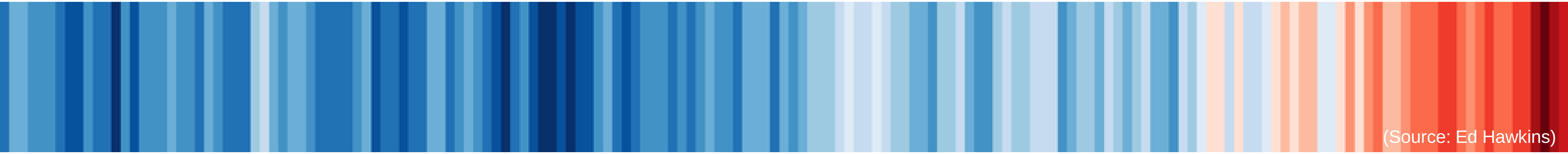
Impact of climate change and groundwater consumption scenarios on a major transboundary karst water resource - The Western Mountain Aquifer in Israel and the West Bank



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Study site

- Western Mountain Aquifer (WMA) in Israel and the West Bank
- Freshwater supply: $370 \cdot 10^6\ m^3$ per year (~20 %)
- The Mediterranean region is a climate change hotspot (Gao and Giorgi, 2008)
- Semi-arid climate with pronounced variability of precipitation
- Mainly limestone and dolomite, interbedded with marl and chalk
- Well-matured karst system (Messinian salinity crisis)
- Several hundred meters thick vadose zone
- Scarce soil cover, karst features exposed at the surface

