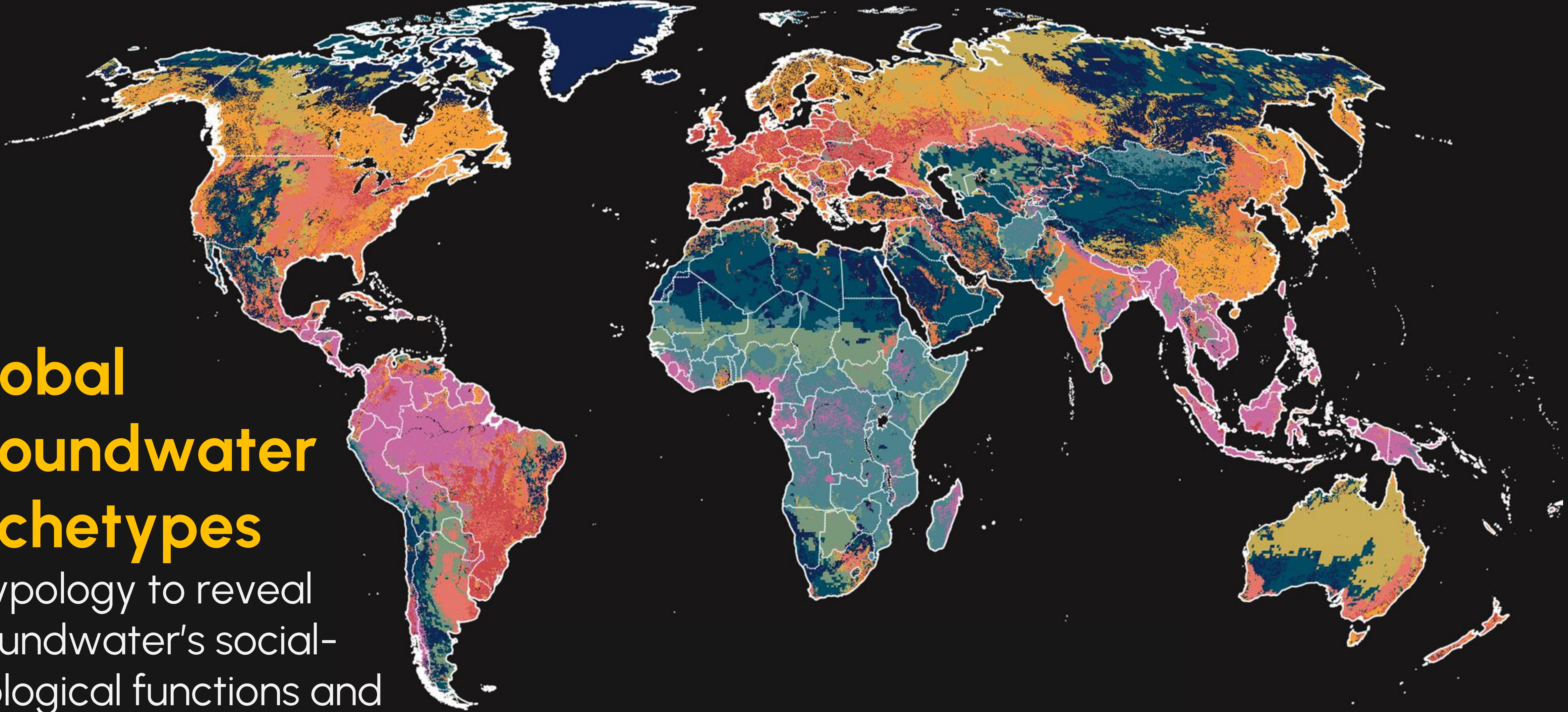


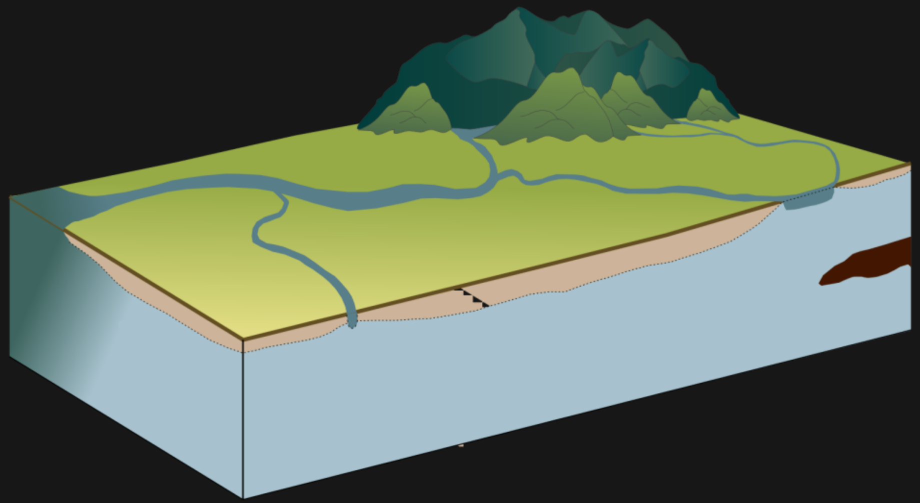
# Global groundwater archetypes

A typology to reveal groundwater's social-ecological functions and system properties for global groundwater research and management

EGU GA 2023
HS 5.16
Abstract ID: EGU23-8930

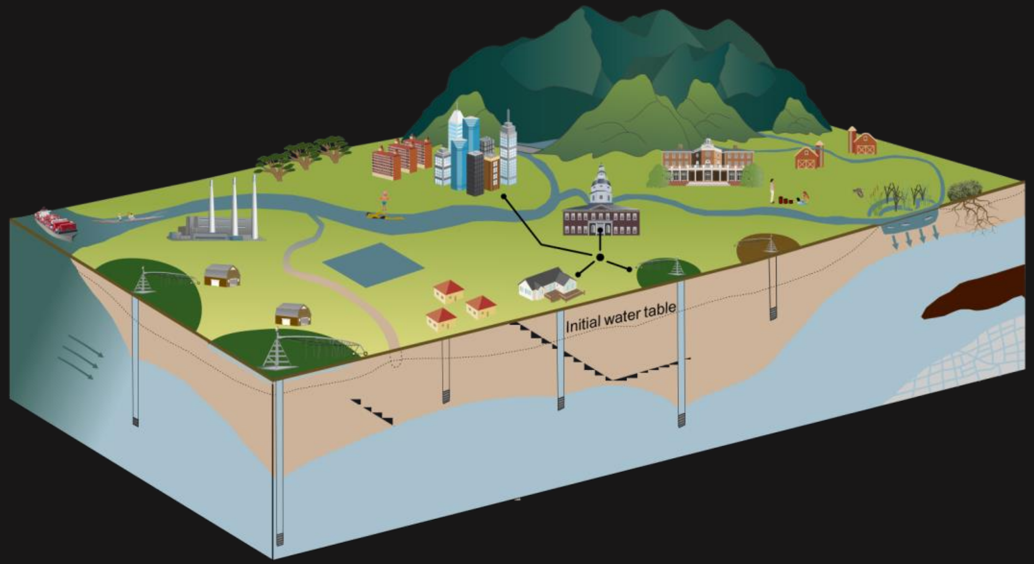
**Xander Huggins**
Tom Gleeson, Karen G. Villholth, Juan C. Rocha, James S. Famiglietti

## groundwater does not exist in isolation



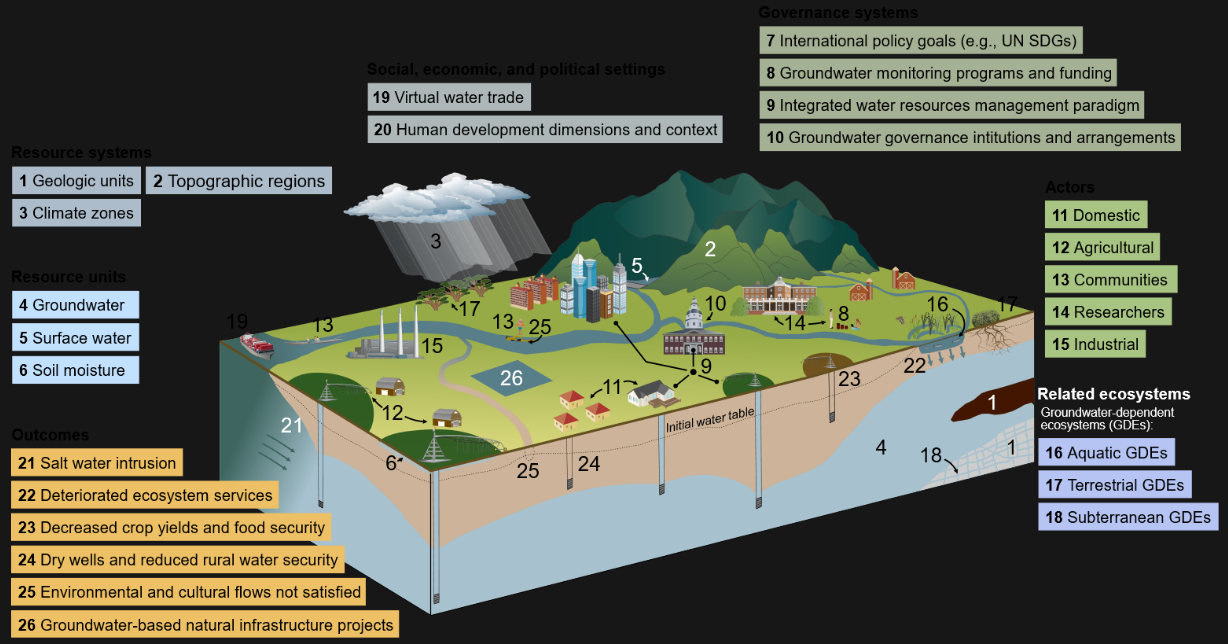
groundwater resources

## but is deeply connected to social, ecological, and Earth systems




groundwater-connected systems

# this *groundwater-connected systems* framing places an explicit **focus on interactions between groundwater and social, ecological, and Earth systems**




issue paper on this framing is out now in *Groundwater*:

groundwater NGWA

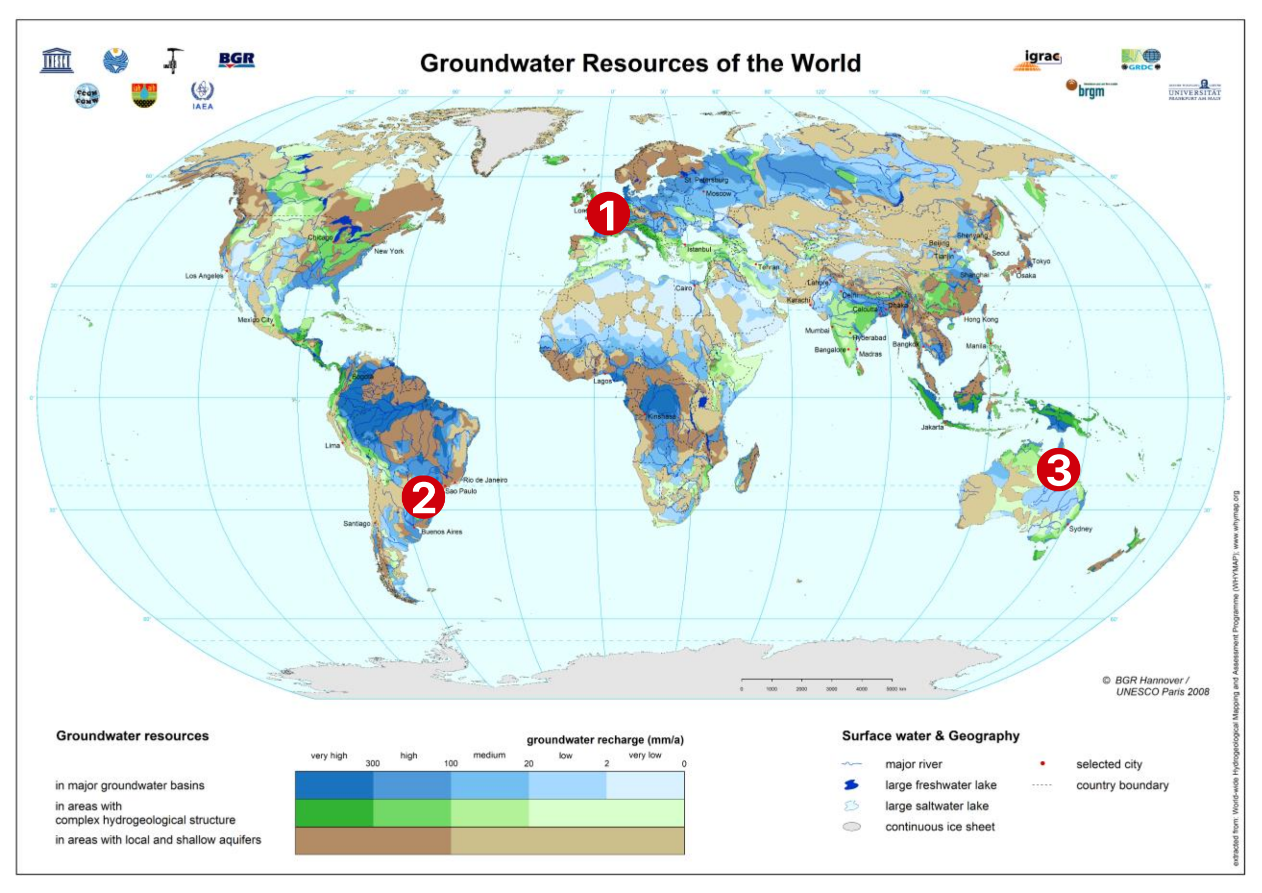
Issue Paper | Open Access

**Groundwater Connections and Sustainability in Social-Ecological Systems**

Xander Huggins, Tom Gleeson, Juan Castilla-Rho, Cameron Holley, Viviana Re, James S. Famiglietti

