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Marrakech, Morocco | 1-5 December 2025

Kingdom of Morocco



Ministry of  
Equipment and Water

# Indigenous Water Management Systems under Global Change: An Interdisciplinary Assessment of the Resilience of the Khettara System in Morocco's Southern Oases

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2 December 2025

# Problematic

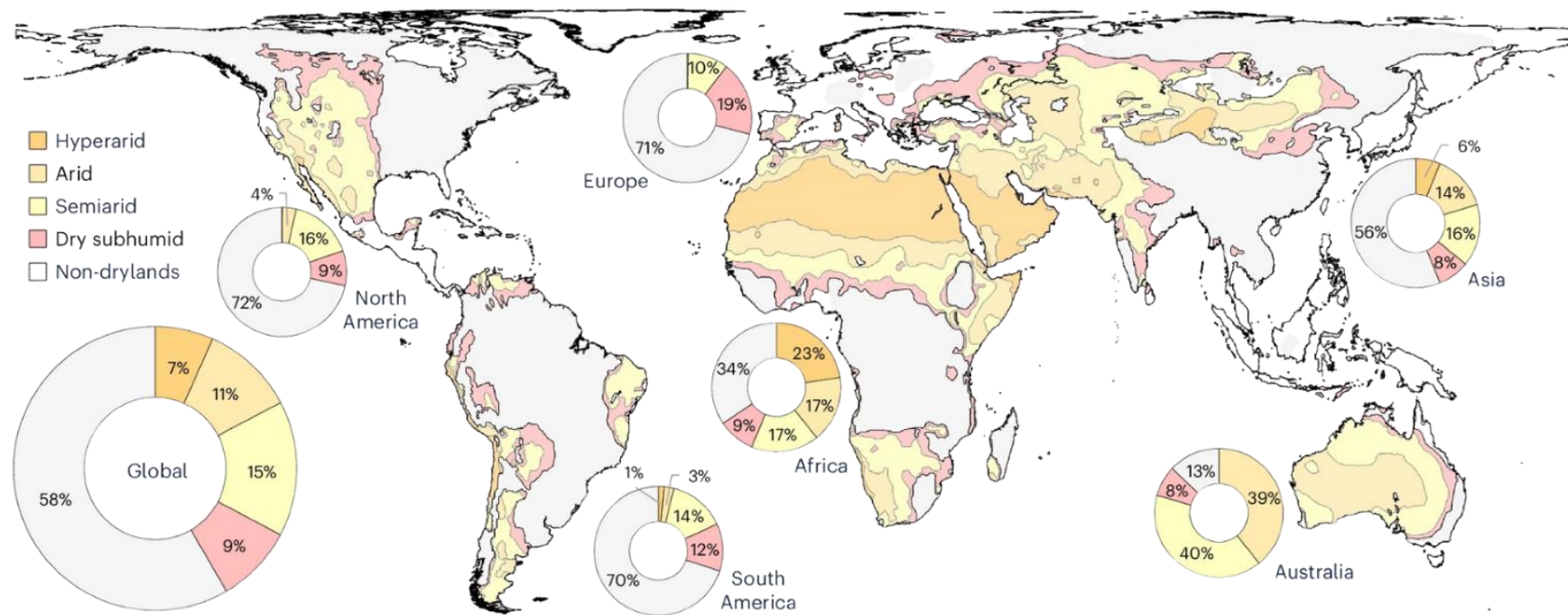
## Water scarcity within dry lands



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The water scarcity define a feature of nearly 40% of the Earth's surface affecting 1-2 billion people

Drylands are divided into hyperarid, arid, semiarid and dry subhumid subtypes (SPI < 0.65)



Circles show the relative terrestrial proportion of dryland subtypes globally and by continent.



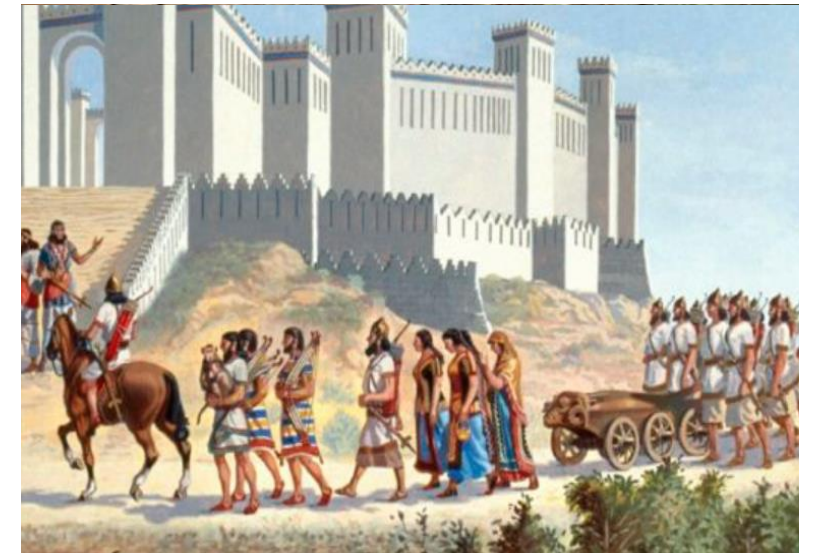
## The challenge become a catalyst for innovation

Only 7.7% of the world's renewable surface water, favorable temperature and radiation condition makes drylands often more agriculturally productive than the wet tropics or boreal forests



