Utrecht University

INTERNATIONAL MEUSE SYMPOSIUM

12th international Meuse Symposium
9 September 2026

Water scarcity under changing climate and extremes:
Complex interplay of water quality, availability, and sectoral use

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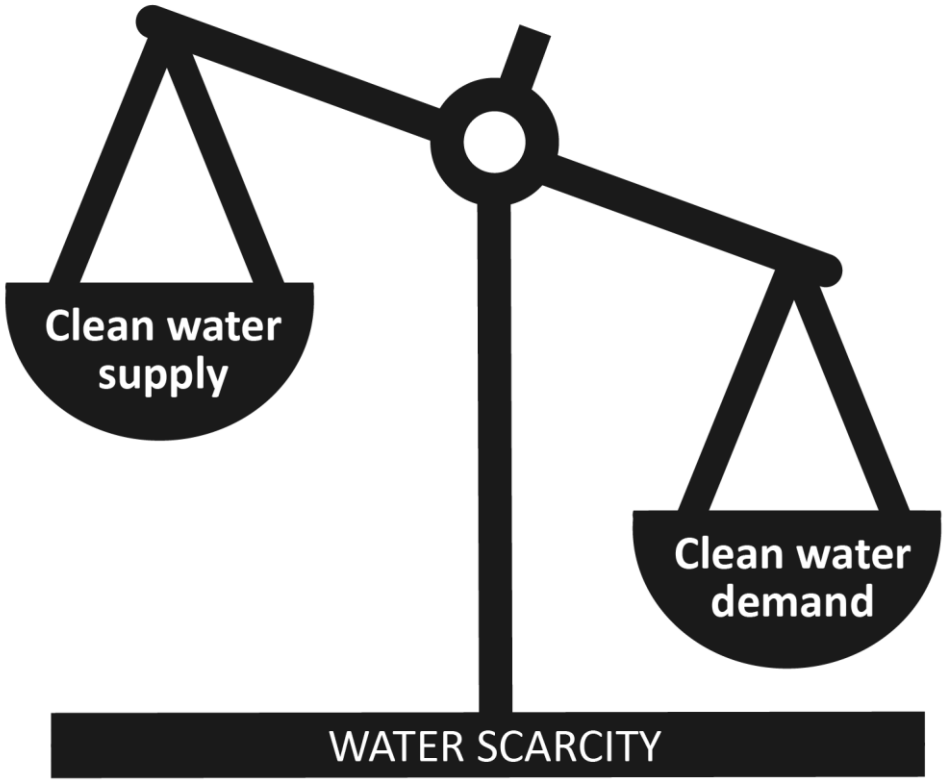
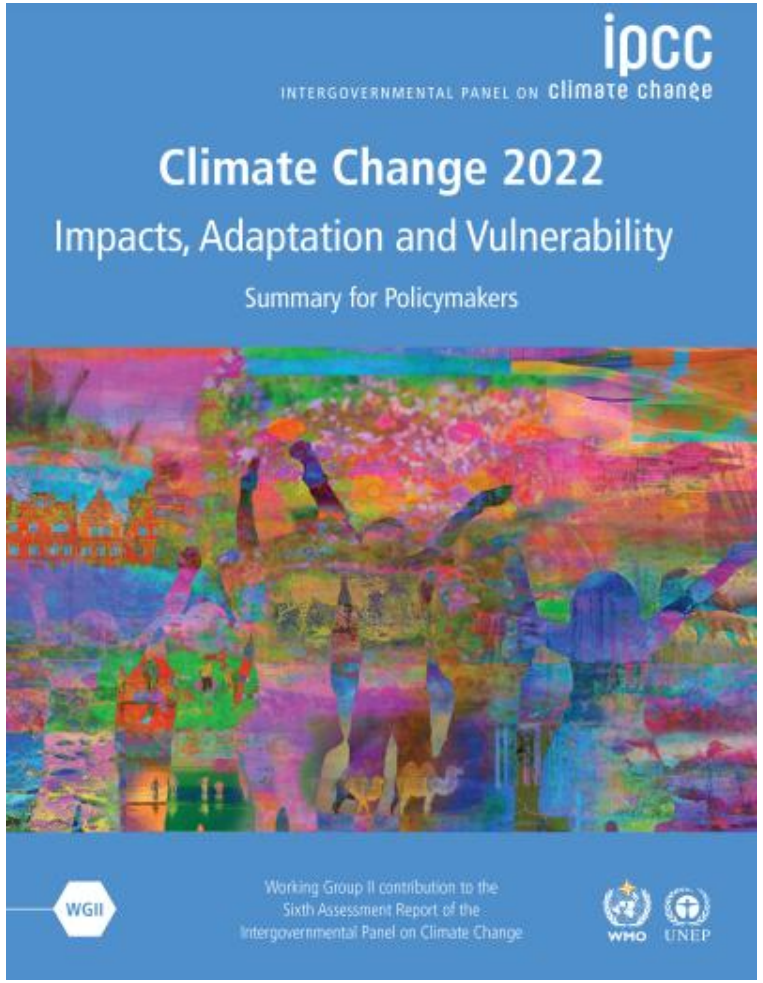
Chair in Water Quality and Sustainable Water Systems
Faculty of Geosciences, Utrecht University

Sufficient water of suitable quality in balance

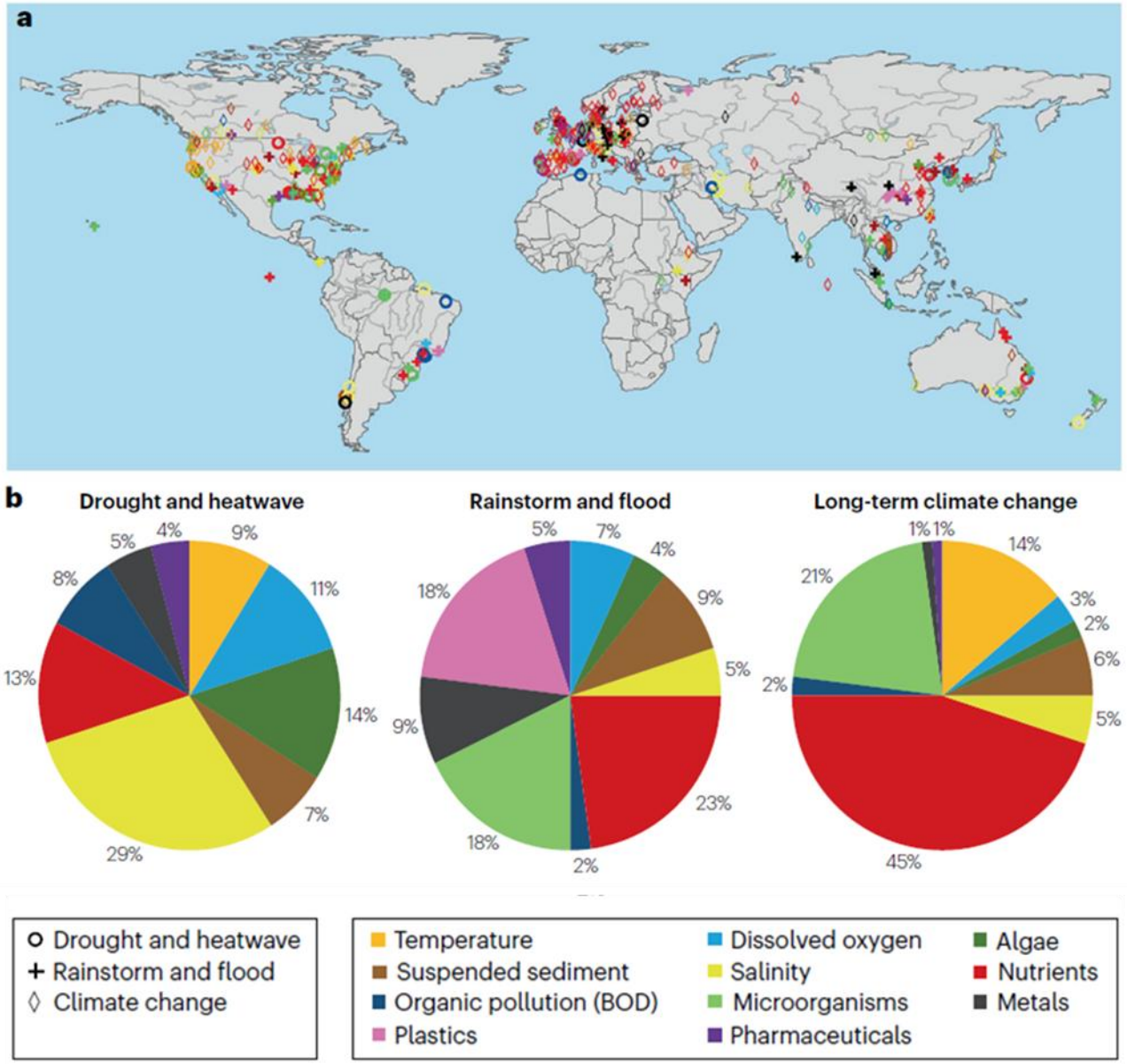


Knowledge gap: Water quality under climate extremes

"Quantifying future water quality changes is still incipient."



Global river water quality under climate change and hydroclimatic extremes



nature reviews earth & environment
https://doi.org/10.1038/s43017-023-00472-3

Review article
Check for updates

Global river water quality under climate change and hydroclimatic extremes

Michelle T. H. van Vliet[1], Josefin Thorslund[1,2], Maryna Strokal[3], Nynke Hofstra[3], Martina Flörke[4], Heloisa Ehalt Macedo[5], Albert Nkwasa[6,7], Ting Tang[8], Sujay S. Kaushal[9], Rohini Kumar[10], Ann van Griensven[6], Lex Bouwman[11,12] & Luke M. Mosley[13]

- **Hydroclimatic** extremes:
  - Droughts, heatwaves
  - Rainstorm, floods
- **Multi-decadal climate change** (hist. & fut.)
- **965** lit. study cases (2000-2022)
- **11** water quality constituents

Global river water quality under climate change and hydroclimatic extremes

Droughts & heatwaves

Deterioration 68% of cases (droughts) and 89% (heatwaves, drought-heatwave)

