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Topographic controls of drought impact on Swedish primary forests

Anthropogenic climate change has increased the frequency of extreme drought events and leads to “hotter” droughts. Topography controls plant available water and site-specific climatic conditions. Drought sensitivity may therefore vary over short distances between wet and dry locations of the landscape. However, topography is rarely included as a factor in research investigating vegetation dynamics. Due to being located in often complex terrain and growing in unmanaged conditions, primary forests offer the opportunity to study the influence of topography on the impact of droughts on vegetation in natural ecosystems.

This study investigated the role of the local environment and topography in controlling drought impact of the 2018 summer drought in primary forests in Sweden, by applying a random forest modelling approach. Drought effects were modelled using summer 2018 Landsat EVI2 anomalies (z-scores) as a function of predictor variables including terrain indices, bioclimatic variables, and forest properties. Topographic predictors included primary terrain indices such as aspect, slope, and the Topographic Position Index (TPI) as well as the more complex compound terrain indices the Topographical Wetness Index (TWI) and Hight Above Nearest Drainage (HAND). The most influential variables were selected with a recursive feature elimination approach, creating a model with 13 predictors. The final model explained 48% ($R^2 = 0.48$) of the variance in an independent subset of EVI2 anomalies. Primary terrain indices described the spatial variability of z-scores better than compound terrain indices. Forest located on steep slopes, high topographic positions, and south facing aspects were associated with negative z-scores, indicative of reduced primary productivity. Valley bottoms and north-facing aspects mostly showed no or positive drought impact. Drought effects, meaning EVI2 anomalies were more negative with increasing distance to wetlands. These topographic and wetland effects on drought impact were seen across all forest types and latitudes, however the severity of negative drought impact differed between forest classes and was more pronounced in the south.

The results clearly show that the impact of the 2018 summer drought was strongly controlled by the local terrain in Swedish primary forests, highlighting the importance of incorporating topography in studies aimed at quantifying and predicting drought impact on vegetation. Previous research suggests that primary forests were less affected by the 2018 drought than managed forests were. This analysis suggests that the widespread drainage of wetlands and establishment of monocultures in managed forests may explain this difference. Forest management may therefore exacerbate the future impact of potentially more severe and more frequent droughts.

Keywords: Physical geography, ecosystem analysis, primary forest, boreal forest, drought impact, topography, drainage, climate change, random forest, terrain index

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