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Using a multi-criteria analysis to identify rivers with hydromorphological restoration priority: Braided rivers in the south-eastern Subcarpathians (Romania)

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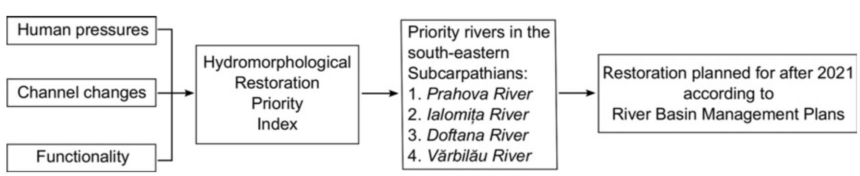
HIGHLIGHTS

- A Hydromorphological Priority Restoration Index (HRPI) was designed.
- The HRPI was computed for braided rivers in the south-eastern Subcarpathians.
- A list of priority rivers for hydromorphological restoration was established.
- Priority rivers raise issues about conflicting goals: restoration versus flood risk.

GRAPHICAL ABSTRACT



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ABSTRACT

In order to systematically plan river restoration actions at a regional scale, this paper develops a multi-criteria analysis that classifies rivers, based on their priority for hydromorphological restoration. This priority is defined by severe human pressures within the erodible corridor of the river, drastic alteration of the stream channel, and low intensity of river pattern functioning. Based on relevant indicators for three groups of features (human pressures, channel changes, and river functionality), a Hydromorphological Restoration Priority Index (HRPI) was designed. The high values (>66%) of HRPI reflect an urgent need for hydromorphological restoration while low values (<33%) reveal a less immediate necessity for restoration. The proposed methodology was applied on braided sectors of rivers crossing the south-eastern (Curvature) Subcarpathians (Romania). The values of the total HRPI ranged between 21% (Zăbrăuţ River) and almost 44% (Prahova River). According to our results, most of the analyzed sectors have a low need for hydromorphological restoration of the braided pattern, while some have a moderate necessity for restoration. Whereas the Prahova River has the highest HRPI, it should be given priority for restoration at a regional scale, which corresponds to the objectives of River Basin Management Plans for the interval beyond 2021.

1. Introduction

According to the requirements of the Water Framework Directive, restoration is defined as a set of measures aiming to regain a river's good status (de Jalon et al., 2016). Among the most common restoration methods, the adjustments of the hydromorphology, such as reconfiguring the

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channel laterally or vertically, the renewing of riverbed composition and structure, the revitalizing of water and sediment flow, or the removal of dams are among the most common ones (Bernhardt et al., 2005; Morandi et al., 2014; Palmer et al., 2014; Castillo et al., 2016). Besides the restoration of the hydromorphological natural functioning of a river, this kind of measures proved to have provided also some good ecological results at a section scale (Jähnig et al., 2010; Haase et al., 2013).

Within the context of the Water Framework Directive, the issue of prioritizing certain rivers for restoration is crucial. Rivers that receive priority for restoration are the altered ones, in terms of status (i.e. moderate, poor, bad) according to River Basin Management Plans (RBMPs) (ABABI, 2015; ABAS, 2015). However, in the EU member countries, about 37% of the river water bodies are affected by water flow regulation and morphological alteration (Fehér et al., 2012). So where do we start? The first phase of the restoration planning should be the definition of a precise goal, followed by the choice of an approach, based on objective criteria (Beechie et al., 2008). To this purpose, quantitative data, knowledge on hydromorphologically related processes and experts are all needed (Sewilam et al., 2007). In practice, the effective characterization of the physical habitat, especially of the geomorphology, is not well established, although managers need to know which aspects are altered and which are the critical locations where intervention will lead to the greatest improvements in terms of ecological condition (Orr et al., 2008). Moreover, the implementation of restoration actions is not necessarily systematic, but depends on a diversity of initiatives, needs, and funding sources of land management agencies and private landowners that motivate these efforts (Castillo et al., 2016). Therefore, at this time, river restoration relies mostly on independent projects with small measures at a section scale being uncertain whether their positive long-term cumulative effects can contribute to achieving restoration goals at larger scales (Kondolf and Podolak, 2014). Combining these approaches, it results that defining a goal and prioritizing an objective approach at a regional scale could answer the question related to the starting point.

In Romania, the 14 river restoration projects completed so far are mostly focused on the Danube floodplain, especially the Danube Delta, and on other important natural protected areas at international (Ramsar) and European (Natura 2000) scales, having as main goals to improve the water quality and to recreate wetlands (Ioana-Toroimac and Zaharia, 2016). However, previous studies showed also other types of altered conditions, especially the decline of the braided pattern of rivers flowing from the Eastern Carpathians (Ioana-Toroimac et al., 2010; Armaş et al., 2013; Rădoane et al., 2013; Salit et al., 2015). Consequently, the previous lack of awareness regarding braided pattern loss in Romania seems a good premise for prioritizing the rehabilitation of these altered hydrosystems.

