Prioritisation of river sections for restoration based on evidence of geomorphological adjustments (Saja River, Spain)

Triage des tronçons de rivière pour la restauration basée sur des preuves d'ajustements géomorphologiques (rivière Saja, Espagne)

E. Fernández-Iglesias[1], M. Fernández-García[2], V. Moro[3], L. Incera[4], G. González-Rodríguez[5], D. Vázquez-Tarrío[6] and R. Menéndez-Duarte[7]

1 INDUROT, University of Oviedo, Spain. elena.indurot@uniovi.es
2 INDUROT, University of Oviedo, Spain. fdezgarciamaria.fuo@uniovi.es
3 INDUROT, University of Oviedo, Spain. morogveronica.fuo@uniovi.es
4 INDUROT, University of Oviedo, Spain. uo255364@uniovi.es
5 INDUROT, University of Oviedo, Spain. gil@uniovi.es
6 Instituto Geológico y Minero de España -CSIC, Spain. d.vazqueztarrio@igme.es
7 Dept. Geology, University of Oviedo, Spain. ramenendez@uniovi.es

RÉSUMÉ

La restauration des cours d'eau est essentielle pour atténuer les incidences anthropiques et rétablir leur fonctionnalité en tant qu'écosystèmes. Cependant, la hiérarchisation et la priorisation des actions le long d'une même rivière peuvent s'avérer complexes en raison, entre autres, de la variabilité des conditions géomorphologiques et environnementales. Cet article propose une classification par tronçons afin de hiérarchiser les actions. Cette classification se base sur des indicateurs morphodynamiques des déséquilibres possibles dans le lit de la rivière. L'analyse est basée sur les caractéristiques du lit de la rivière et de la zone inondable, ainsi que sur les caractéristiques actuelles obtenues sur le terrain et à partir de vols de drones. Elle tient également compte de la trajectoire de changement morphologique depuis 1957 (déterminée par analyse de photographies aériennes). L'étude se concentre sur 30 km de la rivière Saja, un lit de rivière en tresses dans le nord de l'Espagne, principalement affecté par la protection longitudinale des berges et les travaux de défense contre les inondations, ainsi que par l'augmentation de la couverture arborée dans le bassin. La méthode a permis de classer les 10 sections dans lesquelles la zone d'étude a été divisée en fonction des différents signes de déséquilibre et du plus grand potentiel de récupération. Les interventions seront orientées vers une récupération des processus et des formes qui augmentent la connectivité longitudinale et transversale, afin d'assurer un équilibre géomorphologique adéquat à plus long terme.

ABSTRACT

River restoration is a key tool for mitigating anthropogenic impacts on rivers and restoring their ecosystem functions. However, prioritising actions along a river corridor can be complex due, to variability in geomorphological and environmental conditions, among many others. This work propose a categorisation of reaches in the Saja river (NW Spain) based on morphodynamic indicators of possible sediment imbalances in the river channel, with the aim of prioritising restoration actions. The classification is based on two information. First, on present-day channel and floodplain characteristics obtained from field observations and aerial images collected with drone flights. Second indicators of channel changes identified by comparison of diachronic aerial photos (since 1957). The study focuses on 30 km of the Saja River, a wandering river located in northern Spain that has been affected mainly by longitudinal bank protection and flood control works, as well as an increase in tree cover in the basin. We have classified the 10 sections according to different levels of evidence of imbalance and greater potential for recovery, taking into account that the interventions will be directed towards the recovery of processes and forms. The main aim is to increase longitudinal and transversal connectivity to ensure an appropriate long-term sediment balance and geomorphological conditions.

KEYWORDS

Braided rivers, human disturbances, morphodynamic criteria, prioritisation reaches, river restoration.

Rivières en tresses, perturbations anthorpiques, criteria morphodynamique, prioritisation, restauration fluviale.

1 INTRODUCTION

Only few reaches with multi-thread (braided/wandering) morphologies are still present in the Cantabrian region (northern Spain). One of these few examples is the Saja River (Cantabria). Increase in tree cover at the catchment scale and diverse anthropic interventions carried out on river courses of this region, in recent decades, have led to a decrease in sediment inputs. As a consequence, river channels have experienced narrowing, a progressive simplification of their paths and incision processes. All of this have led to a reduction in morphological diversity, which is essential for the maintenance of biodiversity in the river ecosystem (e.g. Scorpio et al., 2024). Several restoration measures that are being evaluated to mitigate these effects, with the aim to providing space in the river for channel processes and morphology to recover. In this context, a geomorphological analysis of the changes in the system and the problems caused is essential to determine the most effective measures to be designed. This type of study has been carried out on the Saja River, establishing a method for prioritising restoration actions between the different sectors of this river.

2 STUDY AREA

The study focuses on 30 km of the middle course of the Saja River in northern Spain, which flows between 350 and 54 m above sea level and has a catchment area of 454 km^2. The river has an average channel and floodplain width of 86 and 778 m respectively. Until 1980s, the river had a multi-thread (braided\wandering) course, although in recent decades it has undergone important morphological changes, mainly related to various works in the banks. This caused a reduction of the braiding index, processes of vertical and horizontal instability and a significant narrowing of the river channel, among other effects. The study area has been divided into 10 sections with similar hydromophological behaviour, varying between 1 and 6 km in length (2.8 km on average) (Figure 1).