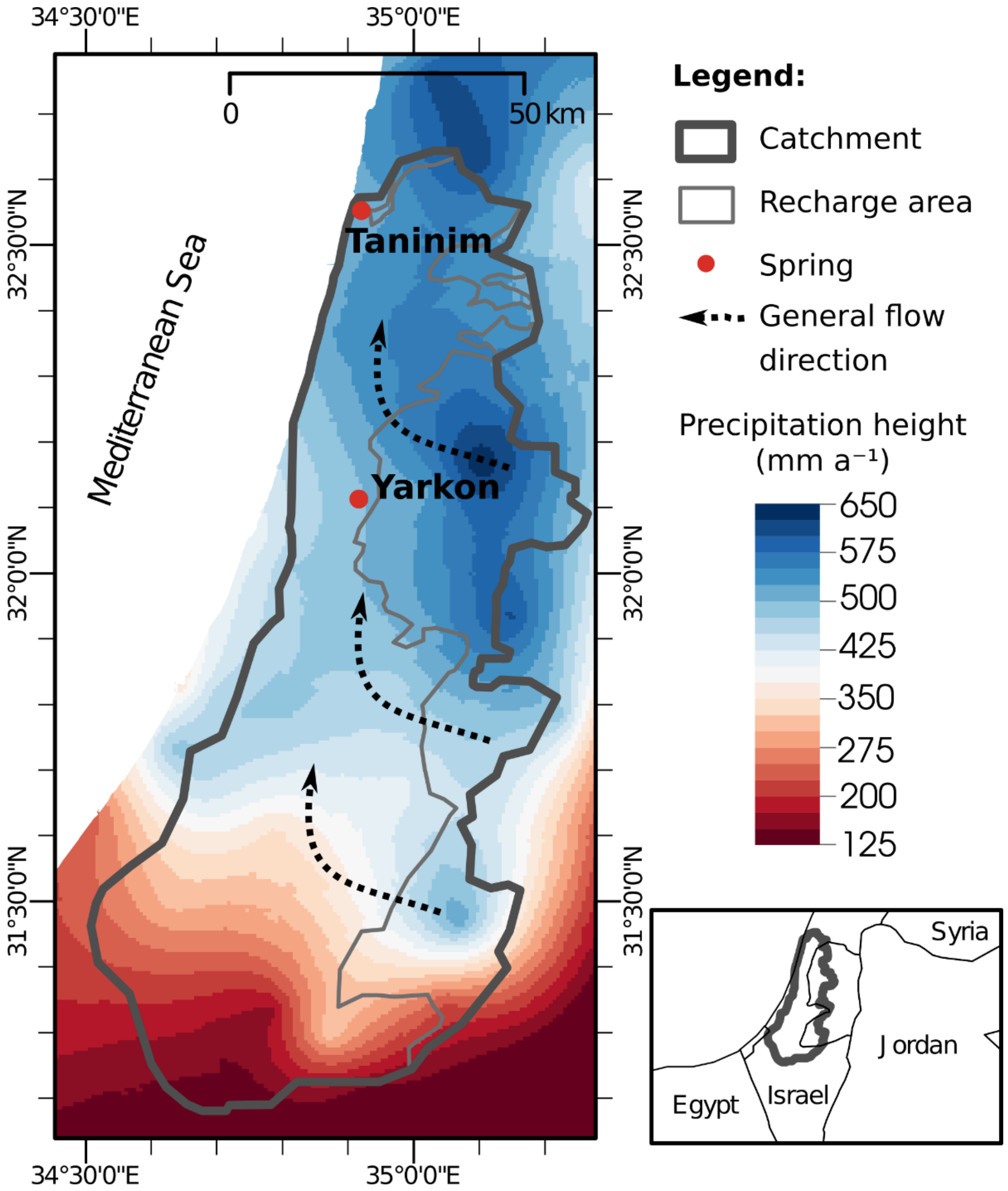


Fig.: Study site location and long-term average annual precipitation depth

Methods and objectives

- Dual-medium soil water balance model to compute daily net infiltration
- Distributed physically-based flow modeling (HydroGeoSphere)
- Dual Continuum Porous Equivalent (DCPE), i.e., bulk-effective parameters for both continua
