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Integrated and adaptive management for sustainable water use along ephemeral rivers under severe uncertainty of future flood regimes

Sven Arnold (1), Sabine Attinger (1), Karin Frank (2), Peter Baxter (3), and Anke Hildebrandt (1)

(1) UFZ - Helmholtz Centre for Environmental Research, Department Computational Hydrosystems, Leipzig, Germany (sven.arnold@ufz.de), (2) UFZ - Helmholtz Centre for Environmental Research, Department of Ecological Modelling, Leipzig, Germany, (3) The Ecology Centre, School of Biological Sciences, The University of Queensland, Brisbane, Australia

Ephemeral rivers are located throughout the world's arid regions. They are characterised by temporary surface flow that strongly varies between seasons and years. Along the river course often a coupled eco-hydrological vegetation-groundwater system has established, which is referred to as linear oasis, reflecting the ecological and socio-economic importance of ephemeral rivers in otherwise dry areas. The Kuiseb River denotes such a linear oasis and is one of the most diversely used environments among the ephemeral rivers in Namibia. Along the entire river course surface runoff and ground water are exploited for drinking, farming, and mining. The middle section of the Kuiseb River is characterised by strong eco-hydrological feedbacks between the vegetation and the ground water resource. Temporary floods infiltrate into sediments, which are accumulated in geological pools of impermeable bedrocks. This enables the formation of shallow ground water. The low depth to ground water allows root water uptake by plants and the establishment of a thriving ecosystem.

The sustainable use of ecological and hydrological resources along ephemeral rivers is crucial to preserve the natural ecosystem. However, the investigation of management strategies that consider both the regulation of water extraction and vegetation structure requires models that explicitly consider the feedbacks between the water resource and the ecosystem structure. Further, uncertainties arise from stochastic hydrologic drivers such as flash flood events. Particularly in the face of climate change, the management strategies have to be applicable to a wide range of possible flood regimes, i.e. they have to be robust to the uncertainty of future flood regimes.

In this study we assess a variety of management strategies regarding their robustness under different theoretical ecosystems and under uncertainty in the future stochastic flood regimes along the Kuiseb River. We consider the trade-off between ecological and human requirements by investigating the management strategies in terms of their ability to sustainably exploit the ground water resource while preserving the natural vegetation structure (here: coexistence of three tree species). We apply a conceptual ecohydrological model and use the information gap decision theory to estimate the robustness of strategies to failure due to flood parameter uncertainty.

The performance of every strategy decreased as flood parameter uncertainty increased. However, ecological performance was more vulnerable with increasing uncertainty than the water supply performance, suggesting that the vegetation structure can be used as sensitive indicator and pre-warning system for changing environmental conditions. With the integrated and adaptive strategy it was most likely to sustainably use the ground water while preserving the natural vegetation structure, however, with the effect of reducing the probability of a large total system biomass.