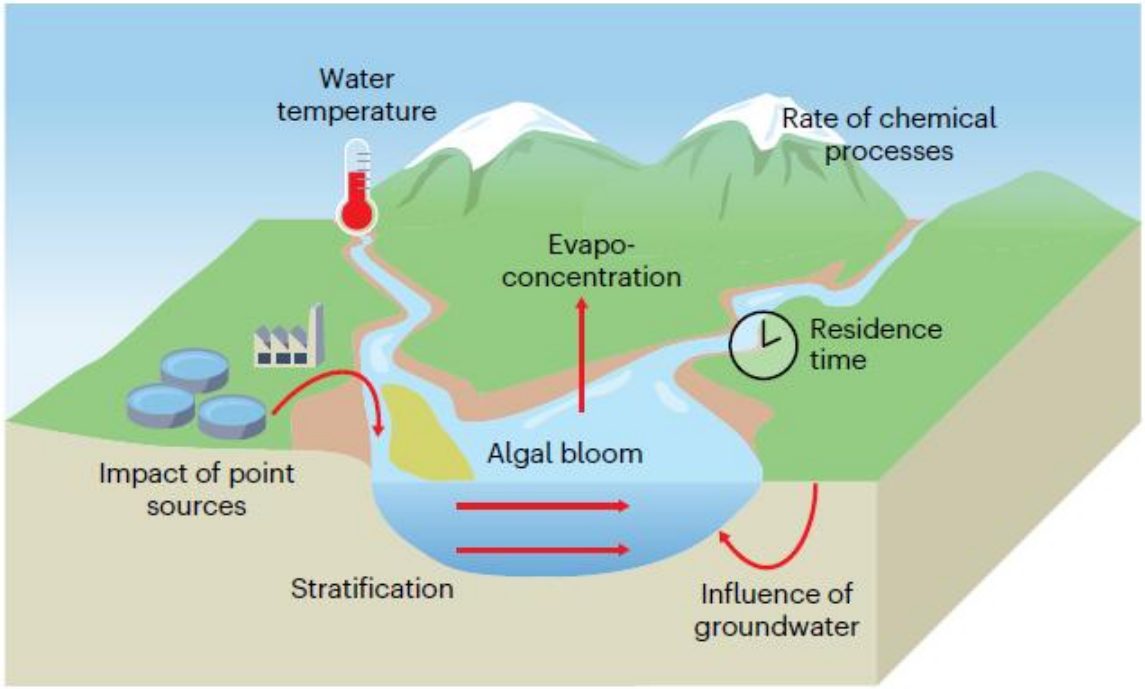
→ water temperature rises, limited dilution of contaminants

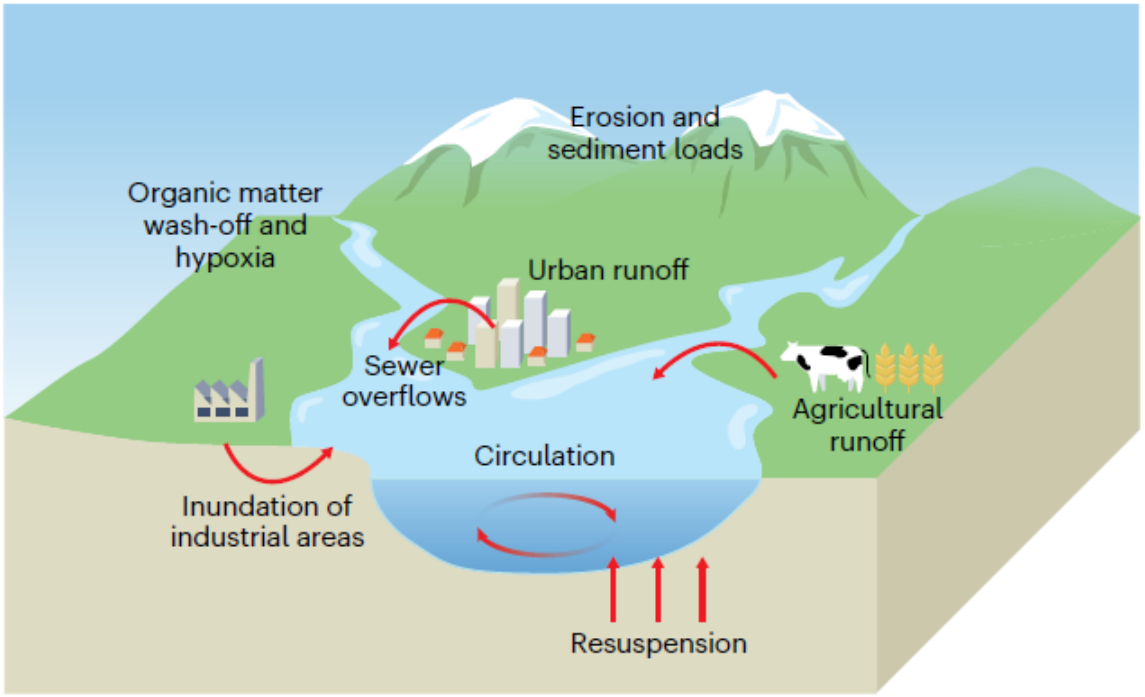
Rainstorms & floods

Deterioration 51% of cases

→ increased mobilization and transport

→ but also increased dilution

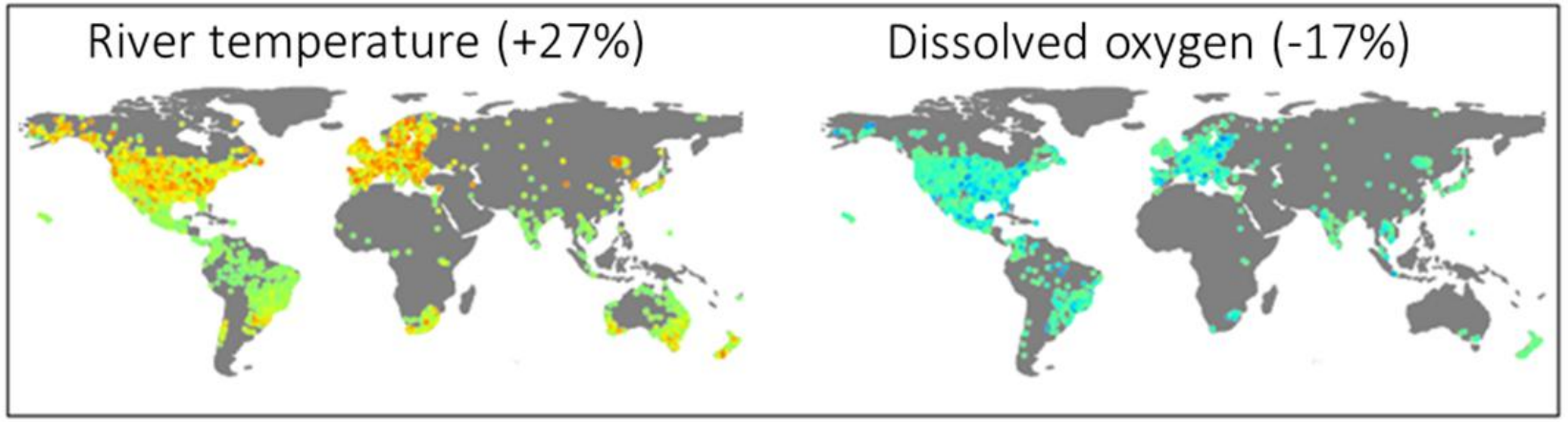




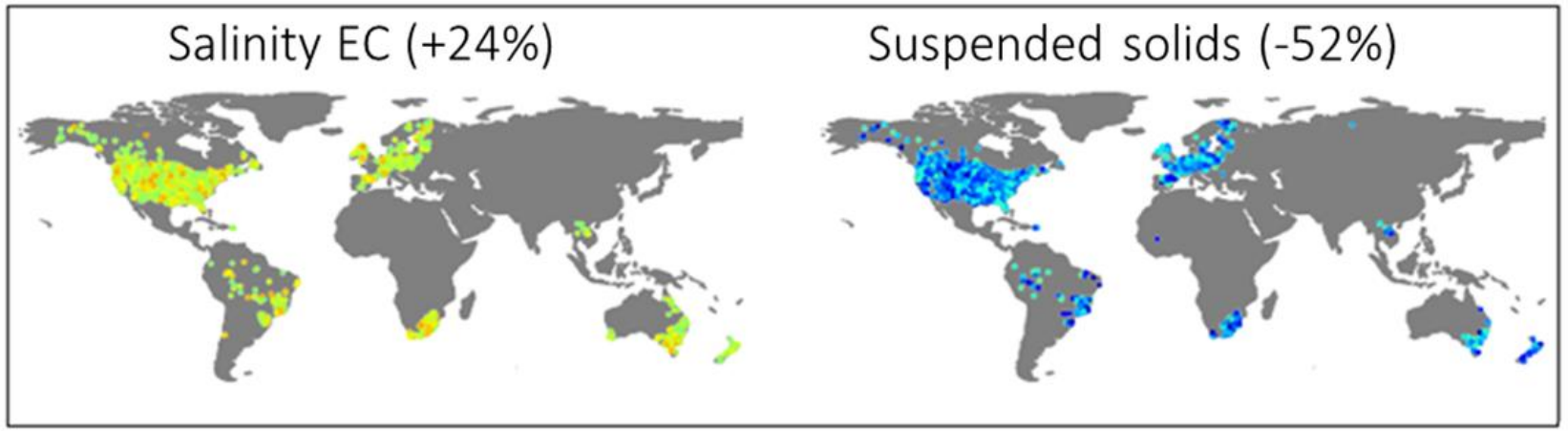
van Vliet et al (2023) Nature Reviews earth & environm.

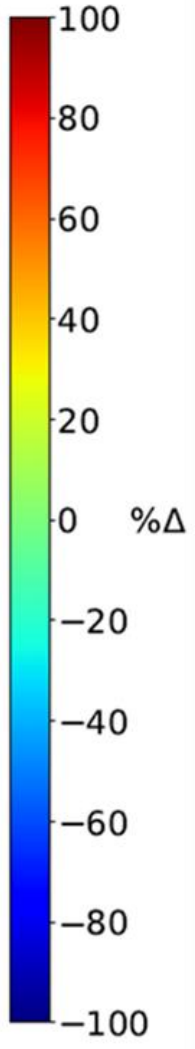
Impacts droughts on global river water quality

