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Modelling impacts of sediment transport and climate change on flood hazard zones

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Abstract

The primary focus of the presented work is an analysis of the specific impacts on flood hazard maps developed for Polish conditions. Long-term sediment transport and climate change are considered. The computational methodology employed is based on geoprocessing, simulations, and automated computations. The results obtained underline the importance of both factors and indicate potential interrelations between them.

1. INTRODUCTION

The presented work is inspired by the implementation of the EU Flood Directive (EC, 2007) in Poland (ISOK, 2015). The flood hazard and risk maps were developed between 2011 and 2015 and between 2017 and 2020. From the first public release in 2015, the maps were examined in light of numerous uncertainties. However, other problems may be generated by non-stationarity of the natural processes. Firstly, the impact of climate change on precipitation needs to be mentioned. The second is sediment transport and associated morphodynamic changes of river beds, including deposition and erosion.

The presented work is based on two different analyses focused on the non-stationarity of flood hazard zones related to sediment transport and climate change. Although there are some differences in the time scale of the obtained results, this preliminary comparison enlightens the potential relationship between these two processes.

2. STUDY CASE: REACH OF THE WARTA RIVER

The selected reach shown in Figure 1 is located in the lowland part of the Warta River course. The length of the reach equals 39 km. Downstream of Oborniki, there is the junction of the Warta and Wełna rivers. The gauge stations located along the Warta River are Oborniki and Wronki. In the tributary, there is Kowanowko (Figure 1). For the presentation of the results, two control areas were chosen. These are denoted as A and B.

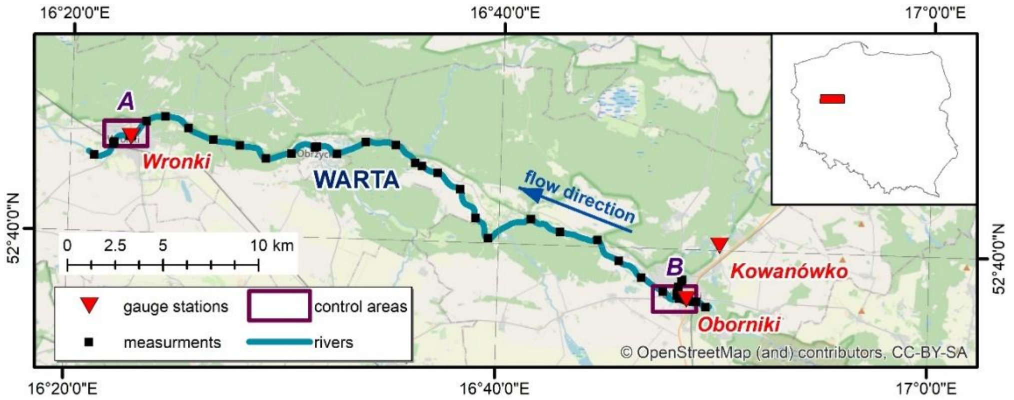


Fig. 1. Reach of the Warta River selected for tests.

The risk of flooding is high in the Warta River valley and threatens mainly the three towns located along the reach: Oborniki, Obrzycko, and Wronki. The flood hazard maps were determined for the Warta River during the implementation of the EU Flood Directive (EC, 2007).

3. MANAGEMENT OF SIMULATIONS

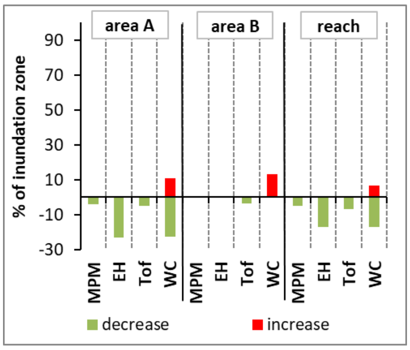
It was assumed that the applied procedures are consistent with the implementation of the EU Flood Directive. Due to this, the computations of water surface profiles in the selected reach were performed using a 1D model. In both cases, HEC-RAS was applied. Although there are different recommendations, the steady state module was used due to its simplicity. The maximum flows chosen for determining the flood hazard maps were 10-, 100-, and 500-year floods. In this case, attention is focused on a 100-year flood, reflecting a 1% probability of exceedance. Such an approach deeply depends on the elements being impacted, namely (1) the configuration of the bed and (2) the variability of precipitation that generates flow in the streams.

