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Drought stress and vegetation characteristics on sites with different slopes and orientations

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Climatic changes are predicted and observed to change our natural environment, amongst others by increased periods of drought, i.e. periods with low rainfall and high potential evapotranspiration. Future droughts will affect future vegetation characteristics, which, through altered actual evapotranspiration, may impact on future groundwater recharge rates and on the future availability of fresh water for e.g. agriculture and drinking water. To timely anticipate on these changes, we need to be able to predict possible vegetation responses to increased drought conditions. Therefore, we introduce a process-based, ecological relevant index for drought stress and its relationship with vegetation characteristics. Together with simulations of future drought stress, we give insight in the effects of climate change on future vegetation characteristics and elaborate on vegetation feedbacks on future groundwater recharge.

We define drought stress in terms of transpiration reduction, which includes the main interacting processes in the soil-plant-atmosphere system, considering both the supply and demand of water, i.e. physiological drought. Because drought induced differences in vegetation characteristics can be observed on surfaces with different slope and aspect, we analyzed drought statistics, i.e. duration, frequency and two definitions of intensity of stress events, on contrasting slopes. Additionally, we compared the predictive capacity of a frequently used integrative drought index ('dynamic stress') based on mean intensity, duration and frequency of stress events, to our novel index that is based on uppermost intensities only. The latter approach assumes that especially the events that deviate most from the average conditions, i.e. the uppermost ones, will have most influence on vegetation characteristics.

We show that our novel index, focusing on uppermost intensities, is a better predictor of the fraction of xerophytes within a vegetation plot than the dynamic stress index. Apparently, it is not the number or duration of events but especially the most severe intensities that drive the vegetation. Therefore, we propose to focus on extremes rather than on means when relating drought stress to vegetation characteristics.

Doing so, we demonstrate an important vegetation response to increased drought stress: the fraction of bare soil and non-rooting species (lichens and mosses) in the vegetation will increase when, according to the expectations, summers become drier. Evapotranspiration of bare soil and non-rooting species is much lower than that of vascular plants and thus the vegetation composition feeds back on the soil moisture conditions.

Knowledge on such feedback mechanisms is indispensable in the analysis of climate change effects on the future groundwater recharge. Important questions are how, in the course of time, climate change will affect both groundwater table depth and dynamics, and how water management could adapt to these changes. We pursue a dynamic modeling approach that takes account of the interacting processes in the soil-plant-atmosphere system, including feedback mechanisms of the vegetation. This allows us to analyze climate change effects on groundwater recharge and thus future freshwater availability.