

Impact of Future Climate Change on Groundwater Resources in an Arid Setting

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Changes of the earth's climate have a direct effect on global and regional hydrological cycles. Changes in precipitation pattern and intensities will influence groundwater recharge and thus available groundwater resources. Especially, arid settings will be most sensitive to the predicted changes of the earth's climate.

The impact of changes in climate on groundwater resources can be estimated by coupling a climate change model with a groundwater model. The climate model (EGMAM (Huebener et al., 2007) or CCLM (<http://www.clm-community.eu>)) simulates the climate change between 2000 and 2099 on a large scale based on three different emission scenarios (A1, A2, B1). The scenarios vary in population growth, primary energy requirements, greenhouse gas emissions and use of gross domestic products. Calculated precipitation, temperature and evaporation are used as input function for the groundwater model. In an arid environment, e.g. the Arabian Peninsula, the expected sea level increase of up to 1.4 m has only minor impact on the groundwater resources compared to the predicted decrease in precipitation by 40 mm/a and a temperature increase of 5°C that is calculated by the most extreme scenario A2.

Precipitation is converted to recharge using a hydrological model and scaled with respect to predicted changes in precipitation. Evaporation calculated by the climate model is directly transformed to evaporation from sapkhas. Population is expected to increase in Asia between 0.3% (low expectation of life and birth rate) and 1.4% (high expectation of life and birth rate) per year until 2050. In 2050 the Asian nation might reach its maximum population and decrease by 0.7 to 0.08% per year until 2100 (UN, 2004). Groundwater extraction rates are considered to vary as function of population growth. However, this might be unrealistic due to improved techniques for waste water use, sea water desalination and adapted agriculture practices.

The climate model is coupled with a long-time and large-scale groundwater model that calculates the impact of climate change since the last 10,000 years on the groundwater resources in SE Saudi-Arabia (Engelhardt et al., in prep). The model is calibrated by groundwater levels that are measured since 1980 until today and by spring discharge. The model is validated by groundwater ages calculated by ¹⁴C data.

The predicted climate change will result in a strong decrease of the groundwater levels of up to 30 m within the main industrial and agricultural areas. Especially, shallow aquifers are mostly affected by the groundwater level decline. However, groundwater levels that are far away from the main industrial and agricultural areas show a decline of a few meters. Thus, these parts of the aquifer system will still yield usable groundwater resources for human needs in future. Within the main industrial and agricultural areas the slightly decreased groundwater extraction rates between 2050 and 2100 are superposed by the shift in precipitation resulting in a further groundwater level decline. While until 1980 recharge exceeds still groundwater extraction rates, in 2050 extraction rates will be about 4 times and in year 2100 up to 8 times higher than recharge rates.

Simulations results bias uncertainties of the predicted climate change, population growth and future technical developments. Therefore, further simulations are carried out that combine the all predicted variations of the climatic and population models. This will give the

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full range of future maximum and minimum groundwater resources within an arid region that is predicted to be strongly affected by the earth's climate change.

References

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Simulation and Prognosis of the Impacts of Climate Changes on Groundwater Recharge under Local Conditions

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Abstract Human activities, like deforestation, burning fossil fuels, use of greenhouses and growing of world population, cause to release of carbon dioxide and increase its amount in the Earth's atmosphere. This leads to serious changes of climate in all over the world. The main climate changes occur to the Earth's temperature and precipitation, which affect the groundwater recharge rate and increase water resources stresses in many regions. Even in parts of the world, where climate change increases runoff, for example in Europe and particularly in southern and eastern Asia, the increases tend to come during the wet season and the extra water may be not available during the dry seasons.

The main purpose of this study is to simulate the effects of potential climate changes, specially the changes of temperature and precipitation intensity, on drainage and groundwater recharge rate, because the infiltration rate is influenced by water conductivity, current water content, properties and texture of the soil, through implementation of different scenarios by means of the program PCSiWaPro (developed at the Technische Universität Dresden, Institute of waste management and contaminated site treatment), which is a 2D computerized forecast advisory system for water balance in the unsaturated soil zone under steady state and transient conditions and it is combined with a stochastic weather generator (WettGen), which enables to generate time series of any length for the observed location on the basis of existing time series from surrounding gauging weather stations. Parameterization of the weather simulation tool is done on the basis of available weather data from local weather stations of the German Weather Service (DWD). The creation of synthetic data time series of precipitation, temperature and evapotranspiration is up to a time resolution of 1 day. Water flow processes are calculated with the Richard's equation. Precipitation and evapotranspiration of soil-plant system are considered in the program as source and sink of water balance. The simulations using PCSiWaPro and WettGen scenarios, which are constructed as 2D-models, also indicate the role of land use and land cover on groundwater recharge rate. Further models like water removal caused by plant roots, snow storage and interception are also integrated. The initial