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Comprehensive approach to the reduction of river flood risk: Case study of the Upper Vistula Basin

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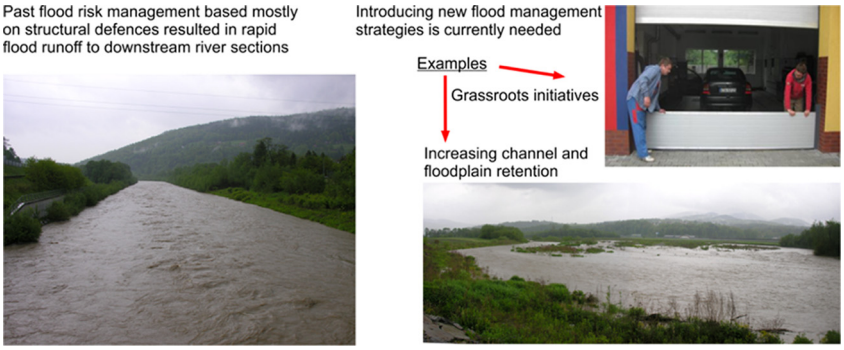
HIGHLIGHTS

- Options for flood risk reduction in the Upper Vistula Basin are considered in light of past and future environmental changes.
- Climate models indicate small future increases in high-flow indices.
- Twentieth-century changes in terrestrial drivers aggravated erosional threat of flood flows to valley infrastructure.
- Traditional flood protection methods result in downstream shift rather than a reduction of flood hazard.
- River restoration measures and grassroots initiatives can enhance flood risk management strategies in the area.

GRAPHICAL ABSTRACT



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ABSTRACT

The paper examines options for river flood risk reduction in the Upper Vistula Basin located partly in the Carpathian Mountains in Poland. Projections of high-flow indices for the periods 2021–2050 and 2071–2100 generally indicate small future increases, although the projected flow changes vary highly both across the study basin as well as among climate models. An overview of twentieth-century catchment and channel changes indicates that some of them decreased and others increased the rapidity of runoff but they largely reduced availability of sediment for fluvial transport, hence inducing bed incision and bank erosion that create risk to roads and bridges. Traditional methods of flood protection in the basin encompassed large structural defences such as river channelization and flood embankments. These have limited floodwater retention within floodplains and accelerated flood runoff, shifting flood hazard downstream rather than reducing it. A range of alternative approaches to reducing future flood risk are thus proposed and examples of their application in southern Poland are described. These approaches include river restoration measures aimed to reduce erosional potential of flood flows and increase channel and floodplain retention of floodwater, as well as grassroots initiatives promoting preparedness for flooding at the community level. There is an increasing need to change the existing paradigm that flood-

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control measures should be based on fast evacuation of floodwater that, in turn, was associated with a significant reduction in floodwater retention on the valley floors. Alternative approaches discussed in this paper extend the roster of flood risk reduction strategies and contribute to a gradual paradigm change.

1. Introduction

Poland is a predominantly lowland country. However, in the south, there are two vast, cross-border, mountain ranges—the Carpathians in the Upper Vistula basin and the Sudetes in the Upper Odra basin. Mountainous areas receive high precipitation (also because of orographic effect) and are characterized by high runoff coefficient. In the highest part of the Upper Vistula Basin (Tatra Mountains with elevations up to 2655 m a.s.l.), the maximum 24 h precipitation reached 300 mm in 1973, and the highest annual total of precipitation was 2770 mm in 2001. Mostly underlain by flysch bedrock, the Polish Carpathians are typified by low soil infiltration capacities associated with relatively high values of specific maximum discharges (cf. Punzet, 1991). Steep hillslopes are the reason for high velocities of surface runoff, while steep channel gradients result in fast concentration of flood waves in mountain catchments. Streams have high power and transport competence. Therefore, considerable flood hazard concerns a large proportion of the Upper Vistula Basin and many river floods have originated there. In the mountainous areas, floods are relatively flashy and erosive. Further downstream, floods convey very large volumes of water, propagating through the lowlands and inundating areas far away from the mountains.

