



What happens in a Carpathian catchment after the sudden abandonment of cultivation?

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ABSTRACT

Changes in land use induced by human activity trigger a number of processes in river catchments. These processes are particularly evident in the mountains, where wild vegetation overtakes abandoned arable land, stabilizing slopes and reducing sediment delivery to rivers. The energy of under-loaded rivers then makes incisions into their beds, which results in lower water levels. What is the rate of environmental changes induced by farmland abandonment, and does the environment restore its primary characteristics through a certain inertia? To answer these questions, we analyzed changes in land use in the Jasiołka River catchment located in the Carpathians, based on topographic maps from three periods covering more than 60 years. We also compared data on land use change with changes in the water levels in the Jasiołka River using regression models and principal component analysis. In the period analyzed, substantial transformations of the landscape were evident, mainly caused by dislocation of the population during and after World War II and, to a lesser extent, by changes in the political system in Poland after 1989. All these events led to the reduction of the arable land area, along with the enlargement of forest areas. Before World War II, arable land was the prevailing form of land use, taking up an area almost twice as large as the forest. Currently, the area of arable and forest land combined in the catchment area analyzed is similar, at approximately 42%. The response of the river to the changes in land use in its upper course, the location of the greatest extent of changes in landscape, is triggered almost immediately, decreasing the mean water level. In the mouth of the river, these processes occurred over a different period of time: The river incision was not as intensive and ended nearly 30 years later. The investigations strongly correlated the changes in almost all landscape elements with processes occurring in the river channel. Therefore, even small landscape components such as settlements or gullies that can exert a significant effect on catchment functioning should not be disregarded in this type of analysis. Together with large areas of forest, they regulate processes occurring on the slope and in the river channel.

1. Introduction

Similar to other mountainous (Chauchard et al., 2007; García-Ruiz and Lana-Renault, 2011; Lasanta et al., 2006; MacDonald et al., 2000; Tasser et al., 2007; and papers cited therein) and upland (Castro et al., 2010) regions of Europe, some parts of the Carpathians undergo intensive spatial changes associated with depopulation (Kozak, 2010; Kuemmerle et al., 2008; Munteanu et al., 2015; Soja, 2008). These changes manifest in the transformation of the types of land cover, mainly through reforestation (Kozak, 2010, 2003; Kozak et al., 2007, 2004; Munteanu et al., 2015; Szwagrzyk, 2004). From a broader perspective, they can also be recognized as changes in the functioning of entire natural systems through the restoration of biotic and abiotic elements of the environment. This process has been described as

renaturalization in the Polish literature (Wolski, 2016, 2007). The ability of the environment to restore its characteristics can also be perceived through the prism of the ecosystem services concept (Maes et al., 2013), in particular as the regulating function of the environment. In the deforested landscapes of the Western Carpathians, below the climatic potential upper timberline, gradual renaturalization is accompanied by increased environmental stability (Balon, 2007). In mountain catchments, farmland abandonment and, therefore, the restoration of various environmental characteristics, reduce erosion and sediment transport to river channels (Liébault and Piégay, 2002, 2001; Sanjuán et al., 2016) due to plant succession in fields (Keesstra, 2007; Lasanta et al., 2006; Liébault et al., 2005), cart tracks (Krocak et al., 2016), and pastures. This reduces connectivity between hillslopes and a channel (Gómez-Villar et al., 2014), increases water flow velocity and

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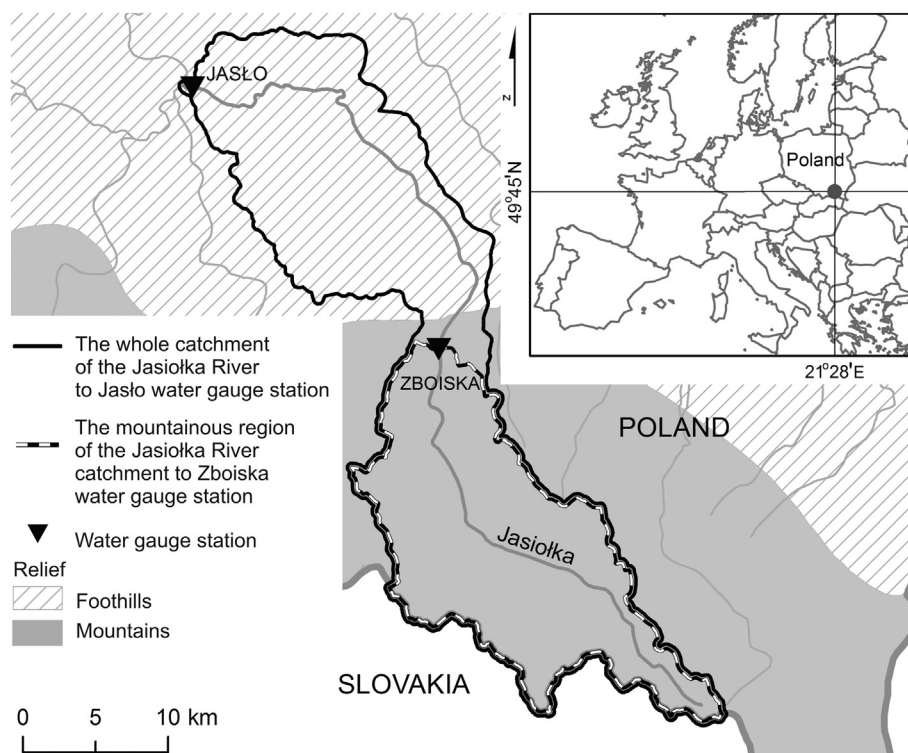