%Δ under Heatwave



%Δ under Drought



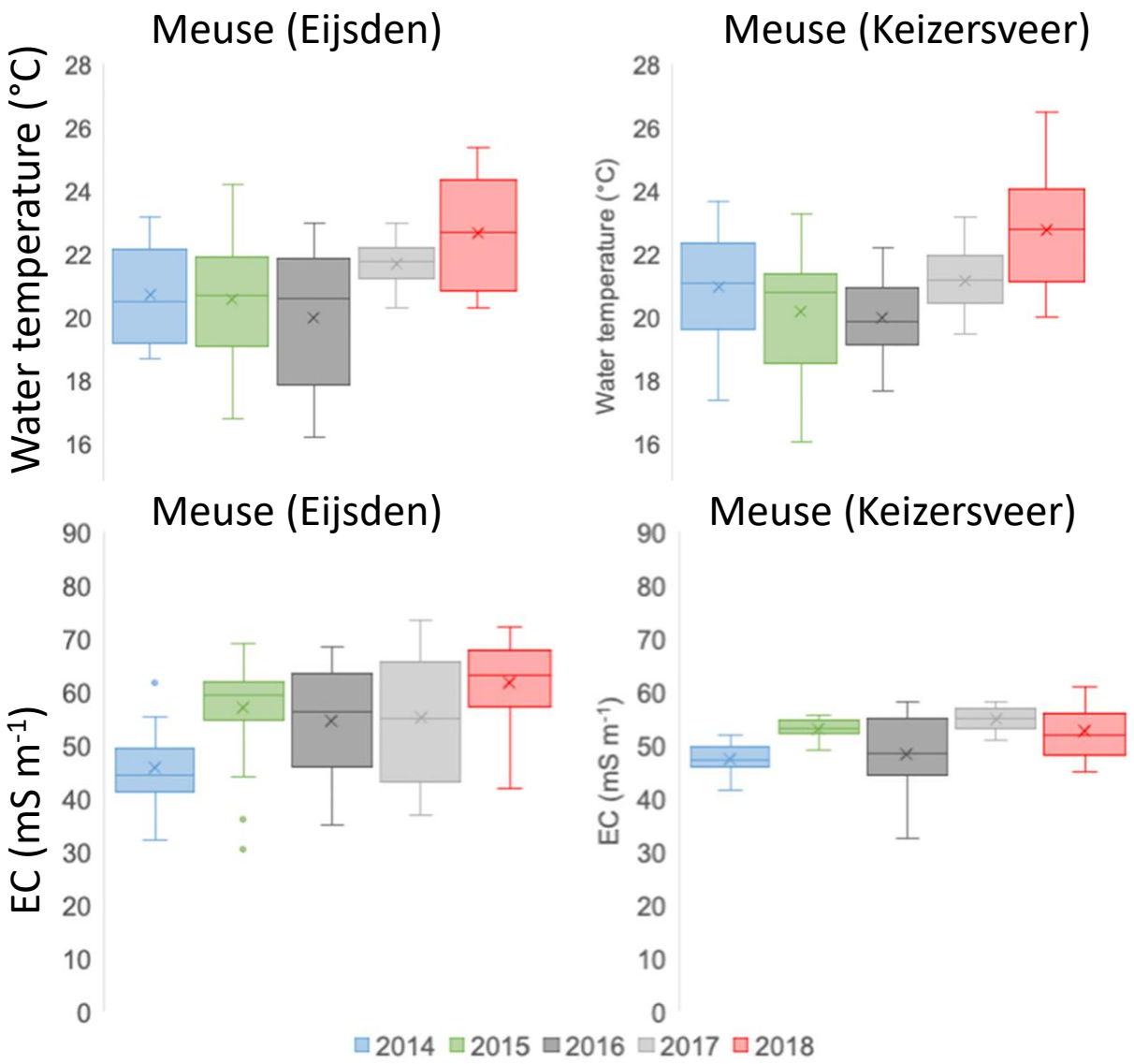


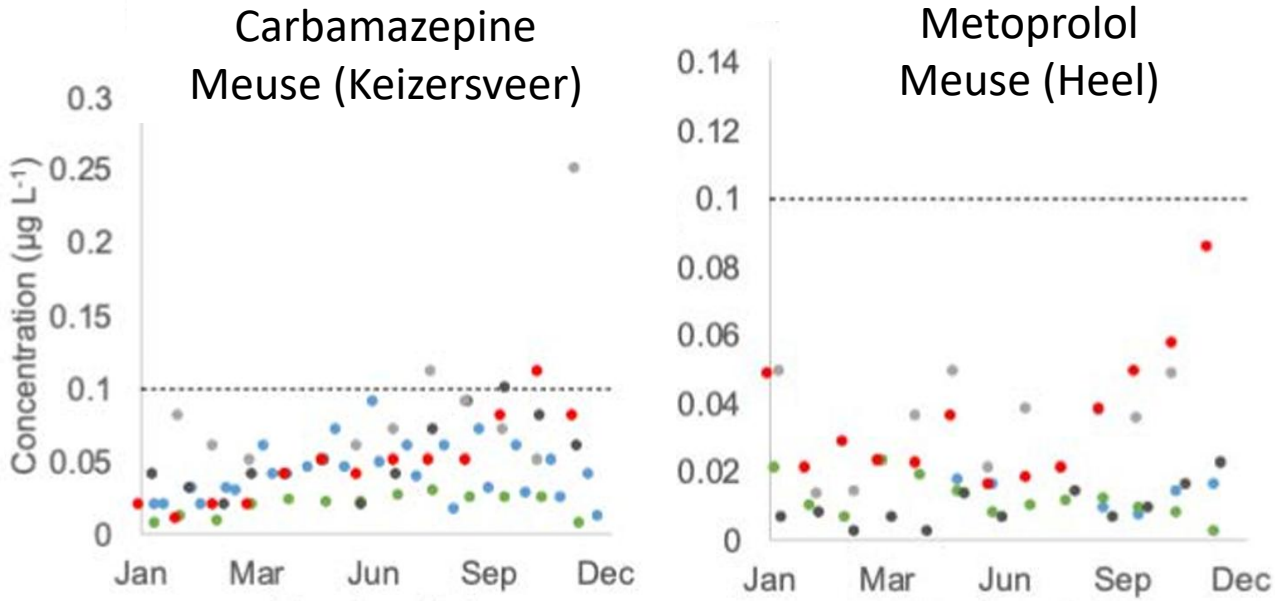
- 314,046 water quality monitoring stations
- 16 water quality constituents
- 1980-2021

→ Deterioration of water quality under droughts, heatwaves, compound events

Graham et al. (2024), J. of Hydrology

Impacts droughts on pharmaceuticals – Meuse





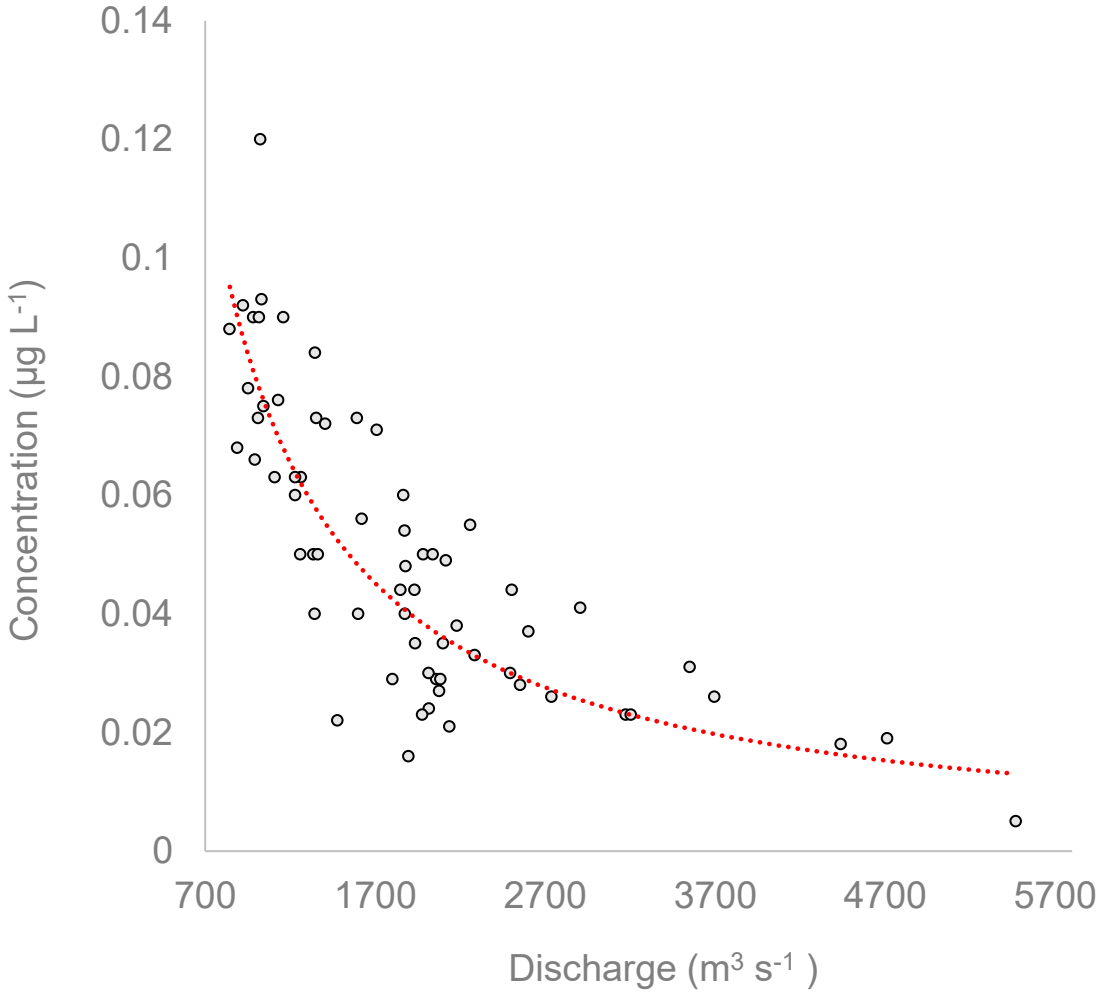
Meuse and Rhine (NL monitoring stations):

- Sign. increases in water temperature (average +1.9 °C) and salinity levels (+11%).
- Higher concentrations of some pharmaceuticals:
  - carbamazepine (+10%)
  - metoprolol (+29%)

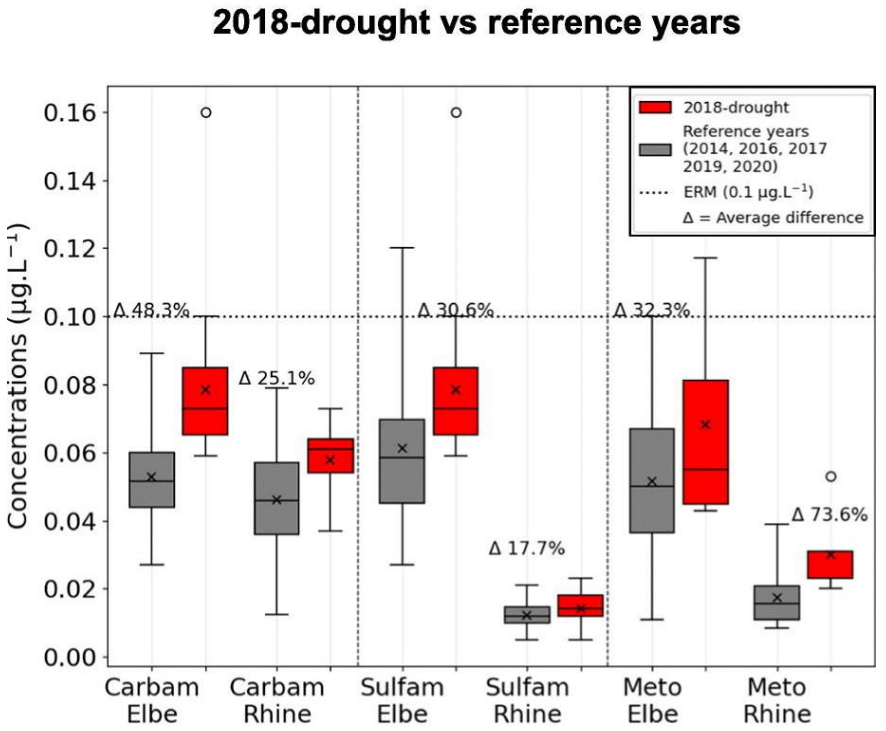
Wolff and Van Vliet (2021) Sci. Total Environ.

Impacts droughts on pharmaceuticals – Meuse

Carbamazepine
Rhine (Lobith)



Wolff and Van Vliet (2021) Sci. Total Environ.



