



## Current and future ecosystem services provided by the Western Aquifer Basin

### Key findings

- The Western Aquifer Basin provides high surface water and groundwater regulation services. We expect them to decrease under future climate change conditions.
- Water quality regulation is high due to low nitrate pollution.
- The ecosystem services index for soil protection is also high.
- The ecosystems responsible for food production provide a relatively low percentage of the total food demand. Food production reliant on groundwater resources is expected to decrease with climate change.

### Motivation

Karst aquifers play a vital role in the regional management of ecosystem services, especially the provisioning of potable water and irrigation water for agriculture (thus safeguarding drinking water and food security), but also erosion regulation. They are vulnerable to human impact and are difficult to manage, especially in the Mediterranean climate where groundwater recharge and flow dynamics are extremely variable. The Western Aquifer Basin (WAB) in Israel and the West Bank faces additional water

stress due to rapid climate change and a high population growth rate. The high domestic and agricultural water demand increases the pressure on groundwater resources, while projected climate change could reduce groundwater recharge due to decreasing precipitation and increasing evapotranspiration. In this study, we quantify the impact of climate change (i.e., altered precipitation and temperature) on ecosystem services in the WAB.

### Methodology

To predict plausible future changes in ecosystem services, we applied the Soil & Water Assessment Tool (SWAT). The model area is split into a recharge zone with mountainous karstic features and a non-recharge zone. The precipitation varies from 150 mm in the South to 500 mm in the North. To capture the different catchment properties well, two separate SWAT models were developed with the data sets listed in Table 1. The models were calibrated with monthly stream discharge data. Due to karstic and non-karstic zones

and multiple rivers in the watershed, multi-sites model calibrations were performed. The model outputs of monthly river discharge, yearly groundwater recharge, monthly nitrate concentration, yearly sediment yield, and yearly biomass and crop yield were used to analyze different ecosystem services. They were determined by i) the index for regulation of surface water quantity, location, and timing (IRSWQLT) from the estimated river discharge (cum) and observed flow, ii) the index for regulation of groundwater quantity, location, and timing (IRGWQLT) from the estimated deep aquifer recharge, well abstraction, and spring discharge (MCM), iii) the index for regulation of water quality (IRWQ) from estimated and allowable nitrate concentration (mg/L), iv) the index for protection of soils and sediments (IPSS) from estimated and allowable sediment yields (ton/ha), and v) the index for food and feed (IFF) from crop biomass (ton), crop yield (ton/ha), and maximum crop yield. These ecosystem services indices were analyzed

Table 1: Data sets used for SWAT model development

Data	Spatial Resolution	Source
DEM	30 m	SRTM
Land-use map	30 m	UBAY based on Hamaraag and IMA
Soil map	250 m	Ravikovich (1970)
Soil profile		The Soils of Israel by Singer (2007)
Crop management		FAO
Weather	daily	IMS, NCEP

SRTM = Shuttle Radar Topography Mission, IMA: Israel Ministry of Agriculture, FAO = Food and Agriculture Organization, IMS: Israel Meteorological Services, NCEP: National Centre for Environmental Prediction

### Ecosystem services

Humans depend on Earth's ecosystems and the services they provide. They include food, water, sediment regulation, nutrient regulation, and hazard regulation. In this study, ecosystem services are quantified with the Soil & Water Assessment Tool (SWAT; Arnold et al., 1998) using the 'Index' approach (Logsdon & Chaubey, 2013). All indices have unitless values between 0 and 1, where ecosystem services are lowest at 0 and highest at 1.

for the period 2003-2015 on the watershed and subbasin level, both for the recharge and non-recharge zone. The ecosystem services indices under future climate change conditions were analyzed until 2070 under climate change scenario RCP4.5.

### Results

The current indices for different ecosystem services (Figure 1) are compared with the indices of ecosystem services under future climate change conditions (Figure 2) for the recharge and non-recharge zone. The IRSWQLT is 0.83 for the

recharge zone and 0.95 for the non-recharge zone. This means that river discharge meets environmental flow requirements 83% and 95% of the time. The IRGWQLT of 0.84 means that groundwater recharge provides 84% of the sum of groundwater abstractions and spring discharge. For both regions, the nitrate concentration is very low, which results in very high water quality regulation indices. Both regions have high relative areas of barren (19%) and urban land (17%), and only 35% of the agricultural area includes field crops, vegetables, and significant areas of orchards. Therefore, the index for food and feed is very low in both regions. The index for protection of soils and sediments is also moderate to high, which means soils are well protected. Under future climate change conditions, the indices for regulation of surface water and groundwater quantity, location, and timing decrease alarmingly because of the reduced precipitation and increase in temperature. While the indices for regulation of water quality and protection of soils and sediments remain high, the index for food and feed drops significantly. This indicates that more food may need to be imported in the future.

### Application

The results of this study can assist policy-makers with a better understanding and management of the region's natural ecosystems and food supply reliant on groundwater resources. The scenario analysis, estimating the impacts of future climate change, raises a concerning issue about the region's freshwater and food supply. It must be noted that the model has not yet been calibrated with nitrate concentration and sediment yield because of the lack of observed data, which reduces the prediction reliability of IRWQ and IPSS. The model will be further developed and used to also investigate the effects of land use changes on ecosystem services until 2070.

### 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>
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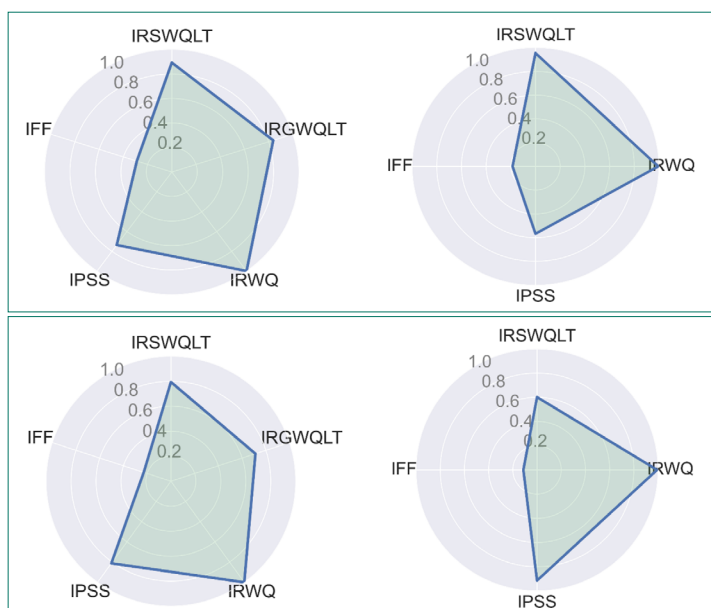


Figure 1: Current indices for different ecosystem services provided by the recharge zone (left) and the non-recharge zone (right). The IRGWQLT is absent on the right, because the non-recharge zone does not contribute to groundwater recharge of the Western Mountain Aquifer. (IRSWQLT: Index for regulation of surface water quantity, location, and timing, IRGWQLT: Index for groundwater quantity, location, and timing, IRWQ: Index for regulation of water quality, IPSS: Index for protection of soils and sediments, and IFF: Index for food and feed).

Figure 2: Indices for different ecosystem services under climate change conditions for the recharge zone (left) and non-recharge zone (right).

#### Authors

Jakirullah Nooruddin  
Thomas Koellner

#### Affiliation

University of Bayreuth  
University of Bayreuth

#### Department

Professorship of Ecological Services  
Professorship of Ecological Services

#### Email

Gm.nooruddin@uni-bayreuth.de  
thomas.koellner@uni-bayreuth.de