- Variably-saturated flow (Richards' equation)
- Mualem-Van-Genuchten material model
- Regional climate projection (daily, 3km, and 8km resolution) based on the RCP4.5 climate change scenario
- **Objective**: Assessment of climate change impacts and the aquifer storage potential as a strategic reserve

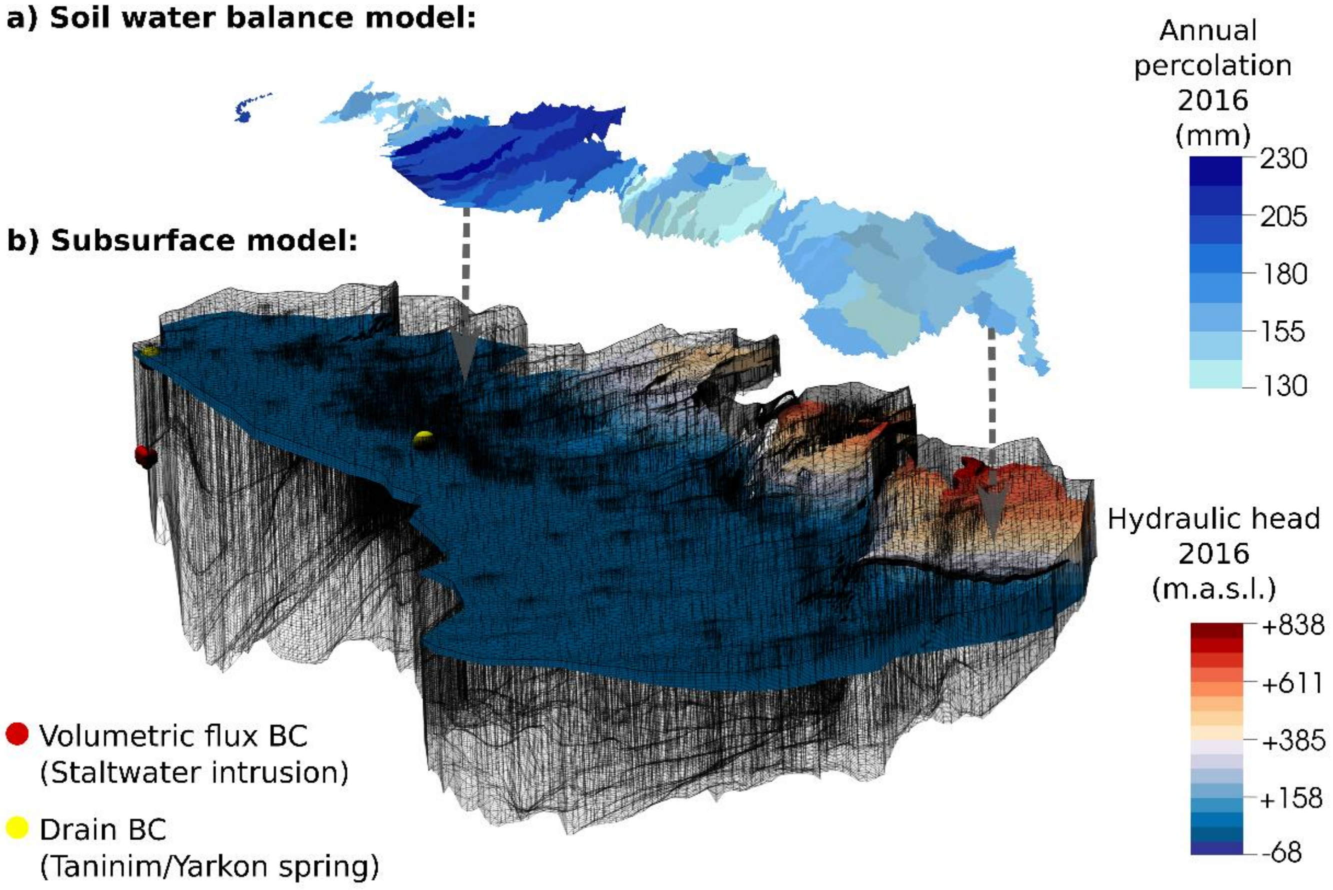
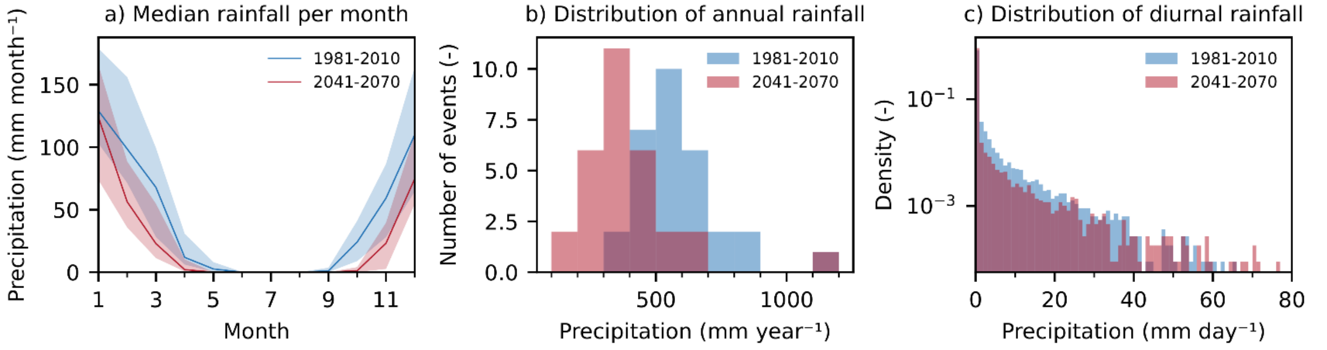


