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MedWater

# SUSTAINABLE MANAGEMENT OF POLITICALLY AND ECONOMICALLY RELEVANT WATER RESOURCES IN HIGHLY DYNAMIC CARBONATE AQUIFERS OF THE MEDITERRANEAN

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- Israel Hydrological Service (IL)
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- Ben-Gurion University of the Negev (IL)
- Hebrew University of Jerusalem (IL)
- Ariel University / Eastern R&D Center (IL)
- Palestinian Water Authority (PS)

# GOALS & STUDY SITES



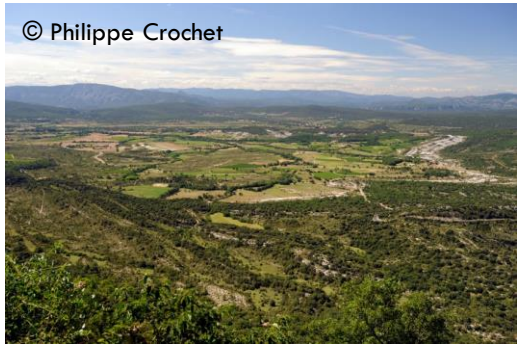



MedWater

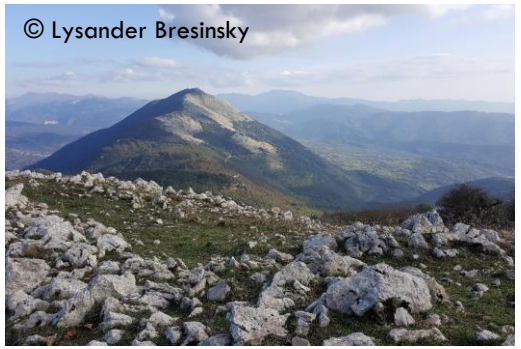
- Develop new tools & strategies for **sustainable management of karst aquifers** within Mediterranean climates
- Prepare for **increased freshwater demand** due to growing populations
- Adapt to climate change (**changes in recharge**) and increase resilience

- MedWater study sites
  - Western Mountain Aquifer, Israel & West Bank
  - Lez catchment, France
  - Capodifiume catchment, Italy


Western Mountain Aquifer




Lez catchment

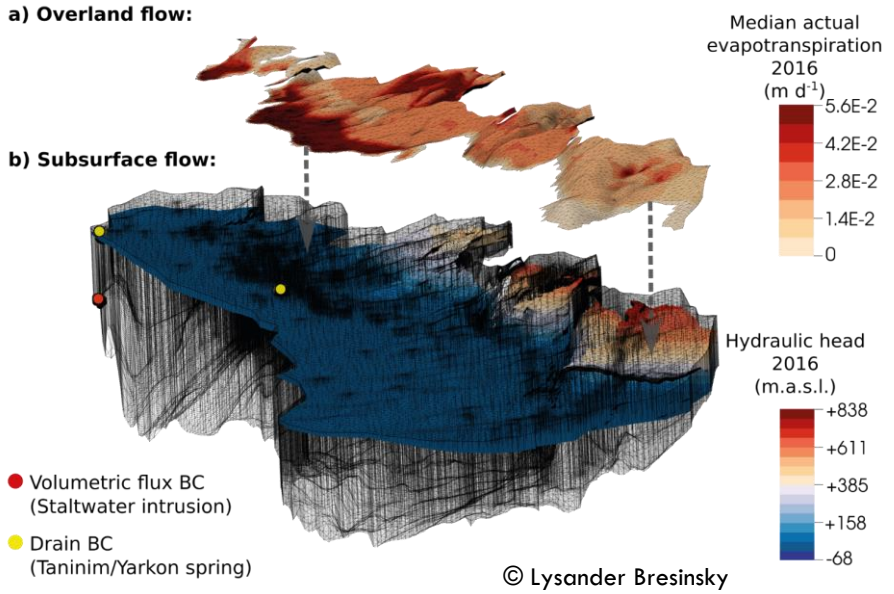



Capodifiume catchment

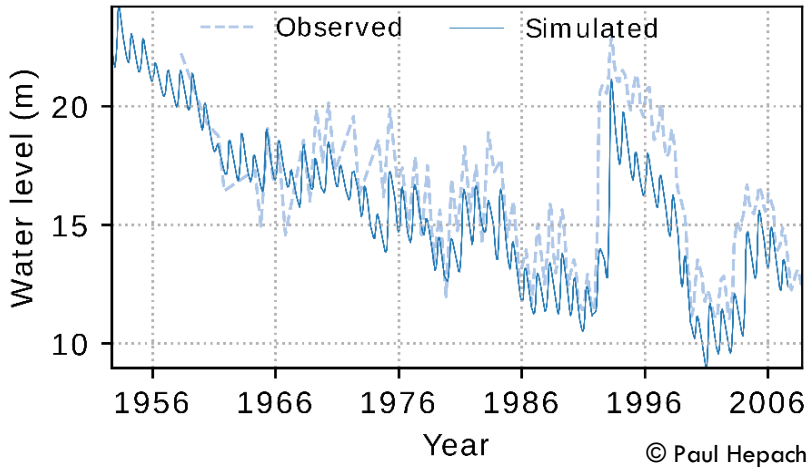
# LARGE-SCALE HYDRODYNAMICS IN KARST AQUIFERS

**To achieve this goal we:**

- developed a complex flow model (HydroGeoSphere) using a **dual-continuum approach**
- simulated the complex **hydrodynamics in the unsaturated and saturated zone** coupled with **overland flow**
- simplified the **complex model to a user-friendly model (Modflow)** as basis for management tools:
  - **Multi-objective optimization**
  - Web-based **Decision Support System**

