Groundwater recharge estimation for the Western Mountain Aquifer with the Soil & Water Assessment Tool

Key findings

- We applied the Soil & Water Assessment Tool (SWAT), which was originally developed for porous medium, to perform high-resolution recharge calculations for the karstified Western Mountain Aquifer (WMA).
- The WMA shows great spatial differences in groundwater recharge. The northern and western parts of the recharge area contribute most to total recharge.
- About 34% of annual precipitation enters the WMA as recharge.
- According to two climate projection models, groundwater recharge may decrease between 16% and 25%.

Motivation

Groundwater recharge is an essential component of groundwater simulations that serve as important assisting tools for management decisions. The accurate estimation of recharge is critical for sustainable water use on a catchment scale. Recharge calculations for the Western Mountain Aquifer (WMA) in Israel and the West Bank have so far solely been based on empirical equations and therefore are limited in their spatial and temporal resolutions. Empirical equations calculate recharge of the entire aquifer by using monthly or annual means of precipitation data. With the Soil & Water Assessment Tool (SWAT; Arnold et al., 1998), we calculate the entire water balance for the WMA on a daily basis with a particular interest in determining groundwater recharge. The goal is to create an accurate model that shows the spatial and temporal distribution of recharge and is able to simulate the effects of extreme weather events.

Methodology

SWAT is a hydraulic-hydrological model that is based on empirical equations calculating the water cycle within a defined system. It can be used to assess water quantity and quality. Furthermore, SWAT can simulate the influence of different land use types on the hydrological cycle. For these calculations, SWAT requires specific information about soil properties, topography, vegetation, and land use in a watershed. This information serves to create Hydraulic Response Units (HRUs) in each sub-catchment. The characteristics of each HRU are combined with daily climate data (precipitation, max-/min- temperature, relative humidity, solar radiation, wind) to calculate the water balance on HRU scale with empirical equations. SWAT calculates the actual evapotranspiration, surface and subsurface runoff as well as recharge to the deep aquifer. In addition to creating models on a large spatial extent, SWAT works over long periods of time with available climate data. Therefore, it is able to simulate long-term climate developments as well as single extreme weather events on the watershed, sub-basin, or HRU level.

Soil & Water Assessment Tool (SWAT)

The Soil & Water Assessment Tool (SWAT) calculates the water balance on a daily basis with spatial information about land use, soil properties, and topography, which form unique Hydrological Response Units (HRUs), and time-dependent climate data. The calculations are based on empirical equations and provide accurate data with high temporal and spatial resolutions. The SWAT model can be calibrated with any observed data such as surface runoff or actual evapotranspiration and adjusts sensitive parameters such as transmission loss.

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

Groundwater recharge estimation for the Western Mountain Aquifer with the Soil & Water Assessment Tool

MedWater

Results

The problem of modeling a karst instead of a porous aquifer is solved by simulating influent conditions within the wadis. This models the fast flow component of karst aquifers, while the large-scale percolation covers the slow flow component. It was due to this addition that surface runoff after extensive rainfall events was able to decrease rapidly after calibration. The calibrated SWAT model shows high spatial variations of groundwater recharge in the model area, which covers around 80% of the WMA's recharge area (Figure 1). Overall, groundwater recharge shows similar trends as precipitation, which decreases with increasing elevation to the east and south. On average, 34% of precipitation in the recharge area contributes to groundwater recharge, while the rest evaporates or becomes surface runoff. SWAT calculates an annual average recharge of 199 mm. After calibration, we applied the SWAT model to predict future recharge rates based on climate projections with resolutions of 3x3 (unpublished) and 8x8 km (Hochman et al., 2018). In the long-term, as total precipitation decreases, we also observe a negative trend in recharge (Figure 2). According to the 8x8 km grid climate predictions, mean groundwater recharge in 2050-2070 is only 84% of the mean recharge in the period 1980-2000. The observed decrease for the 3x3 km grid climate predictions is with 25% even higher.