Home to early world's earliest civilization

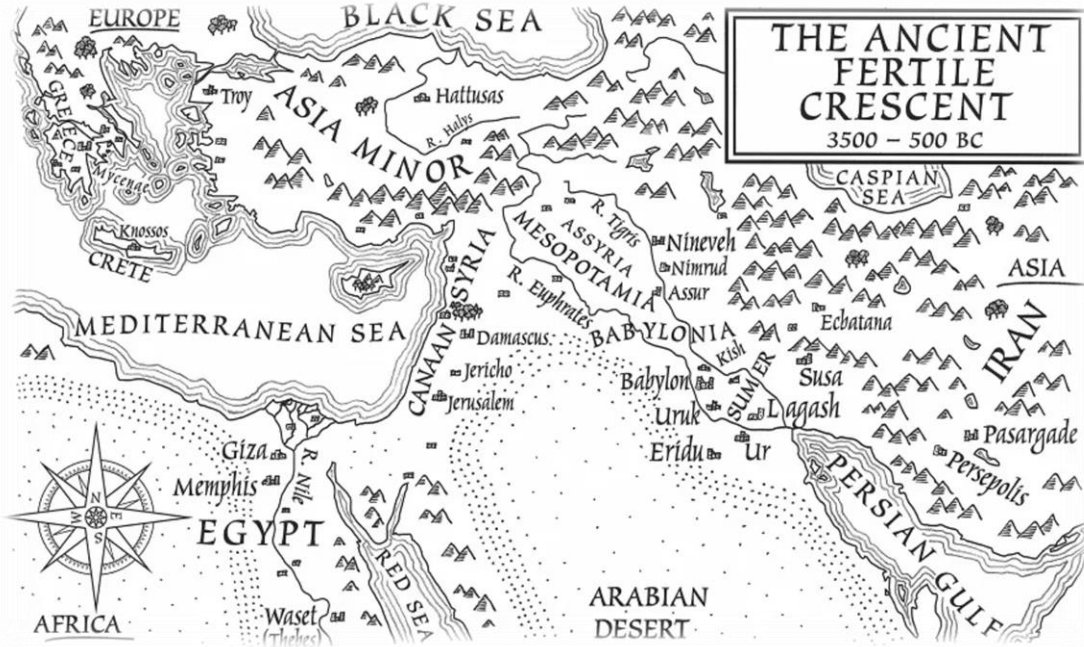
- Mesopotamia
- Ancient Egypt
- Persian Empire



# Historical overview



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Groundwater accounts for **99%** of all liquid freshwater on Earth

Although out of sight GW sustains:

Ecosystems

Feeds streams,

Rivers,

Lakes, wetlands, springs, estuaries, lagoons and the sea.

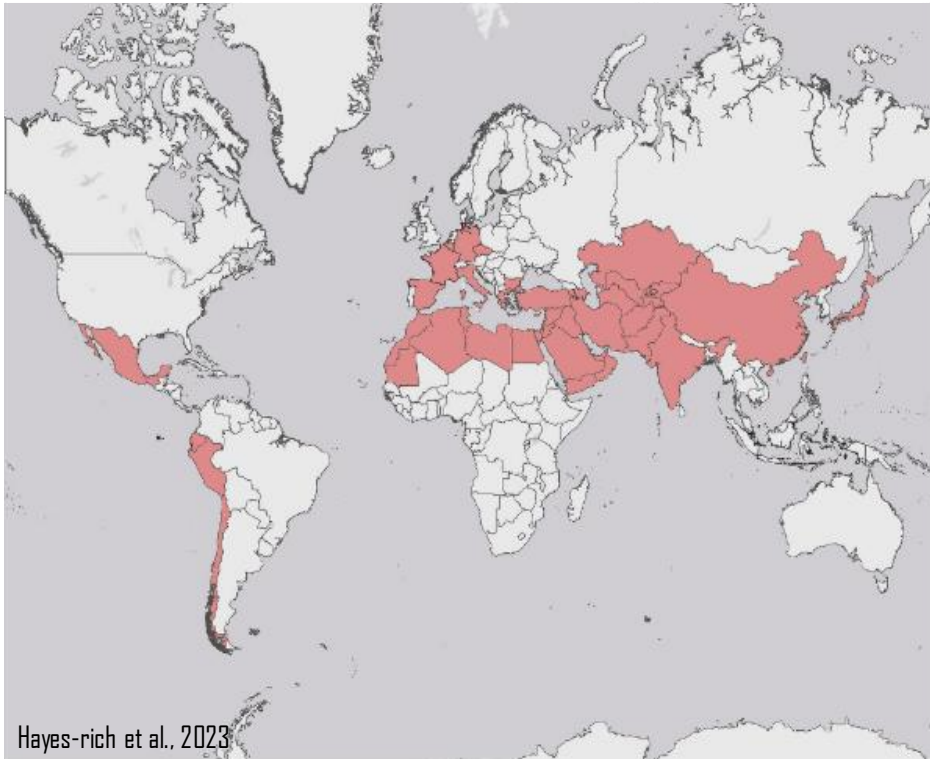
When water supply from springs and rivers became insufficient to raise their increasingly large herds and soil cultivation began, ancient civilisations started searching for groundwater.





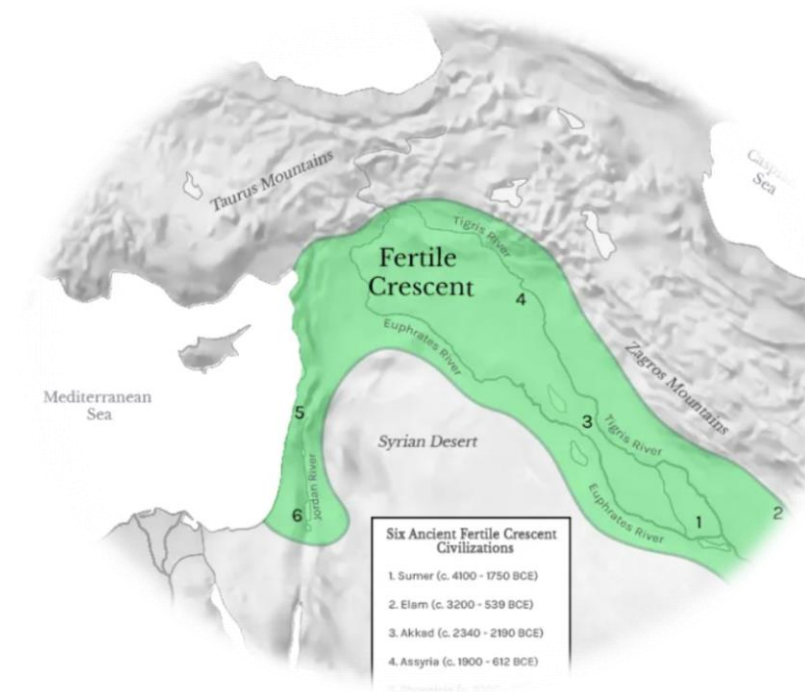
# Khettara system

The Qanat is a traditional earthen water management system known globally under different name as karez, galeria, aflaj, foggara etc