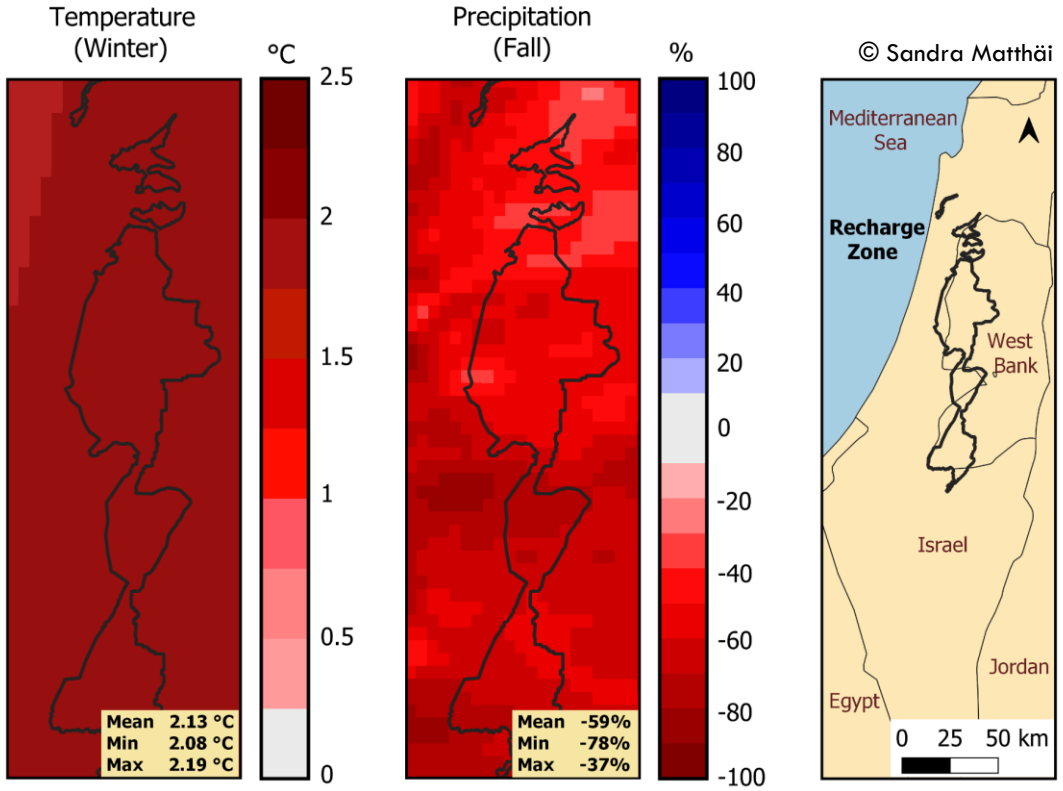



HydroGeoSphere model that considers overland flow and subsurface flow




Simulated versus observed response of the groundwater system to changes of climate, land use, and pumping rates

# HOW IS THE CLIMATE EXPECTED TO CHANGE IN ISRAEL?




Temperature and precipitation changes in the WMA's recharge zone (1981-2010 vs. 2041-2070)

High-resolution (3x3 km) climate projections using RCM COSMO-CLM (RCP 4.5) predict:

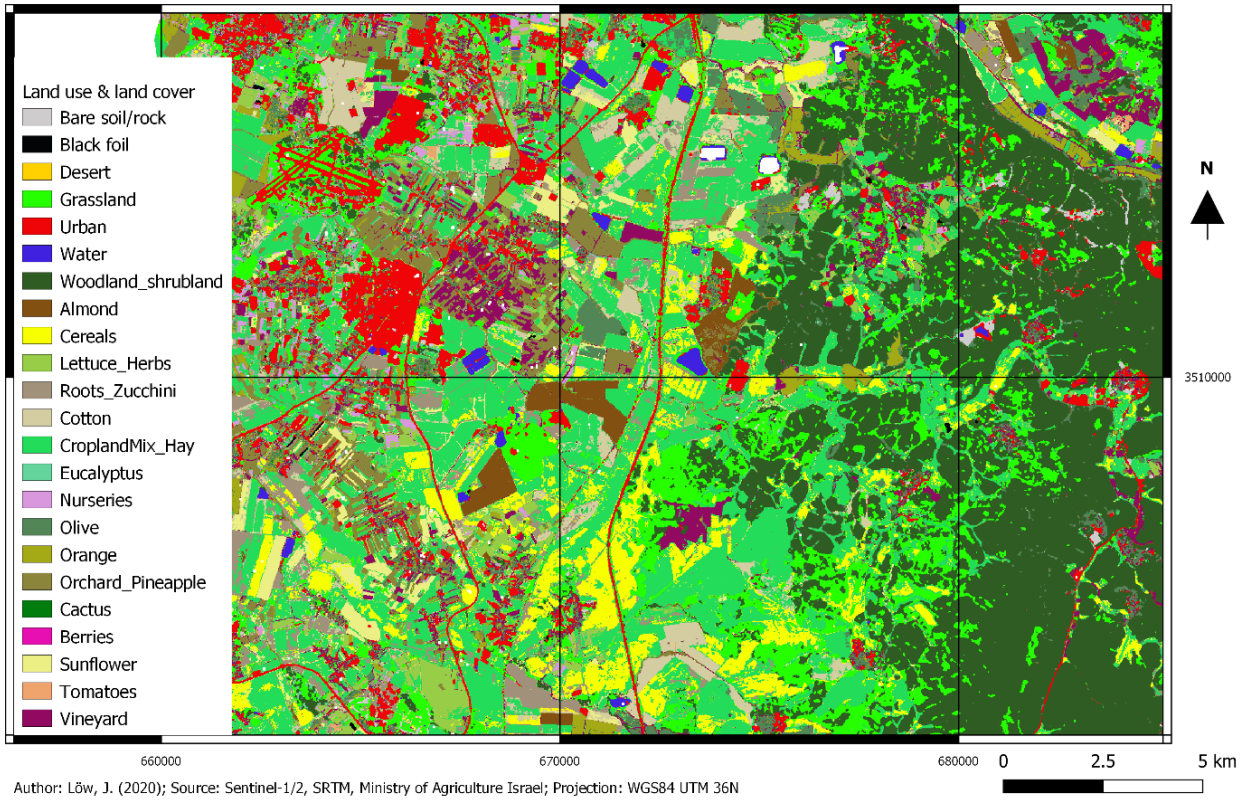
- **Warmer winters by up to 2.2 °C** and **59% less precipitation in fall** until 2070
- Predicted climate shifts result in a **decrease of groundwater recharge by 25%** until 2070
- However, 8x8 km resolution climate model projections result only in a **16% decrease of recharge** showing the high uncertainty of the model results

