Impact of river channelization structures on the floodplain vegetation state in a mountain river valleys

Impact des structures de canalisation des rivières sur l'état de la végétation de la plaine d'inondation dans les vallées fluviales de montagne

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RÉSUMÉ

Les écosystèmes riverains sont particulièrement sensibles aux perturbations anthropiques, notamment aux modifications des chenaux fluviaux, qui altèrent l'hydromorphologie et la végétation des plaines inondables. La canalisation et l'incision des rivières assèchent les plaines inondables, favorisant la dominance des espèces invasives et réduisant la diversité des espèces indigènes. Dans le cadre de ce projet, nous étudions l'état de la végétation riveraine sur des sections de rivières canalisées et naturelles dans les Carpates polonaises. Nos résultats montrent que les sections naturelles présentent une plus grande diversité spécifique, une végétation plus dense et une proportion plus élevée de jeunes classes d'âge des plantes. Les sections canalisées, avec des inondations réduites, ont permis aux forêts d'atteindre un stade mature tout en favorisant les espèces invasives, qui supplantent les espèces locales. Les données multispectrales obtenues par drones montrent que les espèces invasives affichent des valeurs NDRE élevées au début du printemps, des corrélations plus fortes avec la température et une résilience accrue à la variabilité des précipitations. En revanche, les espèces indigènes et non indigènes dépendent des cumuls pluviométriques sur 20 à 30 jours. Ces résultats soulignent l'adaptabilité des espèces invasives aux changements hydrologiques et climatiques dans les rivières régulées, le réchauffement climatique accélérant probablement leur expansion. Restaurer les chenaux naturels et les régimes d'inondation est essentiel pour renforcer la résilience des forêts riveraines et contrôler les espèces invasives.

ABSTRACT

Riparian ecosystems are highly sensitive to anthropogenic disturbances, particularly river channel modifications, which alter hydromorphology and floodplain vegetation. Channelization and incision create drier floodplain conditions, favoring the dominance of invasive species while reducing native species diversity. As part of the project, we are studying the condition of riparian vegetation along both channelized and unmanaged river sections in the Polish Carpathians. Our findings indicate that the natural sections exhibit greater species diversity, denser vegetation, and a higher proportion of younger plant age classes. Channelized river sections experienced reduced flooding, which has allowed forests to reach a mature stage and increased the presence of invasive species that outcompete native ones. Multispectral UAV data indicated that invasive species exhibited higher NDRE (Normalized Difference Red Edge Index) values in early spring, stronger temperature correlations and resilience to precipitation variability, unlike native and non-native species, which depended on 20–30 days of cumulative rainfall. These findings highlight the adaptability of invasive species to hydrological and climatic changes in regulated rivers, with climate warming likely accelerating their spread. Restoring natural river channels and flooding regimes is critical to supporting riparian forest resilience and controlling invasive species.

KEYWORDS

invasive plant species, plant condition indicators, riparian vegetation, river channel morphology, river channelization

canalisation des cours d'eau, espèces végétales invasives, indicateurs de l'état des plantes, morphologie du chenal fluvial, végétation riveraine

1. INTRODUCTION

Riparian ecosystems are sensitive to anthropogenic disturbances which have been documented worldwide (e.g. Nallaperuma and Asaeda, 2019). Human activity in a rivers, especially by the introduction of a different way of channel management leads modification of river hydromorphology which has a serious impact on riparian vegetation changes. Channelization induced then channel incision which can cause drier conditions on river floodplain and terrestrialization, irreversibly changing floodplain vegetation (Janssen et. al., 2020). River regulation was documented as a factor that increases dominance of non-native species in the riparian zone and favours invasion of woody species in the floodplain forest (Catford et al., 2020). However, the question remains, how do trajectories of such changes of floodplain vegetation differ between adjacent river sections of different channel morphologies. It is especially important to integrate river water and plant management in order to limit riparian plant invasion and maximize the ecological benefit of environmental flows in restored mountain rivers. In this context, there is a need to expand existing knowledge on the influence of human impacts on the functioning and management of riparian ecosystems, which until now has been mostly limited to the effects of dam construction on riparian vegetation (e.g. Dott et al., 2022).

2. VEGETATION STATUS IN RIVER SECTIONS OF DIFFERENT CHANNEL MORPHOLOGY

Preliminary results from our studies on both channelized and unmanaged river sections of three rivers in the Polish Carpathians reveal that sections with undisturbed channel processes exhibit greater species diversity, higher vegetation density, and a larger proportion of younger vegetation compared to adjacent channelized sections. The lower flooding frequency along the incised channelized river channels must have led to the changes in plant conditions on the floodplain as evidenced by the currently existing area covered with mature forest and rare shrub vegetation. A greater number and occurrence of invasive species was also found along the channelized river, which will be confirmed after processing the data obtained from multispectral camera images. These plant species occur in larger clusters, which shows that they influence the elimination of native species. Based on these images, the condition of plants species in the valleys of sections with different channel morphology will also be determined, separately taking into account the condition of invasive species.