First published: 16 March 2023 | https://doi.org/10.1111/gwat.13305

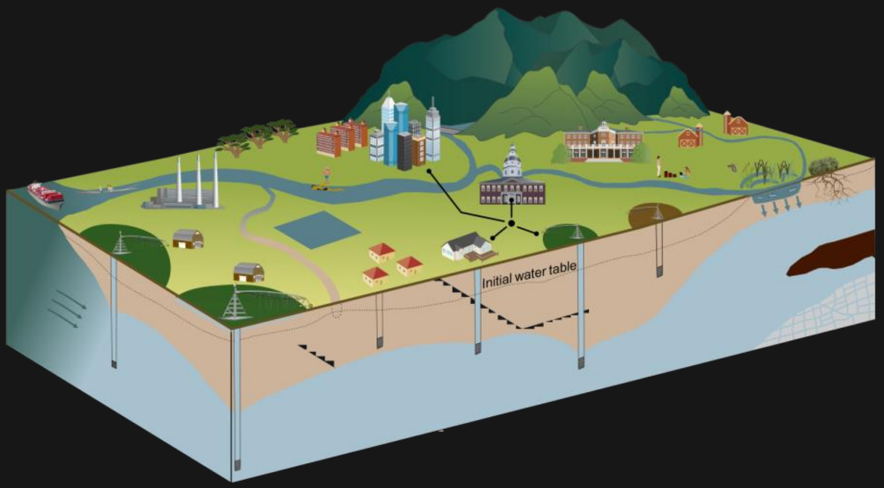
# but existing global classifications of groundwater systems **do not represent** these social, ecological, and Earth system interactions





| | | | | |
|---|---|---|---|---|
| GDE types and density | | GDE types and density | | GDE types and density |
| Agricultural use of groundwater | ≠ | Agricultural use of groundwater | ≠ | Agricultural use of groundwater |
| Groundwater management | | Groundwater management | | Groundwater management |
| ⋮ | | ⋮ | | ⋮ |

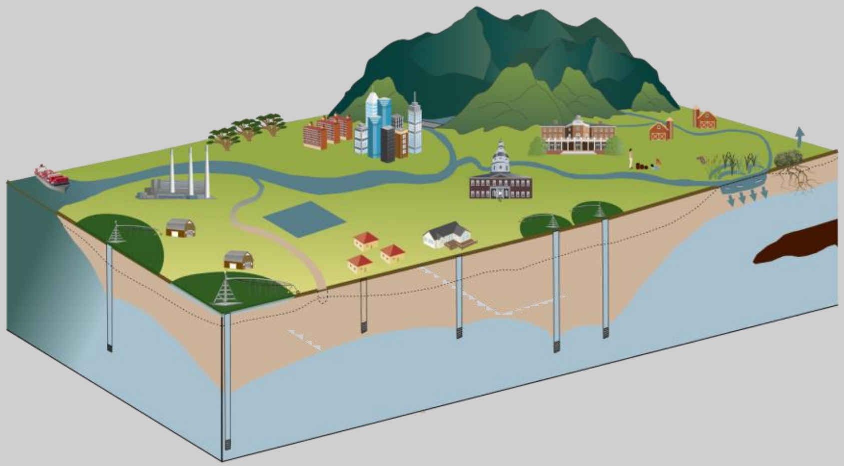
# there is no data-driven global classification of groundwater-connected systems





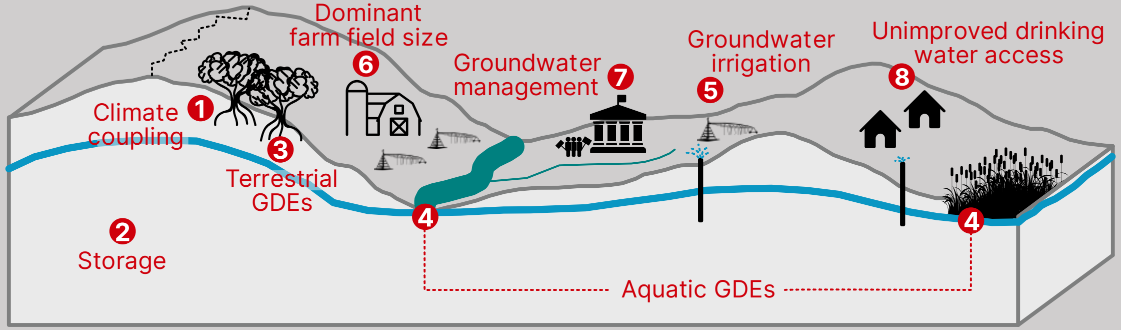
# Conceptual model and data availability drive system simplification

## "messy" reality → simplified conceptualisation



ability to reflect local complexities

ability to guide action at ≥regional scales




Biophysical systems and functions:

### Earth systems

Climate connections (water table ratio)

Subsurface storage (porosity)

### Ecosystems

Aquatic GDEs (lentic and lotic)

Terrestrial GDEs (i.e., phreatophytes)

Social systems and functions:

### Food systems

Groundwater irrigation (GMIA)

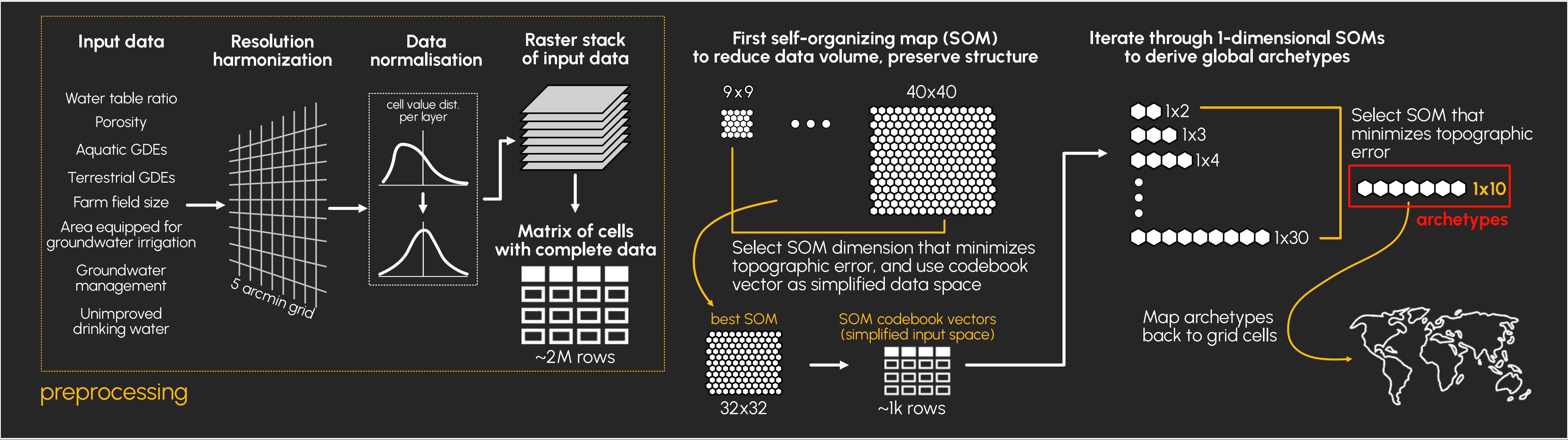
Dominant farm field size

### Groundwater management

IWRM implementation (aquifer level organizations, etc.)

Drinking water management (unimproved water access)

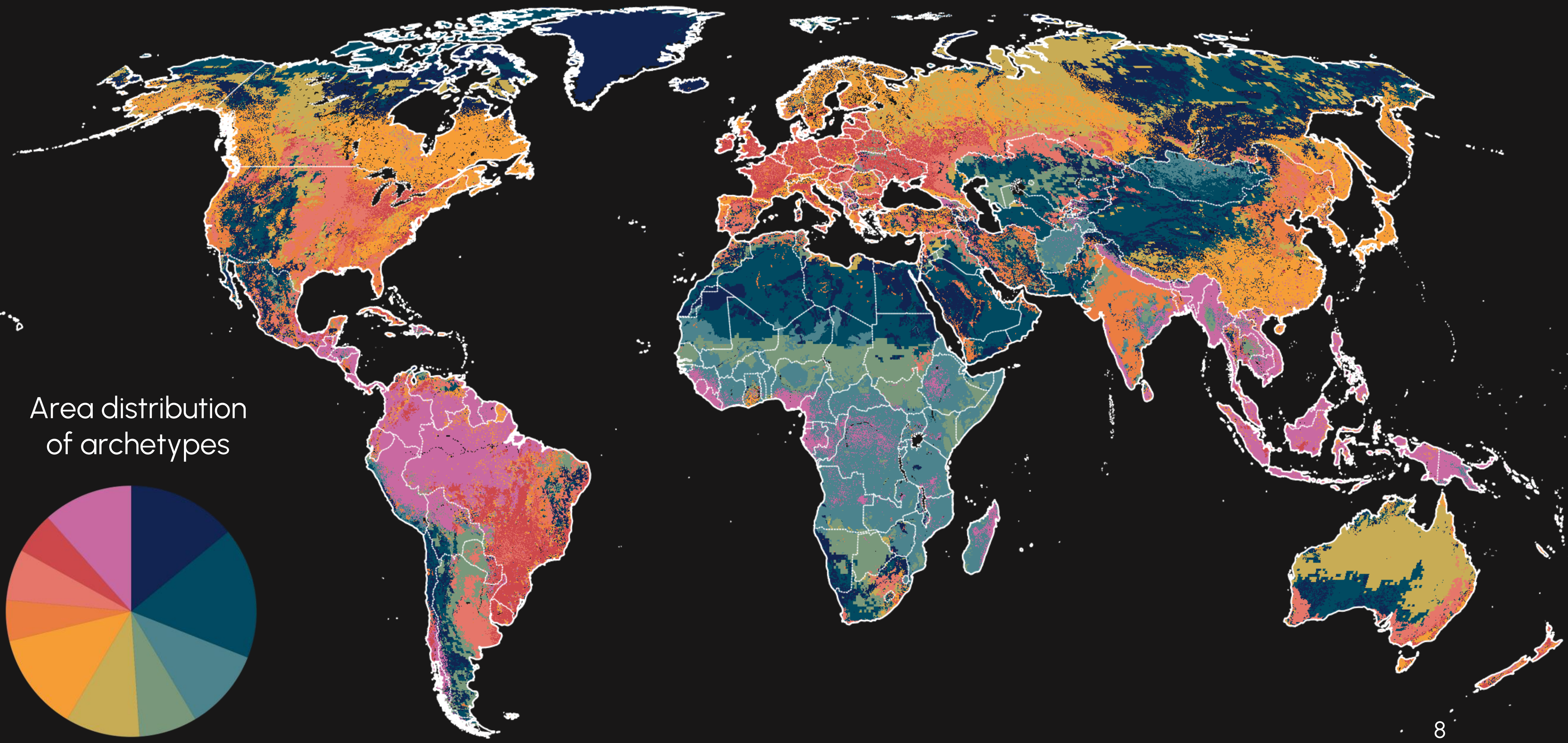
# Archetypes derived through sequential self-organising maps



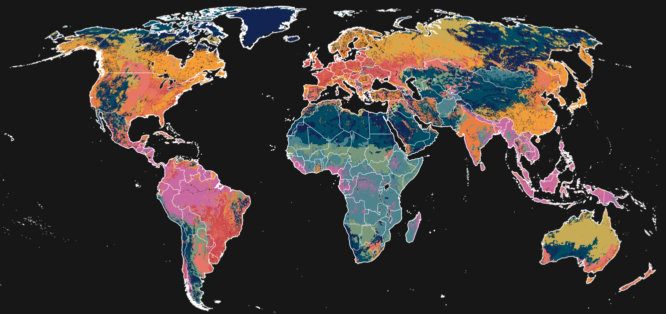

"Human interactions with ecosystems are inherently dynamic and complex; **any categorization of these is a gross oversimplification**. Yet there is little hope of modelling these interactions at a global scale without such simplification".