Application

Calculating recharge in a highly karstified aquifer is challenging but of great importance due to its comparatively lower storage potential. This makes karst aquifers highly vulnerable to potential decreases in precipitation and recharge caused by climate change. With SWAT, we were able to create the first high-resolution recharge map for the WMA. In the future, the significance of each land use type could be investigated to provide more detailed management recommendations that help store water and slow down the rapid congregation and downstream flow after heavy rainfall events, which will intensify according to the climate models. Awareness of a possible recharge deficit is important to adjust future pumping rates. In addition, alternative freshwater sources should be identified to limit water stress in Israel and the West Bank.

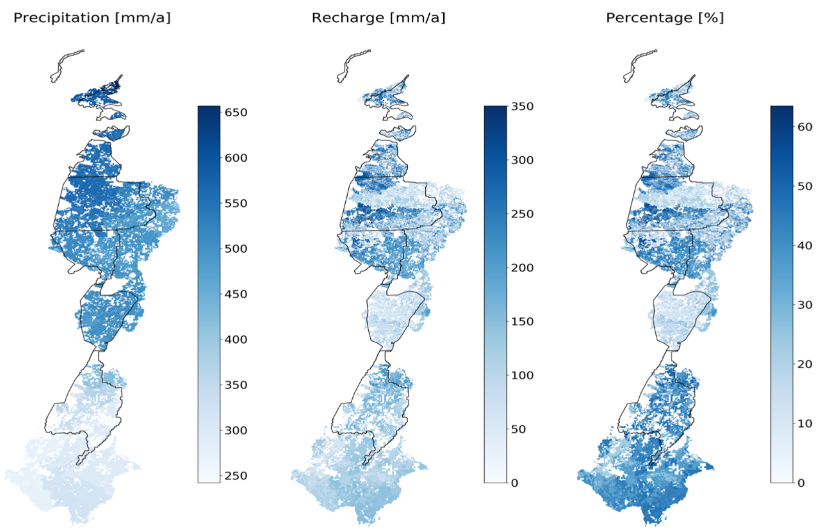

Figure 1: Annual means of precipitation, recharge, and the recharge/precipitation ratio on HRU level for 1990-2018

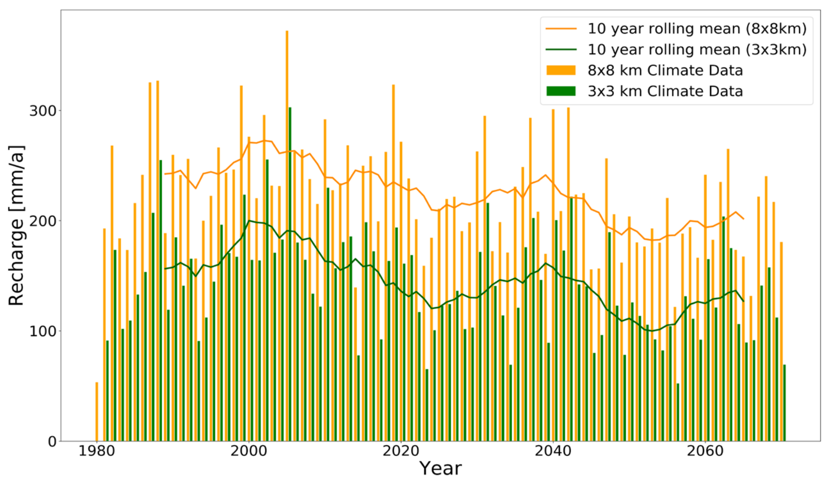

Figure 2: Recharge projections based on 8x8 km and 3x3 km grid climate models. The additional line graphs show the 10 year rolling means.

References

Arnold, J.G., Srinivasan, R., Muttiah, R.S., & Williams, J.R. (1998). Large area hydrologic modeling and assessment part I: Model development. *Journal of the American Water Resources Association, 34*(1), 73-89. https://doi.org/10.1111/j.1752-1688.1998.tb05961.x

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

Authors	Affiliation	Department	Email
Paul Hepach	TU Berlin	Hydrogeology	paul.hepach@tu-berlin.de
Martin Sauter	University of Göttingen	Geoscience Center	msauter1@gwdg.de
Irina Engelhardt	TU Berlin	Hydrogeology	irina.engelhardt@tu-berlin.de