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The relationship between river types and land cover in riparian zones

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ABSTRACT

Fluvial systems are dynamic and the characteristics of every assessed reach are variable and difficult to quantify based on river type threshold values. The authors of this study considered whether taking into account detailed land cover data from the riparian zone could be of any help in more accurately defining river types and establishing hydromorphological reference conditions. Detailed land cover data from riparian zones (50 m and 200 m buffers along main rivers) were included among the hydromorphological characteristics of the main rivers on the territory of the Czech Republic, and the relationship between established river types and land cover in riparian zones was evaluated.

Land cover data from main river reaches categorized by river type indicate fundamental land cover differences between types that closely correspond with the hydromorphological characteristics of channels. If we examine riparian zones with no or minimal anthropogenic impact, significant land cover classes emerge for distinct river types that at the same time facilitate more accurate descriptions of river types. For rivers in agricultural lowlands, land cover contributes to revealing modifications of the river network. This study demonstrates that detailed land cover data can be used to explain differences between river types and can be included among river characteristics for establishing hydromorphological reference conditions or for assessing the level of anthropogenic impact in the riparian zone, which generally has an effect on the channel as well. At the same time, detailed land cover data may significantly help locate new reference sites, or exclude unsuitable sites.

1. Introduction

Rivers are influenced by the landscapes they flow through (Vannote et al., 1980). The stability of a stream channel or its dynamic equilibrium is predetermined by flow conditions (discharge and valley floor slope) and sediment regime (Schumm, 1977, 1985; Rosgen, 1994), as well as bank and riverbed material and bank vegetation (Hey, 1997; Gurnell and Grabowski, 2016). The main dependent characteristics that describe channel geometry include channel width and depth, erosion and accumulation bedforms, channel slope, flow velocity, sinuosity, discharge, and sediment load and size (Leopold et al., 1964; Hey, 1997; Brierley and Fryirs, 2005). Classifying rivers based on their natural channel behavior is a useful tool for understanding fluvial-morphological processes but classifications also serve as flexible management tools that enable assessing the current ecological status of streams according to the Water Framework Directive (WFD, European Commission, 2000), determining reference conditions, forecasting changes, and thus configuring suitable management for river systems including their riparian zones.

Classifications of channel types have established qualitative links between channel processes, forms, and stability (Thorne, 1997). Channels are classified using different approaches and for various applications. Nevertheless, number of river classification systems (since Schumm, 1977 to Rinaldi et al., 2016) is based on respect of continuum of planform patterns and use examination features of channel to classify river type.

According to European standard EN 14614 (CEN, 2004), reference conditions should be determined for all river types so that they reflect undisturbed stream conditions—that is, natural cross-sectional profiles and channel planforms, the free flow of water and sediment in the channel, and natural vegetation in the riparian zone. Hydromorphological reference conditions are a benchmark for assessing the hydromorphological status of streams, and they also represent stream restoration target conditions. According to the WFD (European Commission, 2000) one of recommended ways to establish type-specific reference conditions is by using a spatially based approach (with data from reference sites). Reference conditions, however, must be understood in terms of cultural-landscape changes (Kondolf et al., 2003a; Matoušková, 2008; Dufour and Piégay, 2009). Defining reference conditions as pristine conditions is infeasible and doing so has little

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practical use for stream management and restoration (Dufour and Piégay, 2009; Wyżga et al., 2012; Rinaldi et al., 2013). Therefore, present environmental conditions should be used for establishing reference conditions (Brierley and Fryirs, 2005; Dufour and Piégay, 2009; Wyżga et al., 2012).

The importance of the interactions between riparian zones and channel-forming processes has been pointed out by many researchers (e.g., Kondolf et al., 2003b; Hupp and Rinaldi, 2007; Vaughan et al., 2009; Gurnell et al., 2016). Fluvial-morphological forms and processes significantly influence and limit the establishment, growth, and reproduction of riparian vegetation (Hupp and Osterkamp, 1996; Hupp and Rinaldi, 2007). The distribution of riparian habitats is determined by species tolerance to specific disturbances and stresses and the occurrence of these disturbances. It is also guided by fluvial-geomorphological processes and landforms (Hupp and Bornette, 2003; Hupp and Rinaldi, 2007). Periodic disturbances in the form of relatively frequent flooding and channel migration could be considered the fluvial-geomorphological processes responsible for the high biodiversity of riparian ecosystems (Vannote et al., 1980; Marston et al., 1995; Hupp and Osterkamp, 1996; Škarpich et al., 2016b).

Vegetation may significantly affect erosion rates, sediment accumulation, and the overall stability of fluvial landforms (Hupp and Osterkamp, 1996; Liébault and Piégay, 2002; Hupp and Rinaldi, 2007; Gurnell et al., 2016). This is particularly evident in rivers affected by human activities that are not in equilibrium and that indicate channel incision and channel narrowing (Marston et al., 1995; Liébault and Piégay, 2002; Zawiejska and Wyżga, 2010; Škarpich et al., 2016a).