# DATA USED FOR RECHARGE CALCULATIONS

## **Data analyzed** with SWAT model

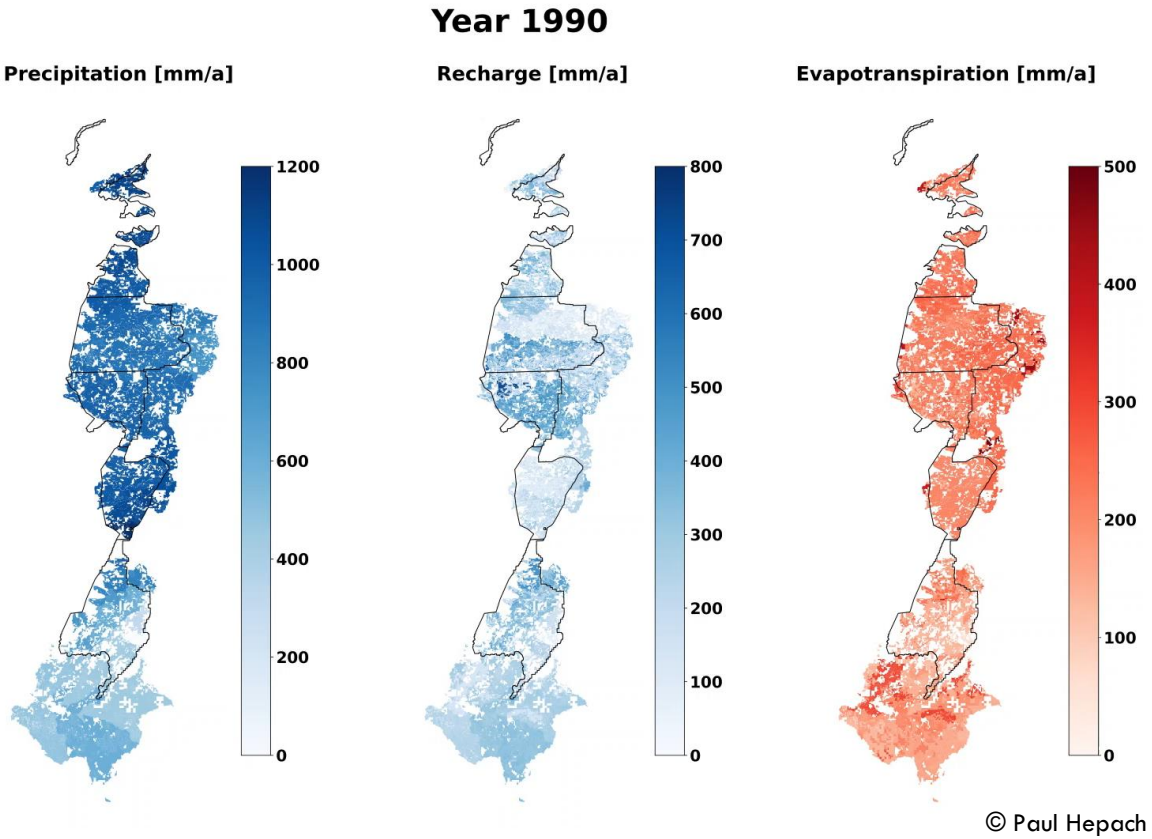
| Data source | Parameter |
|---|---|
| 30 m STRM DEM NASA | DEM |
| FAO, Harmonized World Soil Database (HWSD) | Soil properties |
| 300m ESA CCI land cover | Land use |
| Weather stations IMS | Precipitation<br>Max & Min temperature<br>Solar radiation<br>Relative humidity<br>Wind |
| MODIS | Evapotranspiration |
| RCM COSMO-CLM | Climate projections |
| HSI Hydrological Yearbooks | Surface runoff |

## **High-resolution land cover maps**, based on Sentinel-1/2 remote sensing data




Land cover in the WMA 2016

# HIGH-RESOLUTION RECHARGE ESTIMATES

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Spatial distribution of precipitation, recharge, and evapotranspiration (1990-2018)

- SWAT calculates an **annual recharge of 144 mm/a (30% of annual precipitation)**
- **Hydro-Pedotransfer Functions (HPTFs) result in a lower recharge of 72mm/a** and were **not able to capture rapid flow** components