Ellis and Ramankutty (2008)

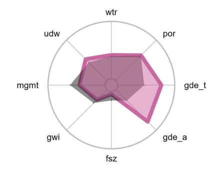
# Global archetypes of groundwater-connected systems



# Archetypes reveal unique fingerprints of groundwater-connected systems

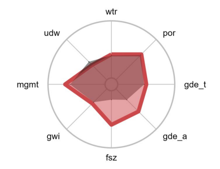


1



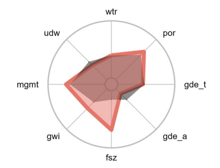

Extensive ecosystems with limited agricultural activity & groundwater management

2



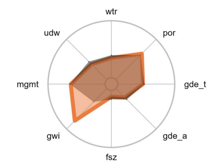

Large-scale agriculture among extensive aquatic ecosystems

3



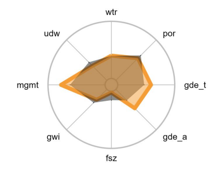

Groundwater reliant industrial agriculture

4



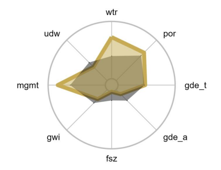

Groundwater reliant small-landholder agriculture

5



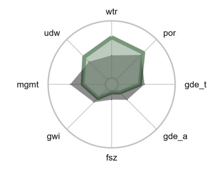

Extensive ecosystems with moderate management

6



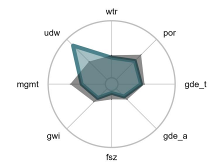

Remote lands with important climate functions but existing management

7



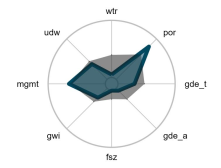

Remote or rural lands with important climate functions but limited management

8



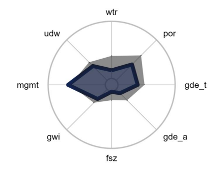

Underserviced areas with limited agricultural activity & groundwater management

9




Arid areas with important Earth system storage functions

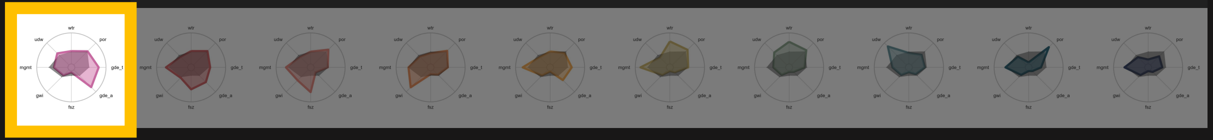
10

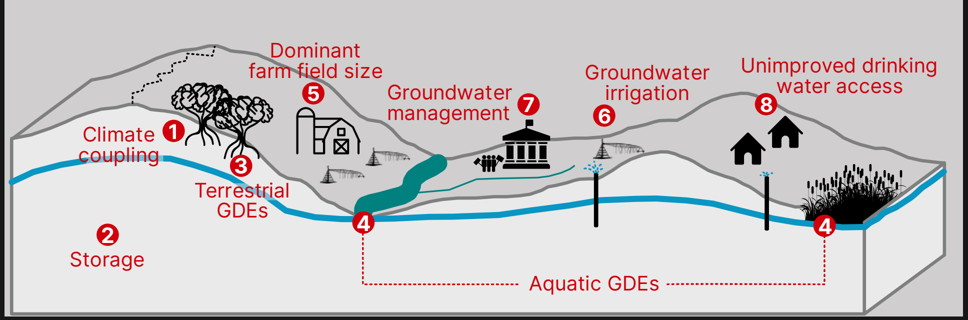


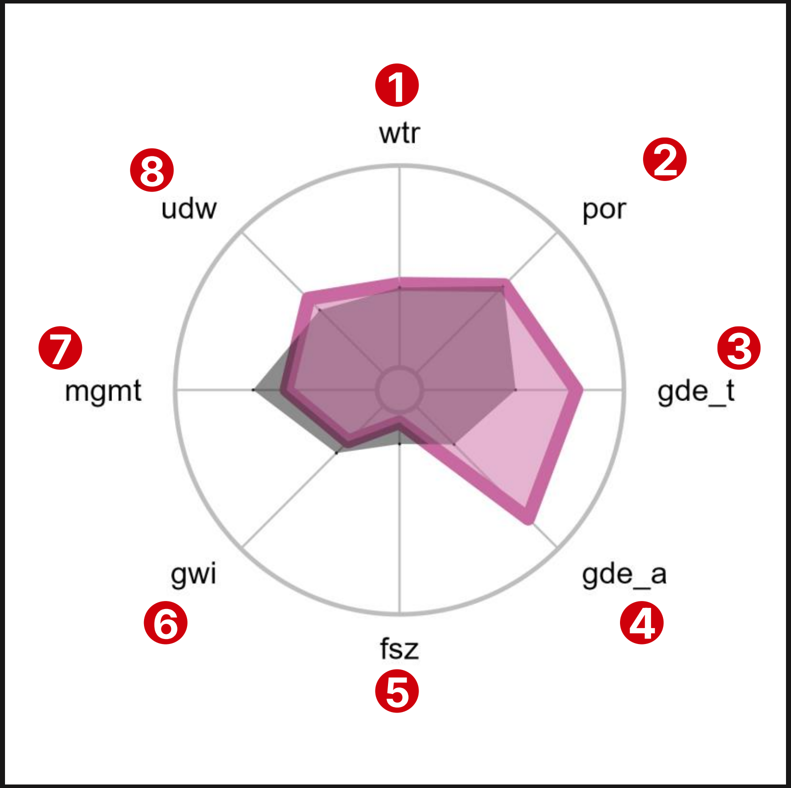

Deep groundwater systems with little storage capacity or social functions

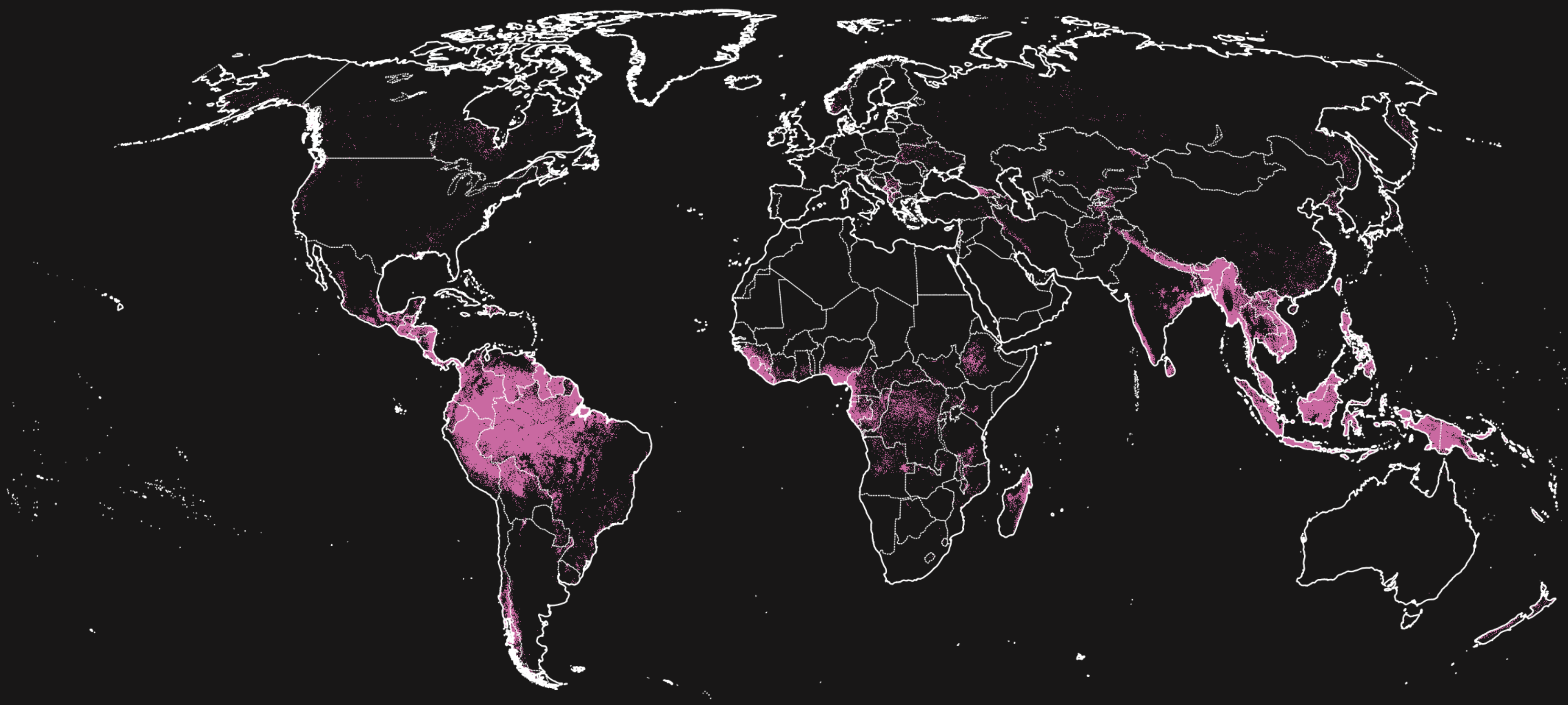
# Extensive ecosystems with limited agricultural activity or management