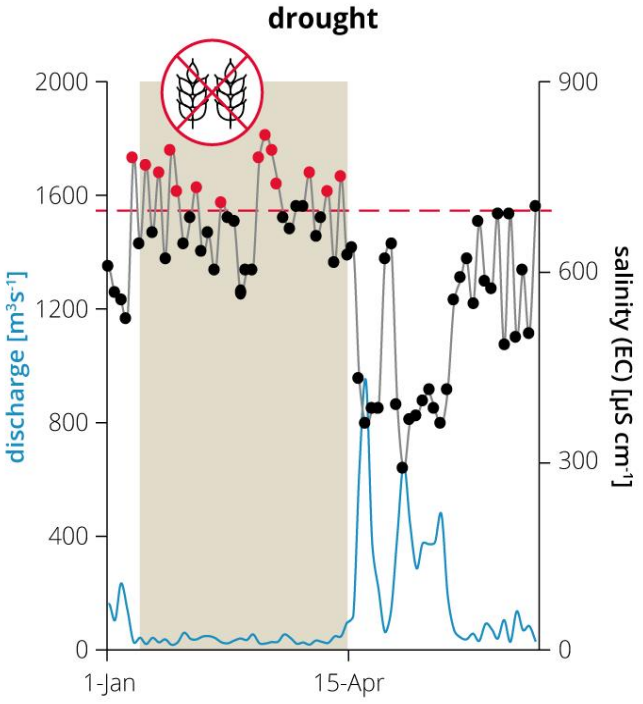
Lentz et al. (2024) Sci. Total Environ.

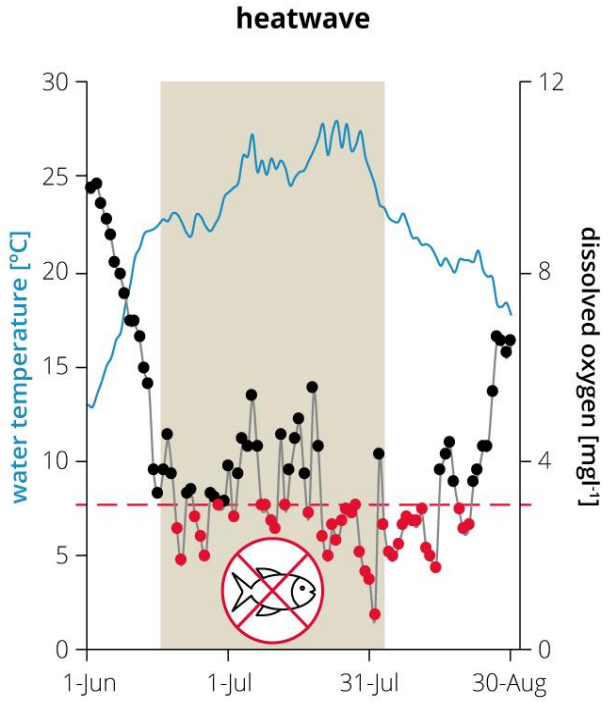
Meuse and Rhine (NL monitoring stations):

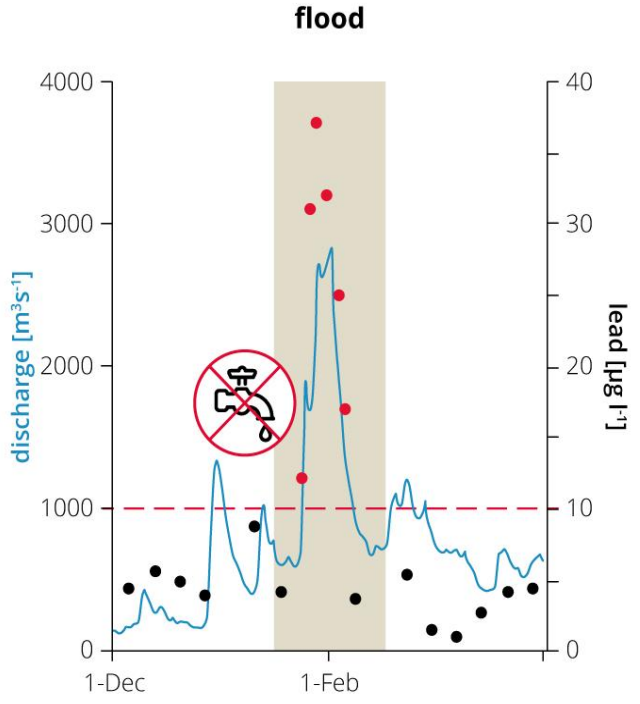
- Sign. increases in water temperature (average +1.9 °C) and salinity levels (+11%).
- Higher concentrations of some pharmaceuticals:
  - carbamazepine (+10%)
  - metoprolol (+29%)

  → limited dilution under droughts

Sector water use constraints due to water quality under extremes







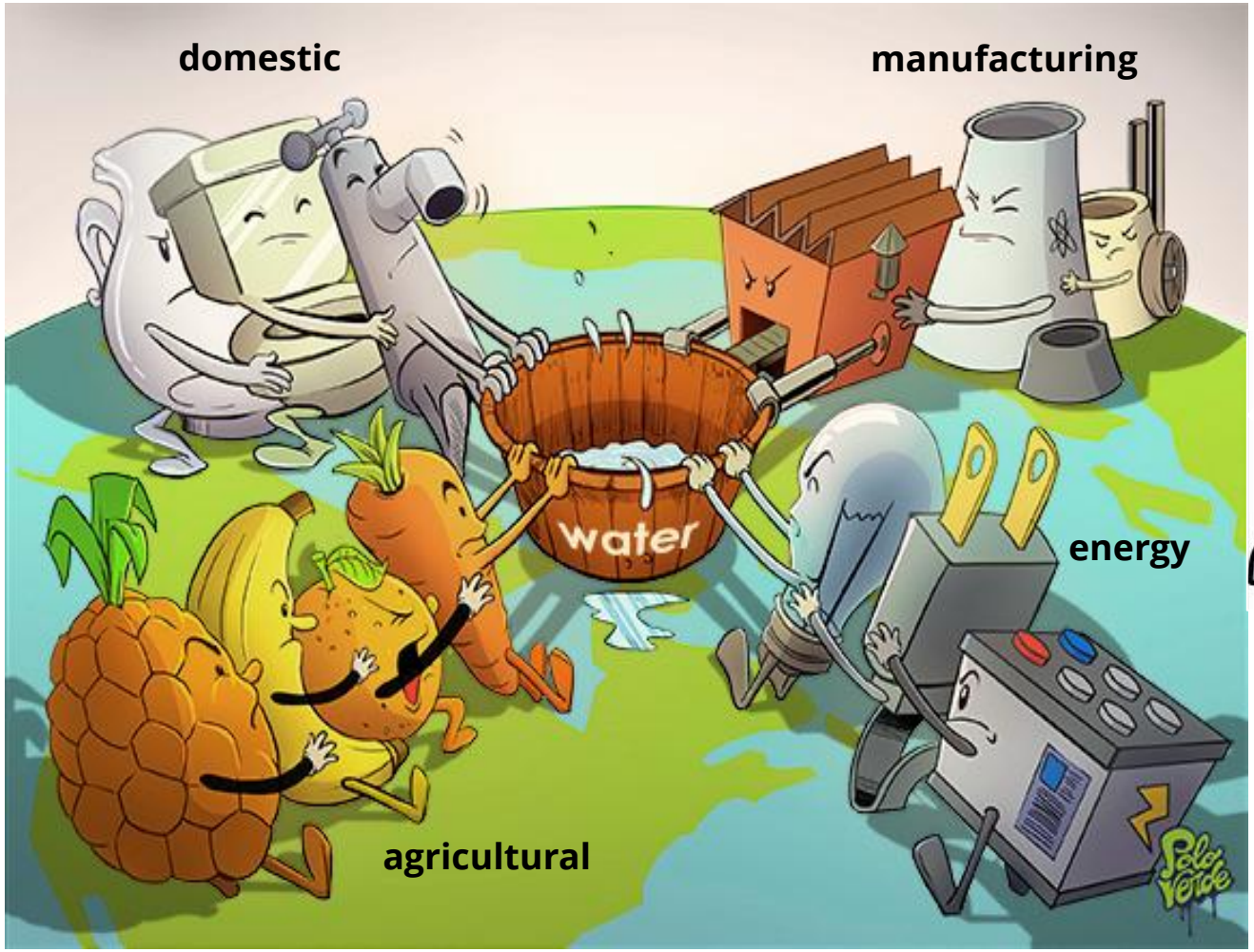
Texas, US (USGS)

Meuse, Netherlands (Rijkswaterstaat)

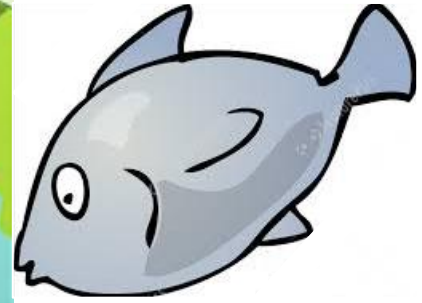
van Vliet et al. (2023)
Nature Reviews earth & environment

What is water scarcity?

*'Demand for water by all sectors and the environment cannot be fully satisfied due to the impact of water use on supply or **quality** of water' (Liu et al., 2017, Earth's Future)*

