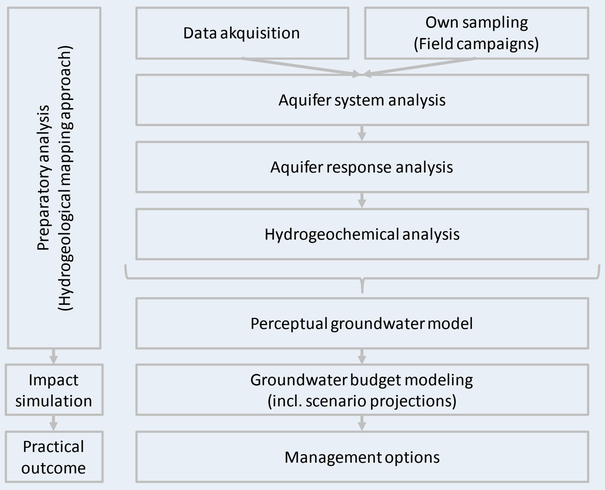


# The Drâa aquifer system in South-Morocco - analysis and groundwater budget simulation

This is an assessment of the regional groundwater resources in the Middle Drâa Catchment (MDC). So, the simulation model BIL is developed to quantify the annual change in groundwater availability of the alluvial aquifers along the Wadi Drâa, the so called Drâa aquifers. The model is based on the characterization of the aquifer system, its response and the groundwater evolution along the main flow paths. The IMPETUS research project provided a multidisciplinary framework focusing on global change and the hydrological cycle.

**Catchment area:** Approximately 15,000 km²
**Climate:** Arid to hyper-arid
**Underground:** Fractured rocks partly karstified and porous sediments partly slightly consolidated
**Relief:** Appalachian style with ridges, cuestas and inter-mountainous basins
**Hydrology:** Wadi network with intermittent stream flow and regulated stream flow from reservoir in the main drain, the Wadi Drâa
**Vegetation:** Dwarf-shrub dominated Saharan rock and Saharan wadi communities, Artemisia and Hamada steppe with Acacia trees
**Population:** Around 300,000 inhabitants; population growth rate of 2.1%
**Human activities:** Irrigation agriculture concentrated along Wadi Drâa (ca. 2% of the area) and extensive pasture

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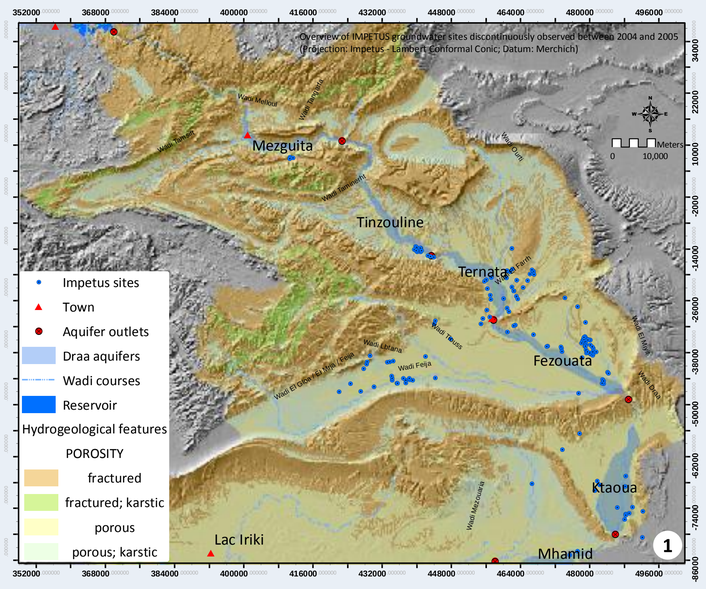
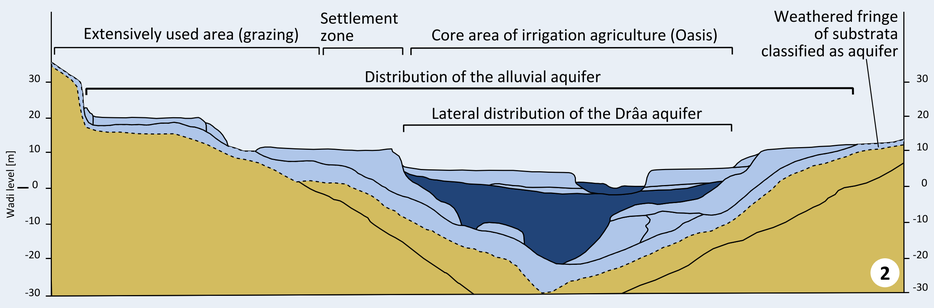
## Regional hydrogeological map