Fig.: Model setup and simulation results for the year 2016

Climate change impacts on precipitation and recharge

- Present long-term average annual precipitation height in the recharge area is 580 mm, projected to decrease to 400 mm (-30%)
- Mitigated impact on long-term average recharge quantities, 280 to 250 Mio. m^3 per year (-10%)
- More pronounced interannual variability of recharge, i.e., increased incidence of drought years (Fig.2b-c)

1) Climate change impact on precipitation:



2) Climate change impact on recharge:

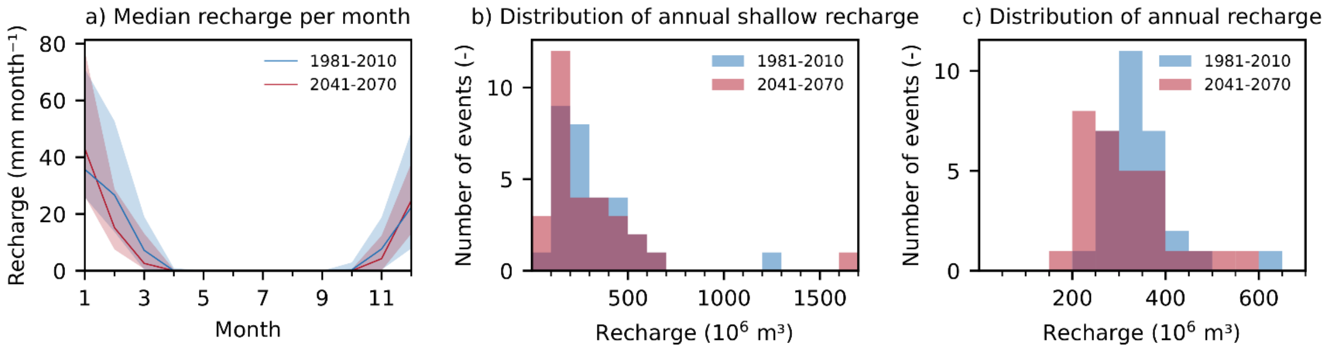


Fig.: Climate change effects

Mitigation of droughts

- Managed Aquifer Recharge (MAR) of desalinated water through infiltration ponds:
- Strategic storage to mitigate the effects of extended drought periods
- Managed Aquifer Recharge Scenario: 100 Mio. m³ per year
- Maximum storage capacity (before losses become uneconomical): 1300 Mio. m³
- Losses: 13 Mio. m³ per year