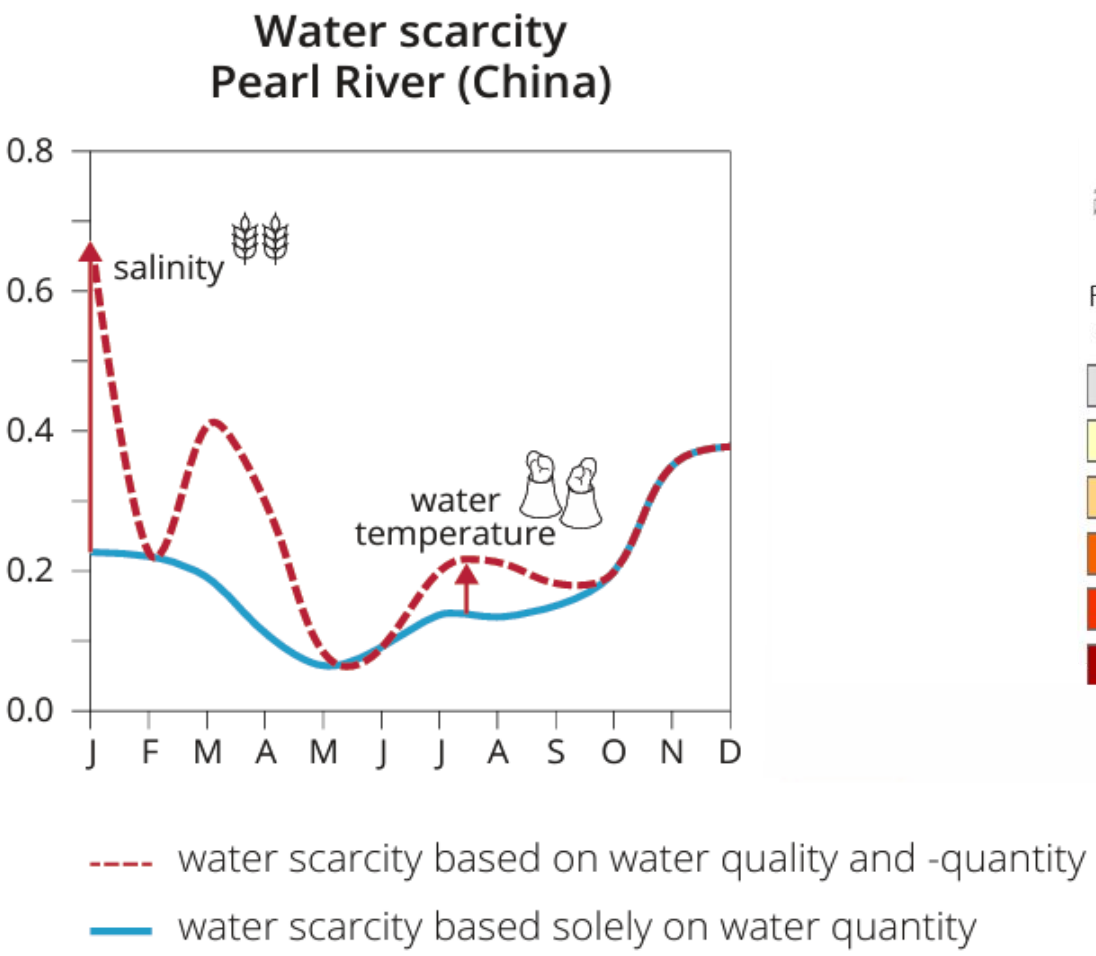


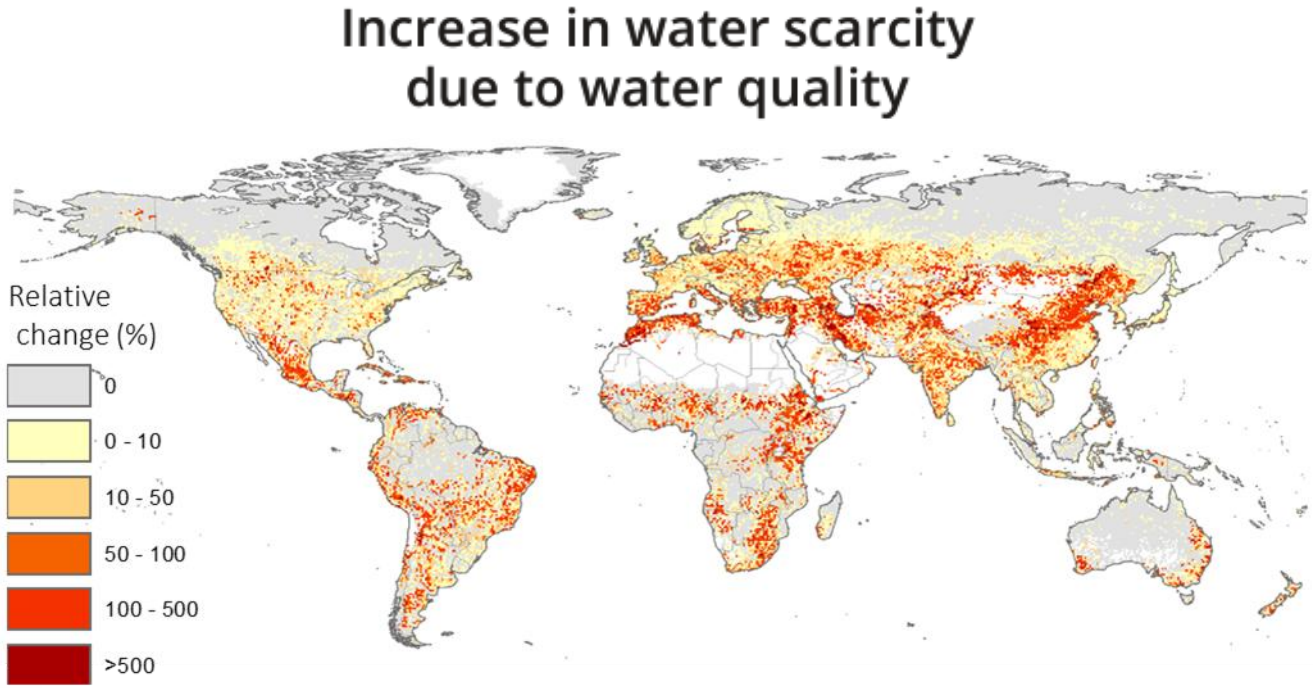
ecosystems



Water and sanitation program (2016)

Water quality matters for water scarcity





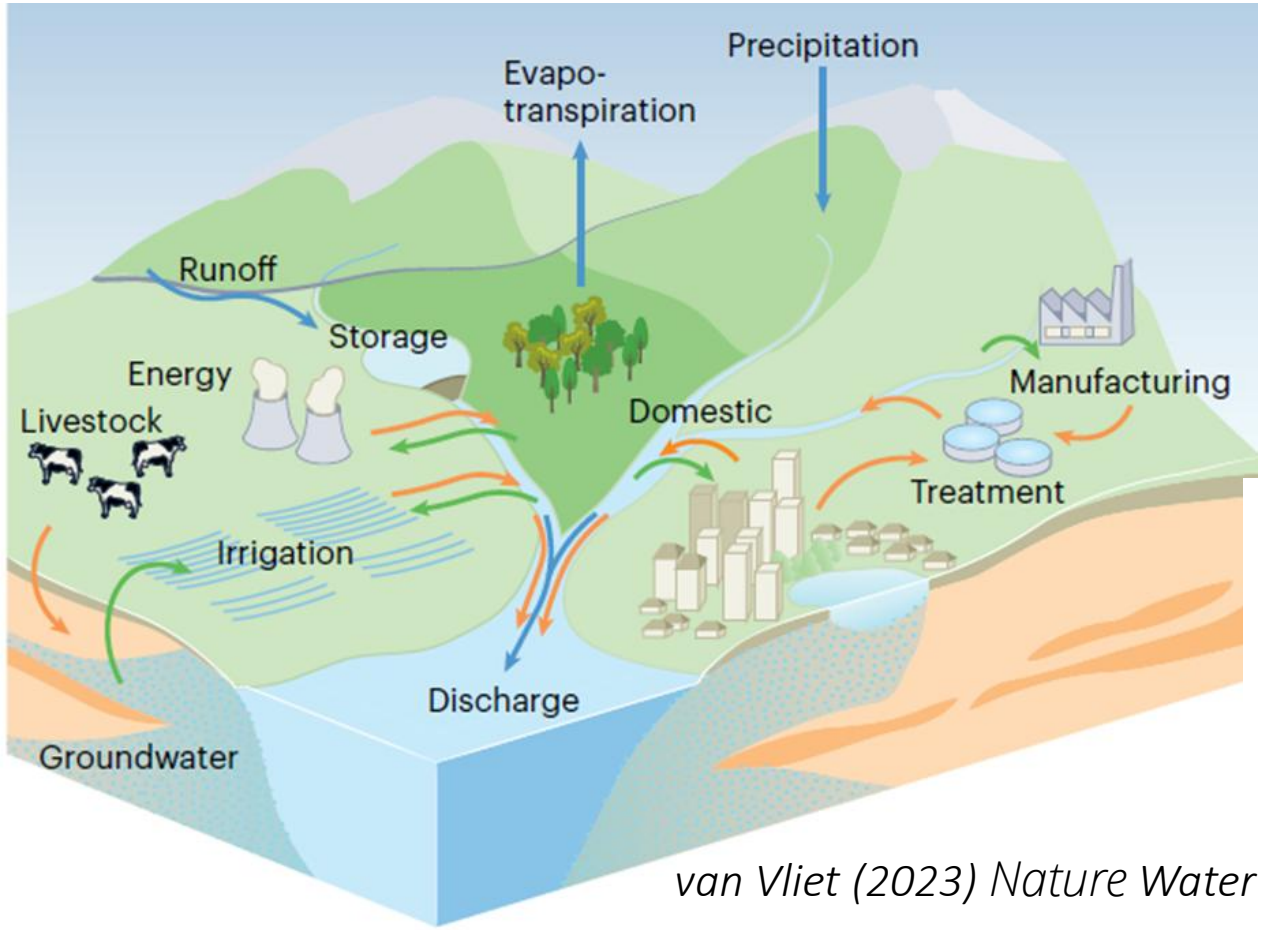
- Water temperature
- Salinity
- Organic pollution
- Nutrients (TN, TP)
- Wastewater treatment & reuse
- Desalination

van Vliet et al. (2017) Nature Geoscience

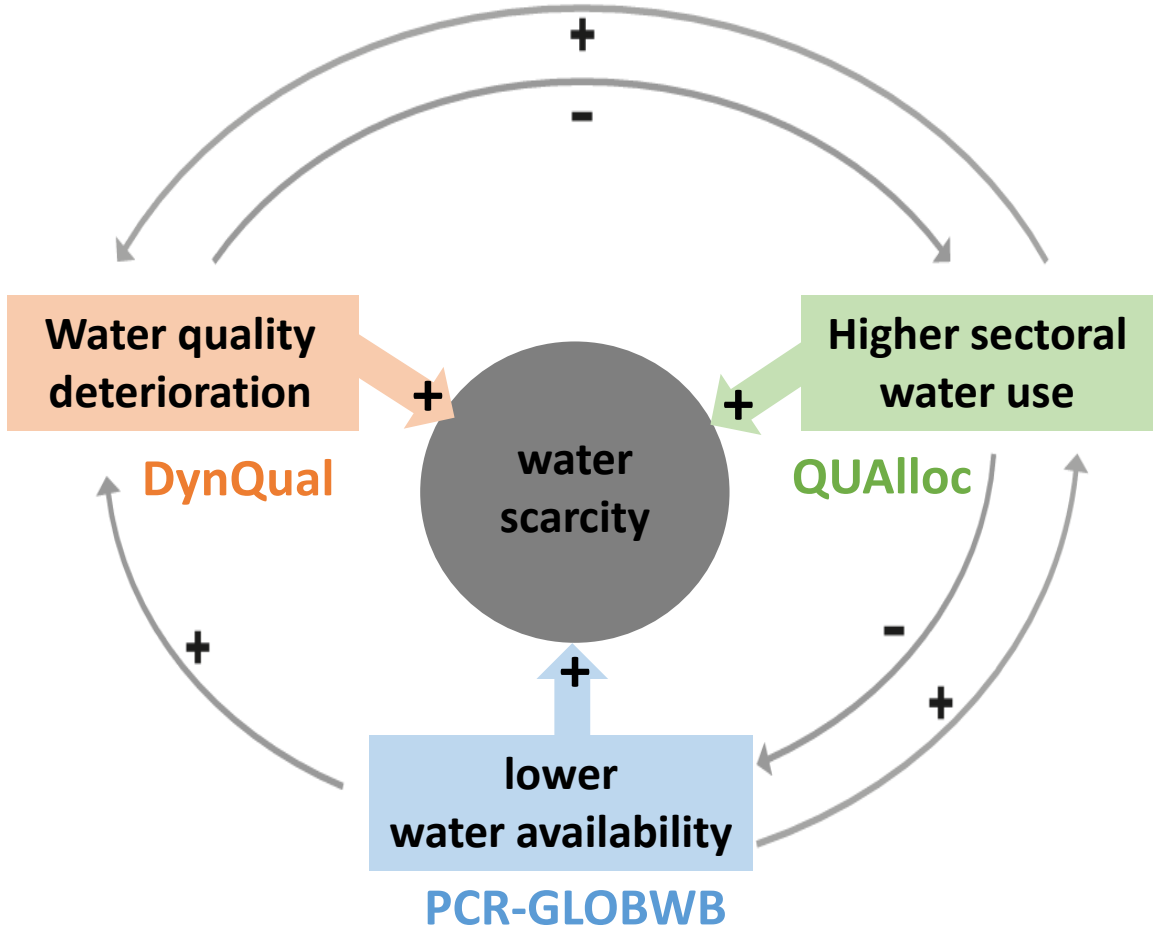
van Vliet et al. (2021) Environ. Res. Lett

