Scenario analysis and prediction of future groundwater resources for the Western Mountain Aquifer

Key findings

- Three scenarios based on projections of low, medium, and high population increase are investigated in terms of their relevance to groundwater management: „Regional Nature Conservation“ (RNC), „Baseline“ (B) and „Regional Resources Intensive“ (RRI).
- We apply the RCP4.5 COSMO-CLM (8 km resolution) climate model, which indicates a temperature increase by up to 2.5 °C until 2070 during the recharge-effective winter season, as well as a precipitation decrease by 40% in the fall.
- Numerical simulations of the non-atmospheric water cycle suggest a 5 m groundwater level decline by 2040 for the resource-intensive scenario.

Motivation

The Mediterranean water resources are characterized by water scarcity due to specific climatic conditions (i.e., seasonality in precipitation and specific groundwater recharge patterns) and due to increased water consumption because of economic growth and population increase. Scenario analysis is a useful tool to reveal the impact of external developments and support stakeholders in decision-making by showing the impact of management options. In MedWater, various scenarios are investigated for the Western Mountain Aquifer (WMA) in Israel and the West Bank based on population growth and various management factors regarding their impact on water resources and ecosystems. Early water management practices (1950 until 1970) consisted solely of the utilization of groundwater and the rapid construction of local and regional water supply facilities to satisfy increasing demands. However, the heavy abstraction of groundwater led to a drop in groundwater levels and the drying up of the Yarkon spring in the 1960s.

Methodology

We investigate three explorativ scenarios of population increase based on the low, medium, and high-variant projections by the United Nations (2019). The RCP4.5 COSMO-CLM climate model (Hochman et al., 2018) with a spatial resolution of 8 km for the CORDEX-MENA region is uniformly considered for all scenarios as an external driving force. Three narrative management scenarios, „Regional Nature Conservation“ (RNC), „Baseline“ (B), and „Regional Resources Intensive“ (RRI), are defined based on the three explorative population growth scenarios, respectively. The scenarios were developed in close cooperation with local water authorities. For the quantification of the individual management factors, input from local stakeholders, publicly available governmental data, and published research was employed. The impact of climatic change on groundwater resources is investigated with an integrated surface-subsurface flow model (HydroGeoSphere), where

Scenario analysis

A scenario is a hypothetical description of the future development of the groundwater system, based on expected changes in recharge and water demand. The acquired information provides insight into the outcome of specific management decisions and external developments. They also serve as a communication tool to figuratively draw public attention to the implications of political decisions and unravel the latitude of potential trends. Normative scenarios assimilate interests and values with the aim of guiding the decision-making process, whereas explorative scenarios investigate possible trends regardless of their desirability and with limited measures of interference.

MedWater – Sustainable management of politically and economically highly relevant water resources in hydraulically, climatically, and ecologically dynamic carbonate aquifers of the Mediterranean.
Funding code: 02WGR1428A
SPONSORED BY THE Federal Ministry of Education and Research
FONA Research for Sustainable Development BMBF
An Initiative of the Federal Ministry of Education and Research GRoW WATER AS A GLOBAL RESOURCE

daily precipitation from the COSMO-CLM climate model directly serves as an input boundary to the overland flow continuum. Daily potential evaporation is computed from the climate model based on the Penman-Monteith equation.

Results

The high-resolution regional climate projections show a median increase of temperature by up to 2.5 °C and an increase of consecutive dry days until 2070. Precipitation will decrease by 40% in the fall. Scenario analyses employing the developed HydroGeoSphere model explored the impact of pumping rate adaptation due to global and political changes. A total of 506 wells are implemented in the model to model accurate temporal and spatial abstraction patterns. The RRI scenario assumes a 25% increase of the pumping rates for 2040 as compared to the levels of 2020 (Figure 1). Simulations indicate a rapid 2 m groundwater level decline over the next 5 years followed by a further drop of 3 m by 2040 in the resource-intensive scenario (Figure 2).

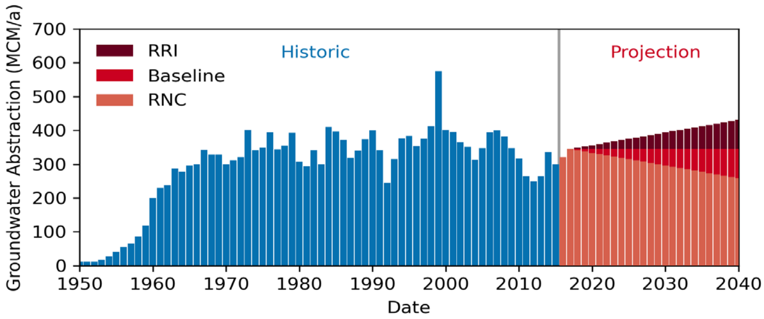

Figure 1: Total annual groundwater abstractions according to the RNC, B, and RRI scenarios

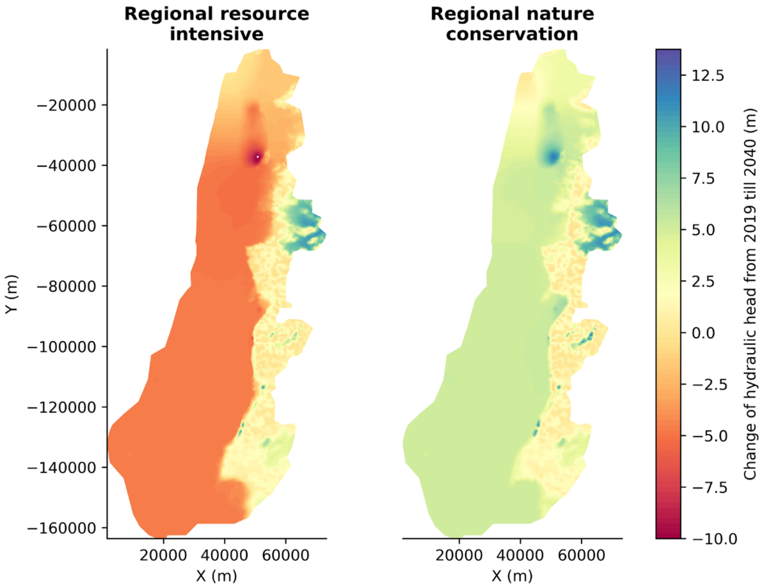

Figure 2: Change of hydraulic head from 2019 to 2040 according to the RRI and RNC scenarios

Application

The analysis of individual scenarios may be complemented in the future with detailed spatial pumping scenarios, i.e., optimizing locations of pumping wells to avoid intrusion of saltwater into the aquifer. In addition, the potential of the WMA as a strategic storage of reclaimed water may be further investigated. Managed Aquifer Recharge (MAR) may allow to effectively store water within suitable locations of the aquifer and provide groundwater resources for exceptionally dry periods under consideration of the aquifer's complex infiltration and flow dynamics. Additionally, the regional model can be scaled down to the recharge area or specific karst features (i.e. dolines), allowing for further detailed studies on the infiltration dynamics. Local authorities repeatedly affirmed their interest in a spatio-temporally distributed recharge assessment that provides a higher accuracy for potential planning purposes.

References

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Authors	Affiliation	Department	Email
Lysander Bresinsky	University of Göttingen	Geoscience Center	lbresin@gwdg.de
Jannes Kordilla	University of Göttingen	Geoscience Center	jkordil@gwdg.de
Martin Sauter	University of Göttingen	Geoscience Center	msauter1@gwdg.de