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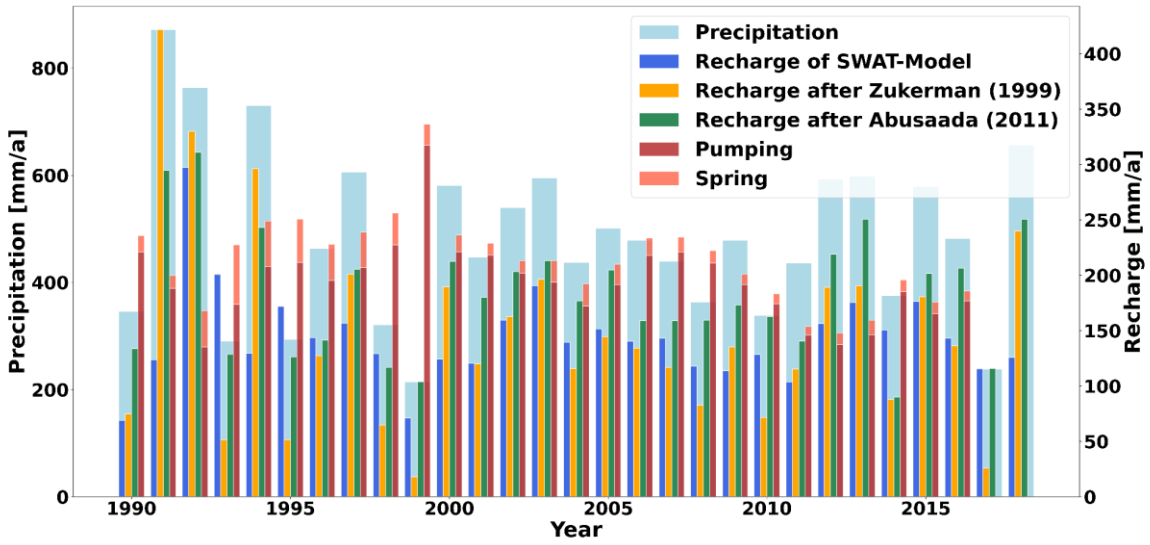
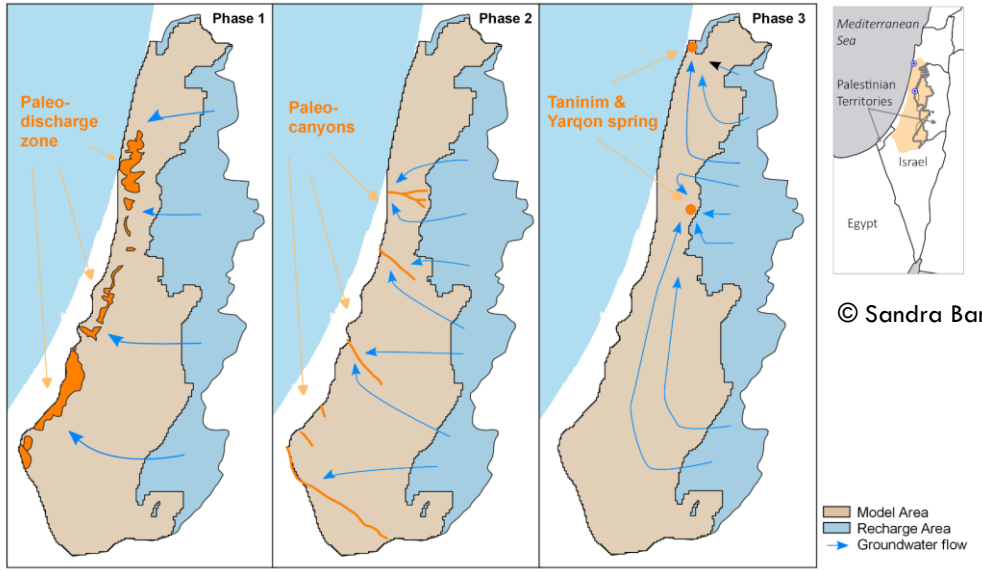



Precipitation and recharge from 1990 to 2018, compared to spring discharge and well pumping

# HYDRAULIC KARST CHARACTERIZATION

- Stochastic Karst Simulator identifies **karst conduit networks**
- Based on **soft information** on karst genesis of the last 10 Mio. years (palaeo-climate, palaeo-canyons, locations of springs) and are **calibrated by geophysical data & location of pumping wells**
- Generation of a **probability map** of the hydraulic parameter field

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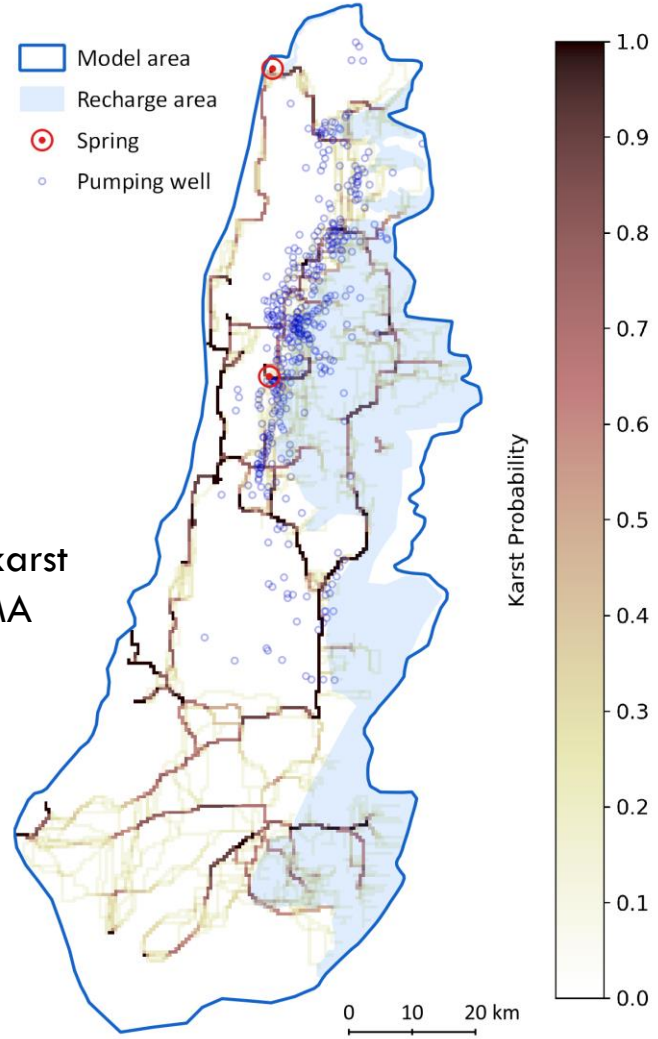
Conceptual model of karst development in the WMA