## Hydrofacies setting of the Drâa aquifers

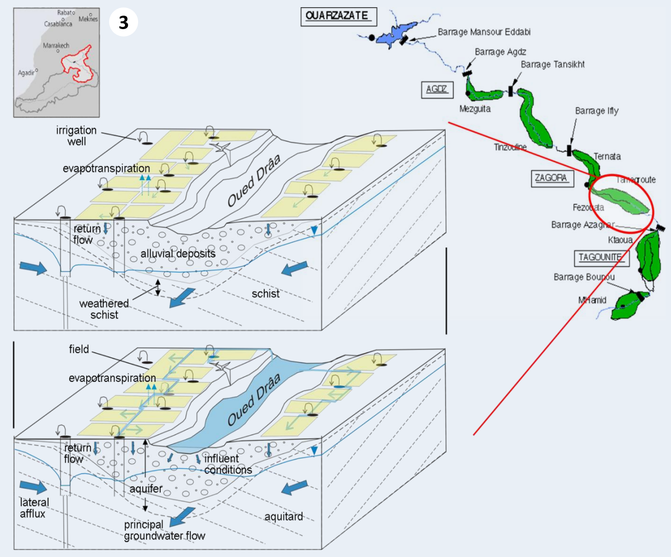



Porous, extensive and highly productive aquifers; permeability generally high

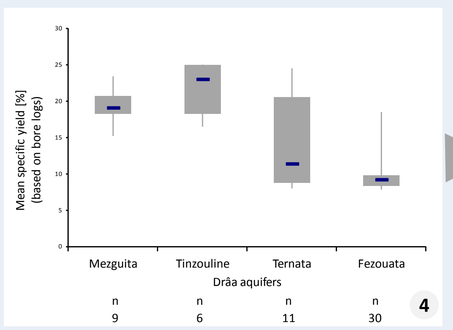
Porous, local or discontinuous productive aquifers, repectively extensive, but only moderately productive aquifers; permeability medicore or variable

Local occurrence of groundwater, especially in zones of fractured and weathered solid rocks, but deeper more productive aquifers not excluded; permeability low to very low

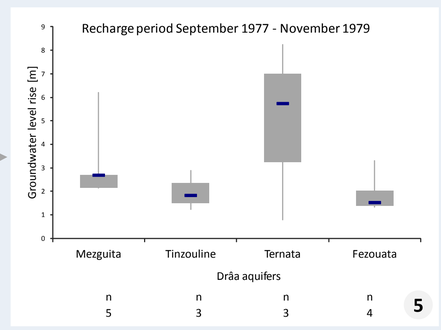
## Scheme of the Drâa aquifers



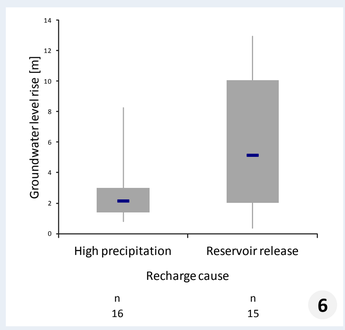

## Specific yield



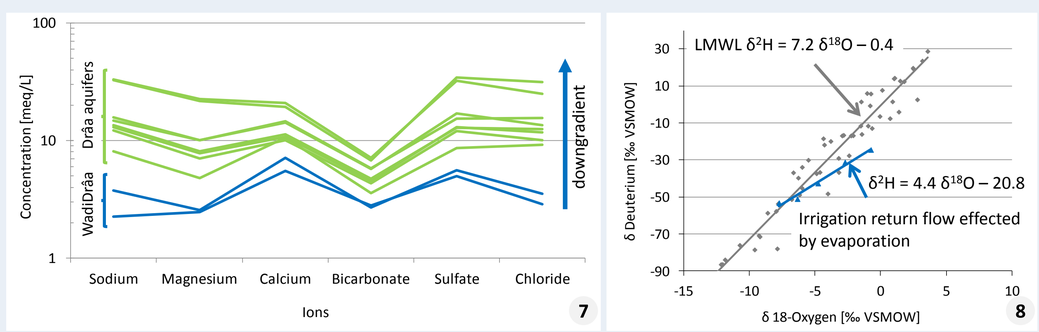

## Aquifer response




## Recharge processes




## Salinization processes




## Perceptual model

**Aquifer setting:** Six aquifers along the Wadi Drâa delineated by dyke, tectonic lineament and aquitard outcrop (see 1 , 2 & 3 )