For the sediment transport simulations, two periods were assumed, 6 and 12 years, following the predicted update periods outlined in the EU Flood Directive. Thirty scenarios of each type were generated from historical data spanning the period 1971-2017. The bed sediment samples were collected along selected reaches of the Warta River to determine the average sample for simulations. Due to some stability issues detected in the computations, the number of tested transport formulas was limited to four: Meyer-Peter & Müller (MPM), Engelund-Hansen (EH), Toffaleti (Tof), and Wilcock-Crowe (WC) (Dysarz, 2020). The simulations produced bed profiles applied in the computation of water surface profiles for given max flows. Based on computations, new flood hazard maps were generated and then compared with reference flood hazard maps.

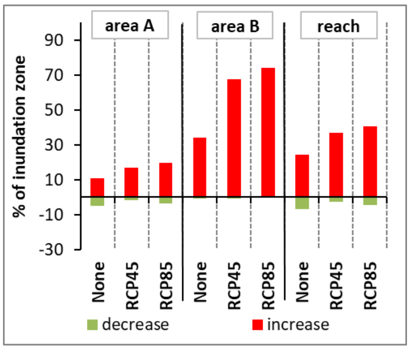
The simulations of climate change are based on the Representative Concentration Pathways (RCP) of the Intergovernmental Panel on Climate Change (IPCC, 2014). The historical data were used to generate nine scenarios of three different types: (1) neutral, denoted as None; (2) RCP4.5; and (3) RCP8.5 (IPCC, 2014). The precipitation scenarios were processed using the SWAT+ model to simulate the rainfall-runoff process. This step generated a synthetic series of data in selected gauge stations. The series were processed as real data and flood flows were calculated for each scenario. The next elements of the procedure were similar to the previous simulations. A 1D model was used to determine water surface profiles, and subsequently, flood hazard maps were developed.

4. RESULTS

In Figure 2, the examples of obtained results are presented. The percentage of increases and decreases in the inundation areas is shown. The results are presented for the 12-year simulations of sediment transport (Figure 2a) and climate change impacts (Figure 2b).



(a)



(b)

Fig. 2. Summary of sediment transport impacts on flood hazard zone in 12-year simulations (a) and climate change impacts (b). The results are shown for areas A, B and the entire reach.

The important factor in the presented results is the range of changes. While the impact of climate change across the entire reach varies between -5% and 40%, the effect of sediment transport depends on the transport function, but generally changes between -17% and 7%. Even if the time horizons in both analyses differ, it must be taken into account that both processes occur in parallel and are interrelated.

5. CONCLUSIONS

The effects of sediment transport simulations are not unambiguous. Complex processes of channel bed transformations can cause fluctuations in the size of inundation zones. The climate change impact is clearer. In general, climate change increases the extent of the flood hazard, though decreases were observed in some scenarios. It becomes clear that sediment transport processes can significantly complicate any analysis of climate change impacts.

References

Dysarz, T. (2020). Development of methodology for assessment of long-term morphodynamic impact on flood hazard. *Journal of Flood Risk Management*, **13(4)**, e12654.

EC (2007). Directive 2007/60/EC of the European Parliament and of the Council on the assessment and management of flood risks. *Official Journal of the European Communities*, Brussels.

IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

ISOK (2015). IT System of the Country's Protection against Extreme Hazards. Available online: http://www.isok.gov.pl/en/ (accessed on 10 June 2015).

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