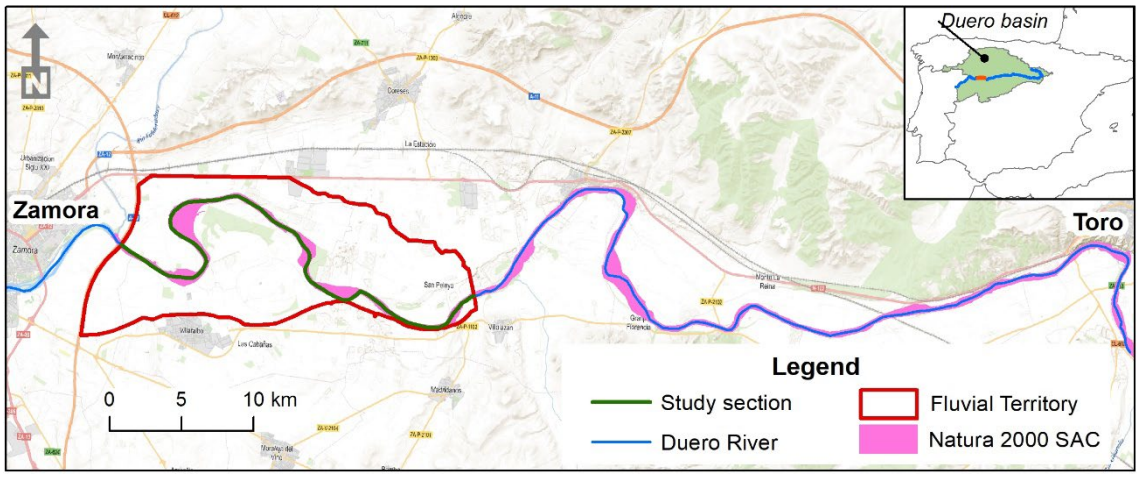

Figure 1. Location of the study area (Fluvial Territory) within the Spanish Duero basin.

2.2 Trajectories of change and Natural Trajectory Index

Aerial imagery for the period 1945-2017 was used to produce maps with natural habitats (water, sediment, colonized sediment, grassland, shrubland and forest), and anthropic habitats (cropland, forest plantation, industry, settlements, canal, gravel pit and artificial lagoon). By intersecting each habitat map with the subsequent one, the resulting areas were associated to four trajectories of habitat change:

- Anthropization: changes to any anthropic habitat.
- Changeless: areas that show no change.
- Progression: habitat development and vegetation succession towards forests.
- Regression: re-setting of river-floodplain habitats.

In order to standardize the results and made them comparable along the total time period, the intersected areas were converted to rates (ha/yr), and a Natural Trajectory Index (NTI) was proposed as a way to assess the potentiality of a balance between natural trajectories (progression and regression). Therefore, the NTI is proposed as an indicator of the existence of, or deviation from, a balance in trajectories of habitat creation and destruction. This index can be categorized as follows:

- Natural Trajectory Index = 1 → balance between progression and regression processes.
- Natural Trajectory Index < 1 → regression processes are dominant, young habitats.
- Natural Trajectory Index > 1 → progression processes are dominant, mature habitats.

3 RESULTS AND CONCLUSIONS

The analysis of the Natural Trajectory Index (Figure 2) indicates that there has been a predominance of progression processes during the total time frame considered in this study. Only in the period 1977-1997 the index shows the existence of a quasi-equilibrium between processes of habitat development and habitat re-setting. However, there is a clear imbalance within natural dynamics in the most recent period 1997-2017, with a Progression rate nearly eight times higher than the Regression rate.

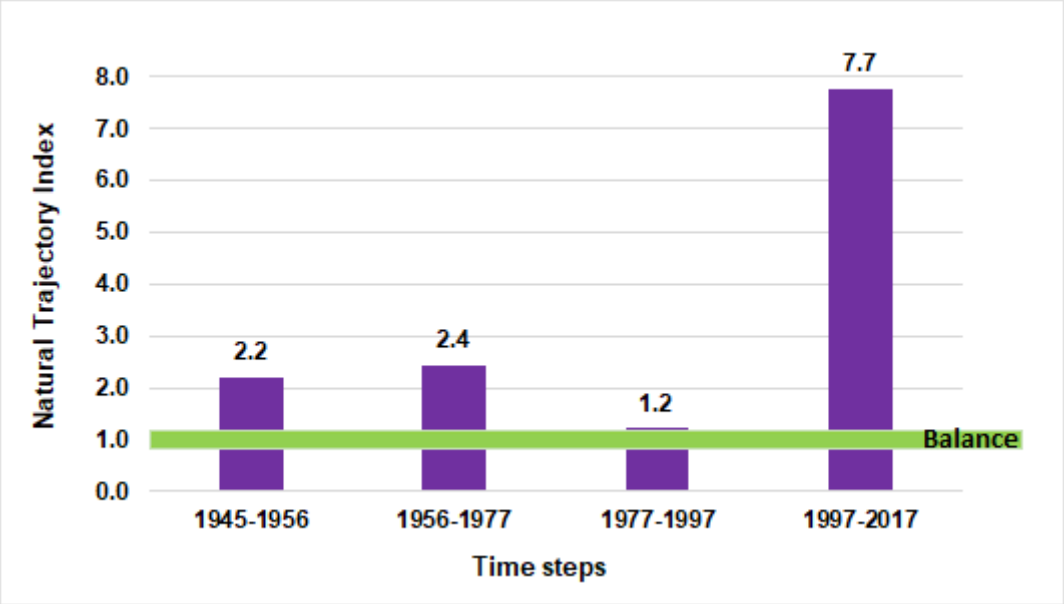

Figure 2. Natural Trajectory Index

Results from this study point to the necessity of recovering mechanisms that activate regression processes (e.g. channel shift, erosion and vegetation rejuvenation) in the study area. This inference was soundly drawn from an historical approach on the temporal variability of fluvial processes. Strategies grounded in historical analysis are likely to be more cost-effective and self-sustaining as they can be tailored to address the root causes of ecosystem change. Therefore, the present study is intended to serve as an example of a consistent basis for process-oriented restoration practice.

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