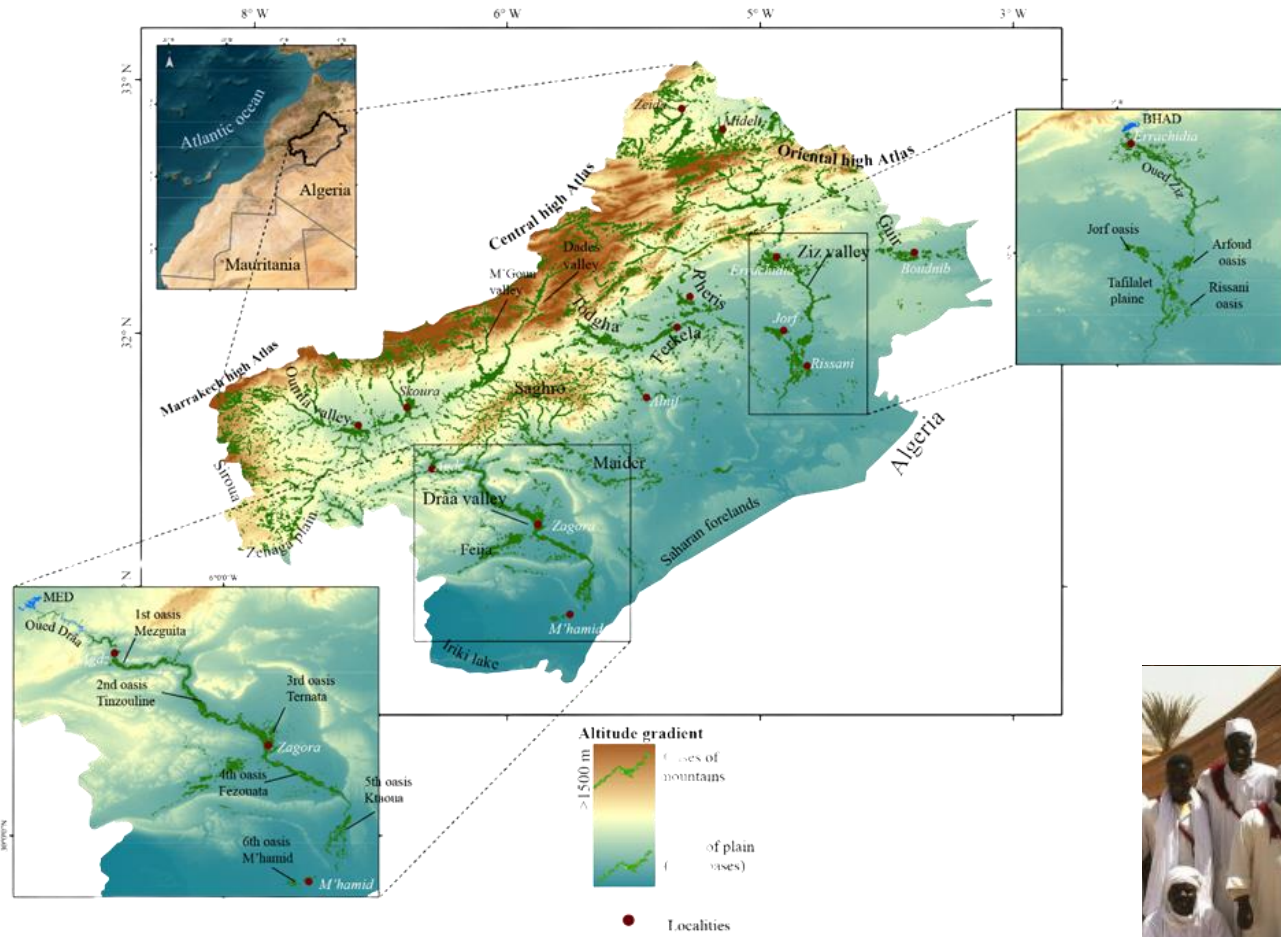
Hayes-rich et al., 2023

Originated in the ancient Armenian-Persian region, about 600-800 years B.C.



Several conflicting narratives dominate the history of the global qanat.

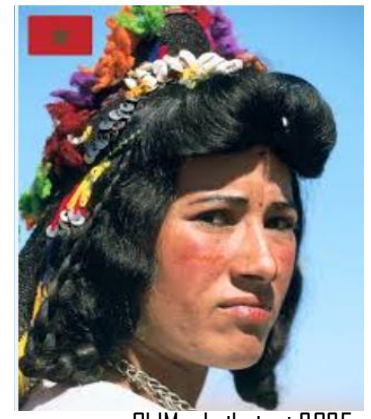
# Oases represent living repositories of indigenous knowledge