3. USING MULTISPECTRAL CAMERA IMAGES TO ASSESS THE CONDITION OF RIPARIAN FORESTS. PRELIMINARY RESULTS

The analysis of riparian vegetation using Multispectral Camera Micasense SE along a channelized mountain river yielded preliminary results for several indicators. NDVI (Normalized Difference Vegetation Index), NDRE (Normalized Difference Red Edge Index), and MTCI (MERIS Terrestrial Chlorophyll Index) indices were calculated for four seasons a year, with the meteorological data (average temperatures and cumulative precipitation for the 30 days preceding each UAV survey) included in the analysis. The average NDRE values were highest on July 1 (N2) for all three distinctive species groups (Fig. 1). In May, at the start of the growing season (N1), non-native and invasive species exhibited higher NDRE values than native species, indicating their faster development in early spring than native species. This was supported by relatively high average temperatures (11.9°C) and the absence of frosts 10 days before the UAV survey made on May 7. NDRE values for invasive species correlated more strongly with mean daily temperatures (R^2 = 0.34) than NDRE values for non-native (R^2 = 0.02) or native species (R^2 = 0.16).

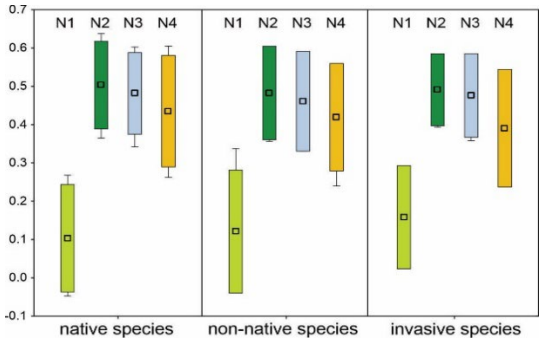

Figure 1. NDRE index values for four UAV survey: N1 - May 7, N2 - July 1, N3- July 8, N4 – September 23, 2022

NDRE values for non-native, planted species, exhibited a relatively strong correlation (R^2 = 0.4) with cumulative precipitation 30 days prior to the UAV survey conducted in May. This correlation was clearly higher than that observed for native and invasive species, highlighting the sensitivity of non-native species to water deficiency during the initial growth stage. In turn, the highest correlation of NDVI values with total precipitation was recorded for native and non-native species and was found for each of the 4 UAV surveys. Precipitation from the 20 days preceding the UAV surveys was particularly critical for these species, whereas invasive species appeared largely independent of rainfall amounts. The correlation between NDVI values and mean temperature was the highest for the two first UAV surveys (N1 and N2) and was stronger for invasive and non-native species. The highest MTCI index values in early spring (N1) were recorded for invasive species, whereas native species dominated the index in subsequent seasons.

These findings suggest that invasive species are highly resilient and well-suited to the floodplain conditions of an incised, channelized mountain river. Their ability to thrive independently of precipitation, in contrast to the reliance of native and non-native species on 20–30-day rainfall patterns, underscores their resilience. This adaptability, coupled with stronger correlations between early spring NDRE values of invasive species and temperature, highlights the competitive advantage these species may hold over non-invasive species in the context of rising temperatures driven by climate change. As climate change intensifies, the spread of invasive species in mountain river valleys, particularly along channelized river reaches, is likely to accelerate.

4. IMPLICATION FOR RIVER RESTORATION

Our research will contribute to understanding the driving factors of riparian vegetation changes under the combined pressures of human activity and climate stress. It will emphasize the importance of restoring natural river channels to improve hydrological conditions critical for the development and survival of riparian forests. Additionally, the study will underscore the vital role of recurring floods in sustaining ecological processes within river valleys. Determining the proportion of non-native and invasive species in floodplains along the rivers with different channel morphology will support future action to prevent the uncontrolled spread of these plant species along the degraded rivers.

The result of this study will be a proposal of an innovative method for evaluating riparian forests using the accurate techniques of remote sensing enabling to obtain of images with increased detail. The riparian vegetation status map (Fig. 2) obtained based on this research will be an original tool to compare the plant formations within the river sections with different channel morphology.

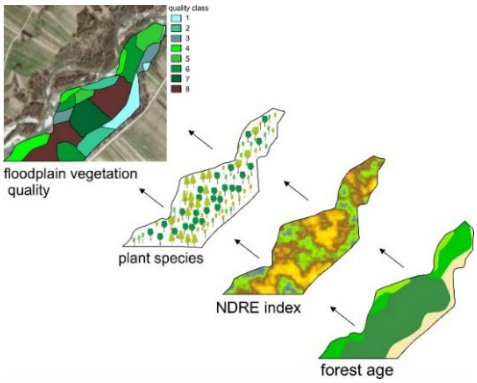

Figure 2. Schematic flow chart to produce a map of the riparian vegetation status

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