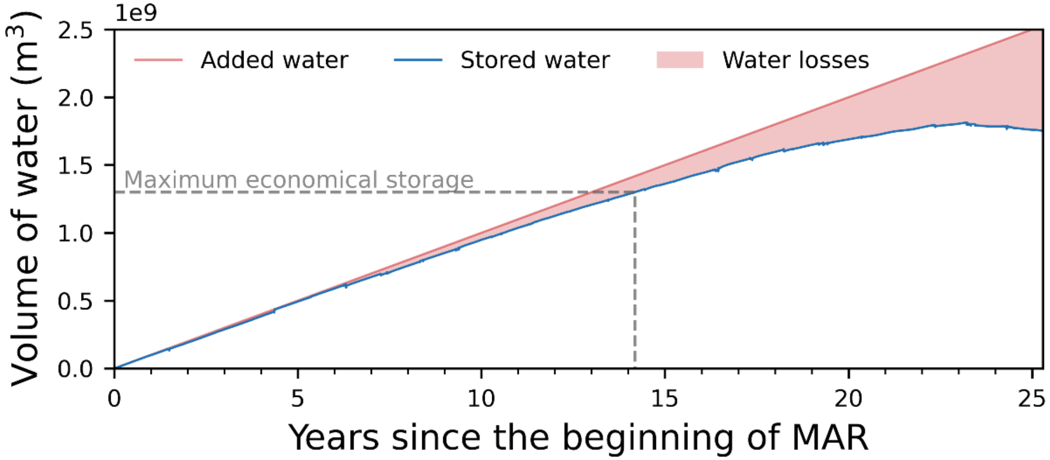


Fig.: Storage losses with respect to the quantity of added water

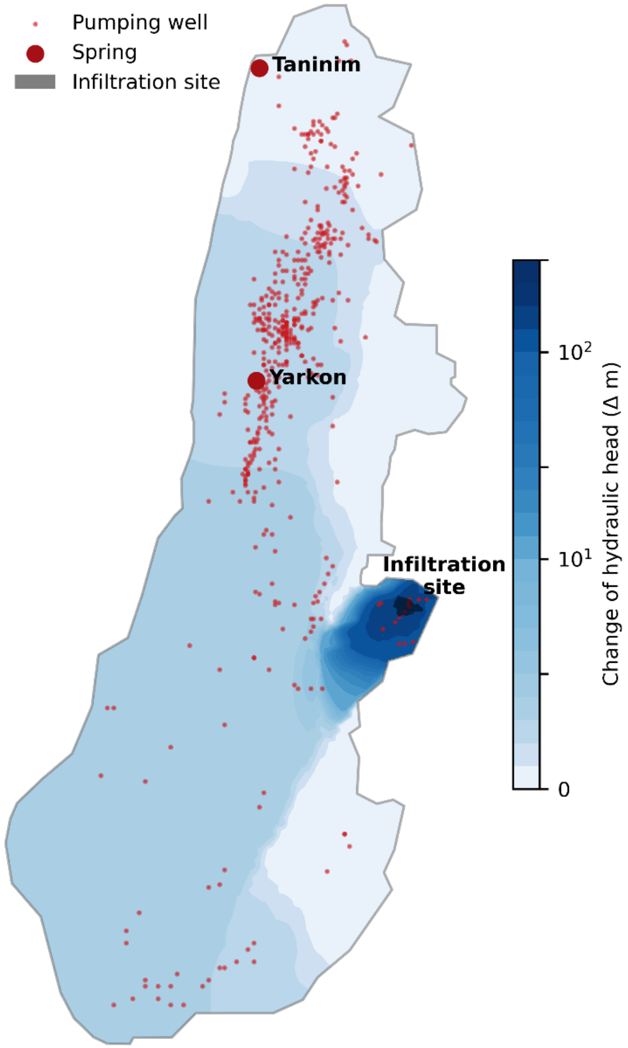


Fig.: Location of the infiltration pond and changes to the hydraulic head after 13 years

Conclusions and outlook

- Decline of the long-term average recharge from 280 to 250 Mio. m^3 (~ -10%) projected according to the RCP4.5 scenario.
- Managed aquifer recharge in periods of high precipitation may aid in the mitigation of extended drought periods. The WMA can store up 1300 Mio. m^3.
- Process-based approaches are required to assess climate change impacts, as precipitation input and desaturation of the vadose zone may expand beyond previously experienced conditions. Data-driven approaches are less capable to generalize outside of its training domain.
- Multiple ensembles of models and climate simulations can improve the reliability of climate impact assessments.
- As a next step, different climate change scenarios should be compared (i.e., RCP 2.6, 6.0, and 8.5). The relative impact of increased consumptions and climate change effects may be compared.
- Simulate and investigate the benefits of MAR for historical and future drought periods.
- The process-based model may also help to develop more generalizable transfer functions to account for vadose flow dynamics.

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Thank you for your attention – Questions?

(Source: Philipp Nußbaum)

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A.1 Model – Calibration results