Paradoxical interplay

Sectors all depend on sufficient water of suitable quality but pollute water during its use



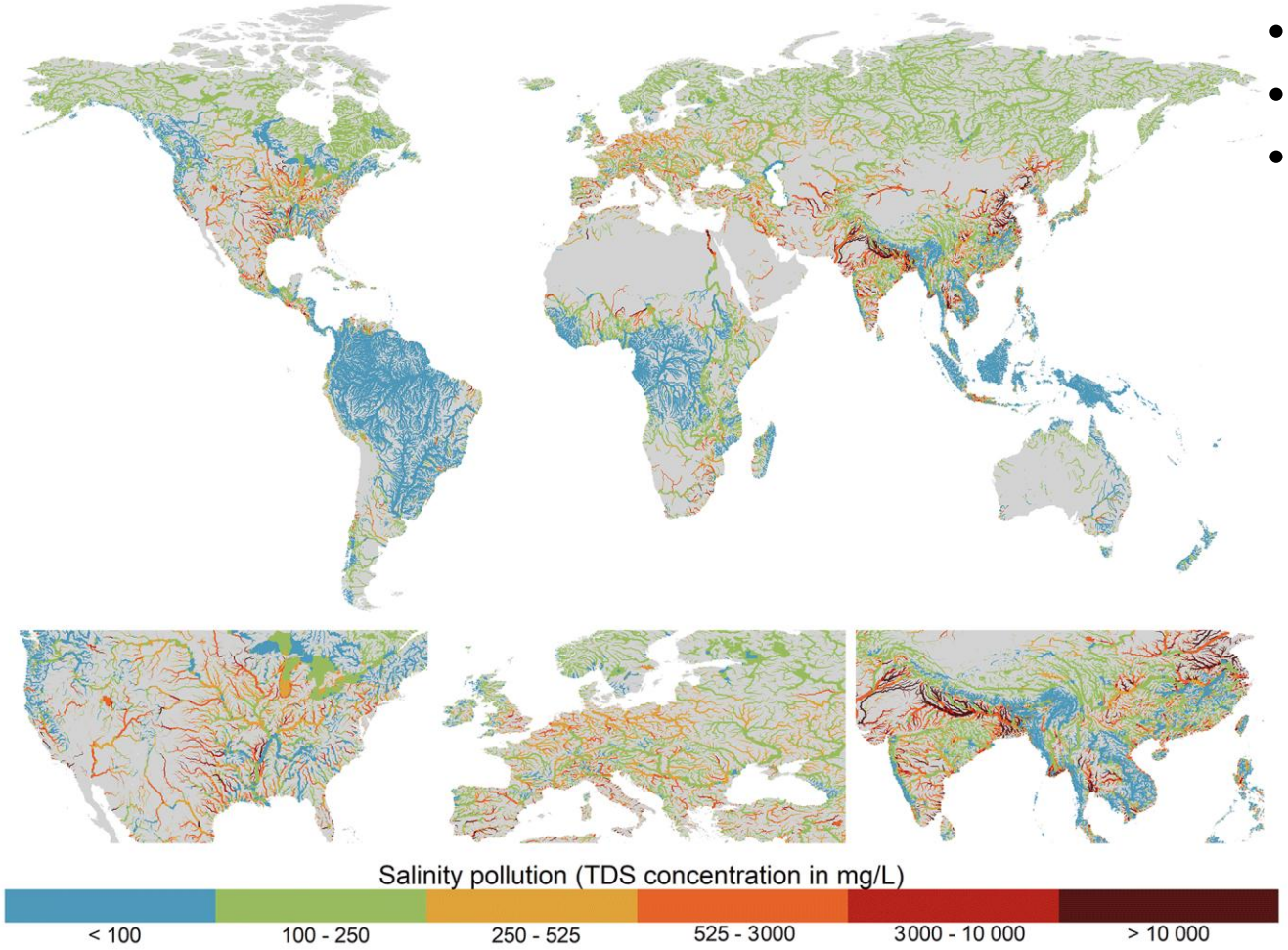
van Vliet (2023) Nature Water



DynQual – Surface water quality model

Salinity (TDS) global

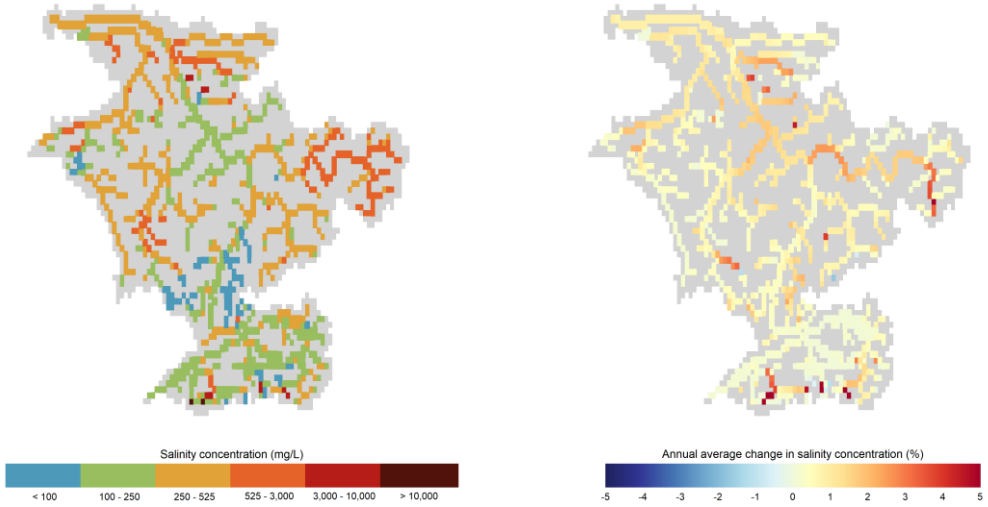
(5 arcmin, daily timestep, 1980-2019)



Jones et al. (2023) Geosci. Model Dev.

- Water temperature
- Salinity – total dissolved solids (TDS)
- Organic pollution - biochemical oxygen demand (BOD)
- Pathogen pollution - faecal coliform bacteria (FC)
- Dissolved oxygen

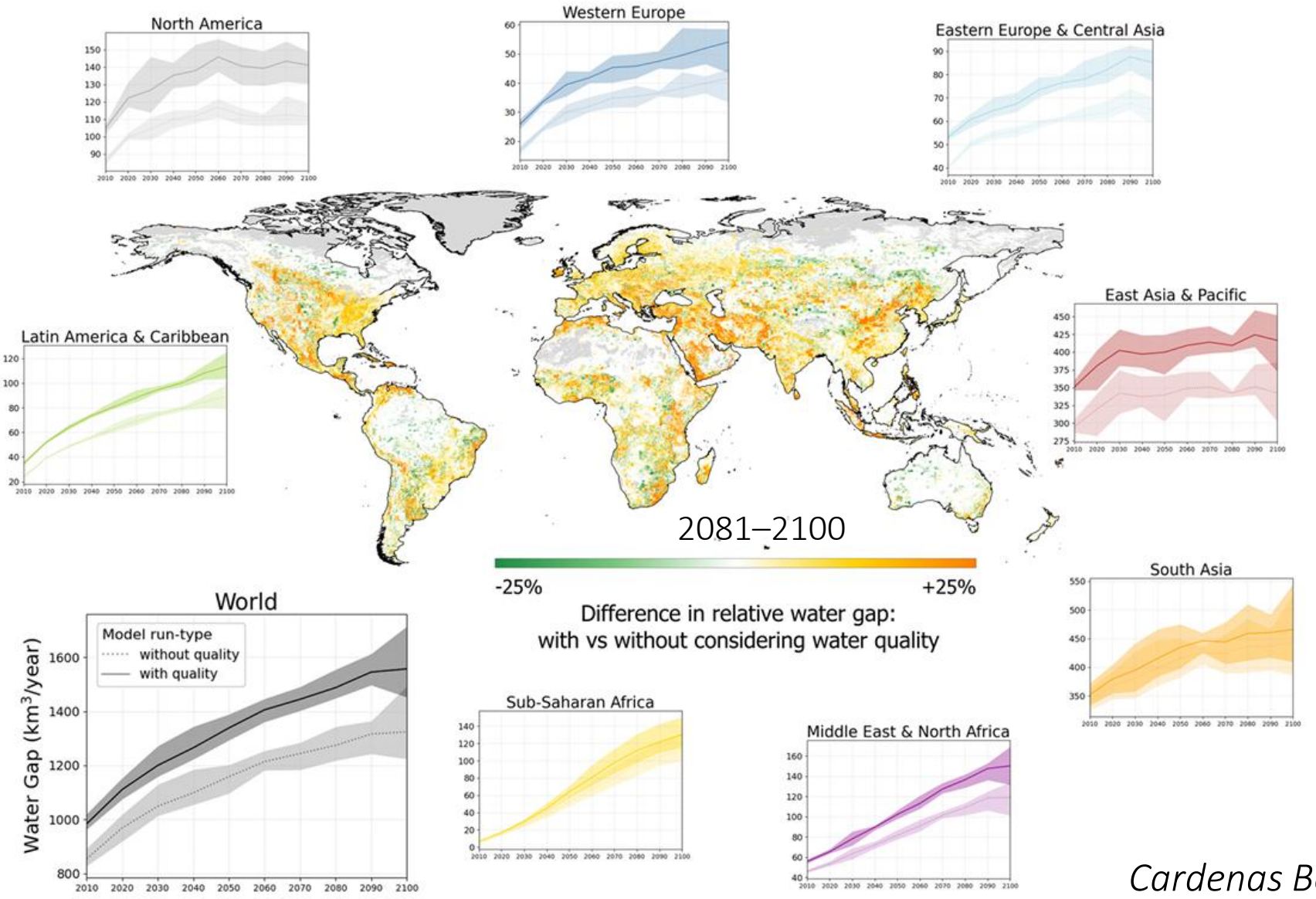
Rhine and Meuse basins



Average TDS concentration

Trend (1980-2019)