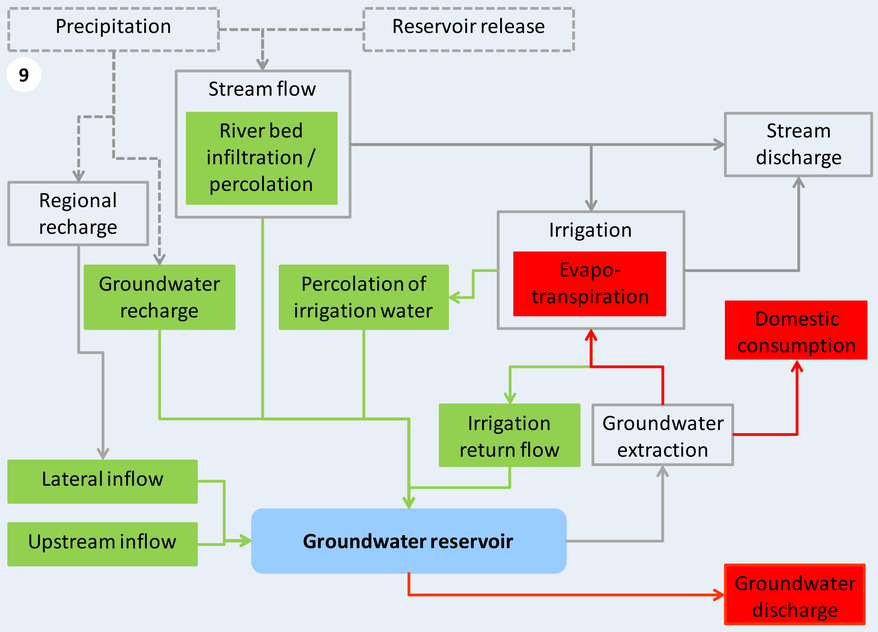
**Recharge:** Wadi bed infiltration / percolation mainly caused by reservoir releases, secondarily caused by precipitation within the Middle Drâa Catchment (see 6 )

**Groundwater flow:** Main path beneath the Wadi Drâa, inflow beneath tributary wadis and from intra-mountainous basins caused by regional groundwater recharge; upwelling from fractured aquitard and deeper zones along faults (see 3 )

**Discharge:** Mainly withdrawal for irrigation, secondarily for domestic consumption (see 3 )

**Salinization:** Increasing salinity downgradient due to aridity, dissolution of evaporitic minerals; salinization is intensified by irrigation return flow effected by evaporation (see 7 & 8 )

## Groundwater balance scheme




## Parameterization

**Precipitation (input):** Observations at Zagora station; regionalized

**Reservoir releases (input):** Observations at reservoir outlet

**Aquifer dimensions:** Based on literature, bore logs and remote sensing

**Aquifer properties:** Based on aquifer tests, bore logs and mapping

**Lateral inflow:** Via linear storage approach; input based on recharge estimations using Chloride Mass Balance (CMB)

**Upstream inflow:** Via Darcy approach based on regional hydraulic gradients

**River bed infiltration / percolation:** Via coefficients from literature

**Groundwater recharge / Irrigation percolation / Return flow:** Via coefficients from CMB

**Irrigation / Evapotranspiration:** Via Penman-Monteith approach using the CropWat model; irrigation efficiency from literature