Historically important caravan crossroads and trading center



OldMaghrib. inst 2025



OldMaghrib. inst 2025



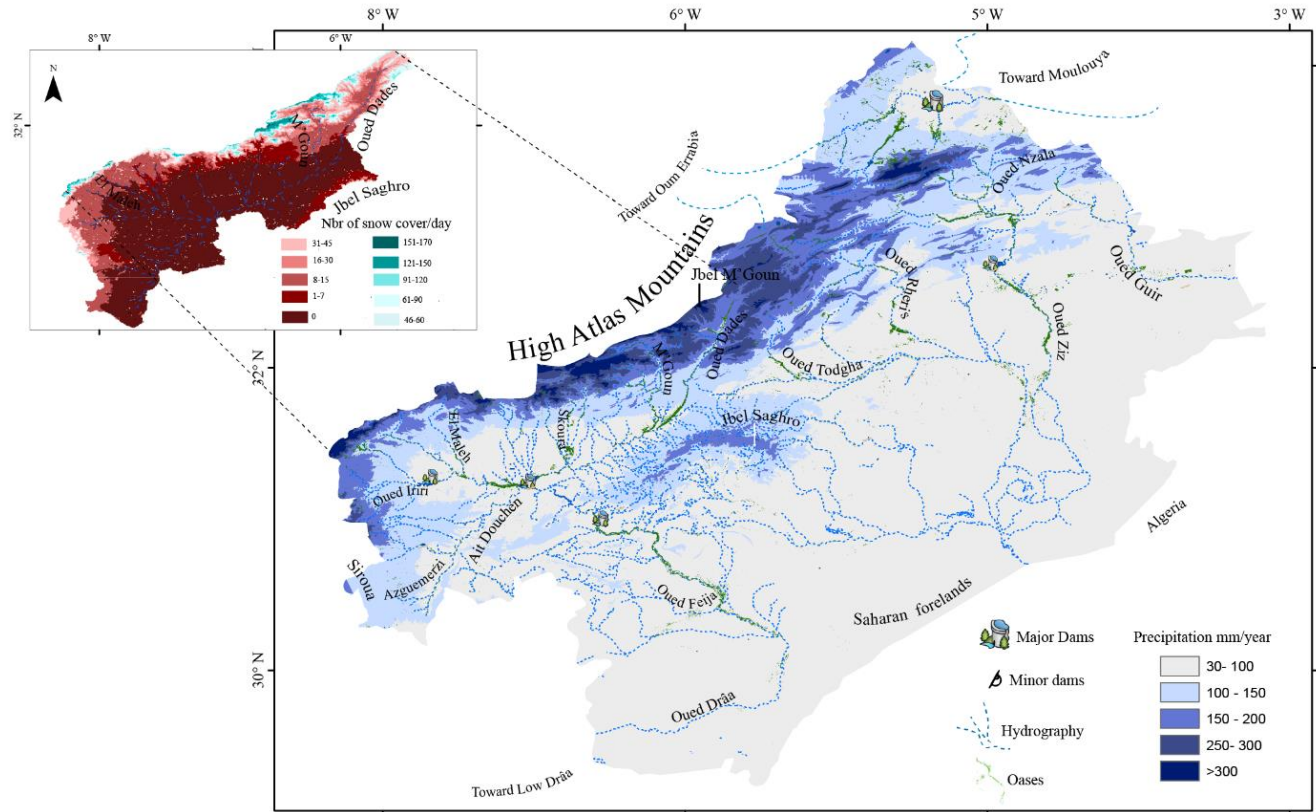
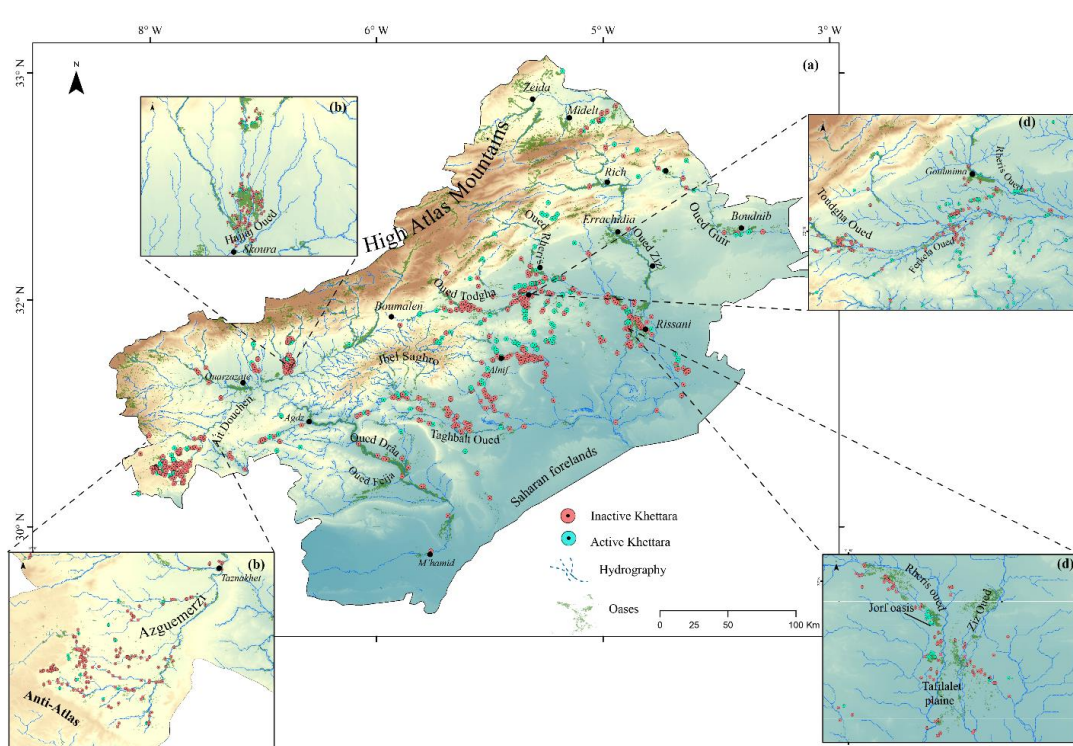
The librarian., 2025

# Khettara system



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## Distribution and current status of the khettara system in the RBDSM region



# Arial views



Photo of the khattara system in the Tafilalet Valley (www. Water history. org)

# Ground views



Hayes-rich et al. 2023



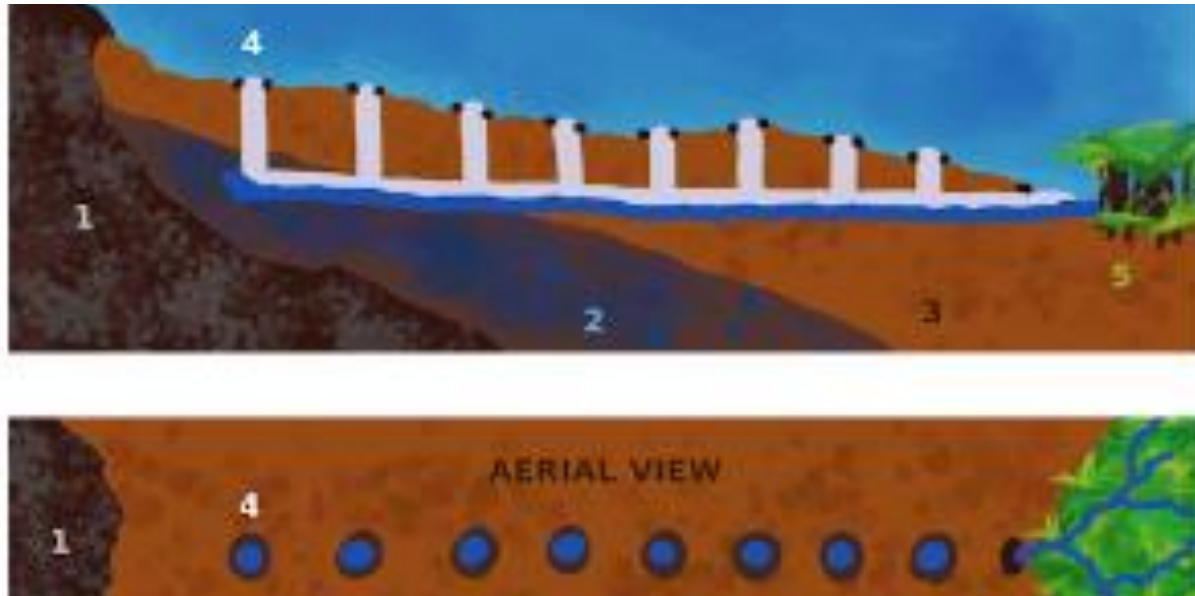
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Sustainable Development Goals



