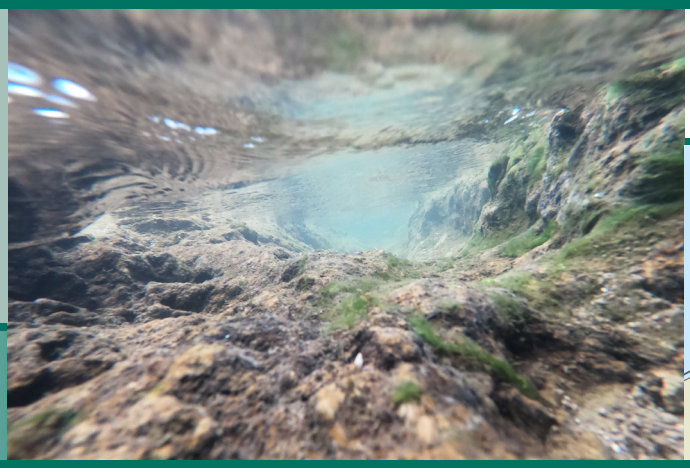

Scenario analysis for the prediction of future groundwater resources in the Western Mountain Aquifer

Key findings

- Three groundwater management scenarios – Regional Nature Conservation (RNC), Baseline (B) and Regional Resource Intensive (RRI) – are investigated with regards to their respective impact on groundwater resources.
- The RCP4.5 climate change scenario is the basis for all management scenarios.
- The results indicate an average groundwater level decline under the RRI scenario by 7.8 meters over the next 25 years, while the RNC scenario suggests that groundwater levels increase by 3.3 meters until 2050.

Motivation

Groundwater resources in the Mediterranean region are vulnerable to drought because of specific climatic conditions (i.e., temperature, seasonality in precipitation, and specific groundwater recharge patterns) and increasing water consumption due to economic and population growth. Scenario analysis is a valuable tool to reveal the impact of external developments and support stakeholders in decision-making by showing the impact of different types of management options. For the Western Mountain Aquifer (WMA) in Israel and the West Bank, early water management practices from 1950 until 1970 consisted solely of utilizing groundwater and the rapid construction of local and regional water supply facilities to satisfy increasing demand. However, heavy abstraction led to a drop in groundwater levels and the drying up of the Yarkon/Ras Al Ain spring in the 1960s, highlighting the importance of adequate groundwater management. Here, we assess the impact of groundwater management options and climate change on groundwater resources.

Methodology

We employ a downscaled RCP4.5 COSMO-CLM climate model (Hochman et al., 2018) with a spatial resolution of 3 km for the CORDEX-MENA region. This climate change scenario is considered uniformly across all management scenarios as an external driving force. With precipitation and reference evapotranspiration from the COSMO-CLM climate model as input to a dual-continuum soil water balance model, daily infiltration was calculated at the level of the zero-flux-plane (Figure 1a). Three groundwater management scenarios – Regional Nature Conservation (RNC), Baseline (B), and Regional Resources Intensive (RRI) – are assessed, each associated with different abstraction rates from the WMA (Figure 1b). The abstraction rates for the Baseline scenario are

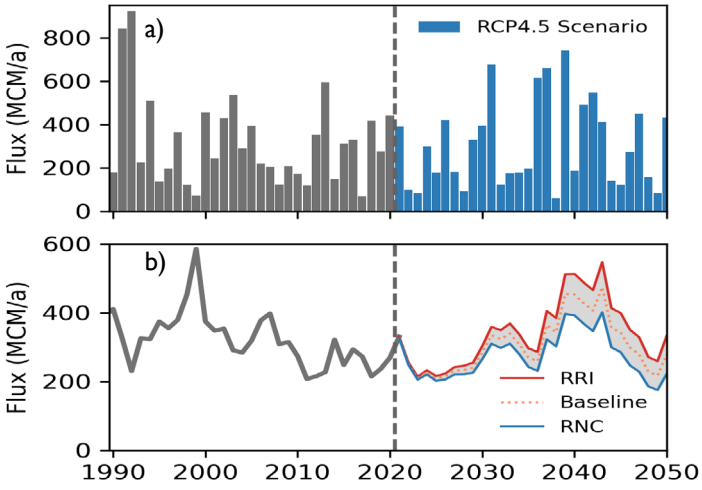

Figure 1: Model input for a) infiltration at the level of the Zero-Flux-Plane under the RCP4.5 climate scenario and b) annual groundwater abstractions under the RNC, B, and RRI scenarios