1 · 2 · 3 · 4 · 5 · 6 · 7 · 8 · 9 · 10



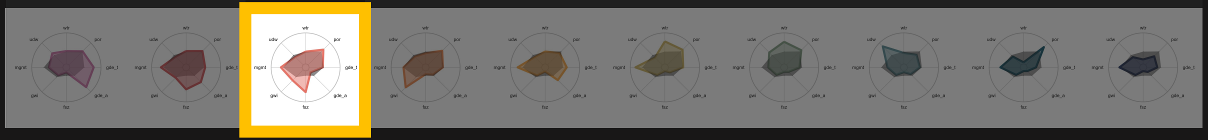


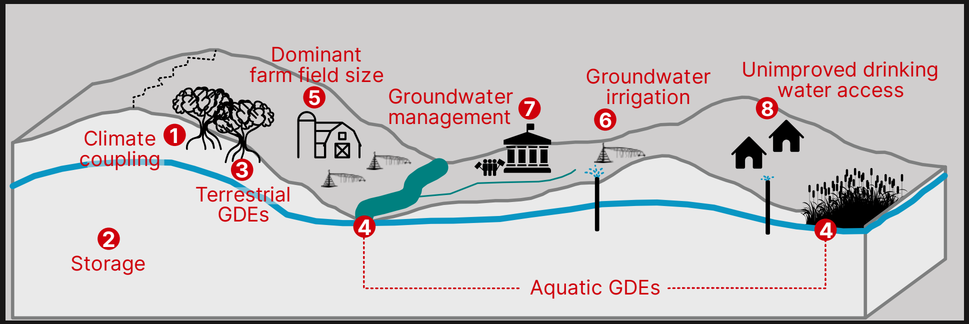



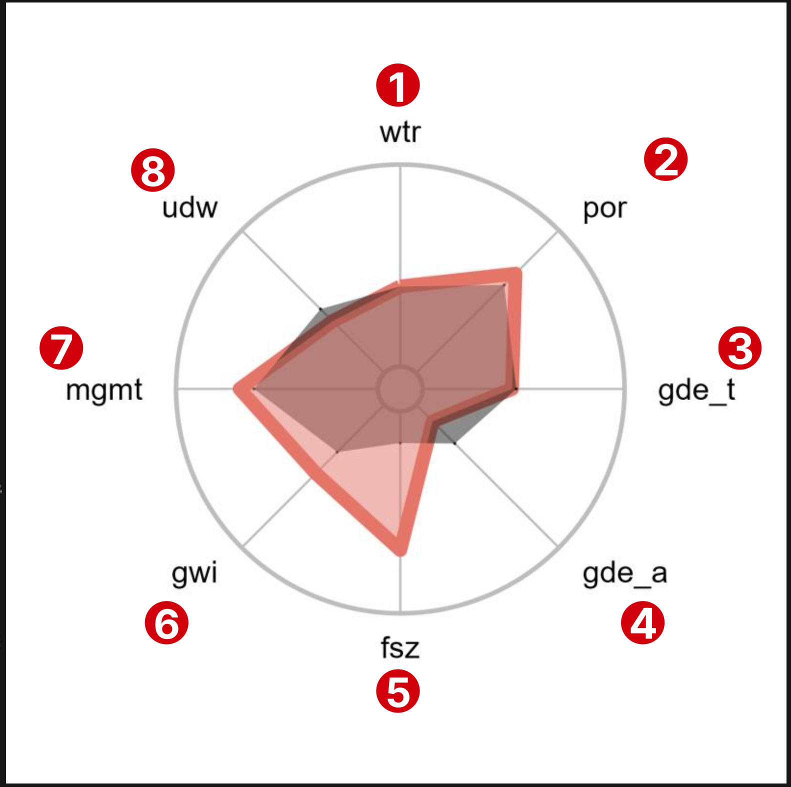



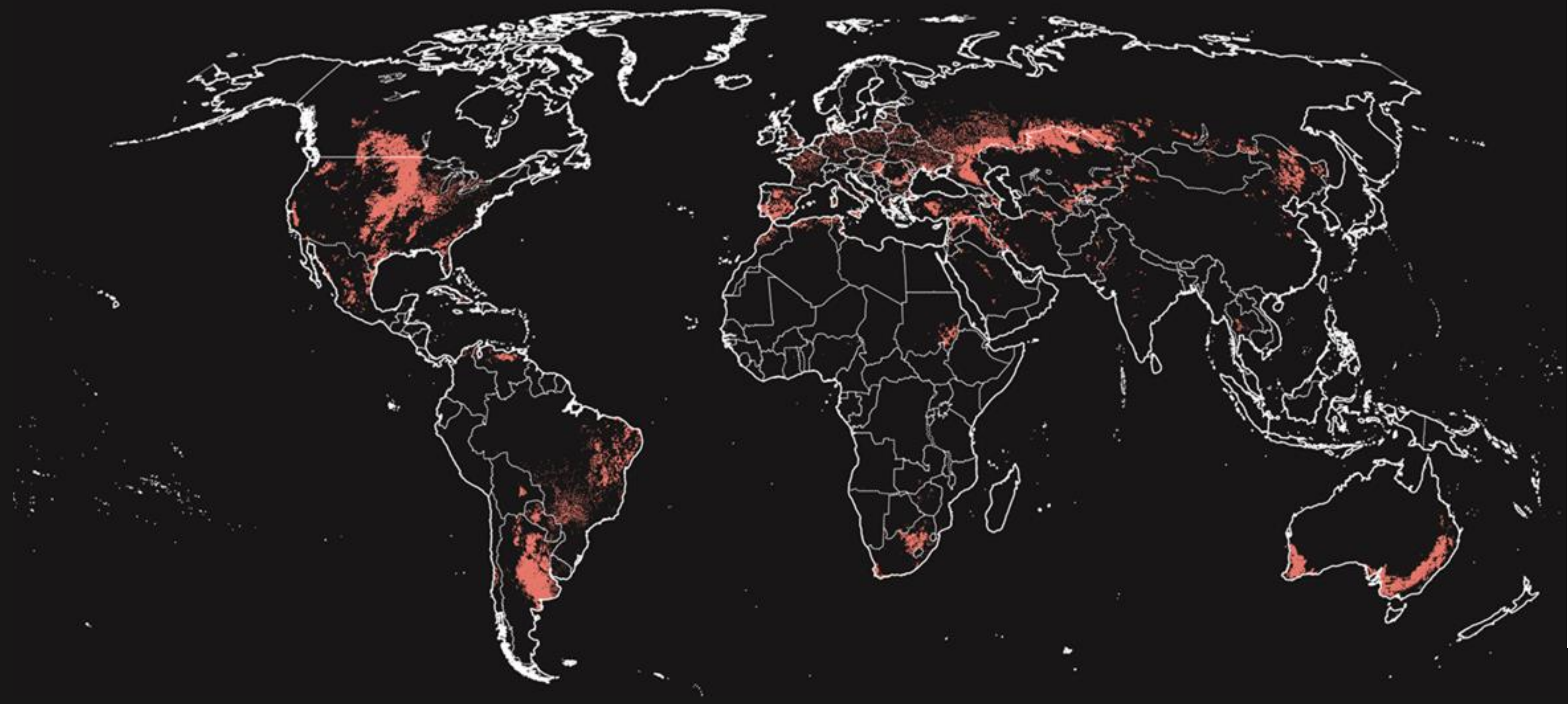
# Groundwater reliant industrial agriculture

1 2 3 4 5 6 7 8 9 10



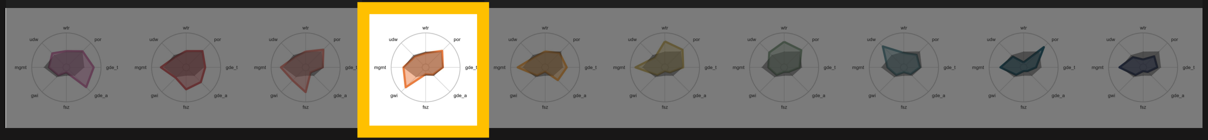


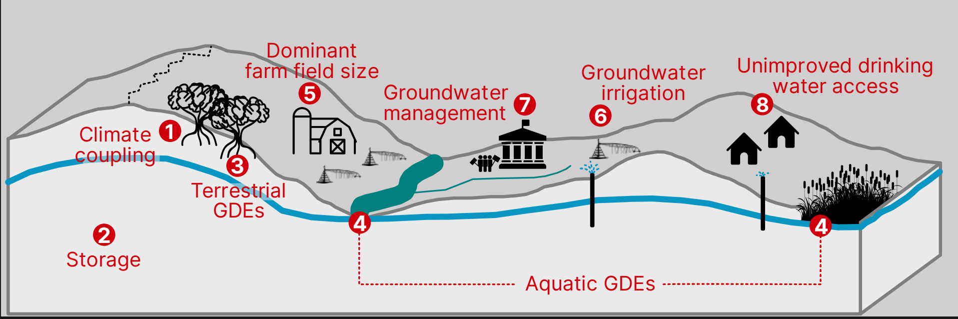



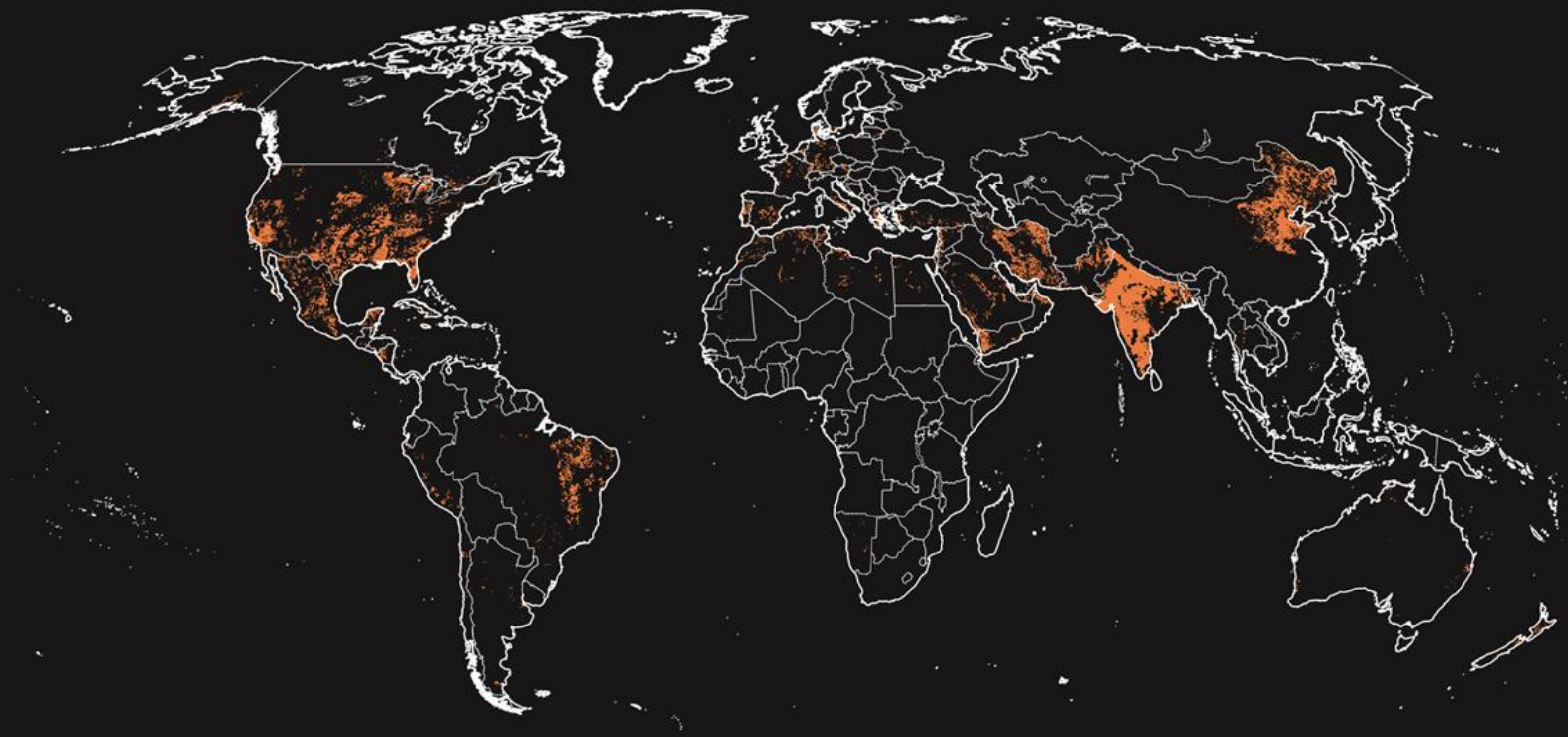



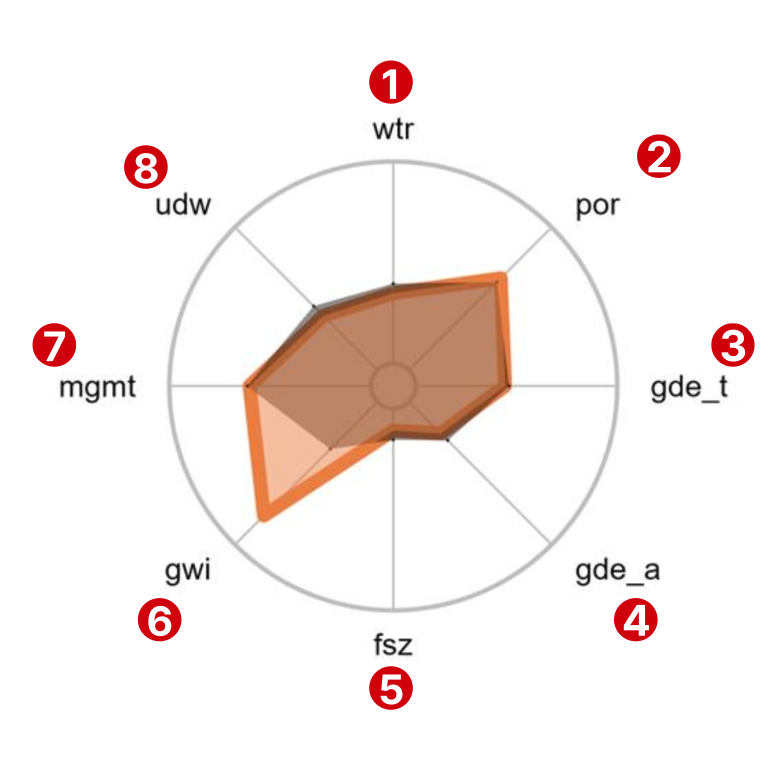
# 4 Groundwater reliant smallholder agriculture

1 2 3 4 5 6 7 8 9 10

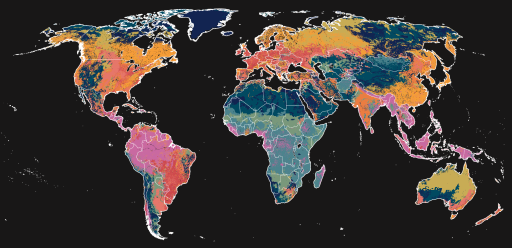


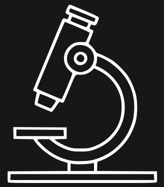




# Archetypes face different sustainable development opportunities and challenges





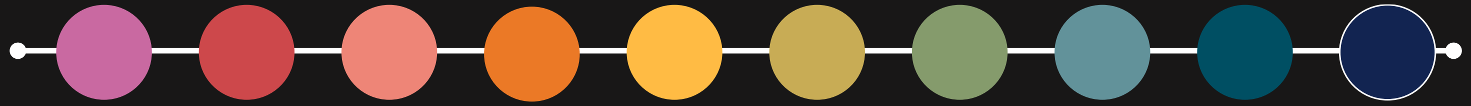
system characterisation

future outlook


Cropland expansion potential

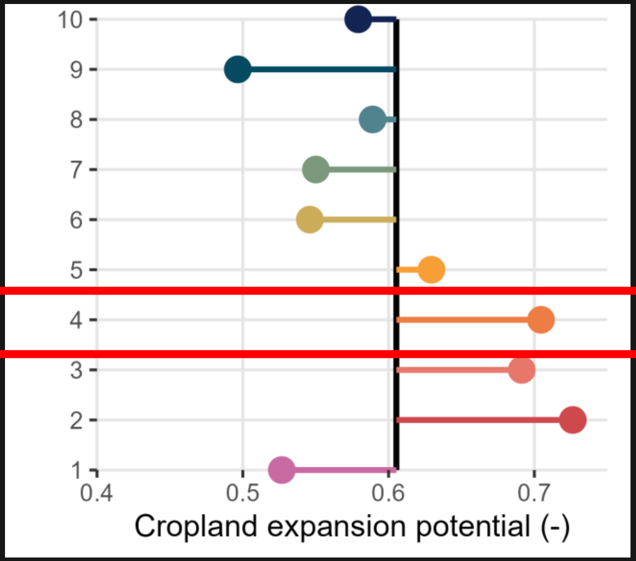

Groundwater storage trends


Likelihood for hydropolitical interactions

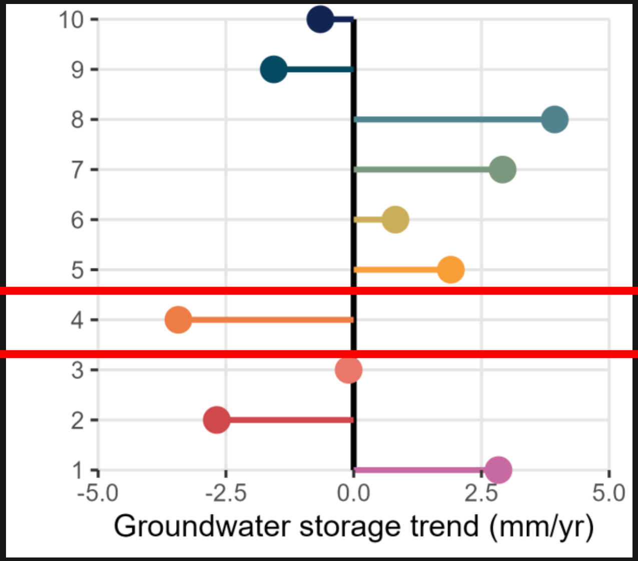


How are these pressures distributed across the archetypes?