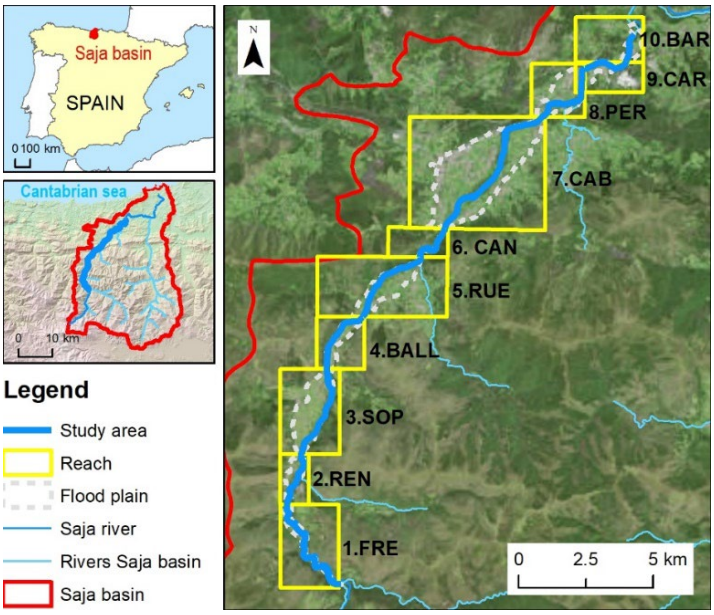

Figure 1. Study area of 30 km of the middle course of the Saja river (Cantabrian Mountains).

3 METODOLOGY

An evolutionary analysis was conducted using aerial photographs (1957-2024) and digital terrain models (2009-2024), supported by fieldwork and recent UAV observations to map geomorphological variables, such as channel and active channel widths, sinuosity, and braiding indices. Anthropogenic impacts were identified, including longitudinal bank protection works, transverse channel obstructions, artificial floodplain infills, and land use changes at the catchment scale. Channel deformation was mapped vertically (bed aggradation and degradation) and horizontally (bank erosion). Based on the comparison with the 1957 aerial photo, it was estimated the percentage of channel area that reduced fluvial activity due to narrowing/incision or major artificial impacts in each of the 10 sections. Lateral mobility was evaluated by the percentage of erosive banks. Vertical adjustments were based on field observations and was assessed by the length of the reach showing vertical adjustment and adjustment height. Thresholds and scores for each criterion determined restoration priority levels (high, medium, low) for each section.

4 RESULTS

The analysis shows that the Saja River experienced a 31% narrowing since 1957, in 2020 there were 12% of eroded banks at 25 sites and 43 points are currently recognised with evidence of vertical instability.

Looking at the analysis by sections (Table 1), sections 3 and 5 are those that have lost most active river surface area due to narrowing and incision (31 and 28%, respectively) and sections 7, 9 and 8 are those that have experienced the greatest alterations due to artificial actions (37, 33 and 28%, respectively). Furthermore, incision processes are most pronounced in sections 10 and 2, although there are occasional sectors where 2 m have been reached (sections 2, 3, 7 or 10). Sections 3, 4 and 7 are notable for the high presence of erosive banks (24, 21 and 17% respectively). Combining the criteria, sections 3, 10 and 7 (in descending order of priority) would be the highest priority sections in terms of orienting restoration efforts.

Table 1. A. Thresholds and scores assigned to each morphodynamic parameter (%NAR: Percentage of narrowed channel area, %ART: Percentage of artificial impacts, %ERO: Percentage of erosive banks, INC: Vertical imbalance points, H: Imbalance height). B. Results obtained by section. C. Priority ranges.

A.

PARAMETER	THRESHOLD	POINTS
%NAR	≥5-10	10
	10-20	30
	>20	50
%ART	≥5-10	5
	10-20	20
	>20	40
%ERO	≥5-10	10
	10-20	30
	>20	50
INC	≥1-3	5
	4-5	10
	>5	30
H (m)	≥1	5
	≥2	10

B.

REACH	%NAR	%ART	%ERO	INC	H	TOTAL
1.Fre	0	0	10	0	5	15
2. Ren	10	5	30	10	10	65
3. Sop	50	20	50	0	10	130
4. Ball	10	5	50	5	0	70
5. Rue	50	5	10	5	5	75
6. Can	0	0	0	5	0	5
7. Cab	10	40	30	5	10	95
8. Per	30	40	10	5	0	85
9. Car	0	40	0	5	0	45
10. Bar	30	0	30	30	10	100

C.

TOTAL POINTS	PRIORITY
0-40	Low
41-90	Medium
>91	High

5 CONCLUSIONS

The Saja River has undergone significant morphological changes since the 1950s, including a reduction in the braided channel and the disconnection of old secondary channels, fragmentation of the riparian forest and the destabilisation of the banks. This has led to incision and erosion of the channel in several places. Changes in land use and longitudinal bank protection works have played key roles in this evolution.

This study aims to propose restoration actions that promote the recovery of processes and forms and increase longitudinal and lateral connectivity. The triage aims to identify the areas for action according to the main morphodynamic adjustments identified and considering if the Saja River has the necessary liquid and sediment fluxes to support the actions and ensure long-term geomorphological response. Of the 10 sections analysed, 4 have high priority, 4 medium, and 2 low. This diagnosis should be accompanied by other biological and socio-economic criteria in order to guarantee the viability of the measures.

LIST OF REFERENCES

Scorpio, V., Comiti, F., Liébault, F., Piegay, H., Rinaldi, M. & Surian, N. (2024). Channel changes over the last 200 years: A meta data analysis on European rivers. *Earth Surface Processes and Landforms*, 1–26. Available from: https://doi.org/10.1002/esp.5848

ACKNOWLEDGEMENTS

This research was carried out within the framework of the project Sediment management study in Saja river (Cantabria) and Aller river (Asturias), financed by Tragsatec for the Confederación Hidrográfica del Cantábrico under Next Generation EU funds and based upon work from COST Action HiTec, CA21163, supported by COST (European Cooperation in Science and Technology).