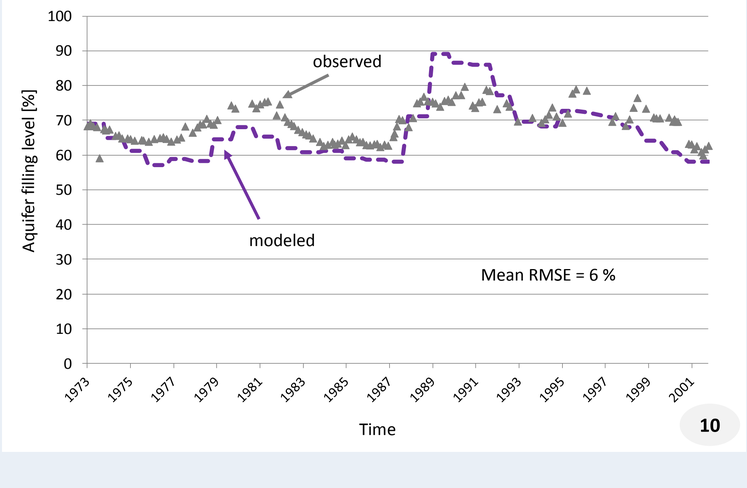
**Groundwater extraction:** Based on irrigation demand with priority in use: first surface water then groundwater

**Stream discharge:** Residual stream flow which is not used for irrigation or lost during transmission

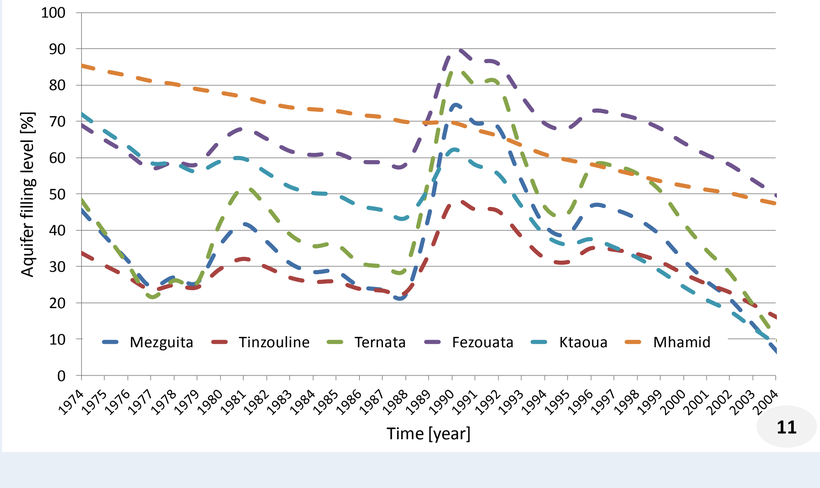
**Domestic consumption:** Based on water use survey

**Groundwater discharge:** Via Darcy approach based on regional hydraulic gradients

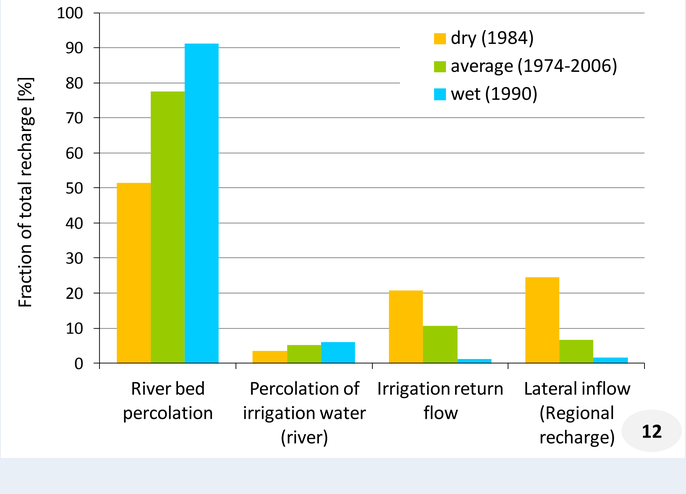
## Model plausibility at the Fezouata aquifer




## Simulation results




## Comparison of recharge components




## Conclusions

The regional analysis of the aquifer system, the aquifer response and groundwater flow in combination to hydrogeochemical investigation leads to enhanced insight to the hydrogeological processes in the Middle Drâa Catchment. Knowledge about the importance of the specific recharge and salinization processes is gained. The re-interpretation of aquifer properties results in an appropriate parameterization of the groundwater budget model BIL. The dynamic of the response of the Drâa aquifers is modeled with good accuracy for the a 30 year period using BIL. BIL is used for further analysis of the hydrogeological system and the buffer function of the aquifers against droughts.
So, the model is capable of impact assessment and model-based scenario analysis of climate and socio-economic change to support regional groundwater planning and long-term aquifer management.

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