Therefore, this paper aims to design a methodological framework that prioritizes rivers for hydromorphological restoration as a phase of the planning activities based on the disfunctionality of a precise fluvial process, such as river braiding. The methodological framework intends to fill the gap of large scale decisions and of insufficient hydromorphological characterization of rivers, and to develop the habit of thinking in hydromorphological terms while making decisions for river restoration. More precisely, we try to answer the question "where do we start?", by hierarchizing rivers based on their intensity of human-induced changes on the hydromorphological features, assessed by using a multi-criteria analysis. The methodology was applied on some braided sectors of rivers crossing the south-eastern (Curvature) Subcarpathians and allowed to identify rivers with priority for hydromorphological restoration.

2. Materials and methods

2.1. Study area

Over the last century, a decline in the braiding activity was detected on sectors of rivers crossing the south-eastern Subcarpathians, in Romania (Ioana-Toroimac, 2016) (Fig. 1). This decline was probably due to the decrease of water discharge and sediment load, as well as to changes in transported sediment size in relation to hydroclimatic variability, run-off catchment management and various land reforms, similar to other regions in Europe (Liébault and Piégay, 2002; Piégay et al., 2009; Surian et al., 2009; Zaharia and Ioana-Toroimac, 2009; Habersack et al., 2016; Wyżga et al., 2016). In this study, we chose to consider the beginning of the 20th century (~1900) as historical reference conditions. At the end of the 19th century and during the first part of the 20th century, rivers in the south-eastern Subcarpathians were subjected to increasing amounts of sediments because of the deforestation (Armaş et al., 2014; Munteanu et al., 2014), which could explain the intense braiding activity. After 1950, rivers were modified due to flow control by damming, weirs, embankments, and sediment mining, which could have determined the decrease of the braiding activity (Ioana-Toroimac, 2016); some engineering works might have disappeared, while others are still functioning today. However, all these engineering works aimed at mitigating the river dynamics and especially at reducing the sediment transport (Teodorescu et al., 1973). Since 1990, deforestations and the abandonment of engineering works in the Eastern Carpathians could have reactivated the braiding activity in this region (Rădoane et al., 2013; Munteanu et al., 2014). Additionally, hydroclimatic variability seems to have had a minor influence on the braiding activity over the last century as the flow regime was impacted by anthropic actions, such as engineering works. For example, in Romania, the period between 1901 and 2006 was characterized by an increase in the mean air temperature by 0.5 °C (more obvious after 1961), as well as by an increase in the mean of minimum summer temperatures and of maximum winter temperature (up to 2 °C in South and South-East in summer) (MESD, 2008). The period between 1901 and 2000 was individualized by a slight decrease of annual amounts of precipitation (with regional differences) and by an increase of the droughts intensity (MESD, 2008). During the period between 1900 and 2009, an important variability of wet and dry pluviometric extreme years was noticed (Levanič et al., 2013), which became more evident after 2000. More precisely, between 1961 and 2013, the maximum daily precipitation increased especially in summer and autumn, with an impact on floods; the number of days with snow cover and depth decreased at a large number of weather stations in Romania, influencing river flow in winter and spring (Bojariu et al., 2015). As a consequence, the annual streamflow variability since 1961 has no significant trend, but seasonal increases have been recorded in spring and autumn in the Eastern Carpathians (Bîrsan et al., 2014). Additionally, very large floods occurred in Romania in 1890s, 1940s, 1970s and 2000s (Gâştescu and Ţuchiu, 2012; ANAR, 2015). Consequently, the choice of 1900 or another year at the beginning of the 20th century as a reference condition reflects an optimum for the braiding activity before major human interventions that reduced river dynamics.

In this study, we considered rivers crossing the south-eastern Subcarpathians and the adjacent plain, which have a present-day braided sector longer than 5 km. The 17 identified watercourses are tributaries of two main first order streams of the Danube River: the Siret River (the Zăbrăuţ, Şuşiţa, Putna with its tributary Milcov, Râmnicul Sărat, and Buzău with its tributaries Bâsca Chiojdului, Slănic, and Câlnău rivers) and the Ialomiţa River (the Cricovul Dulce with the tributary Proviţa, and the Prahova with the tributaries Doftana, Teleajen with its tributary Vărbilău, and Cricovul Sărat rivers) (Fig. 1). Among them, only 15 were analyzed in this paper; the Buzău and Slănic rivers were not considered due to incomplete supporting cartographic documents (Crăciunescu et al., 2011). Some of the hydromorphological and hydrological features of the analyzed rivers are presented in Table 1.

In 1900, considered as representing quasi-natural conditions with a very low human impact, rivers used to form a braided pattern when crossing the south-eastern Subcarpathians and the adjacent plain area. The length of their natural braided sector varied between 20% of the river length (Ialomiţa River) and 79% of the river length (Proviţa