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Hydrological contrast between peatlands and forests: Implications on extreme flow in the boreal landscape

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One of the most important benefits of natural and restored peatlands in boreal ecosystem is their critical role in storing water and consequently reducing flood peaks at the basin outlet. Compared to forests, peatlands have been suggested to have different hydrological behaviors altering the water transit time, flood peaks and runoff volumes, but the science underpinning such statements are largely lacking. This is problematic, as peatland restoration to regain landscape hydrological functioning has become high on the management agenda. However, if it is true that peatlands behave differently they can help mitigate the impacts of both extreme flooding and drought conditions by storing large volumes of water that will delay runoff and keeping streams and rivers flowing during low flow conditions. Accordingly, an accurate estimation of potential and available volume of catchment water storage with different physical characteristics would help us to choose the best peatland management strategies for reducing flood and drought risk in the future. However, the direct estimation of water storage requires an extensive amount of field observations. Hydrological models provide an indirect estimation of water storage and allow us to compare several catchments over a wide range of spatiotemporal scales.

Here, we tested the role of peatlands by using data from 14 nested sub-catchments within a 68 km² boreal forest landscape in Northern Sweden and then classified them into four different groups (forest on till, forest on sediment, peatlands, and mixed land cover) based on their landscape characteristics. We focused on the “dynamic storage” of catchment which directly controls the catchment streamflow generation. The simple bucket-type hydrological model, HBV-light, with a calibration period of 7 years (2010 to 2017) was deployed to simulate catchments storage dynamics. The calibration trials were repeated 100 times to assess the uncertainty of simulated results. The evaluation of model performance carried out using the coefficient of efficiency, ranged from 0.76 to 0.87. The relationship between storage characteristics and physical catchment properties such as soil depth, peatland percentage, elevation, and area were then analyzed using Spearman rank correlation.

The results of this study shows not only high differences in dynamic storage values among the sub-catchments but also the differences in locations of dynamic storage within the soil layers of peatland dominated catchments. The variations become even greater as we aggregate the storage amounts in shorter temporal scales. The magnitude and variability of total storage change calculated using water balance method was much higher than the dynamic storage estimated by HBV, indicating that not all the water stored in the catchments were available for draining to the stream. We also found that the total amount of dynamic storage in peatland dominated catchments were higher than the amount stored in forest on till and mixed characteristics catchments. Moreover, in peatlands, the proportion of water stored in the upper zone reservoir was much higher than the estimated amounts in other catchments (Spearman rank correlation $r=0.73$, $p < 0.05$), which also shows the ability of HBV in capturing the hydrological function of peat soils.