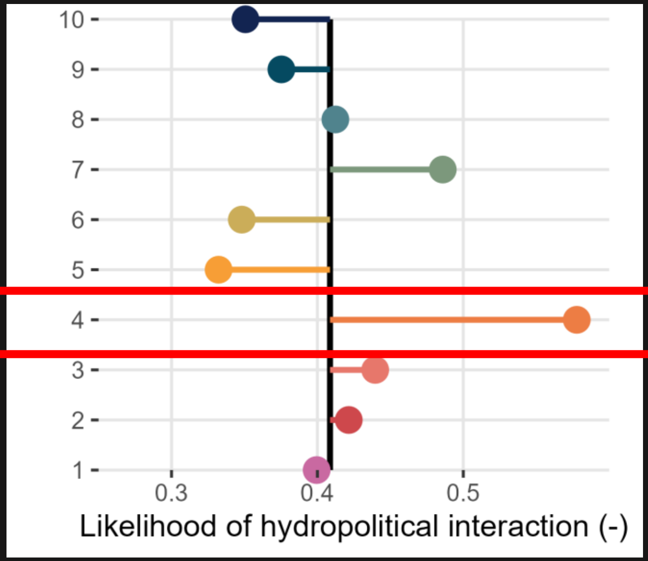
## Cropland expansion potential

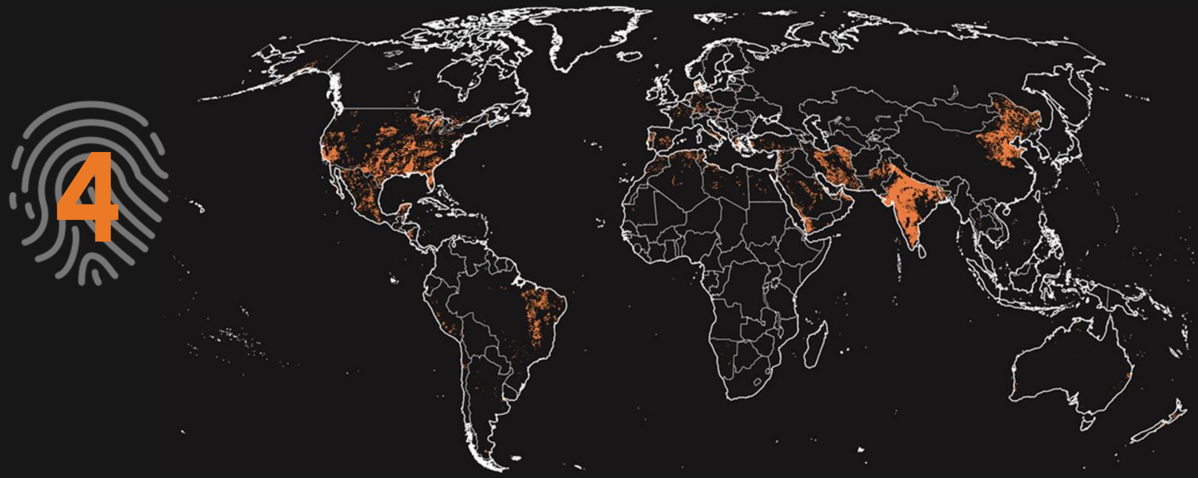


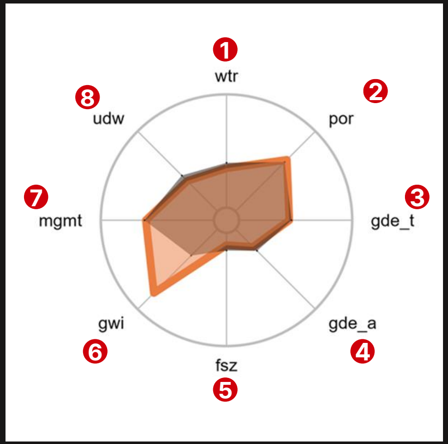

## Groundwater storage trends




## Likelihood for hydropolitical interactions



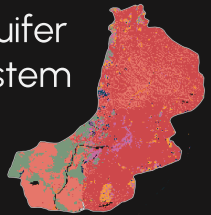




## Groundwater reliant smallholder agriculture

California's
Central
Valley

Guarani
Aquifer
System



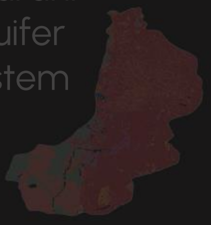
evaluate state of global data availability for groundwater-connected systems

inform context-appropriate groundwater sustainability goal setting


support development of added social-ecological representations in global groundwater models?

California's Central Valley

Guarani Aquifer System

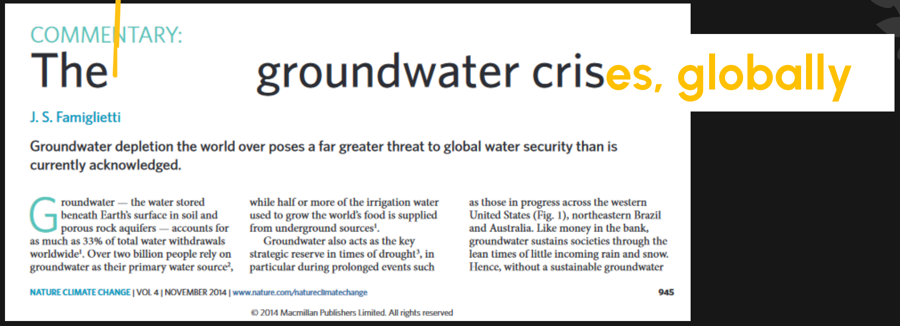


evaluate state of global data availability for groundwater-connected systems

inform context-appropriate groundwater sustainability goal setting


support development of added social-ecological representations in global groundwater models?

many and varied



COMMENTARY:

The groundwater crises, globally

J. S. Famiglietti

Groundwater depletion the world over poses a far greater threat to global water security than is currently acknowledged.

Groundwater — the water stored beneath Earth's surface in soil and porous rock aquifers — accounts for as much as 33% of total water withdrawals worldwide[1]. Over two billion people rely on groundwater as their primary water source[2], while half or more of the irrigation water used to grow the world's food is supplied from underground sources[3].

Groundwater also acts as the key strategic reserve in times of drought[3], in particular during prolonged events such as those in progress across the western United States (Fig. 1), northeastern Brazil and Australia. Like money in the bank, groundwater sustains societies through the lean times of little incoming rain and snow. Hence, without a sustainable groundwater





**promote thinking about global groundwater in complex social-ecological systems among researchers and policy makers**

thank you!

Xander Huggins

To read more about the groundwater-connected systems framing:


groundwater

NGWA

The Groundwater Association

Issue Paper | Open Access

**Groundwater Connections and Sustainability in Social-Ecological Systems**

Xander Huggins, Tom Gleeson, Juan Castilla-Rho, Cameron Holley, Viviana Re, James S. Famiglietti

First published: 16 March 2023 | https://doi.org/10.1111/gwat.13305

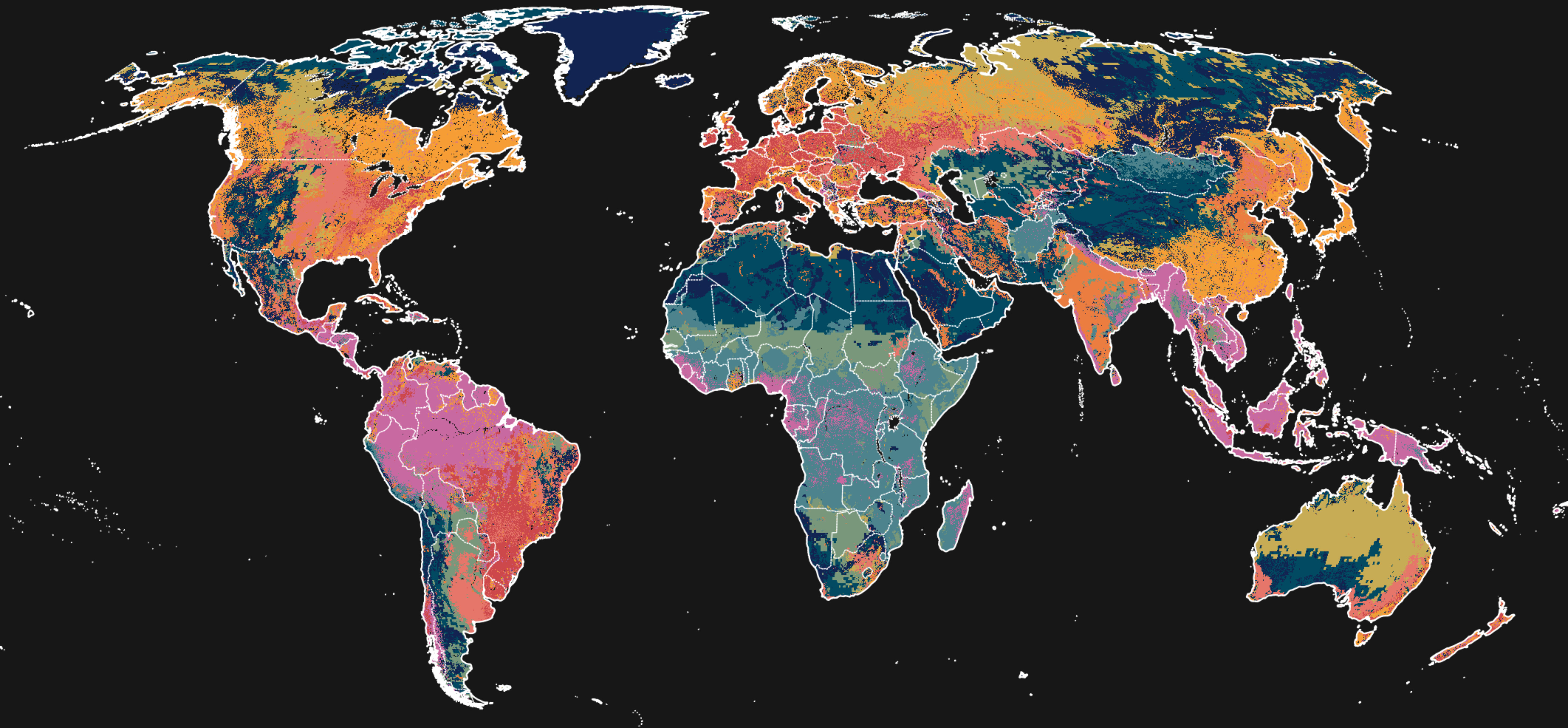
Stay in touch/be in contact for a soon to be shared preprint on these archetypes:

xanderhuggins.github.io

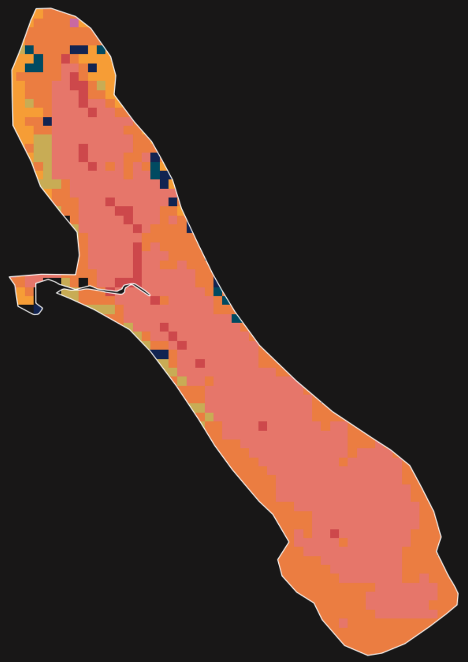
@xander_huggins

xanderhuggins@uvic.ca

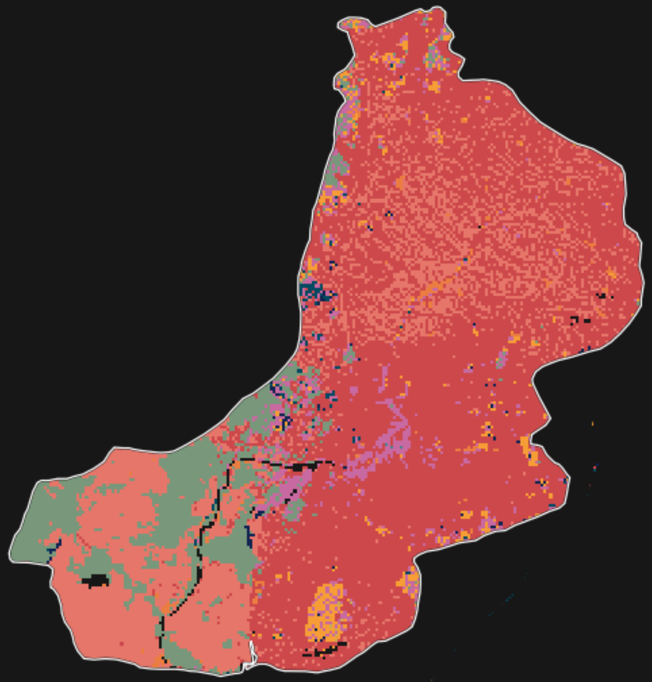
additional slides



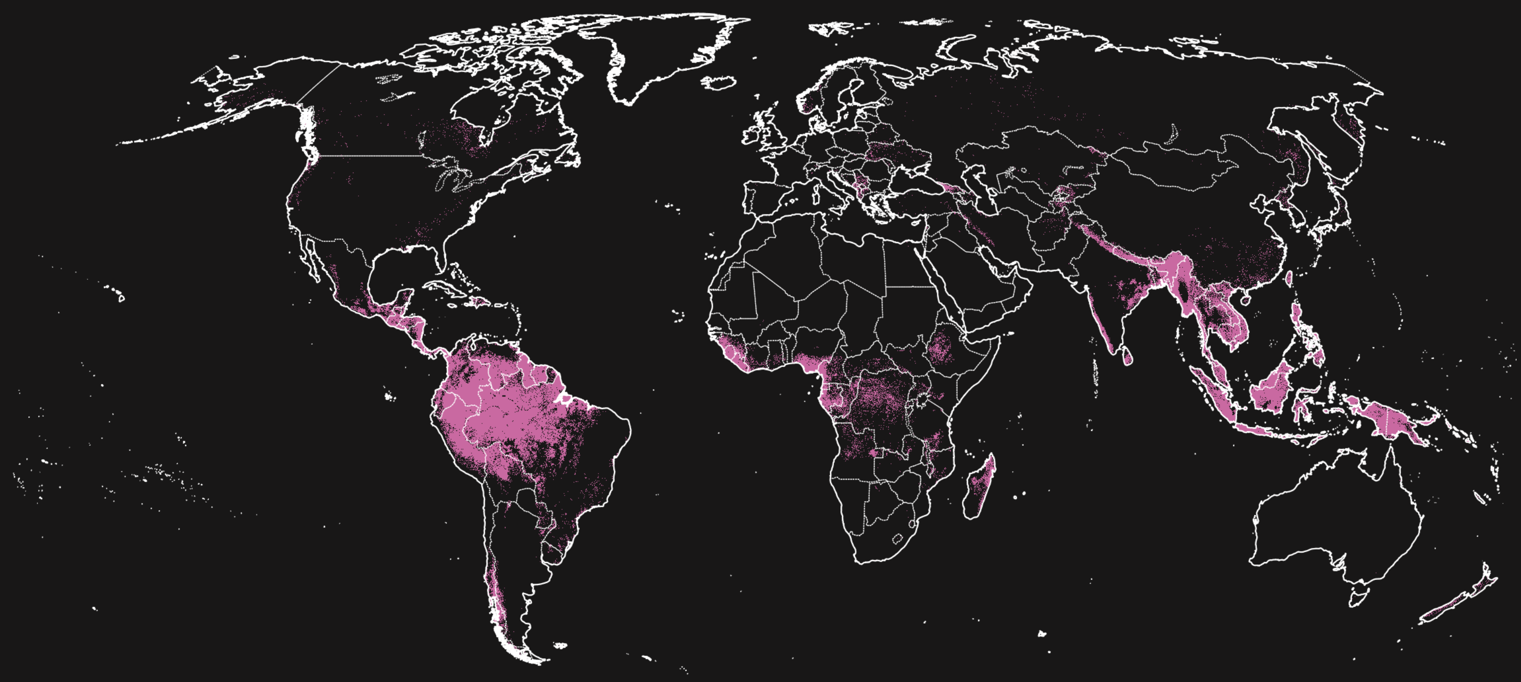
## Central Valley

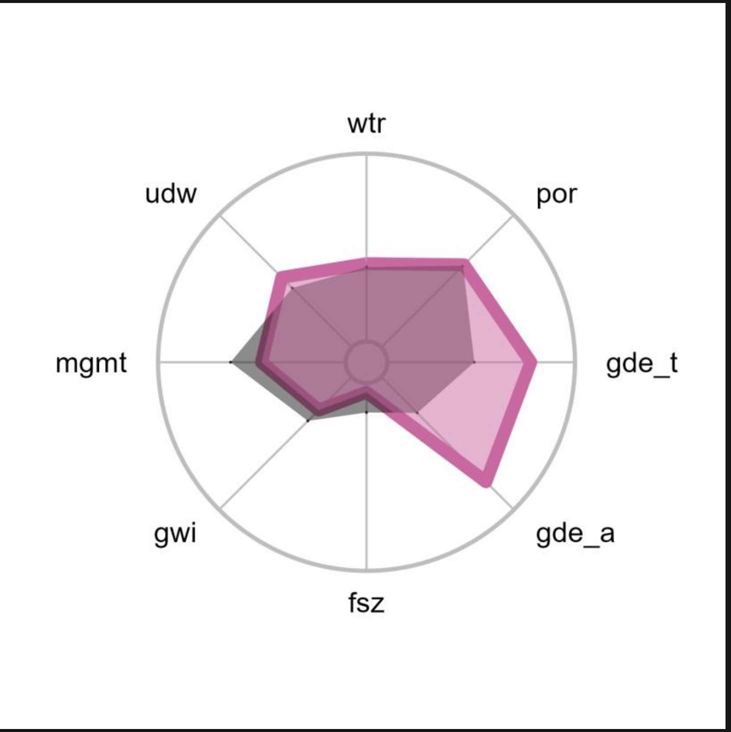


## Guarani

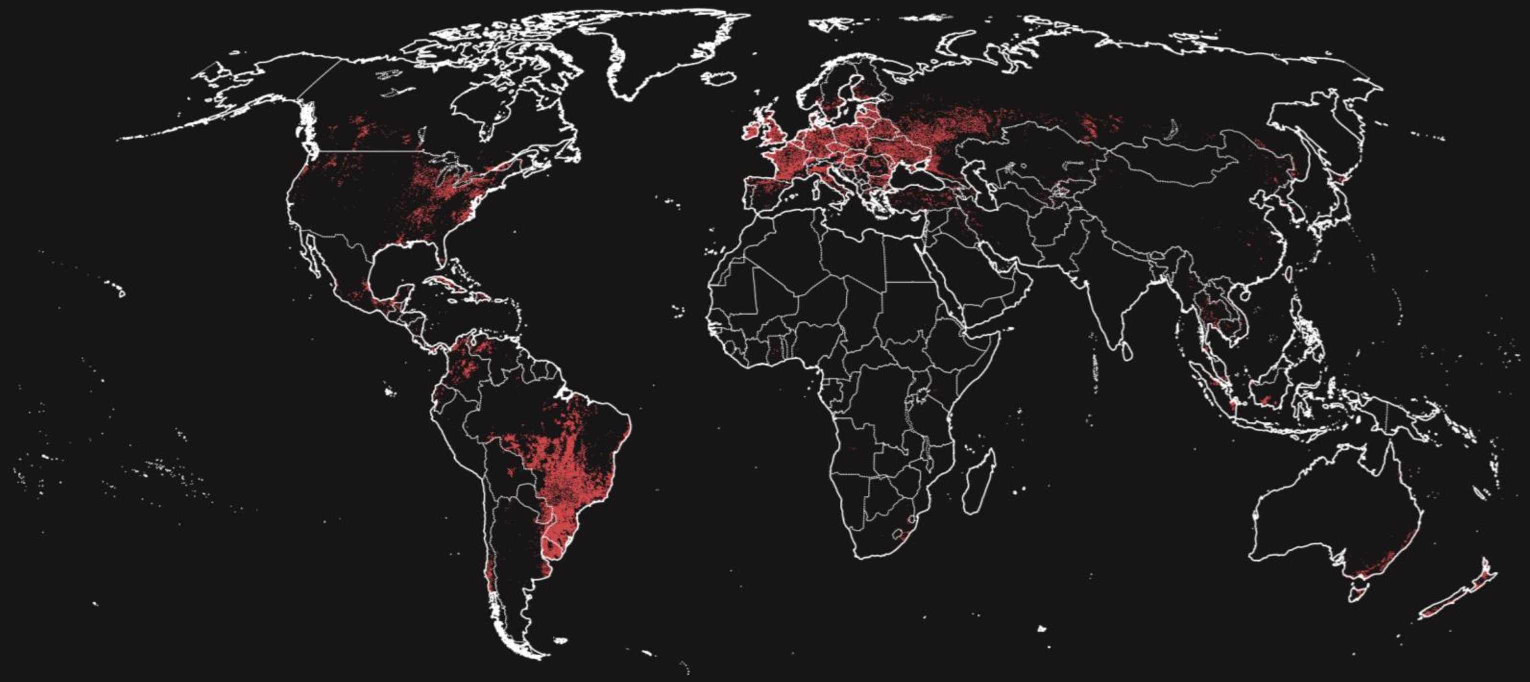


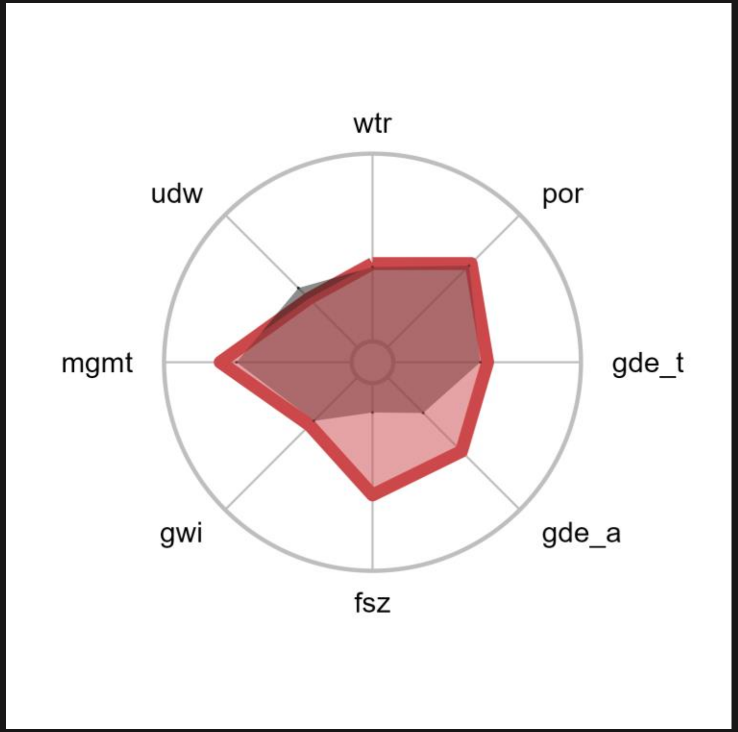
# 1: Extensive ecosystems with limited agriculture and management



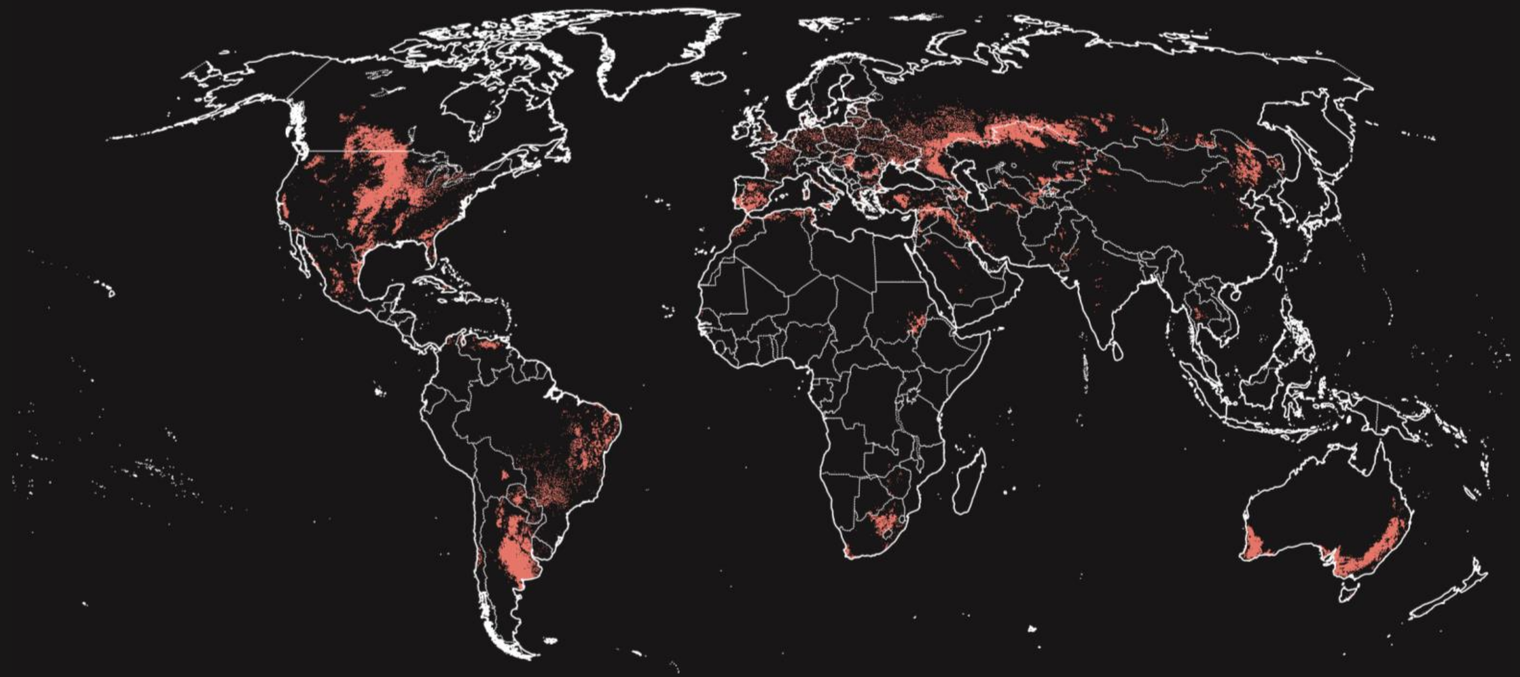


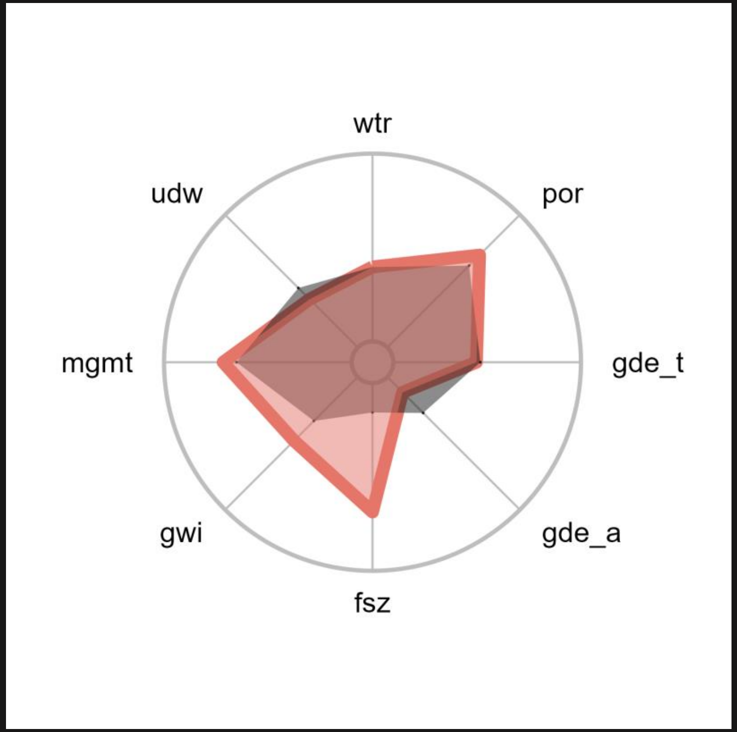
## **2:** Large-scale agriculture among extensive aquatic ecosystems