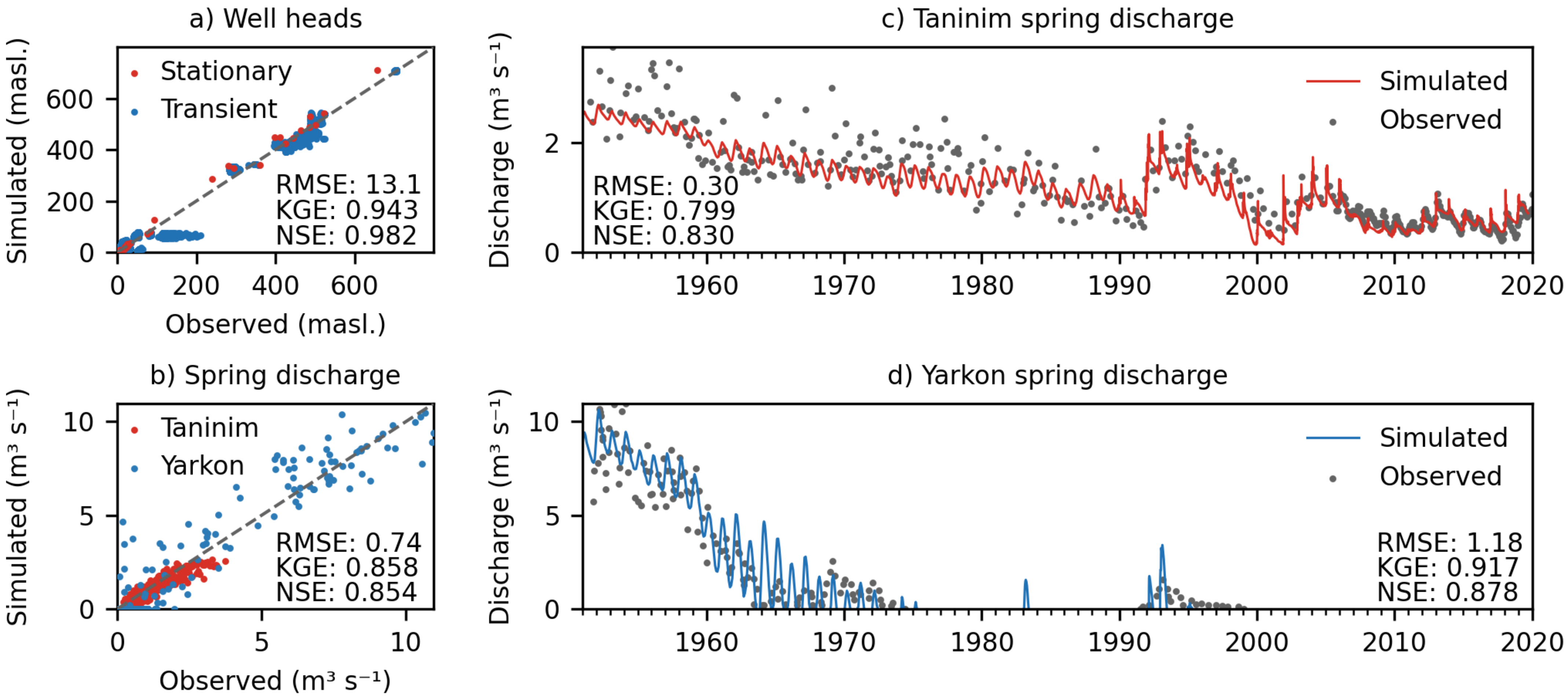


Fig.: Calibration results of the simulated well heads (a) and spring discharge (b-d) for the transient, variably saturated, dual-permeability flow model