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defined based on the current management plan of the Israeli water authority that currently limits groundwater abstractions to the 5-year moving average of recharge. In contrast, the RNC and RRI scenarios assume respectively a 20% decrease and increase from the Baseline scenario. We implemented the groundwater abstraction scenarios for a total of 506 wells presently operating. The distribution of pumping rates is assumed to be proportional to the present distribution. The impact of climate change and management scenarios on groundwater resources is subsequently simulated by a variably saturated dual-continuum flow model (HydroGeoSphere), computing the time-dependent storage of a several hundred meters thick vadose zone and the duality of karst groundwater flow dynamics in the vadose and phreatic zones.

Results

The high-resolution regional climate projection indicates a median increase in temperature by up to 2.5 °C and an increase in consecutive dry days until 2070. Furthermore, the climate model projects a more pronounced inter-annual variability of precipitation, resulting in a more pronounced variability of recharge. The numerical simulations of dual-domain infiltration and groundwater flow indicate an average groundwater level decline under the RRI scenario by 7.8 meters during the next 25 years. The RNC scenario suggests that groundwater levels increase on average by 3.3 meters by 2050. Figure 2a shows simulated groundwater levels at the observation well "Petah Tikva 01", located in the east of Tel-Aviv, which serves as a reference well representative of the central part of the WMA. Simulations suggest that groundwater levels and spring discharge may drop substantially below the red line under the Baseline and RRI scenarios (Figure 2a & b).

Application

The analysis of individual scenarios may be complemented in the future by detailed spatial pumping scenarios, i.e., optimizing locations of pumping wells to avoid intrusion of saltwater into the aquifer in the North-West. In addition, the potential of the WMA as strategic storage of reclaimed water may be further investigated. Managed Aquifer Recharge 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. Suitable locations are defined by extended mean residence times characteristics. Additionally, the regional model can be scaled down to the recharge area or specific karst features (i.e., dolines), allowing further detailed studies on the infiltration dynamics. Local authorities repeatedly stated their interest in a spatiotemporally distributed recharge assessment that provides higher accuracy for planning purposes.

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 independent of their desirability and with limited measures of interference.

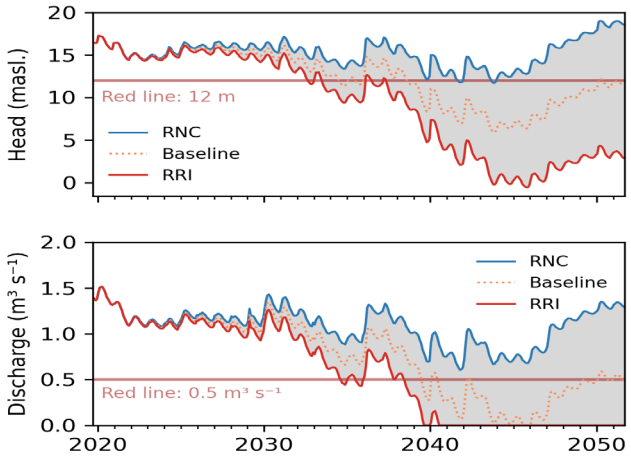

Figure 2: Change in a) hydraulic head in the observation well "Petah Tikva 01" and b) spring discharge at the "Taninim/Al Timsah" spring from 2020 to 2050 according to the RNC, B, and RRI scenarios

References

Hochman, A., Mercogliano, P., Alpert, P., Saaroni, H., & Bucchignani, E. (2018). High-resolution projection of climate change and extremity over Israel using COSMO-CLM. *International Journal of Climatology, 38*(14), 5095-5106. https://doi.org/10.1002/joc.5714

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