Water scarcity increase under global change

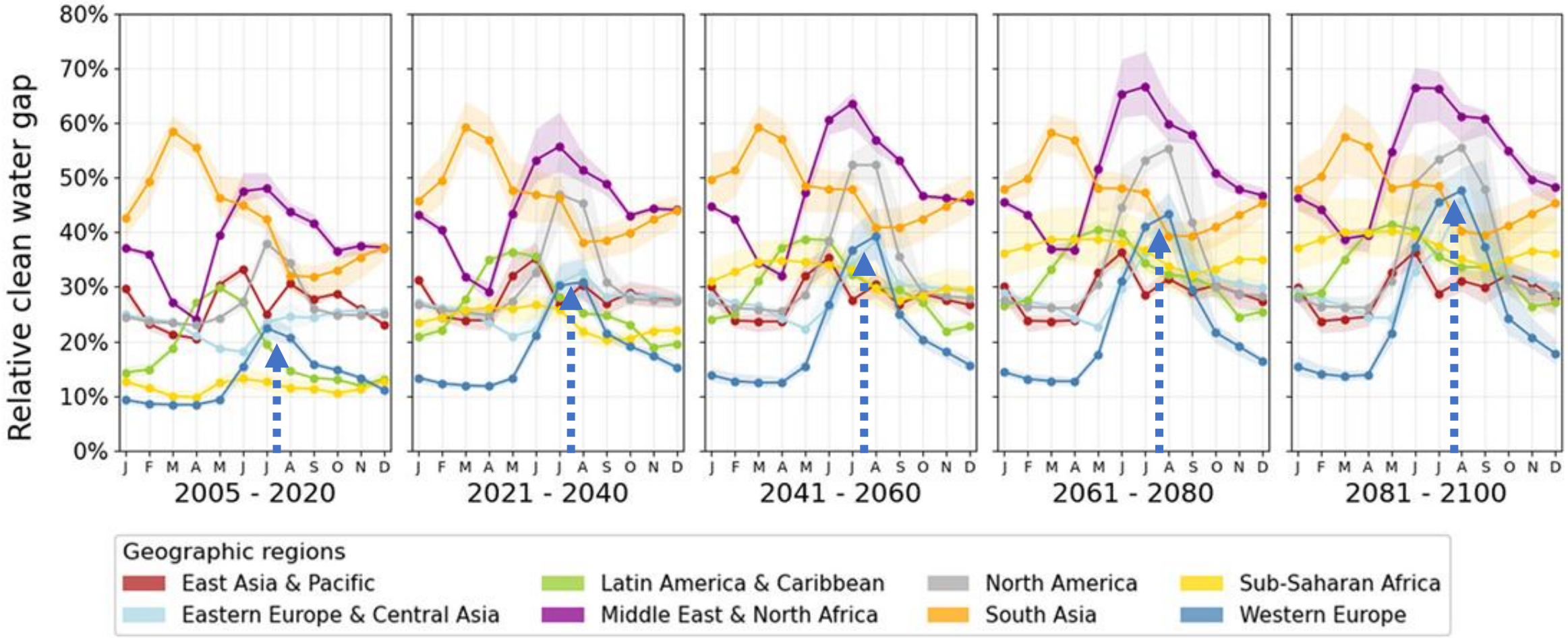


clean water gap

$$WG_{sector} = D_{sector} - (A_{sw} + A_{gw} + A_{dw} + A_{rww})_{sector}$$

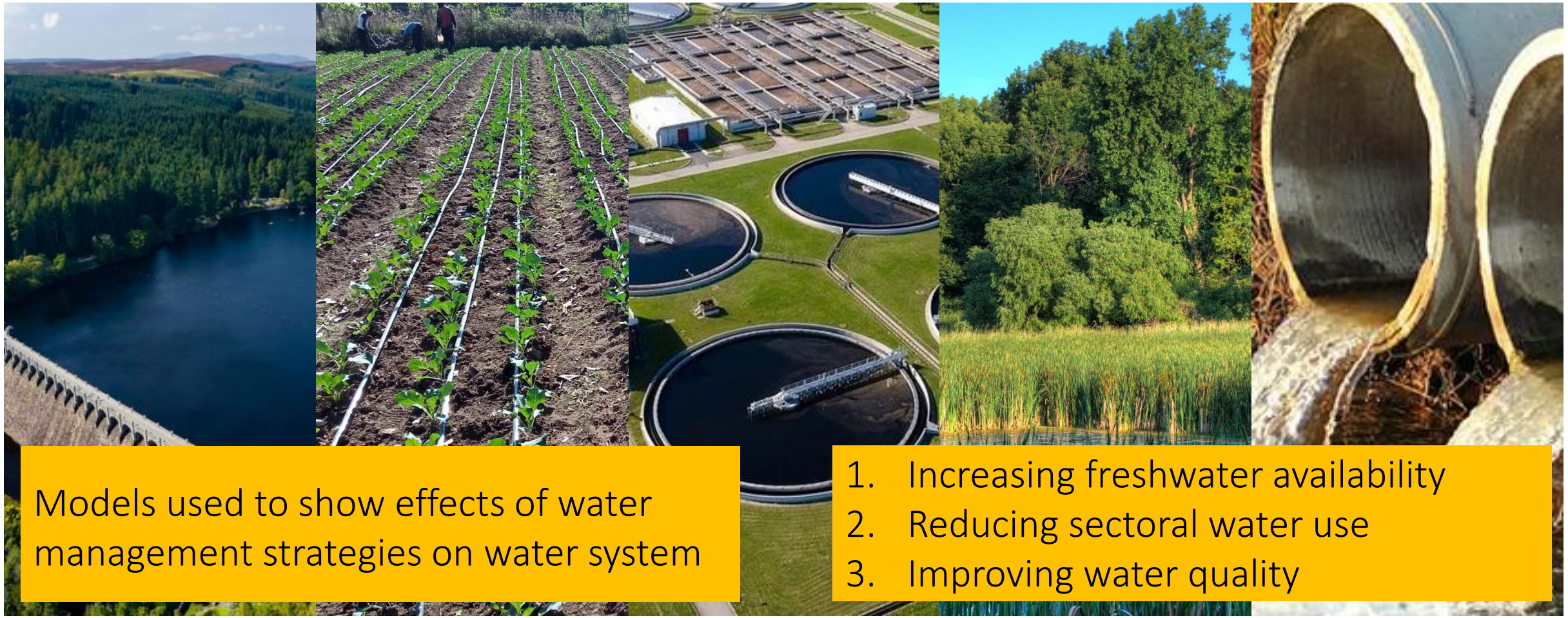
Cardenas Belleza al. (2026) npj Clean Water

Clean water gaps increase under global change, particularly during summers



Cardenas Belleza al. (2026) npj Clean Water

Strategies for sufficient clean water



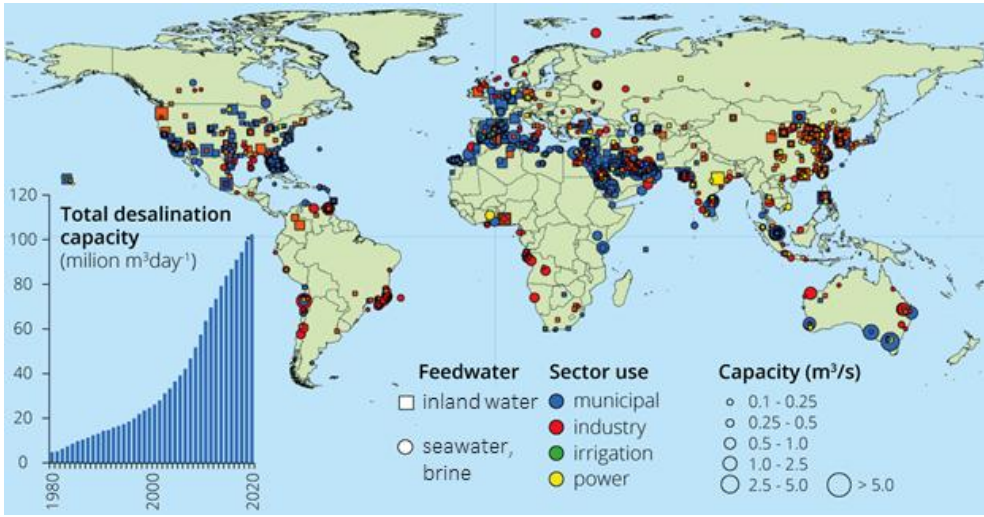
Models used to show effects of water management strategies on water system

1. Increasing freshwater availability
2. Reducing sectoral water use
3. Improving water quality

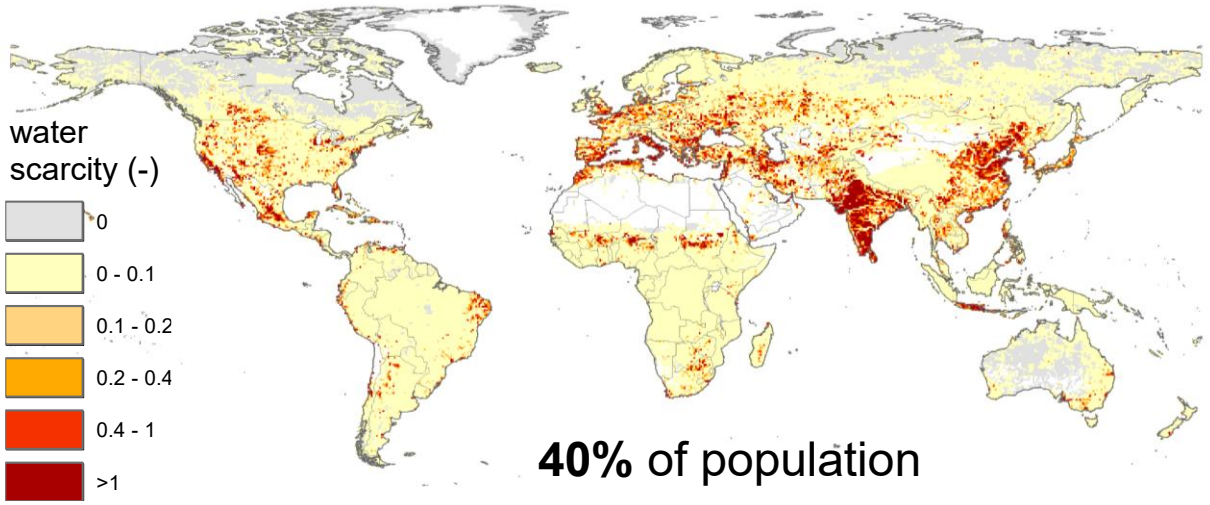
Water scarcity alleviation – Desal and WWT

SDG 6.4: reducing the number of people suffering from severe water scarcity

- Expansion in **desalination** (inland/sea) → **domestic** and **industrial uses**
- Expansion **wastewater reuse** → **irrigation**