A.2 Climate change projections 1981-2010 vs. 2041-2070

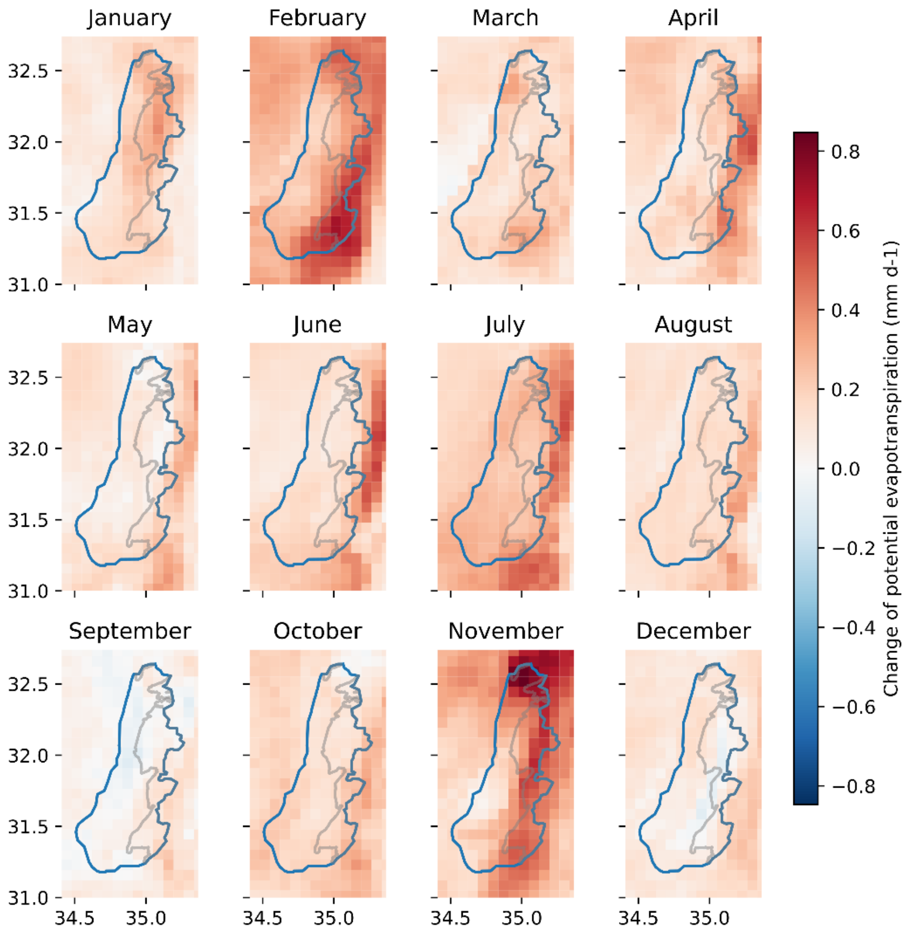


Fig.: Changes to evapotranspiration

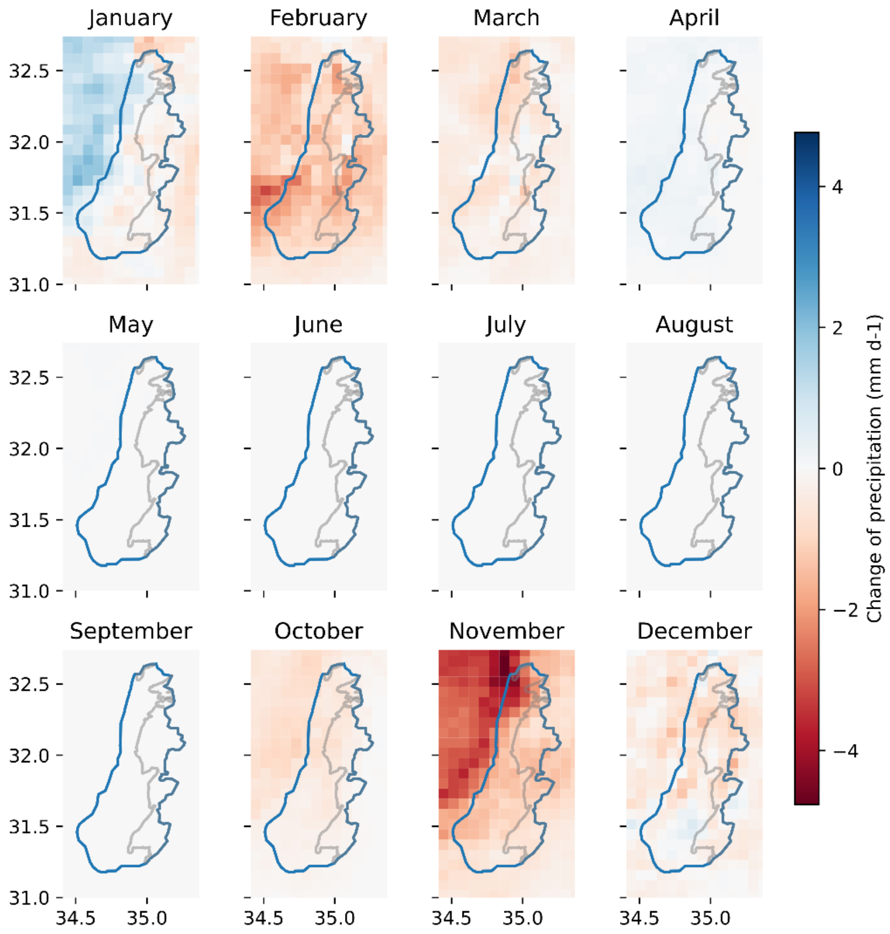
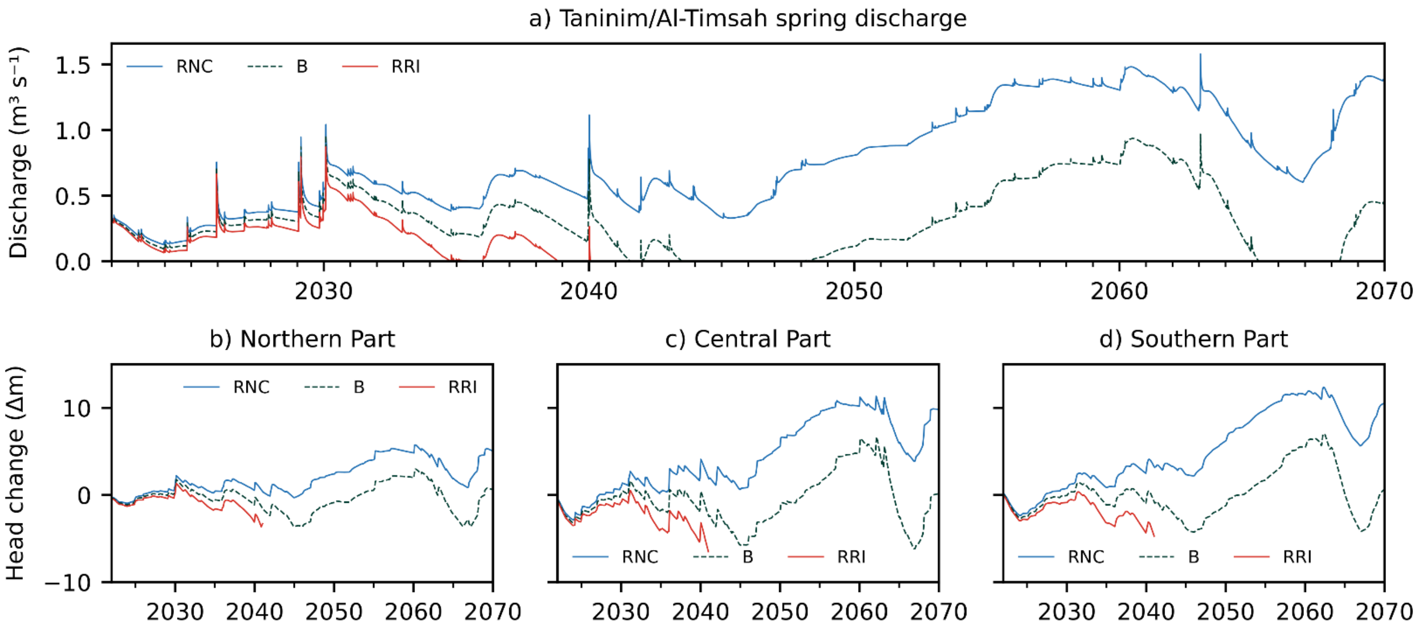