When river channels are near equilibrium conditions, riparian vegetation indicates specific landforms and hydromorphological conditions (Hupp and Osterkamp, 1996). In Cetral Europe, relatively stable behavior of unmodified channels prevails over bank erosion and surface disturbances; while anthropogenic impact increases farther away from the channel, near by the channel grasslands are not maintained, the share of woody plants increases, shrub vegetation and alluvial forests expand. This leads to changes in riparian zone behavior during flood periods (Cebecauerová and Lehotský, 2012; Wyżga et al., 2012). Locally, however, arable land and urban areas increase. Liébault and Piégay (2002) describe similar situation in southeastern France.

Bottomland landscapes can be characterized as all fluvially generated landforms and the vegetation they support (Hupp and Osterkamp, 1996), or variable mosaics (Swanson et al., 1988). The variability of hydromorphological processes can also appear over short distances, such as within the width of the floodplain (Hupp and Bornette, 2003). In humid temperate regions, fluvial-geomorphological processes support diverse forested ecosystems (Hupp and Bornette, 2003). The roots of living trees, branches, and large woody debris help form the channel and its habitat, leaves and invertebrates falling into the channel provide food, and tree shading influences water temperature (Vannote et al., 1980; Kondolf et al., 2007; Gurnell and Grabowski, 2016; Škarpich et al., 2016b). Moreover, a well-vegetated riparian zone can also act as a filter of sediments, nutrients, and contaminants and thus improve water quality (Kondolf et al., 2003b). Therefore, riparian zones are significant management and conservation areas, where restoration efforts are important (Kondolf et al., 2007; Gurnell and Grabowski, 2016; Škarpich et al., 2016b).

Riparian zones also often minimize conflicts between dynamic fluvial processes and human development activities (Kondolf et al., 2003b; Dufour and Piégay, 2009). The width of the riparian zone is therefore important. Osterkamp and Hupp (1984) define a riparian zone as a surface inundated or saturated by the dominant discharge equivalent to Q_2. Most floodplains and all surfaces lower in the valleys meet these criteria; terraces with long flood-return intervals are not included (Hupp and Bornette, 2003). Cebecauerová and Lehotský (2012) define a riparian zone as the corridor along a river bank with specific spatial and ecological gradient that includes bank structures and vegetation in addition to the periodically inundated parts of the floodplain. European standard EN 14614 (CEN, 2004) defines a riparian zone as an area of land adjoining a river channel (including the river bank) capable of directly influencing the condition of the aquatic ecosystem (e.g., by shading and leaf litter input) and a floodplain as an area of land adjoining a river channel that is or had regularly been in the past inundated during the flood period. If a river valley is less than 100 m wide it is possible to include the entire floodplain in the riparian zone. For all other rivers, a standard distance of 50 m on either side is suggested (CEN, 2004).

This paper focuses on assessing interactions between land cover in the riparian zone and the fluvial-morphological characteristics of a wide range of river systems in temperate Central Europe, the meeting place of rivers from two different geomorphological units: the Bohemian Massif and the Western Carpathians. This study is unique in that it assesses a number of river systems without a subjective selection of specific rivers. Additionally, the diverse physiographic conditions of the study area and the detailed nature of the land cover data acquired from field surveys in the entire study area add to its value. Verifying the results of field surveys increases their relevance and enables them to be used for establishing type-specific hydromorphological reference conditions as well as to be more broadly applied to similar river systems in temperate climates.

The objective of this study was to assess the significance of the occurrence of land cover classes in riparian zones for characterizing hydromorphological river types in the Czech Republic and for interpreting the relationships between these types and land cover classes in riparian zones. This transparent, broadly applicable approach should enable the identification of specific (local) reference conditions upon which appropriate management and restoration measures can be based.

2. Study area

The broadly defined study area comprises the entire territory of the Czech Republic. Lithologically, the majority of the area is covered by the expansive, flattened surfaces of the Bohemian Massif primarily on Precambrian and Paleozoic igneous and metamorphic rock. The younger Western Carpathians, which consist primarily of flysch and whose terrain is significantly rougher and more sloped, are located on the eastern margins of the study area. The mean altitude of the study area is 450 m, with a maximum altitude of 1602 m and a minimum of 115 m. The Czech Republic has a temperate climate. The average annual temperature ranges from 0.4 °C to 10.1 °C depending upon location. Average annual precipitation varies between 435 and 1392 mm. Maximum discharge occurs during the spring thaw and rains, that is, in March at medium and low altitudes and in April at high altitudes. The lowest discharge occurs in the autumn. The runoff regime of water courses is significantly affected by the presence of reservoirs and extensive modifications of the river network. Our main focus was on the river network consisting of the main rivers (Fig. 1) and their riparian zones within a 200 m buffer zone.

The area within 200 m of main rivers is largely forested (30.4%), and a large part is covered in arable land (17.3%) and intensive grasslands (19.0%). Alluvial meadows cover a mere 4.8% of this 200 m buffer zone (NCA CR, 2013). This area has been significantly affected by human activities, which the high percentage of urban fabric, industrial, commercial and transport units (a total of 17.3%) bears witness to.

Special focus was on reference sites (RSs). Initially, 44 verification sites that cover the diversity of physiographic conditions present in the Czech Republic were verified through field surveys. Sixteen of these 44 sites were surveyed in detail and act as RSs for verifying defined river types, assessing the relationships between river types and land cover in riparian zones, and determining river characteristics for establishing type-specific hydromorphological reference conditions. The location of these sites can be seen in Fig. 1. Table 1 contains the names and basic features of RSs.