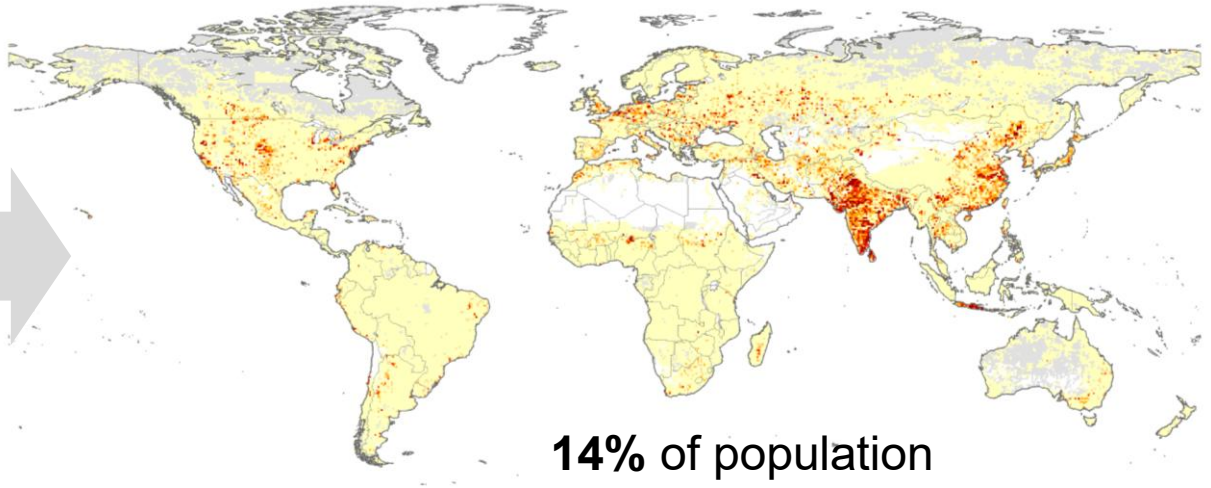


water scarcity
present



40% of population

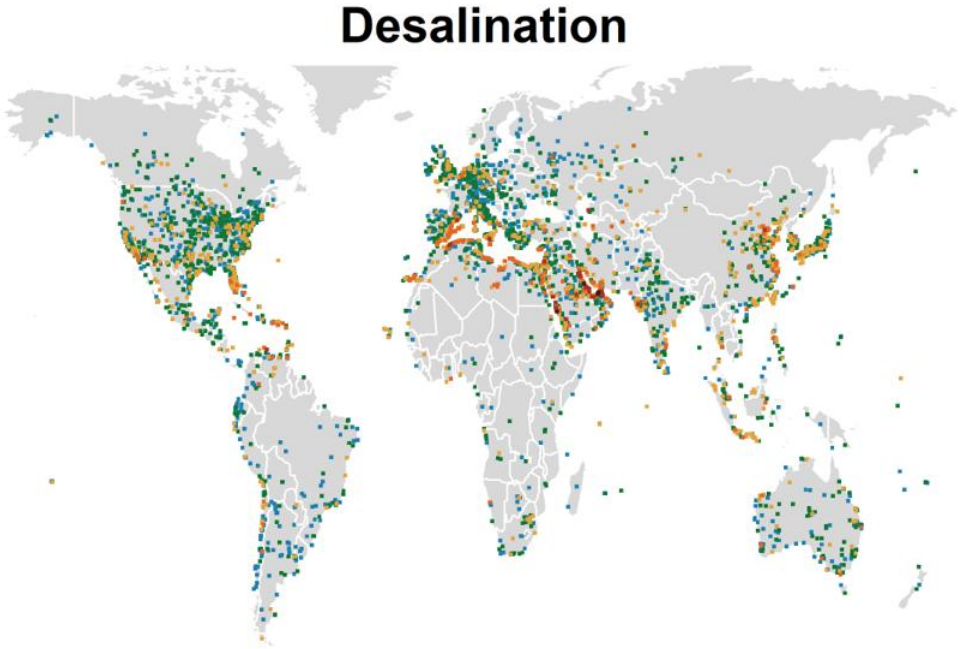
water scarcity
expansion in desalination & treated wastewater reuse

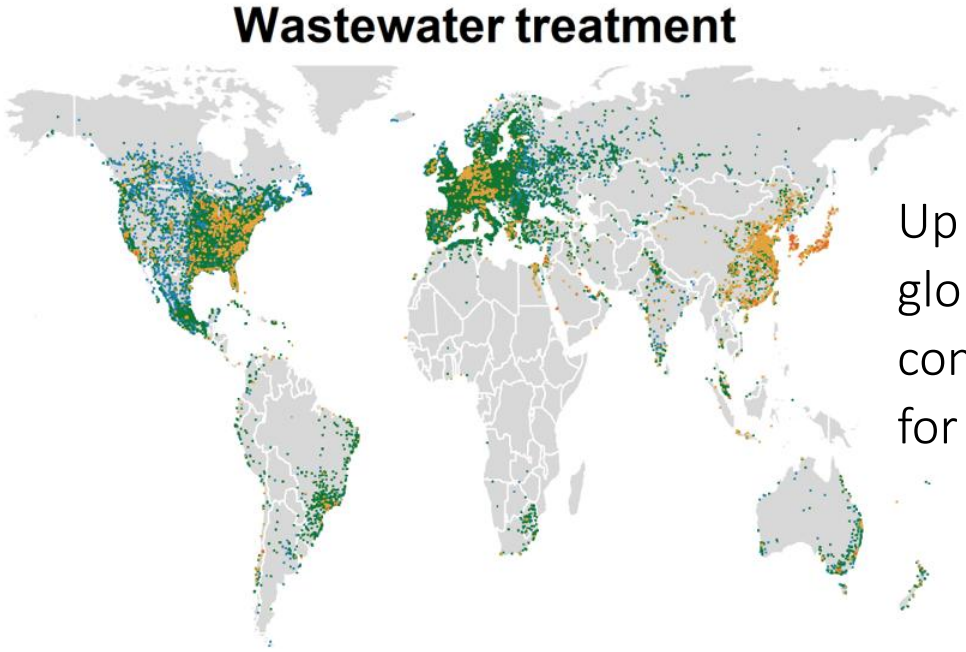


14% of population

van Vliet et al. (2021) Environ. Res. Lett

Energy consumption for water treatment



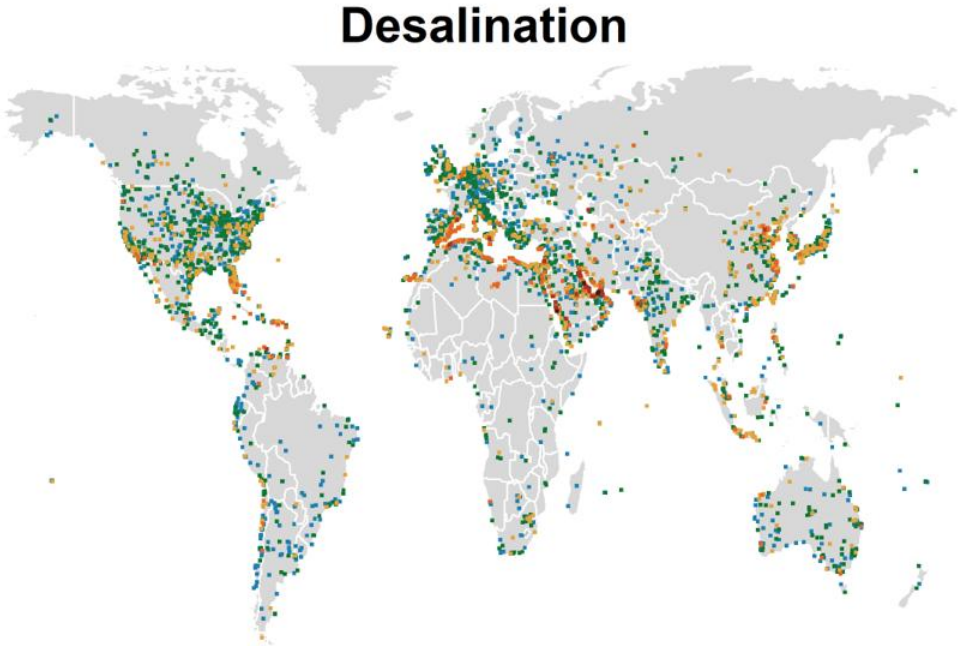


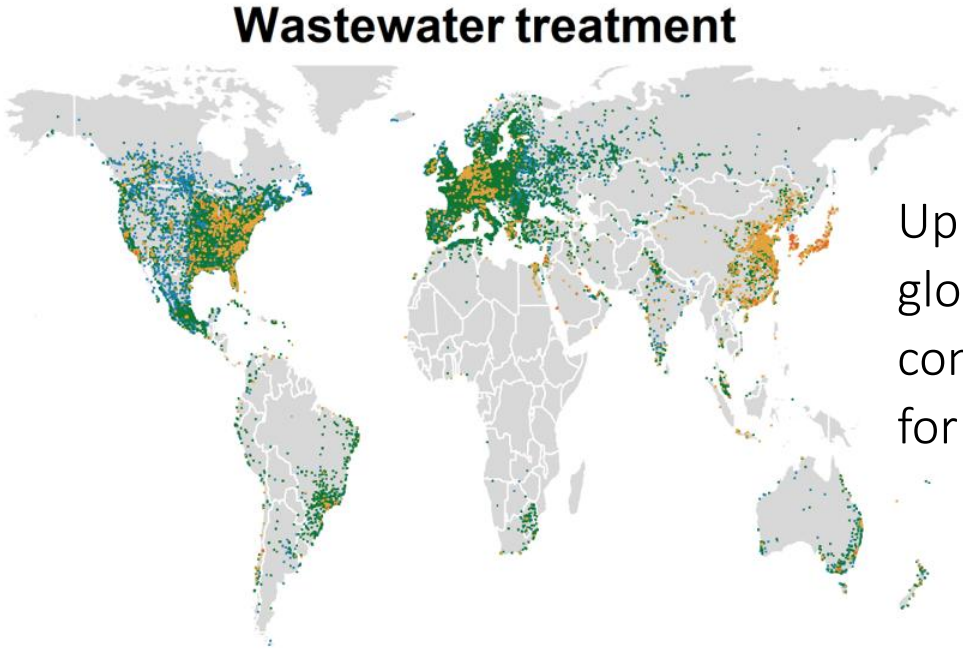
Up to 5.4 % of total global electricity consumption for year 2015

Energy consumption (GWh y^{-1})

0 1 10 100 1,000 10,000 20,000

Energy consumption for water treatment





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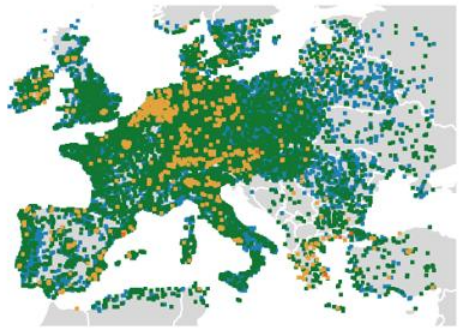

Key take home messages

- **Quality matters for water scarcity**
- **Deterioration of surface water quality** under climate change and extremes.
- To develop **sustainable water management solutions**, we need account for the:
  - **Complex interplay of water quality, sectoral water use** and **water availability**, particularly under droughts and heatwaves.
  - **Tradeoffs** between **clean water** and other **sustainability objectives** (e.g. clean energy, climate mitigation, biodiversity)

Thank you!

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