Fig.: Changes to precipitation

A.3 Risk to the integrity of the WMA

- Regional Nature Conservation (RNC), Baseline (B), and Regional Resources Intensive (RRI) scenarios with different abstraction rates
- The results are not to be misunderstood as exact predictions in time (on a daily, monthly, and yearly timescale) since the climate model only provides a statistically-representative prediction of the weather



A.4 WMA – Vadose flow and storage

- Dirac-type impulses of precipitation (see Fig. a)
- Strong dissipation of the hydraulic signal within the vadose zone (Fig. b); i.e., minimum recharge flux: 6.5 m^2 s^{-1}
- About 40% of the dynamic water is stored in the vadose zone (see Fig. c)
- Recession of vadose storage over ~1.5 years

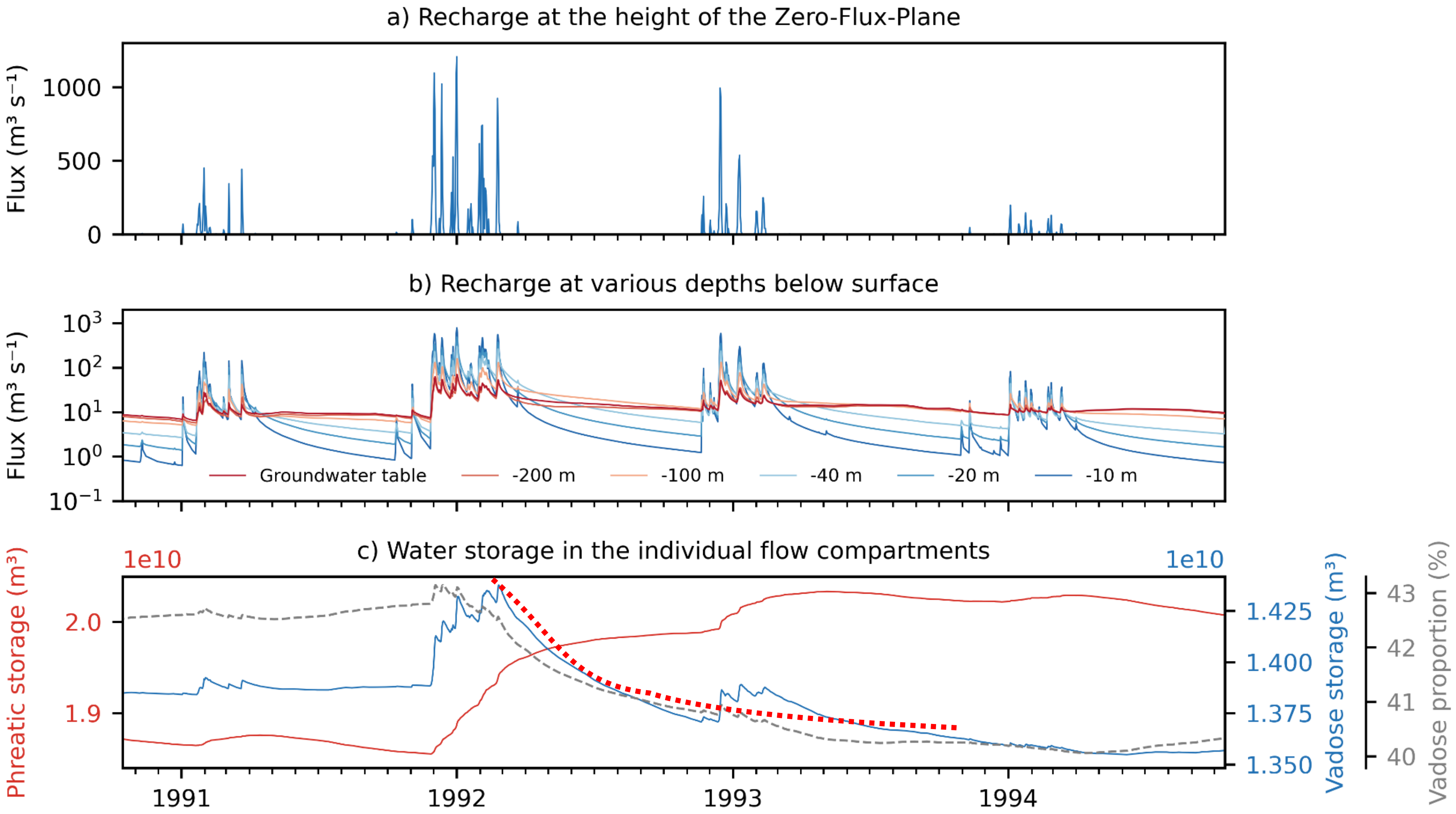


Fig.: Simulation results of a) shallow recharge, b) deep recharge at various depths below surface and c) the water storage in the individual flow compartments.

A.5 WMA – Stratigraphy

- Upper and Lower aquifer composed of limestone and dolomite
- Separated by the non-permeable layers of the Moza/Beit-Meir Formations (marl)
- Largely separated from seawater intrusion by non-permeable Talme Yafe Formation (marl)

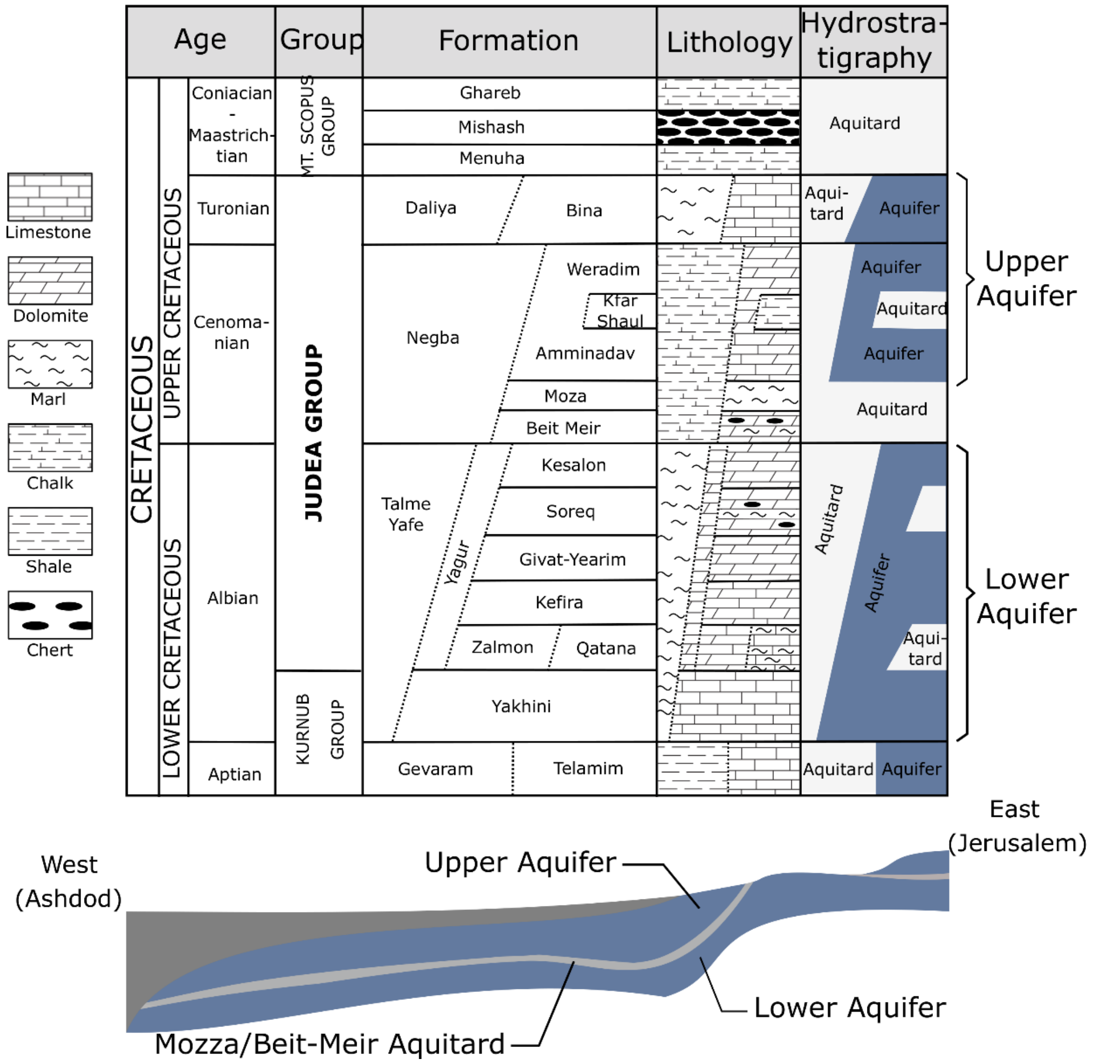


Fig.: Stratigraphic column and hydrogeological cross section