Enhancing Sustainable Groundwater Use in South Africa - ESGUSA

Introduction

The overall objective of the project was to enhance the scientific basis for improving groundwater management in semi-arid areas in South Africa. With population growth and increasing climate variability, groundwater plays an increasingly important role in South Africa to enhance water and food security. Many communities depend on groundwater for their domestic and livelihood needs, including for irrigated farming. However, with increasing pressure on groundwater and intensive land-use, the resource is vulnerable to depletion and degradation. This is compounded by limited capacity and inadequate resources allocated to its protection and sustainable management.

The specific objectives of the project were: (1) to establish research partnership between Denmark and South Africa, (2) to improve the understanding of hydrogeological conditions in typical geological settings and farming communities in South Africa exemplified by the Hout/Sand river catchment (~8000 km^2) in Limpopo Province, (3) to develop an integrated hydrological model for the catchment in order to improve the understanding of the hydrological functioning of a typical semi-arid catchment highly dependent on groundwater in the rural areas, benefitting from remote sensing techniques for acquiring data on e.g. rainfall and soil moisture, (4) to involve and train stakeholders and citizens in groundwater monitoring and protection, and (5) to increase the research capacity in South Africa in groundwater resource assessment and management.

Results

Extensive spatial data on topography, land use, soil and geology as well as historical time series of climate, hydrology and hydrogeology data have been collected and stored in a database. The data are crucial for development and calibration of the integrated hydrological model for the Hout/Sand catchments, which has been applied to understand and assess the hydrological dynamics.

The geological and hydrogeological settings of the study area have been reviewed based on existing information and supplemented by dedicated hydrogeological and geophysical field investigations. The analysis confirmed that the gneiss crystalline basement lithological settings are of major significance for groundwater resources in this part of South Africa. Faults and dykes are important geological structures, which control the presence and abstraction potential of groundwater. Based on the field investigations, hydrogeological monitoring infrastructures have been established next to two river segments in the catchments for automatic monitoring of groundwater levels at different depths and distances from the riverbank of the ephemeral river. The infrastructures have provided data for investigating the dynamics of groundwater flow in response river flow. Groundwater recharge can occur as focused recharge beneath ephemeral rivers in response to intermittent river flow from intense rainfall, or as diffuse distributed recharge at catchment scale. The project has documented a large influence of focused recharge and that this component can be significant in the overall recharge to aquifer systems in semi-arid regions, especially close to rivers. It has further been shown that even though the total amount of rainfall may be less in a future climate, recharge may in fact increase as rainfall may be more concentrated in high-intensity events thus potentially leading to more overall groundwater replenishment. Recharge in semi-arid regions is generally of episodic nature and enhancement of episodic recharge during intense rainfall events can offer a strategy for purposefully increasing recharge through various means. Such methods, referred to as managed aquifer recharge, are important means to enhance climate change adaptation.

An integrated hydrological model based on the MIKE SHE code has been developed for the Hout/Sand catchments. Also, a complementary simple rainfall-runoff model has been developed. Hydrological modelling for the semi-arid catchment is extremely challenging as the hydrogeological conceptualization of the catchment and the dynamics of rainfall transformation into river runoff are subject to many unknowns. Various satellite rainfall products have been tested. Although such data are uncertain, they provide an improved spatial resolution, which is important for simulating the hydrological response and dynamics. In addition, a procedure for combined use of data from SMAP and Sentinel-1 for downscaling information on soil moisture has been developed.

For a hydrological system where groundwater and rivers are loosely or intermittently connected, sustainability indicators are very different from those that apply to temperate regions such as Denmark. The average annual groundwater recharge is one indicator but since recharge has a significant inter-annual variation and moreover

may be absent for several years with an associated long-term decline in groundwater levels, the inter-annual recharge dynamics and particularly the episodic events are important and constitute a key indicator under both current and future climate conditions.

As part of the citizen science activities, data on groundwater levels, rainfall, and river levels have been collected in three sections in the Hout catchment representing both small-scale and commercial farmers. The data have been transferred via an app to the website https://www.citizenscientists.biz/about, where the observations can be displayed. The results had implications for the local citizens, as they previously did not have a clear understanding of how groundwater level fluctuations could impact their access to water for homesteads as well as commercial farms. Especially small-scale users had little knowledge of groundwater, and the citizen science component also played a critical role in raising awareness and having users take more responsibility in the management of their own resources. Furthermore, farmers could communicate with each other through the citizen science app on their smartphones. Hereby they were able to perceive the catchment as a whole rather than just their own isolated area and that they all depend on groundwater, a resource that unites rather than divides them.

Five junior researchers from South Africa and two from Denmark contributed to the project and worked together on the various project components. In addition, several BSc and MSc thesis students from both countries contributed to the research activities.

Conclusions

The project has given important insight into the hydrological functioning of the semi-arid Hout/Sand catchments. Groundwater recharge is of critical significance for the water resources availability in the region, and it is of episodic nature both for the diffuse and focused components. This implies that groundwater replenishment may not occur annually, leading to multi-year decline in groundwater levels eventually constraining the use of the resource. Our analyses clearly documented that focused recharge is an important recharge component for areas near the river segments. Further investigation of these processes is in focus in the next project phase.

With further refinement, including additional use of satellite-based spatial data and elaborate calibration of the integrated hydrological model, more reliable projections of the impact of climate change on the hydrological regime can be made. Likewise, the refined model will underpin the development and analysis of water management scenarios under current and future climate conditions, guiding policy decisions.

The citizen science activities have shown that citizens want to gain more knowledge of groundwater as they depend heavily on this for their everyday life and livelihoods. Furthermore, in these relatively remote areas, people feel disconnected from one another, and it is positive for them to feel connected through a smartphone chat option. Hence, citizen science has a positive spinoff from both a data procurement point of view and from the human/social aspect. It is a relatively inexpensive way to collect useful data that is otherwise unavailable and also to foster stewardship of a precious resource.

Recommendations

The research will be used to further develop the hydrological model in collaboration with stakeholders and benefitting from citizen science data to provide targeted water management information and guidance at catchment, community and farm level and thereby enhance the sustainable use of groundwater at different scales. The research can also be further developed to enhance sustainable management of irrigation and climate-smart agriculture and to support climate change adaptation and build climate resilience. To increase security in domestic water supply, solar-driven SafeWater water dispensers will be installed and tested in medium-sized communities under significant water stress in the next phase of the project. Such dispensers will enhance access to clean and safe groundwater for domestic and multiple uses. The research results will further be used for developing schemes for augmenting and managing the groundwater resources by managed recharge of reclaimed water in the target catchments.

Innovative citizen science technologies developed in the project now allow volunteers and the project team to communicate and interact effectively. Based on the success of the first phase of the project, citizen science activities are now supported by projects funded by the Water Research Commission (WRC) of South Africa.

Stakeholders and local citizens will in the next phase be further capacitated in groundwater resources and bio-physical process understanding, monitoring and sustainable water management to enhance water security under future uncertainty.