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Evaluating nature-based solutions in a non-stationary climate with changing risk of flooding

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Abstract

Under climate change scenarios, it is important to evaluate the changes in recent behavior of heavy precipitation events, the resulting flood risk, and the detrimental impacts of the peak flow of water on human well-being, properties, infrastructure, and the natural environment. Normally, flood risk is estimated using the stationary flood frequency analysis technique. However, a site's hydroclimate can shift beyond the range of historical observations considering continuing global warming. Therefore, flood-like distributions capable of accounting for changes in the parameters over time should be considered. The main objective of this study is to apply non-stationary flood frequency models using the generalized extreme value (GEV) distribution to model the changes in flood risk under two scenarios: (1) without nature-based solutions (NBS) in place and; (2) with NBS i.e. wetlands, retention ponds and weir/low head dam implemented. In the GEV model, the first two moments i.e. location and scale parameters of the distribution were allowed to change as a function of time-variable covariates, estimated by maximum likelihood. The methodology is applied to OPEn-air laboRAtories for Nature baseD solUtions to Manage hydro-meteo risks, which is in Europe. The time-dependent 100-year design quantiles were estimated for both the scenarios. We obtained daily precipitation data of climate models from the EURO-CORDEX project dataset for 1951–2020 and 2022–2100 representing historical and future simulations, respectively. The hydrologic model, HEC-HMS was used to simulate discharges/flood hydrograph without and with NBS in place for these two periods: historical (1951-2020) and future (2022-2100). The results showed that the corresponding time-dependent 100-year floods were remarkably high for the without NBS scenario in both the periods. Particularly, the high emission scenario (RCP 8.5) resulted in dramatically increased flood risks in the future. The simulation without NBS also showed that flooded area is projected to increase by 25% and 40% for inundation depth between 1.5 and 3.5 m under RCP 4.5 and RCP 8.5 scenarios, respectively. For inundation depth above 3.5 m, the flooded area is anticipated to rise by 30% and 55% in both periods respectively. With the implementation of NBS, the flood risk was projected to decrease by 20% (2022–2050) and 45% (2071–2100) with a significant decrease under RCP 4.5 and RCP 8.5 scenarios. This study can help improve existing methods to adapt to the uncertainties in a changing environment, which is critical to develop climate-proof NBS and improve NBS planning, implementation, and effectiveness assessment.

Keywords: Nature-based solutions; flood frequency analysis; climate change; wetlands; GEV model

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