# Hydrogeological concept

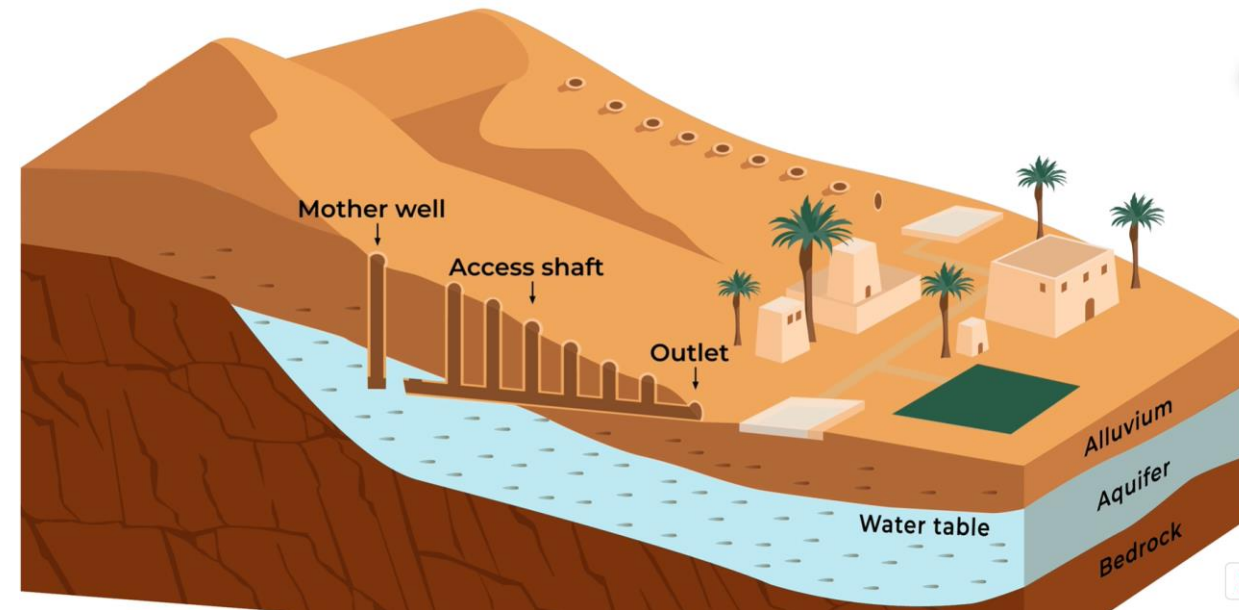


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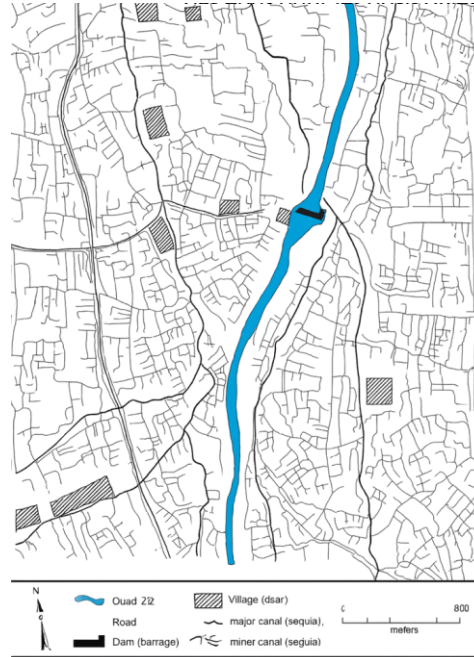


The Khettara involves an underground earthen tunnel extending horizontally from an aquifer to the surface with vertical shafts that connect the subterranean channel.

The natural supply of water in a filtration gallery can never exceed groundwater recharge



# Surface earthen canals (Saguias)



Intricate system of earthen canals  
incrementally built over centuries  
and maintained to this day.

Total length reaches 1095.91 km  
in Tafilalet oases

## How This Water Is Managed



The systems embody social organization, as  
their maintenance and operation rely on  
communal cooperation



The hydraulic clock system or Tanast



Each time the Tanast sinks down, a knot is formed

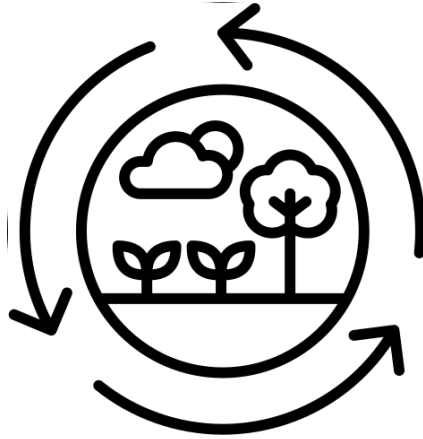
# A symbol of harmony between human and nature



## Ecosystem services

### Provisioning services

Freshwater for....  
Food security  
Biodiversity



### Cultural services

Cultural heritage  
Traditional knowledge  
Tourism

### Regulation services

Microclimate regulation  
Soil stabilization  
Aquifer recharge



# Recognition

Learning places for sustainable development

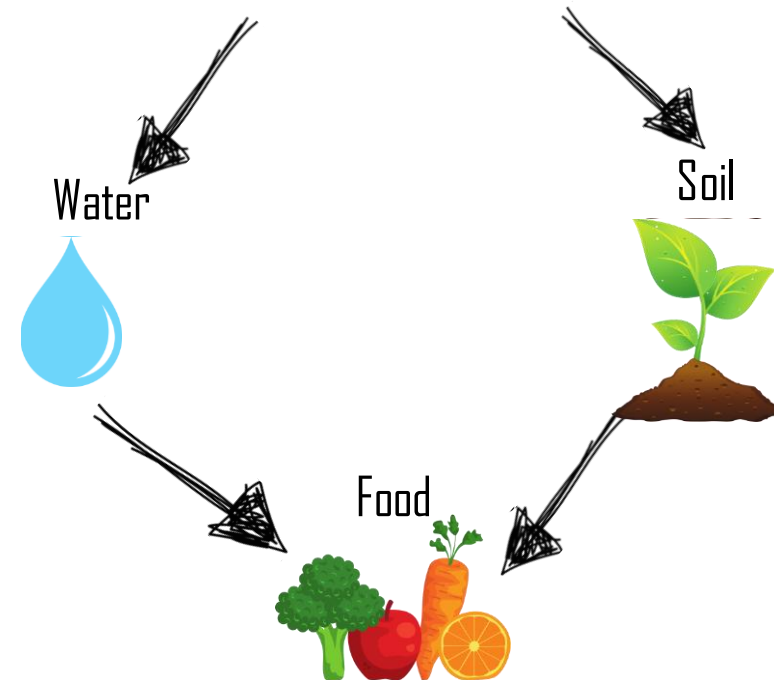


Globally Important Agricultural Heritage Systems (GIAHS)