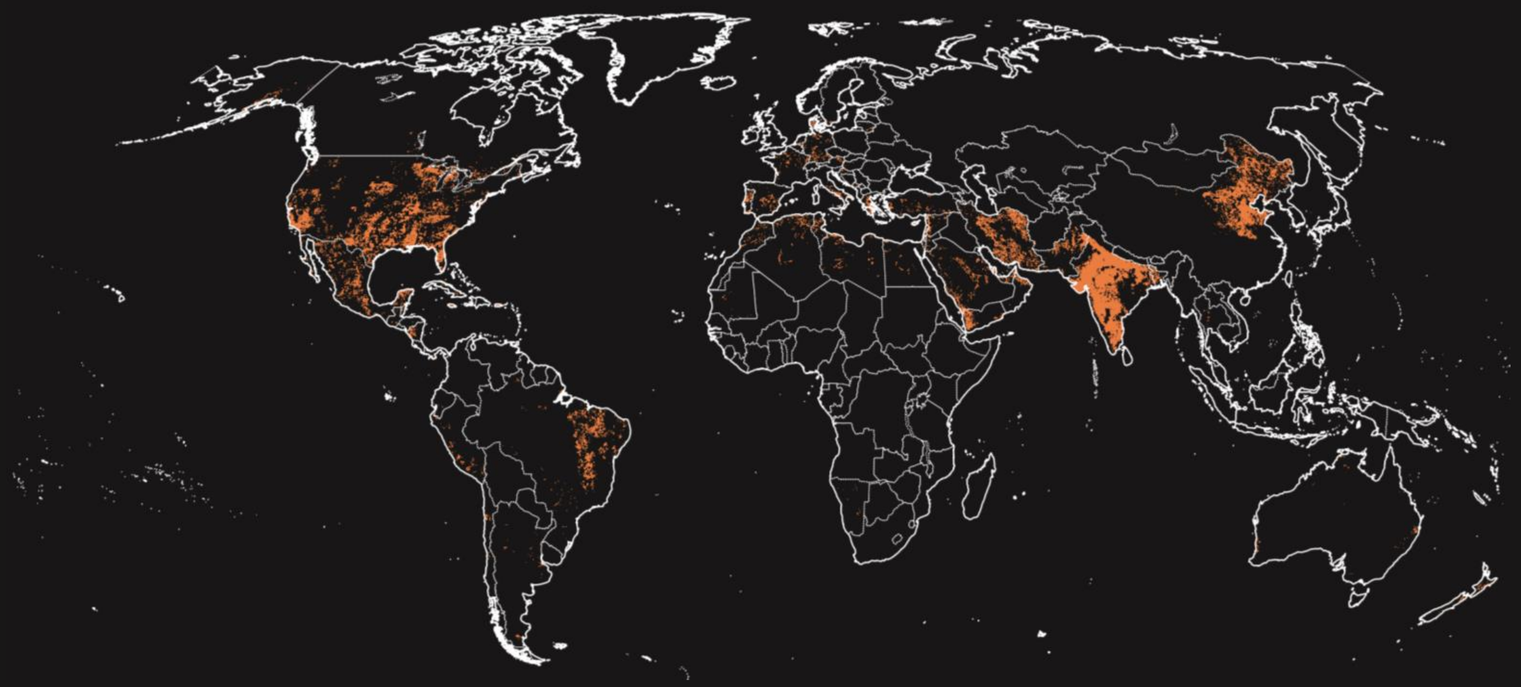


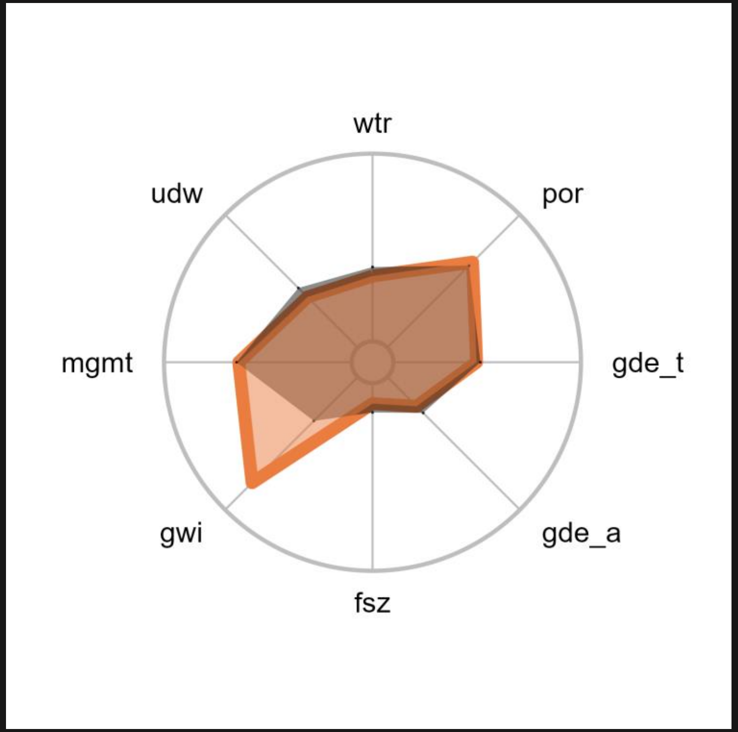
# 3: Groundwater reliant industrial agriculture



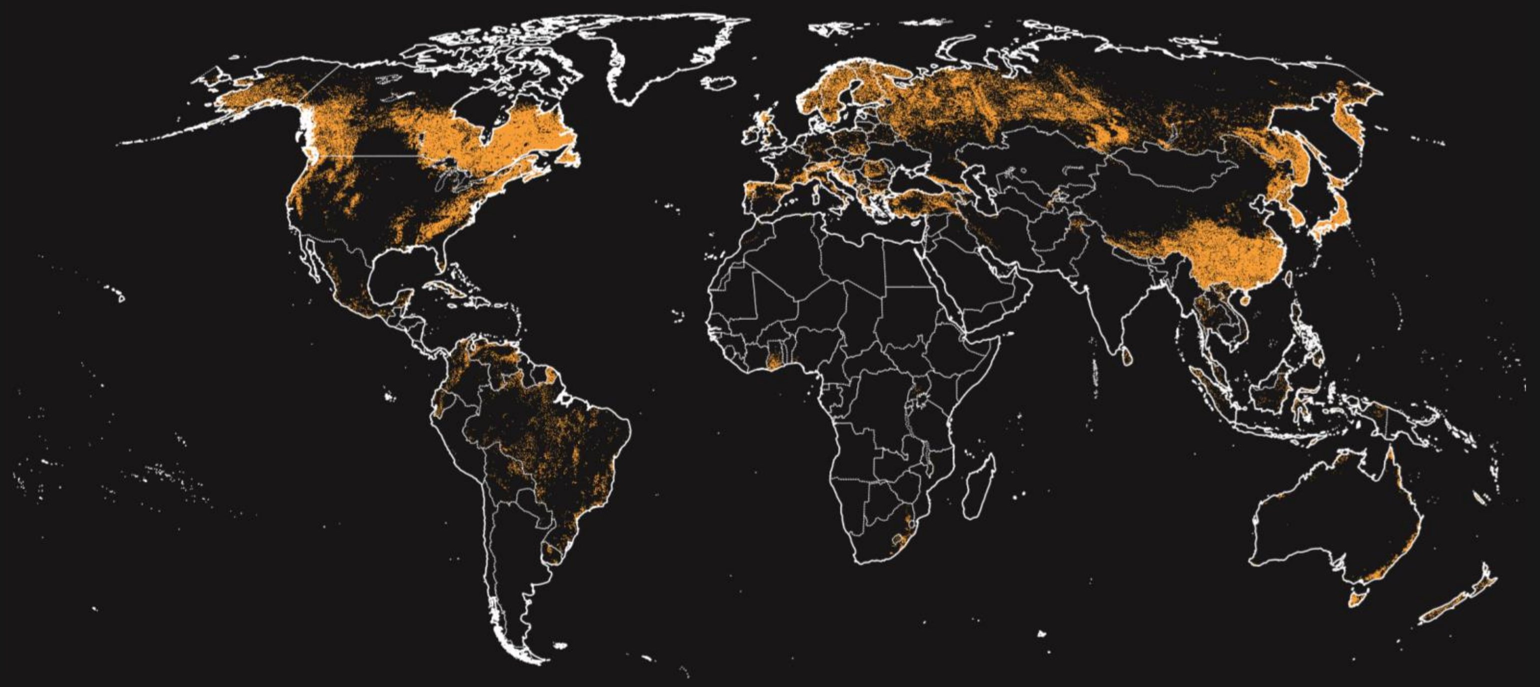


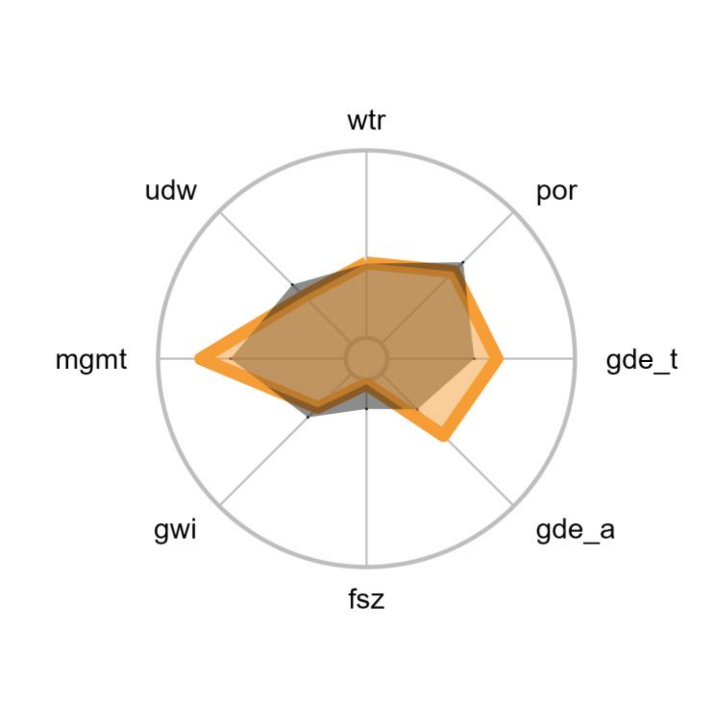
# 4: Groundwater reliant small-landholder agriculture