Probability Map of karst conduits in the WMA

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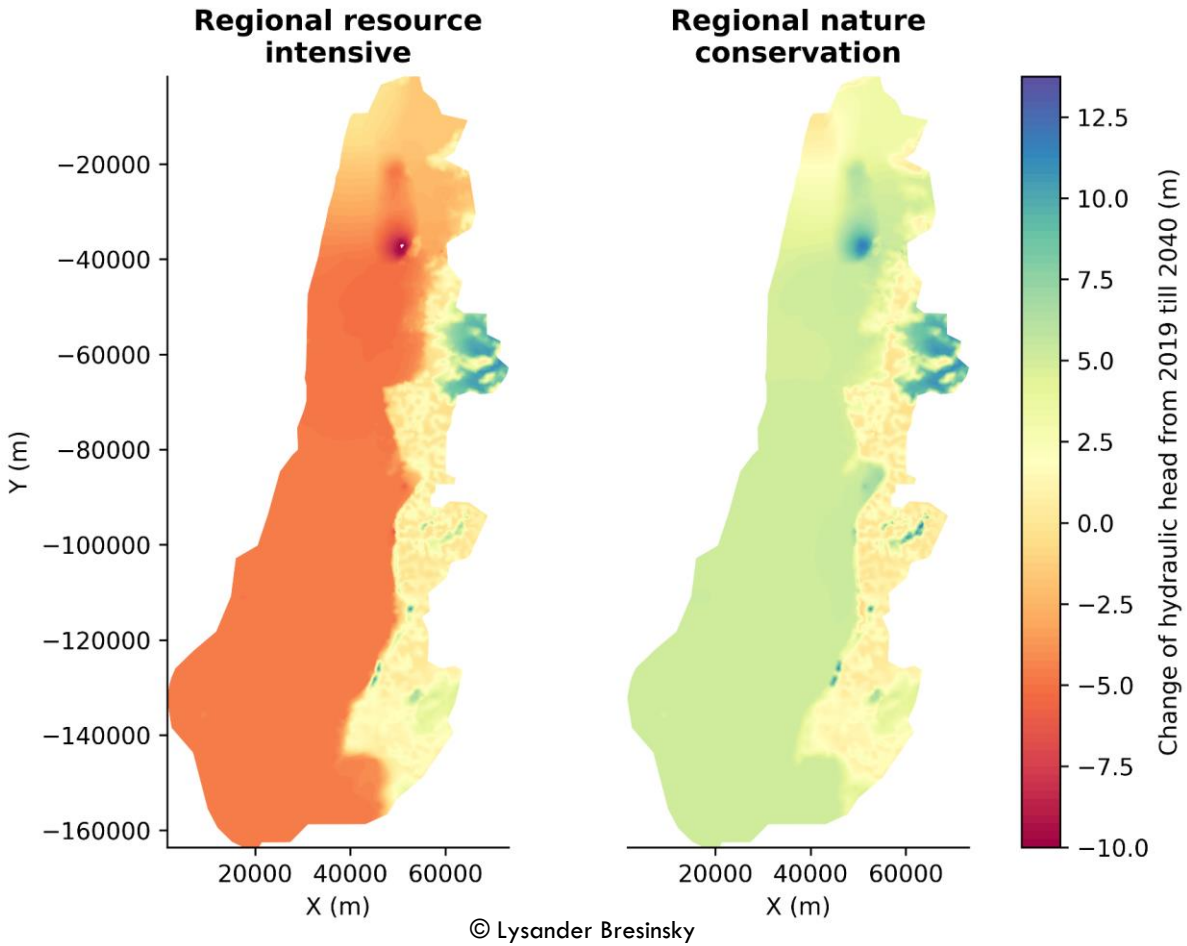
# RESPONSE OF GROUNDWATER LEVEL ON GLOBAL CHANGES






Simulated change in groundwater levels (2019 to 2040)

Three scenarios based on the Israeli and Palestinian water management plans are defined and predict:

- Resource-intensive scenario:
  - **2 m groundwater level decline** (next 5 years)
  - **Further drop of 3 m** until 2040
- Nature-conservation scenario:
  - **Groundwater level increase** in the Southern dry regions by **up to 6 m** until 2040
  - **Increase of 12 m** in regions with high abstraction (North)

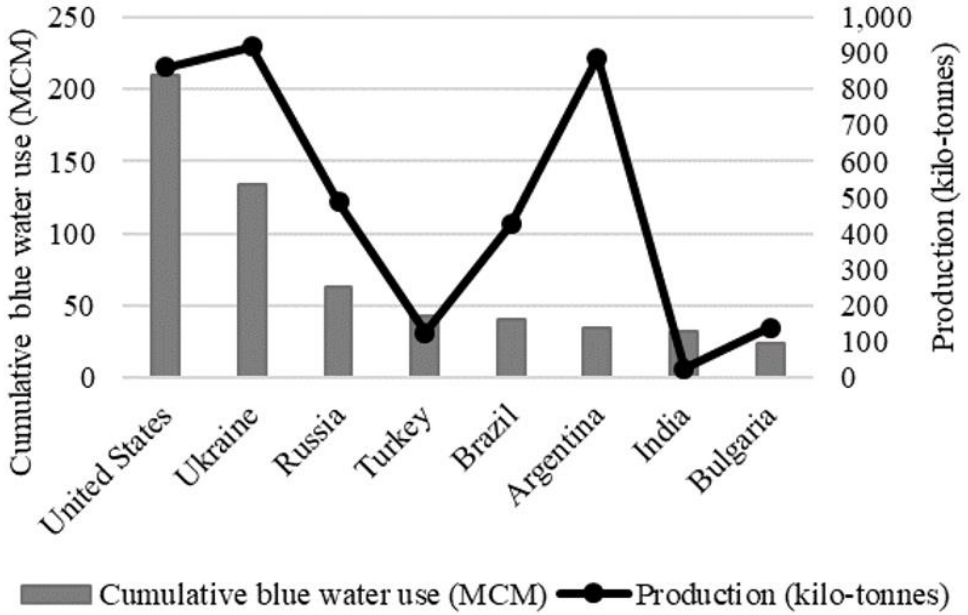
# CAN WE OPTIMIZE VIRTUAL WATER FLUXES AND WATER USE?