Interactions between social and ecological systems,  
including conflict prevention and management of  
biodiversity

A form of adaptation

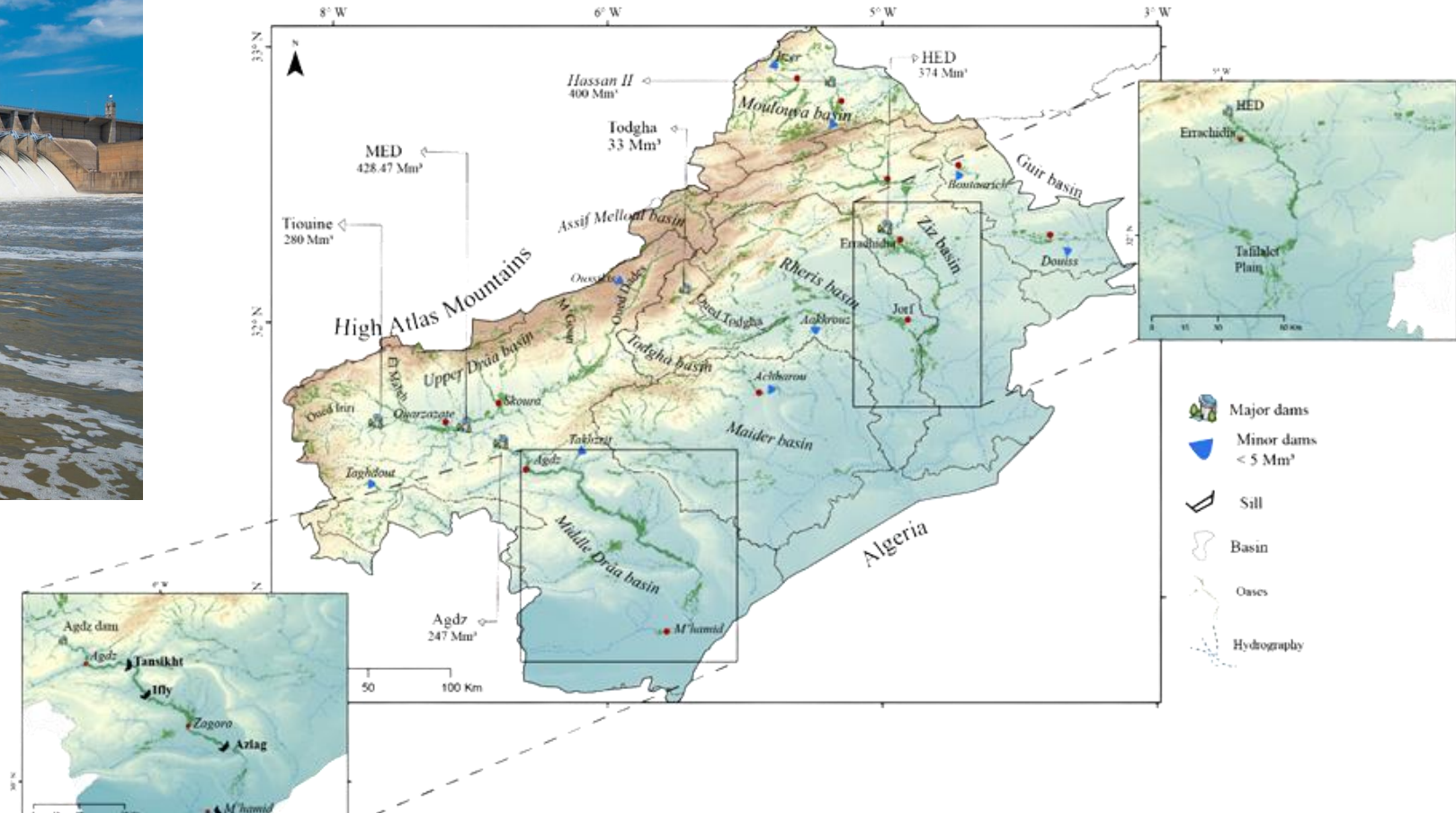




# Modernization and Westernization of Water Management

Creation of public institutions charged to manage water resources

Launch of major dam construction programs



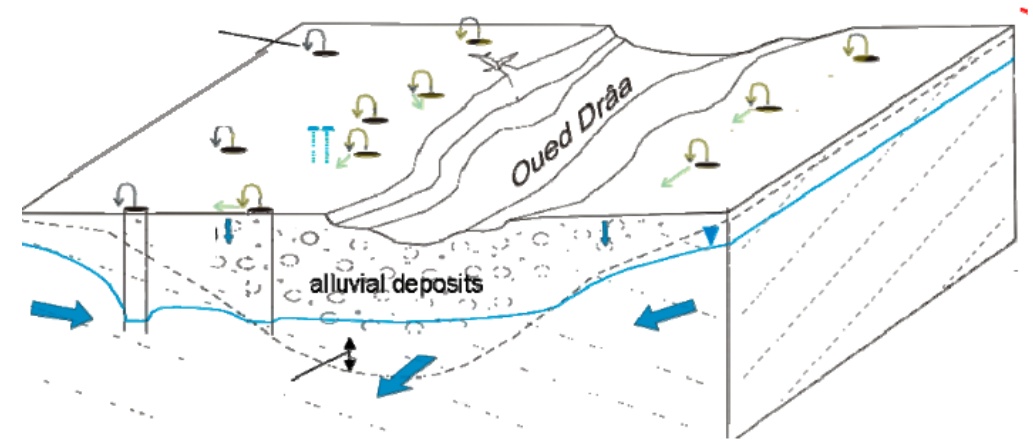
# Alteration of hydrological regime of intermittent rivers

**CHALLENGE**



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## Natural recharge processes

