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Uncertainty in parameterisation and model structure affect simulation results in coupled ecohydrological models

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In semiarid environments water is not only a scarce resource, water availability also varies greatly in timing and magnitude. Both natural ecosystems and people have to adapt to these conditions, and often they share the same water source. Thus, management of the water source might influence natural ecosystems, but also inversely, the management of vegetation might affect the water fluxes. In order to understand, what implications human development in semiarid regions has, models are required that help investigating the effect of management actions. Such models need appropriate description of both ecological and hydrological processes.

In this study we developed and applied a conceptual ecohydrological model framework to investigate the effects of model structure and parameter uncertainty on the simulation of vegetation structure and hydrological dynamics. The model was applied for a typical water limited ecosystem along the middle section of the ephemeral Kuiseb River in Namibia. We modelled this system by coupling an ecological model with a conceptual hydrological model. The latter is storage based with stochastical forcing in form of flooding. The ecosystem is modelled with a population model representing three dominating tree species along the Kuiseb River. In appreciation of uncertainty about population dynamics, we applied four model versions differing in the assumptions on ecological traits of the plant species (phenology, sensitivity to floods) determining the plants' response to the water resources. We assessed these models regarding their ability to predict three observed qualitative ecological and ecohydrological patterns: (1) The coexistence of three tree species, (2) the species specific access to the unsaturated soil or ground water storage, and (3) the species specific vulnerability to the magnitude of flood events. Depending on the applied model version the parameter space was constrained differently, which revealed different coexistence mechanisms. The parameter combinations that complied with the observed patterns were subject to further investigations. We used ensemble statistics of average values of hydrological variables such as transpiration and depth to ground water to investigate the influence of uncertainty in model structure and parameterisation on the model output.
Our results suggest that average values of hydrological variables are mainly controlled by the applied hydrological model, whereas their fluctuations are probably controlled by the applied ecological model and the underlying coexistence mechanism. Further, uncertainty about ecosystem structure and intra-specific interactions influence the prediction of the hydrological variables.

This study illustrates that pattern-oriented modelling allows the identification of different model structures and parameter combinations that are potential ecosystems of the reality. The subsequent process of changing the model structure and comparing the outcomes with observed ecohydrological patterns helps to reveal driving system mechanisms that are essential when applying the model as management support tool.