- **1.8 $10^9$ $m^3$/a of blue water** and **6.5 $10^9$ $m^3$/a of green water** were used for Israel's crop consumption (domestic consumption & crop imports) in 2005
- **Wheat and maize consume highest virtual water volumes**

| | |
|---|---|
| Blue water used for crop production | 1.8 $10^9 m^3/a$ |
| Domestic consumption | 1.0 $10^9 m^3/a$ (56%) |
| Crop Imports | 0.8 $10^9 m^3/a$ (44%) |

| | |
|---|---|
| Blue water used for **crop exports** | 0.1 $10^9 m^3/a$ |






Relevant countries for blue water import to Israel [$10^6 m^3$]

# ECOSYSTEM SERVICES OF THE WESTERN MOUNTAIN AQUIFER

- **Surface water provision** (min. discharge needed for water supply) is low **(0.11)** due to high evapotranspiration and recharge
- **Food provision** (biomass & yield for food supply) is low-medium **(0.31)**
- **Erosion mitigation** (value below the max. erosion allowed) is high **(0.78)**

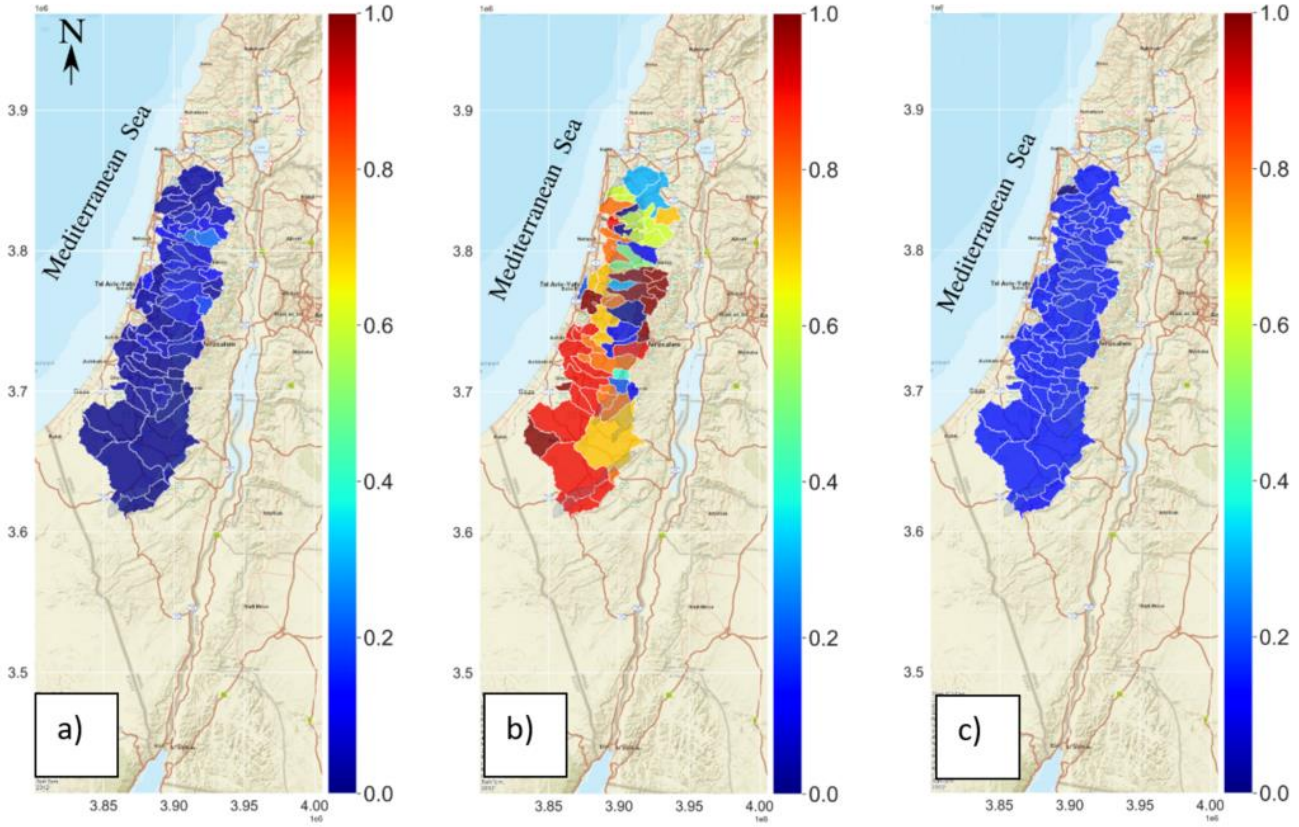
**Ecosystem service capacity**

*0 = no ecosystem services*

*1= maximum ecosystem services*

Calculations of the ecosystem services are made according to Logsdon and Chaubey (2013)






a) Food provision, b) erosion regulation, and c) freshwater provision within the surface and subsurface catchment of the WMA

# PRODUCTS

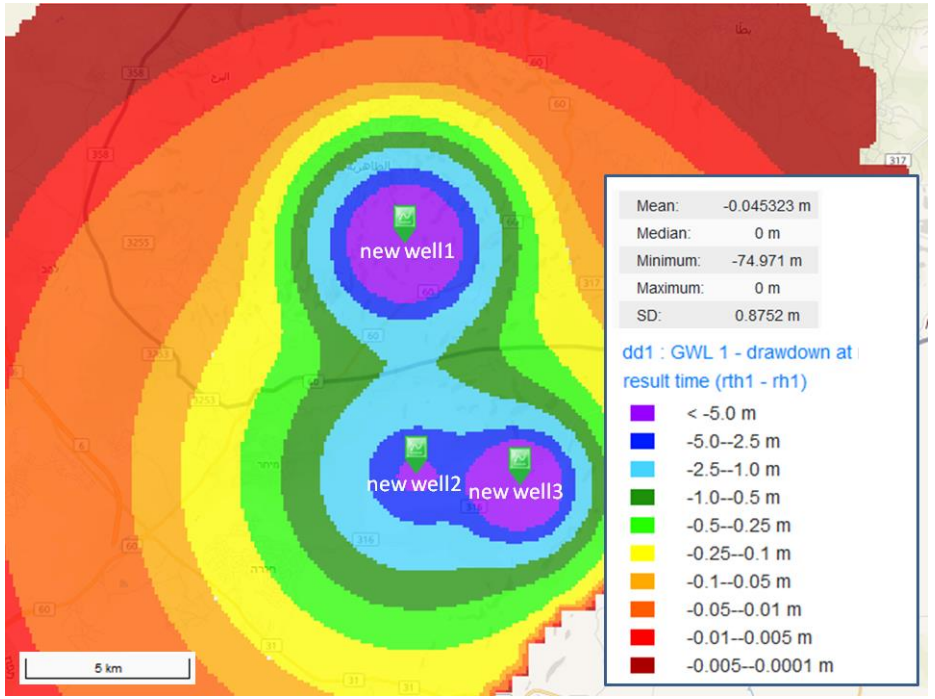
## FOR SUSTAINABLE MANAGEMENT OF KARST AQUIFERS