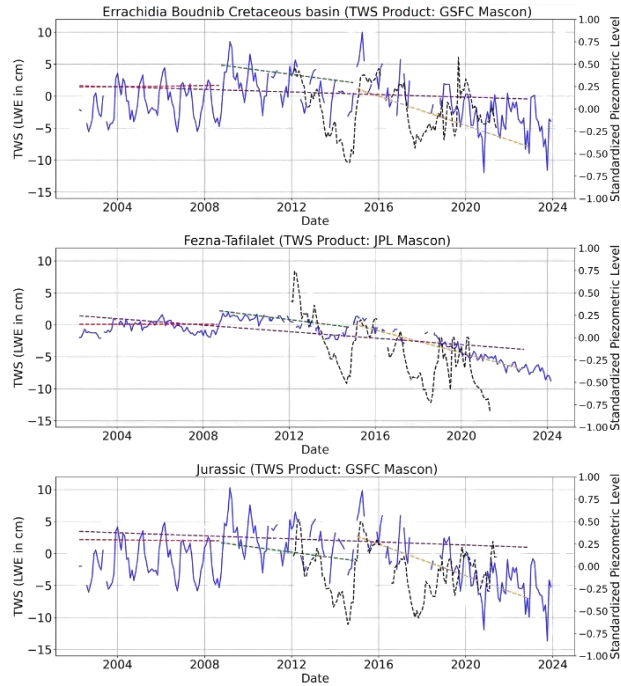


# Water availability



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## -30 m decrease for the period of 10 years



## Temporal variations for groundwater level for aquifers in southern Morocco

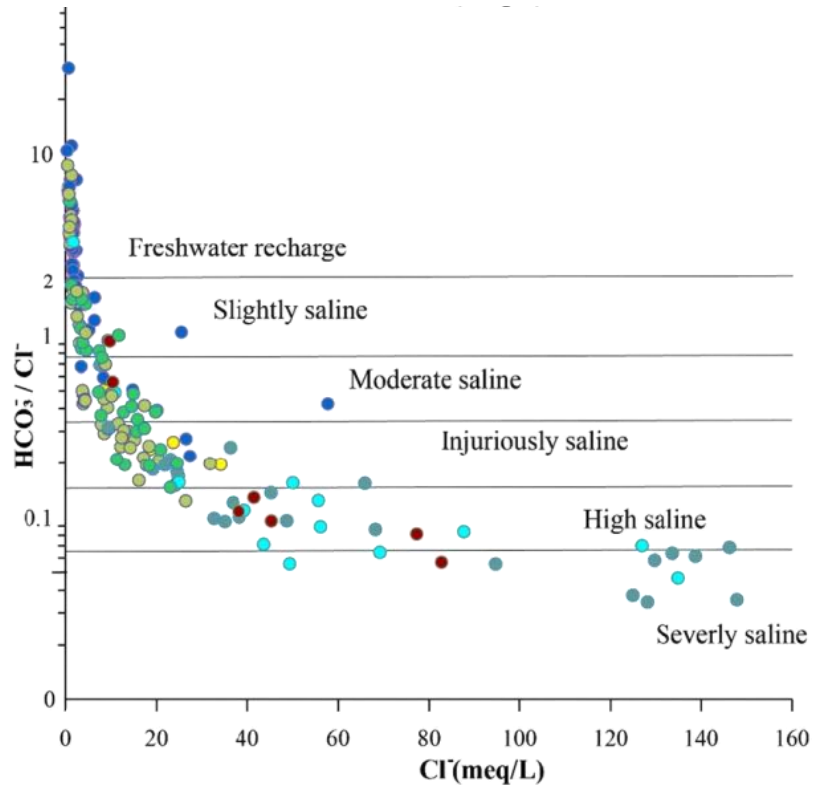
Abbad et al., 2025



# Water quality

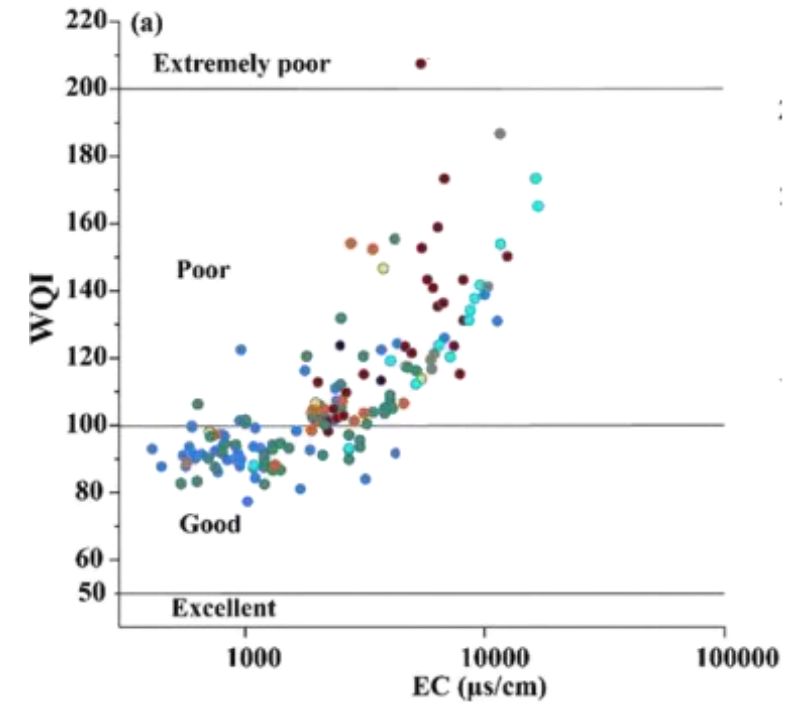


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Evolution of groundwater salinity from upstream oases to downstream

(Khettouch et al., 2025)