Fig. 1. Location of the study area.

deepens riverbeds (García-Ruiz and Lana-Renault, 2011; Lach and Wyżga, 2002; Wyżga, 2008). The phenomena are accompanied by changes in aquatic ecosystems (Skalski et al., 2017; Wyżga et al., 2009) and vegetation patterns of valley floors (Lallias-Tacon et al., 2017; Liébault and Piégay, 2002; Picco et al., 2017). Depopulation and abandonment of traditional farmland management are detrimental to the biodiversity of semi-natural mountain meadows, previously extensively used for grazing, and their overgrowth (Castro et al., 2010; Chauchard et al., 2007; Marini et al., 2009; Prince et al., 2012). Awareness of natural processes associated with farmland abandonment is essential in planning the management of mountain catchments to ensure the sustainable development of these areas. Planning socio-economic development based on knowledge of the functioning of the natural environment is a significant challenge for the seven Carpathian countries that adopted the *Carpathian Convention* (2003). The entire Carpathians have undergone various transformations associated with spatial management (Munteanu et al., 2015)—for example, over the last two centuries, the central part of the Beskidy Mountains and their foothills, located in the Western Carpathians in Poland, is an extremely valuable area for research on restoration processes. Abandonment of farmlands or transition from intensive to extensive land use in less favorable areas such as mountains is determined by economic and social factors (Baumann et al., 2011; Castro et al., 2010). The area analyzed was depopulated for political reasons by the forcible removal of the Ruthenian communities living in Polish lands during and immediately after World War II (Trzeszczyńska, 2015). Completely or partially deserted villages appeared on the landscape, which was a new phenomenon at that time in Europe (Soja, 2008). The abandoned land underwent spontaneous vegetation succession (Wolski, 2007), and the natural environment in this part of the Carpathians began to establish a new state of equilibrium. Research on these phenomena is dominated by spatial analyses of changes in land cover, with the increasing forest area comprising an important component (Dec et al., 2009; Kolecka et al., 2015; Kozak, 2010, 2003; Kozak et al., 2007, 2004; Munteanu et al., 2015; Szwagrzyk, 2004). There are also reports of the phenomenon of river incision, although river channelization and the extraction

of gravel are regarded as the main cause of this phenomenon (Rinaldi et al., 2005; Wyżga, 2008; Zawiejska et al., 2015; Zawiejska and Wyżga, 2010). The deepening of river channels and farmland abandonment are linked. However, as in the first reports on the area (Lach and Ziętara, 1989; Soja, 1988) and studies on the functioning of Carpathian (Korpak, 2007; Lach and Wyżga, 2002; Wyżga, 2008; Wyżga et al., 2012, 2009; Zawiejska and Wyżga, 2010) and other (Kondolf et al., 2002) river geosystems, no attempts at a comprehensive statistical analysis of the relationships among these phenomena have been made. This study is intended to fill this gap. Furthermore, it appears that the rate of restoration of environmental components after farmland abandonment varies and renaturalization proceeds with some inertia. Although these facts have been reported for other depopulated Carpathian areas (Wolski, 2007), no multivariate analyses have confirmed this way of the environment functioning so far. Based on these considerations, two interesting research questions arise: (i) Do changes in land use affect the functioning of valley geosystems, and if so how, particularly with regard to the river incision process? and (ii) At what rate do these changes occur, and does the environment restore its primary characteristics with a certain inertia? These questions will verify the hypothesized very strong relationship between the spread of land cover forms that limit denudation processes and the deepening of stream channels. They will also confirm the hypothesis of the delayed response of the environment to farmland abandonment. Generally, answers to these research questions provide a better understanding of the functioning of selected natural environment characteristics over the past seven decades in response to the sudden depopulation of a mountainous area, namely the Jasiołka River catchment in the Polish Western Carpathians.

2. Materials and methods

2.1. The study area

The Jasiołka River catchment is located in the upper Vistula basin in the Polish Carpathian Mountains (Fig. 1) within two mesoregions: (i)

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