# DECISION SUPPORT SYSTEM (I)

- Developed for **water users and decision-makers**
- Illustrates **land use and climate change**
- User can define **new wells** & **pumping rates**
- Modeling results are visualized and post-processed to **calculate groundwater levels, depression cones, and stored water volumes**

- Tomorrow, 12:15
  Stakeholder Forum C: Decision Support Systems to prevent water conflicts

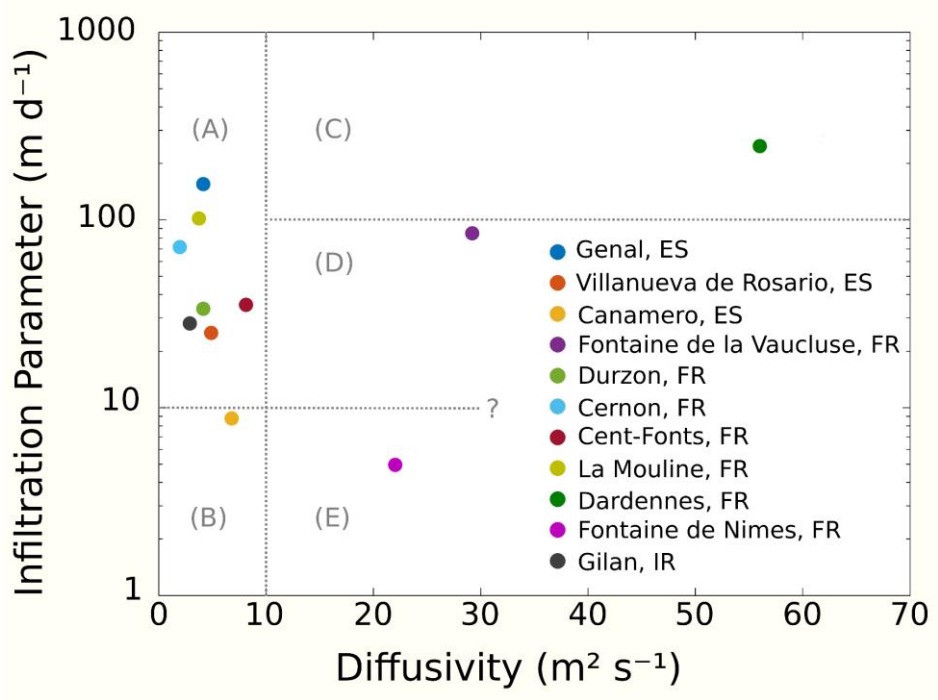





Recalculated groundwater level drawdown based on the user-friendly MedWater DSS system

# AQUIFER CLASSIFICATION FOR MANAGEMENT PROPERTIES (II)

- **Spring discharge** time series are **generalized** based on hydraulic diffusivity and infiltration capacity
- **Classification scheme** provides an **efficient generalization tool** for aquifer management






(A) Moderate infiltration in poorly karstified systems

(B) Slow infiltration in poorly karstified systems

***Optimal** for water resources management **(storage is high!)***

(C) High infiltration in strongly karstified systems

(D) Moderate infiltration in strongly karstified systems

***Not suitable** for water resources management*

(E) Very slow infiltration in moderately karstified systems

***Unfavorable** for water resources management*

# GLOBAL GROUNDWATER STRESS INDEX (III)

**Indicators**

I1 – Groundwater recharge[1]
I2 – Groundwater storage[1]
I3 – Groundwater abstractions[1]
I4 – Climatic water balance[2]
I5 – Water intensity of crops[2]
I6 – Groundwater-dependent ecosystems[3]

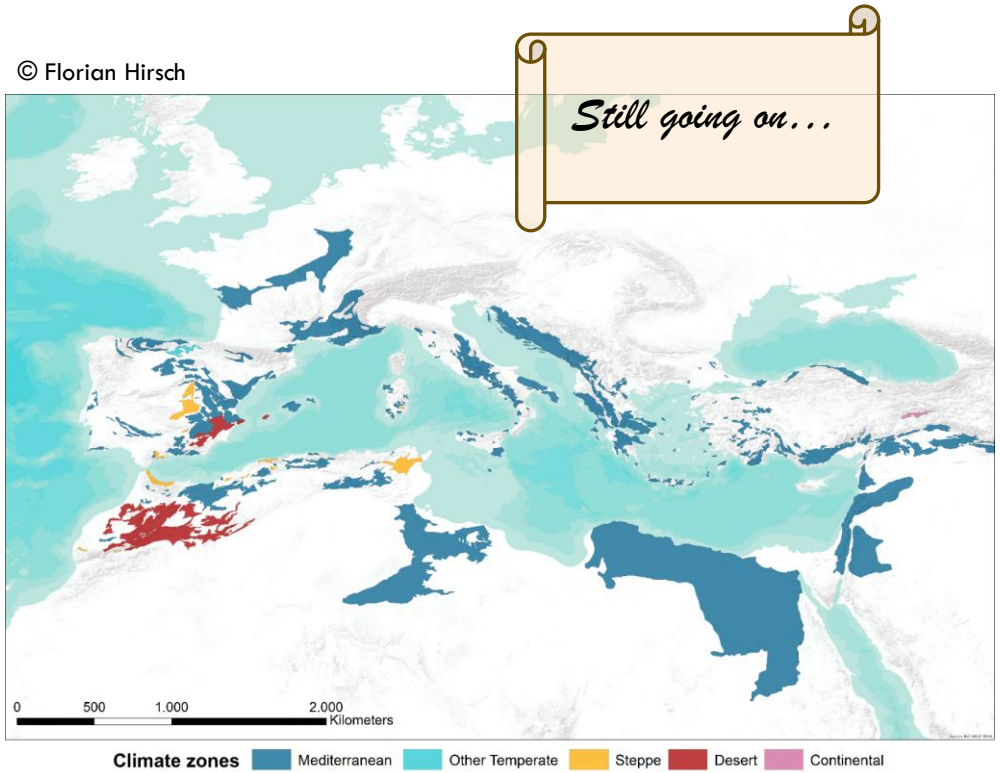
**Superposition**

| Aquifer | I1 | I2 | … | I6 | Groundwater Stress Index |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| … | | | | | |
| 356 | | | | | |

