Comparison of methods to calculate groundwater recharge for the karstic Western Mountain Aquifer

Key findings

- We calculate groundwater recharge for the Western Mountain Aquifer (WMA) with the Soil & Water Assessment Tool (SWAT) and compare the results with two established empirical methods: Zukerman (1999) and Abusaada (2011).
- While Zukerman calculates higher recharge in wet years, Abusaada calculates higher recharge in years with average to low precipitation.
- The SWAT and Zukerman methods estimate recharge to be ca. 30 % of annual precipitation, while it is 37% according to Abusaada.

Motivation

Recharge is the most important input factor of groundwater models. It occurs in the outcrops of the karstic Western Mountain Aquifer (WMA) in Israel and the West Bank at different rates due to a dual-type flow system comprising conduit flow (fast flow component) and diffuse infiltration (slow flow component). Recharge is not only determined by surface properties but also by the distribution of precipitation throughout the year. The Soil & Water Assessment Tool (SWAT; Arnold et al., 1998) addresses this problem and calculates daily recharge rates on a small spatial scale. This great spatial and temporal resolution is not offered by any other recharge estimation method. Standard empirical equations are used traditionally to calculate recharge with one set of equations without taking into account spatial differences or the influence of extreme weather events. Here, we compare the recharge estimates from a SWAT model to those calculated with two established empirical methods.

Methodology

Recharge estimates from the developed SWAT model were compared to recharge rates calculated with the empirical methods of Abusaada (2011) and Zukerman (1999). While SWAT calculates the water balance with daily climate data and therefore takes into account the influence of extreme precipitation events and potential over-saturation of the soil, the empirical methods only use monthly (Abusaada) or annual (Zukerman) precipitation amounts. As Abusaada assumes that recharge occurs mostly during the wet months of November – March, he specifically developed a set of equations for these months. Zukerman on the other hand developed equations for different annual precipitations, claiming that the percentage of precipitation resulting in groundwater recharge increases with greater annual precipitation. All three methods have been used to calculate and visualize annual recharge in the WMA´s recharge area based on the same climate data (Israel Meteorological Service).

Results

The recharge comparison for the period 1990-2018 shows an average annual recharge of 144 mm (SWAT model), 182 mm (Abusaada), and 147 mm (Zukerman). Annual mean precipitation was 485 mm. Figure 1 shows the annual correlation between precipitation

Recharge estimation

Recharge rates for the WMA are estimated with different methods such as empirical equations by Zukerman (1999) and Abusaada (2011), as well as a SWAT model, which calculates the water balance. While the empirical methods only use monthly or annual precipitation data averaged over the entire recharge area, SWAT requires additional information about temperature, solar radiation, relative humidity, wind velocity as well as information on soil and topography.

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and recharge, as calculated by the three methods. During the extremely wet years 1991, 1992, and 1994, Zukerman´s equation calculates the highest recharge, while it underestimates recharge during years with average precipitation compared to Abusaada. The SWAT model does not calculate greatly increased recharge in wet years, while two consecutive wet years affect the recharge volume heavily (Figure 1; 1991-1992). The extremely dry years of 1999 and 2017 on the other hand resulted in an underestimation of Zukerman´s recharge and slightly below-average recharge for SWAT and Abusaada. Overall, the SWAT model does not show a strong correlation between annual precipitation and recharge (Figure 2). The percentage of precipitation resulting in groundwater recharge is around 30 % as calculated with the SWAT model and Zukerman´s equation, compared to 37 % for Abusaada's equation.

Application

Over a long period of time, recharge should be equal to spring discharge plus abstractions if the pressure heads are constant. This still has to be calculated for validation of the three compared methods. 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. Identifying and applying the most accurate method for recharge estimation is very important for future management of the Western Mountain Aquifer and to better assess the volume of stored water.

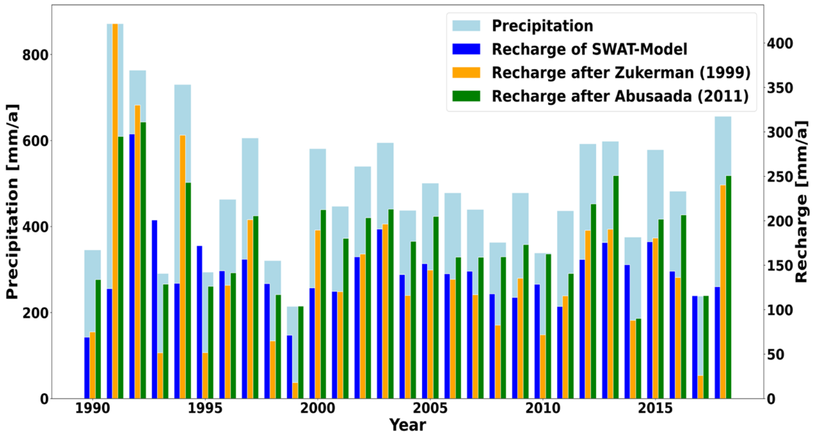

Figure 1: Precipitation and recharge from 1990 to 2018, as calculated by the SWAT model and empirical functions from Abusaada (2011) and Zuckerman (1999)

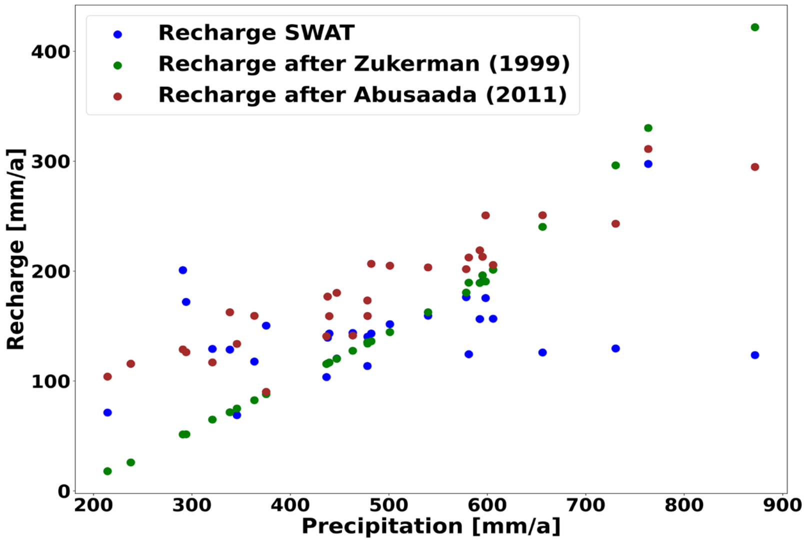

Figure 2: Scatter plot of annual precipitation and recharge as calculated by the three methods

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