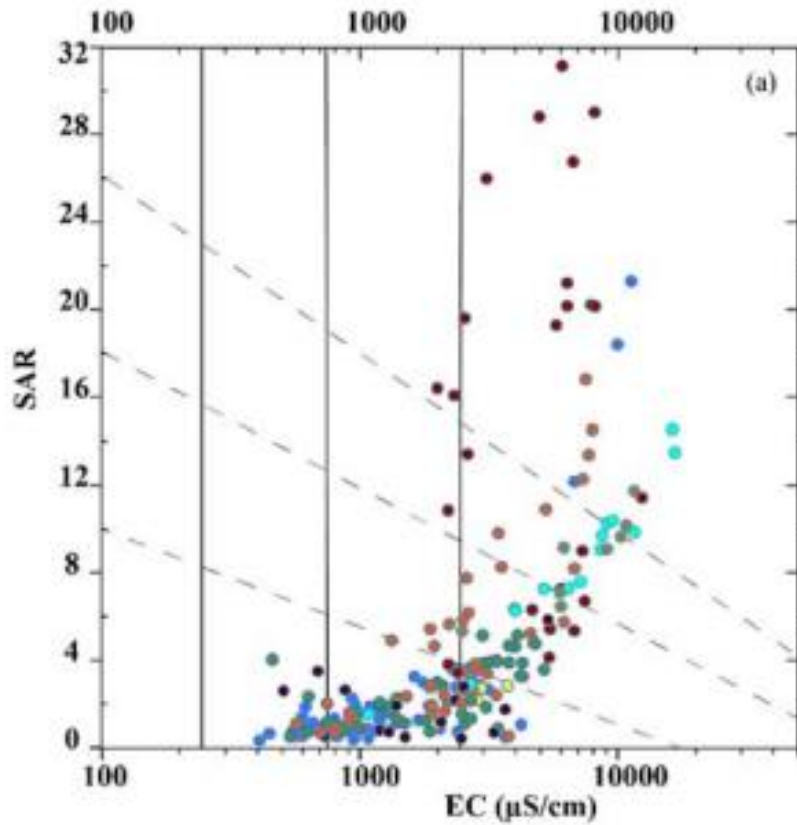


Degradation of water quality for drinking purposes

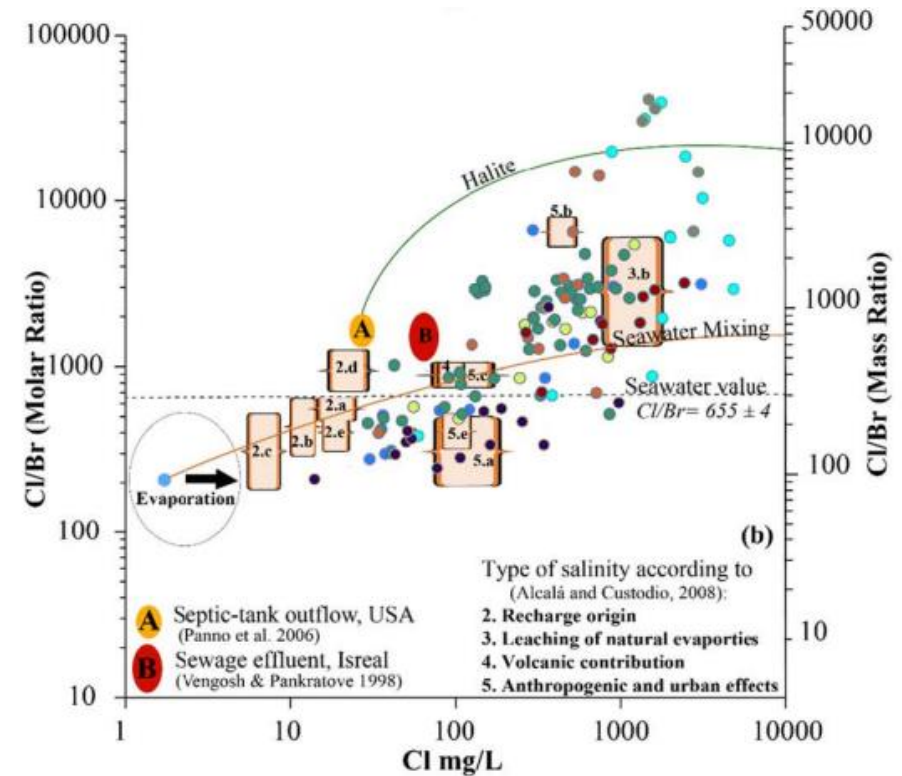
(Khettouch et al., 2025)



# Water quality



Salinity hazard intensifies along attitude gradient



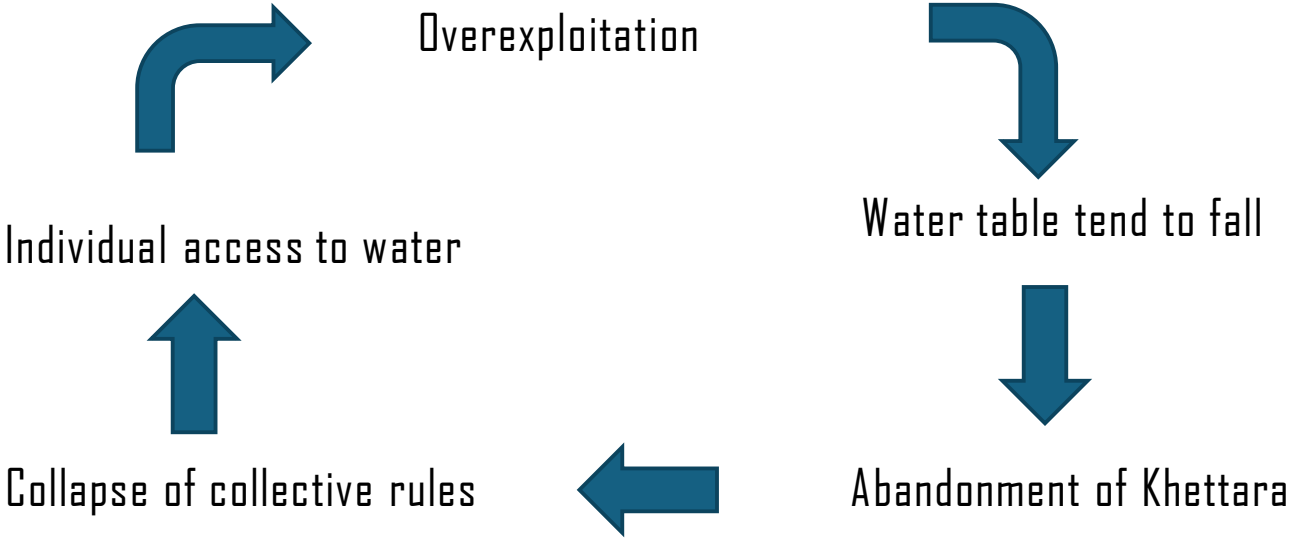
Distinguish potential geogenic from anthropogenic source on chloride content

# Consequences



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## Decline in the ecosystem services they once provided





# More details

Environmental Research Communications



PAPER

## Towards sustainability in dry land oases: water quality challenges

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Research paper

## Characterization of groundwater in the arid Zenaga plain: Hydrochemical and environmental isotopes approaches

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## Qanats: Ancient Innovations Nurturing Sustainable Futures in Water Management

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