IAHS2017-240
IAHS Scientific Assembly 2017

Representing the impact of agricultural water use on hydrology in semiarid regions – A distributed modelling approach in Southern African catchments

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Process-based hydrological modelling is a useful method to predict water availability and environmental impacts under scenarios of future development, which in turn is a crucial requirement for a sustainable water resources management. However, one of the challenges to accurately predict the hydrological implications of future changes is the adequate representation and assessment of the current hydrological conditions. This is especially problematic when considering human activities at small to medium scales such as water abstractions for agricultural purposes. Limited or unreliable climate and gauging observations can cause additional uncertainty to the hydrological assessment.

The Gaborone Dam catchment in Botswana is an example for the influence of human activities on flow dynamics. Here, the construction of more than 200 small farm dams spread across the catchment in conjunction with seasons of low precipitation are suspected to be the cause for a reduced dam inflow over the last years. Still, the individual effect of human activities on runoff generation and its associated impact on the dam inflow were not quantitatively assessed. Therefore, a spatially distributed, process-based hydrological model was developed for the basin. Based on the JAMS/J2000 hydrological modelling framework and a novel simulation component that reproduces the influence of small farm dams, this model aims at explicitly quantifying the impact of small-scale water abstractions throughout the basin. Accounting for the fact that precise information especially about smaller farm dams is often missing, this approach allows simulating the function of farm dams in a conceptual way. Using this new simulation module, the number of dams, their capacity and thus their impact on the runoff generation can be easily increased or decreased in order to adapt the model to any conceivable scenario.

In a validation step, the extension was transferred to the Verlorenvlei catchment, a part of the Sandveld area located in the Western Cape region of South Africa. Extensive dry periods in combination with an increasing domestic water demand, expanding irrigation agriculture and expected reduction in rainfall due to climate change present a challenging setup for water management in this region. As a result of the particular conditions, the use of improved management techniques, such as centre pivot irrigation and contour-bank farming, are necessary. In this context, the hydrological model was further adapted by implementing simulation routines that reflect these specific techniques.

In the present study we present modelling results from both applications indicating a notable impact of human activities on runoff and storage dynamics in the investigated basins.