[1]WaterGAP (version 2.2d)

[2]ERA5 data

[3]MOD13Q1 data




52 Mediterranean karst aquifers of 356 are predicted to shift towards more extreme arid climate zones by 2100

# KEY RESULTS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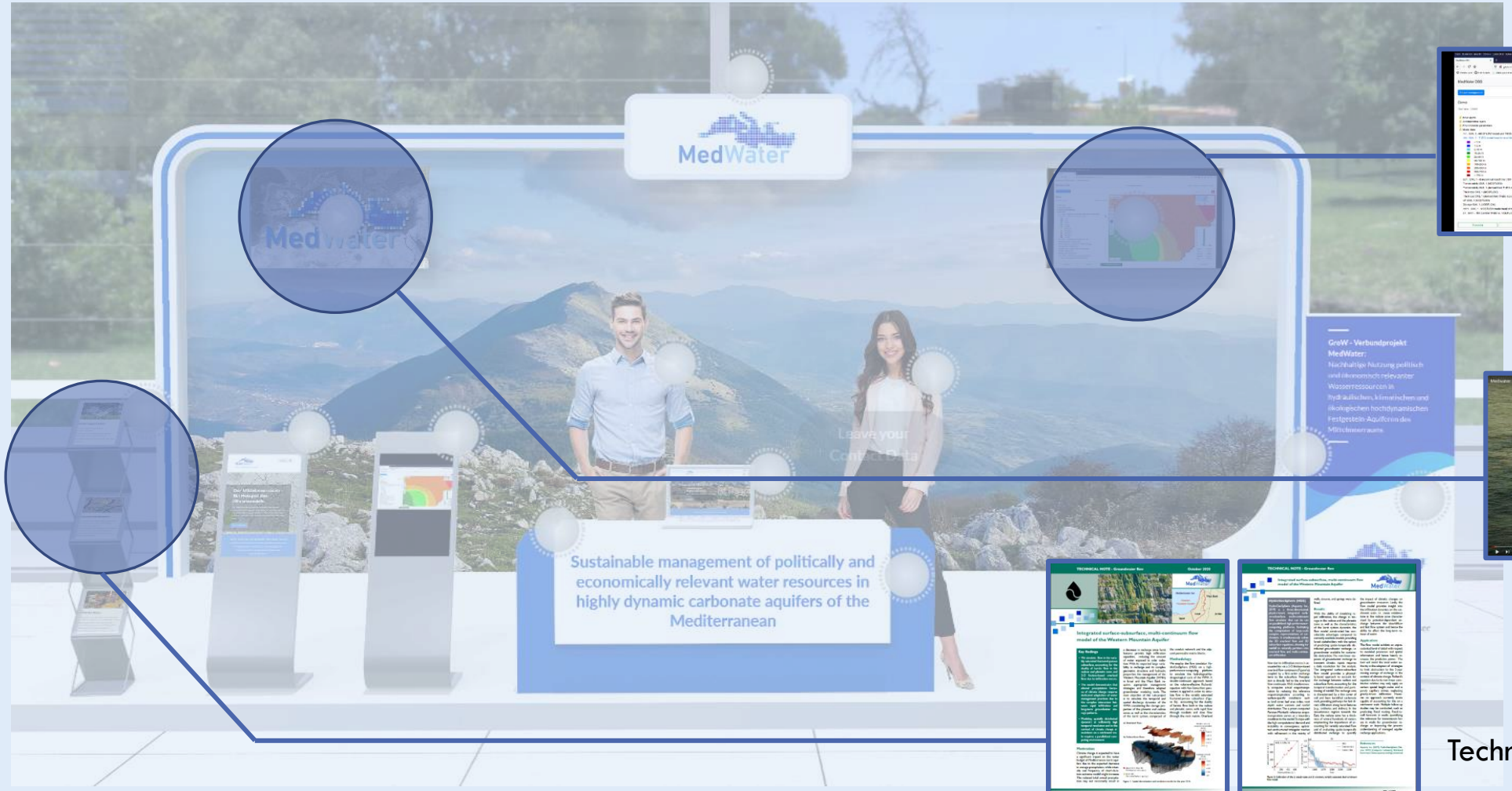
- Understanding and prediction of **high-resolution recharge** is the key to manage groundwater resources under Mediterranean climate
- **Remote sensing, machine-learning, and stochastic approaches** can overcome data scarcity issues
- **Reducing domestic crop production** will be essential for a more sustainable water use in Israel
- Only a **nature-orientated society** allows groundwater levels and volumes to recover in future
- Numerous **karst aquifers in Northern Africa and Spain** can be expected to shift towards more extreme climate making them **highly vulnerable to groundwater stress** and overexploitation

# VIRTUAL MARKETPLACE

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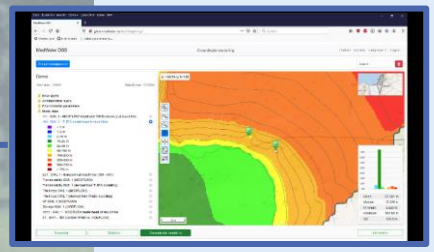
DSS-Demo



MedWater Film






Technical Notes (17)