This paper examines possibilities for river flood risk reduction in the Upper Vistula Basin located partly in the Carpathian Mountains. For the sake of this study, we have defined the Upper Vistula Basin as the one upstream from the Zawichost gauge that is located below the confluence of the River San with the River Vistula (Fig. 1). The paper aims at:

- presenting projections of future changes in high-flow indices to demonstrate a possible impact of climate change on flood hazard in the study basin,
- overview of twentieth-century land use and channel changes in the basin as possible determinants of recent changes in flood hazard,
- discussion of the effectiveness of traditional methods of flood protection in reducing flood hazard and flood risk at the regional scale,
- presenting alternative approaches to reducing flood risk as measures allowing to broaden the spectrum of possible flood risk management strategies in the region.

2. Observed and predicted changes in flood hazard and flood risk in the Upper Vistula Basin

2.1. General information

Floods in the Upper Vistula Basin are generated by rainfall and/or snowmelt locally linked with ice-jam formation. The category of rainfall as a generating factor can encompass a range of situations, from short-duration, high-intensity rainfall to long-duration (few days), moderate-intensity rainfall (Table 1). Most floods in the region have been caused by summer precipitation, mostly in June, July and August, but occasionally also in May and September. Short-lasting convective rain of high intensity can lead to a local flash flood, while long-lasting rain of moderate intensity can lead to large-scale flooding (Table 1; see also Wyżga et al., 2016a). At times, a few hundred millimetres of precipitation fall within a few days and some circulation patterns, especially those induced by cyclones moving along the so called Vb track from the Mediterranean region to Central–Eastern Europe, have predisposition to produce high 2–3 day rainfall totals resulting in flood hazard (Niedźwiedź et al., 2015; Niedźwiedź and Łupikasza, 2016). Then, huge

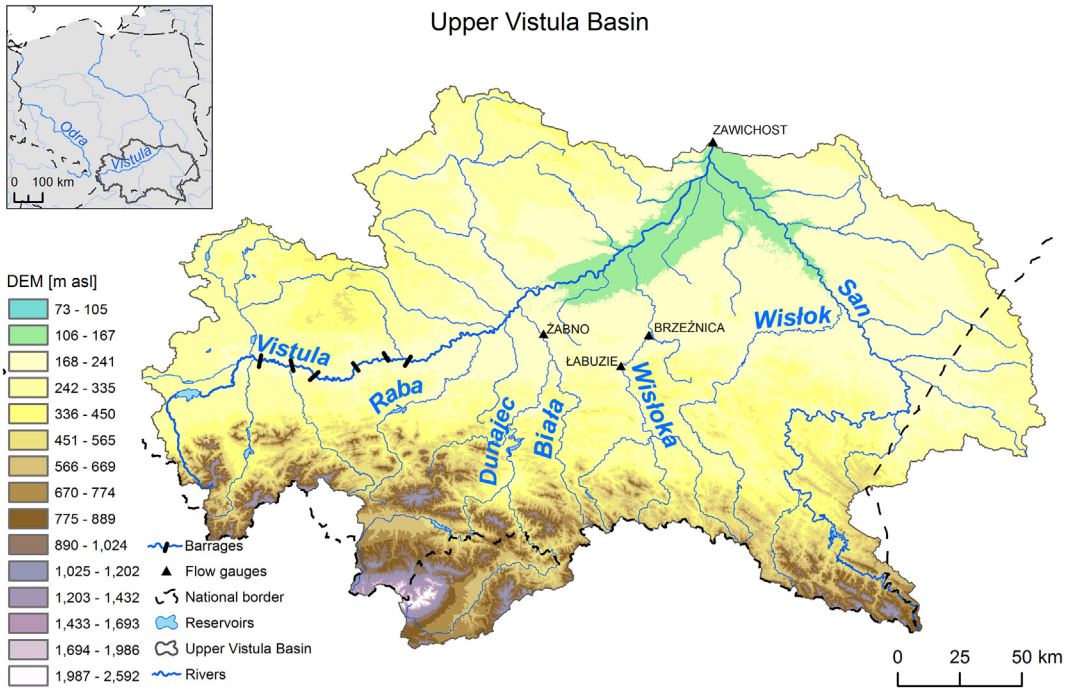

Fig. 1. Location, topography and drainage network of the Upper Vistula Basin in Poland.