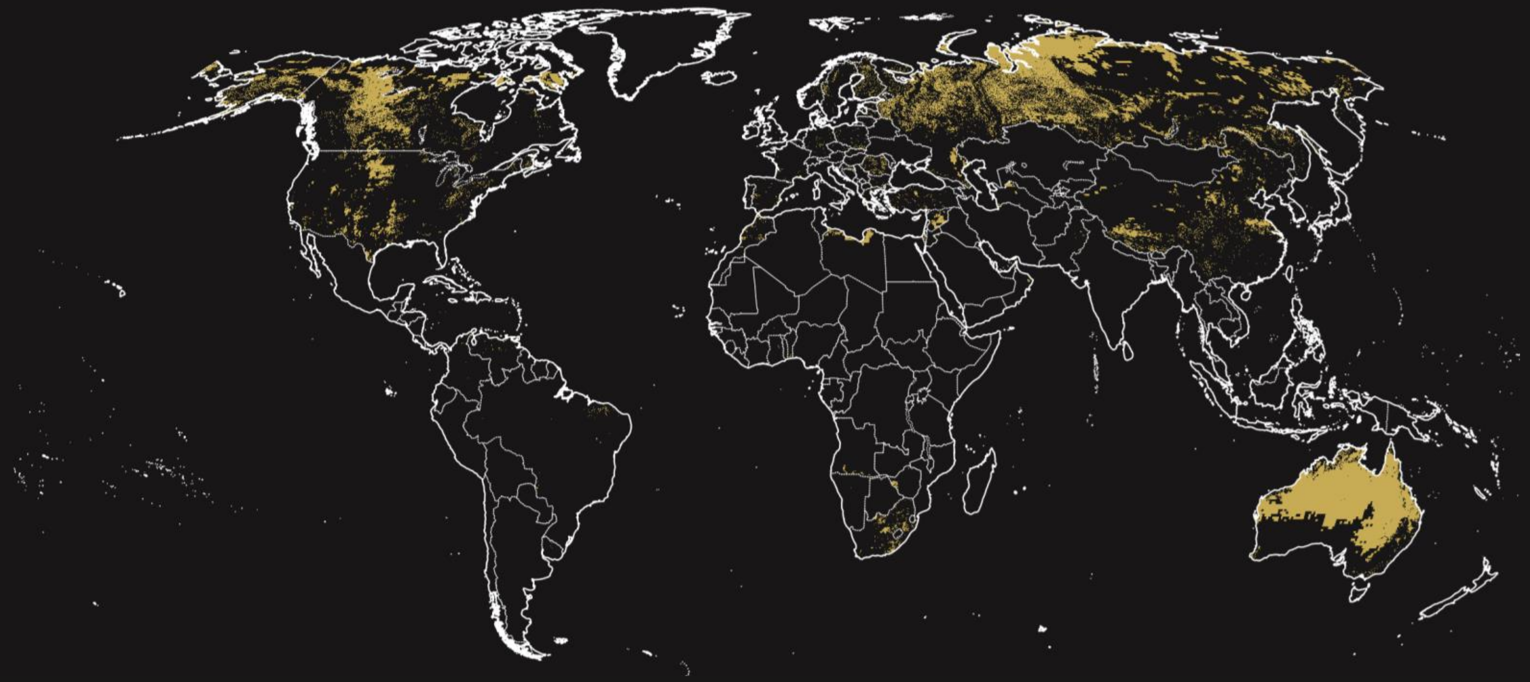


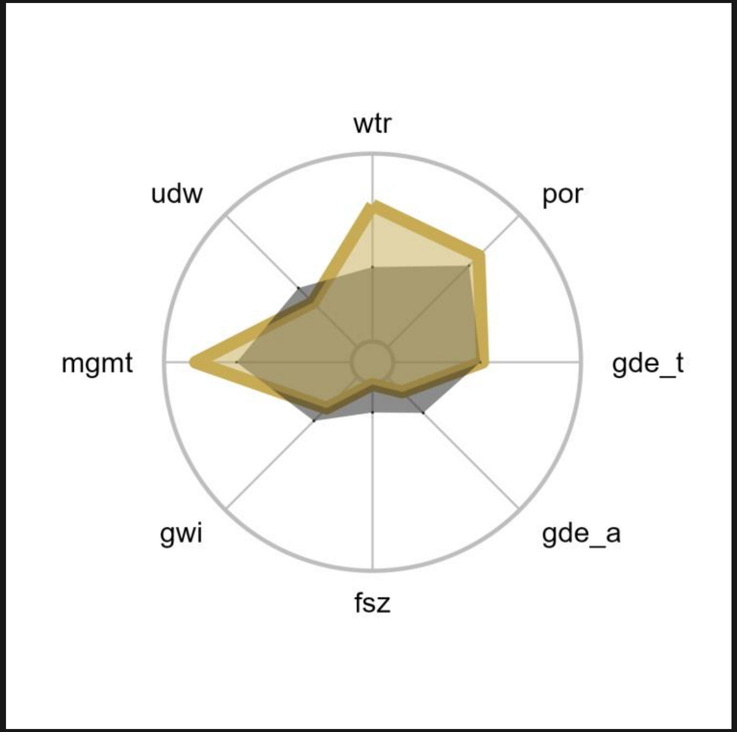
**5:** Extensive ecosystems with moderate management



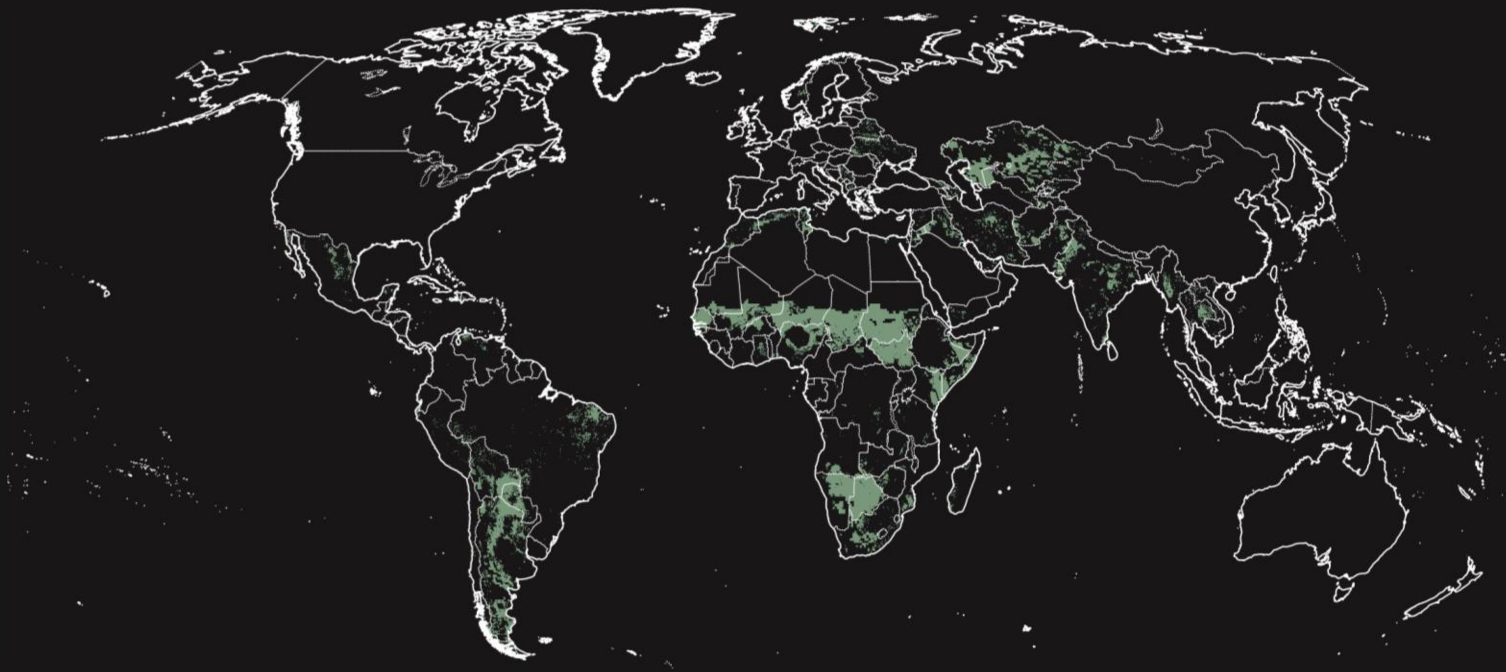


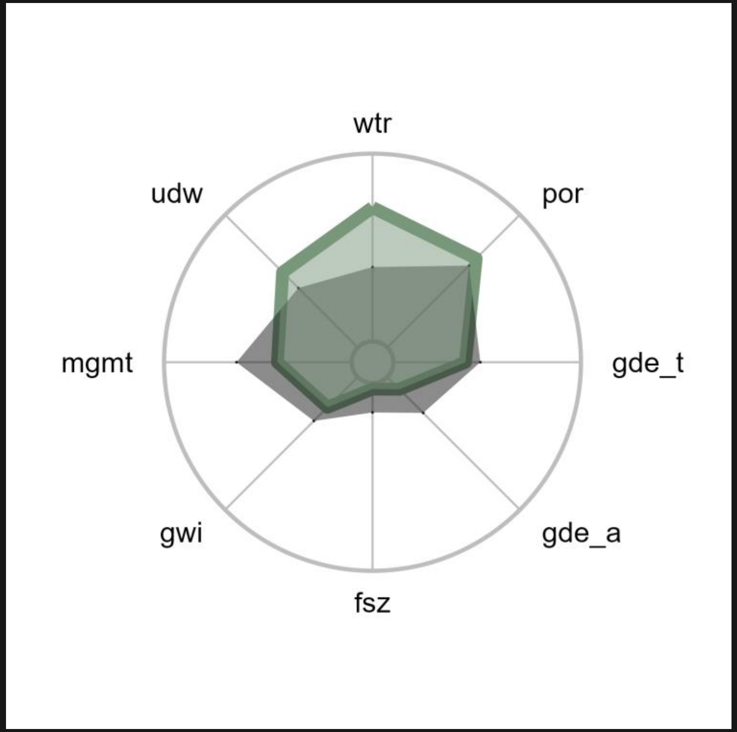
# 6: Remote lands with important climate function but existing management



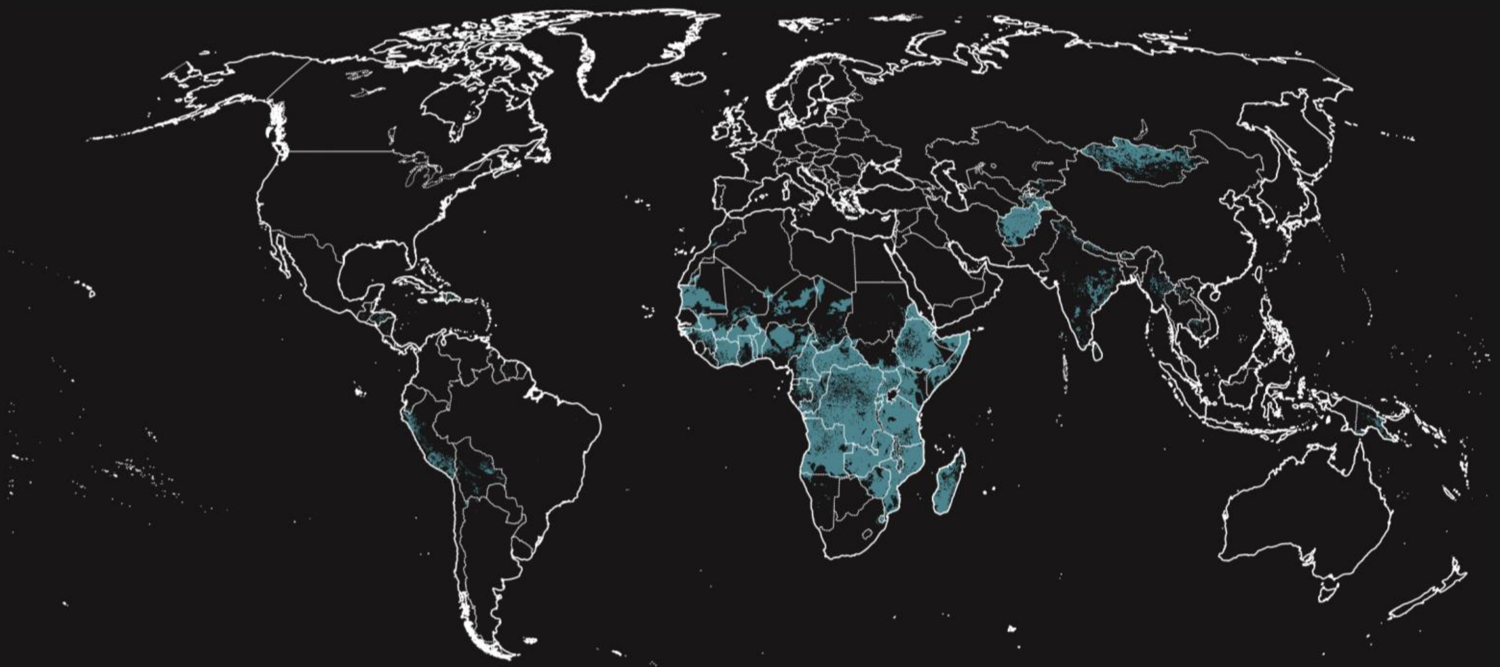


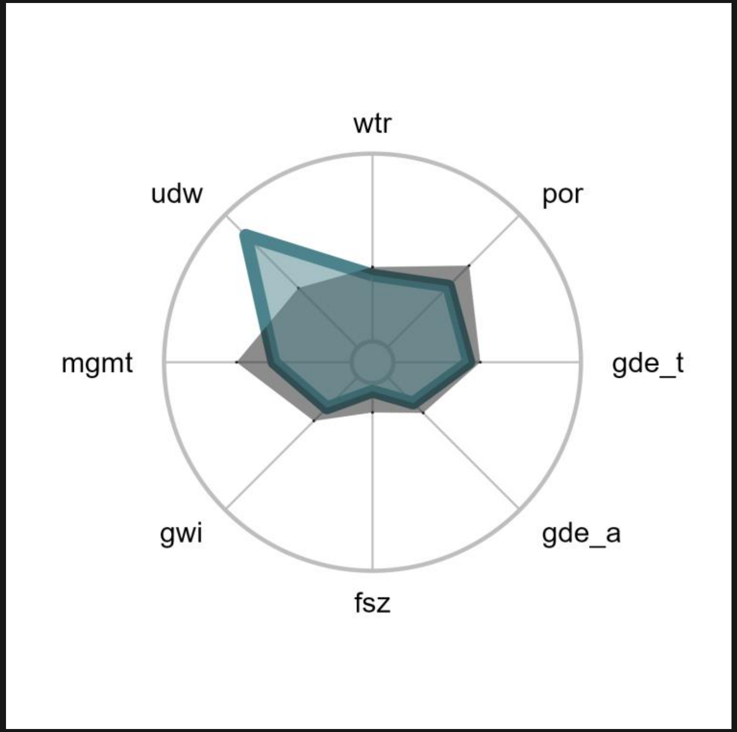
# 7: Rural/remote lands with important climate functions but limited management



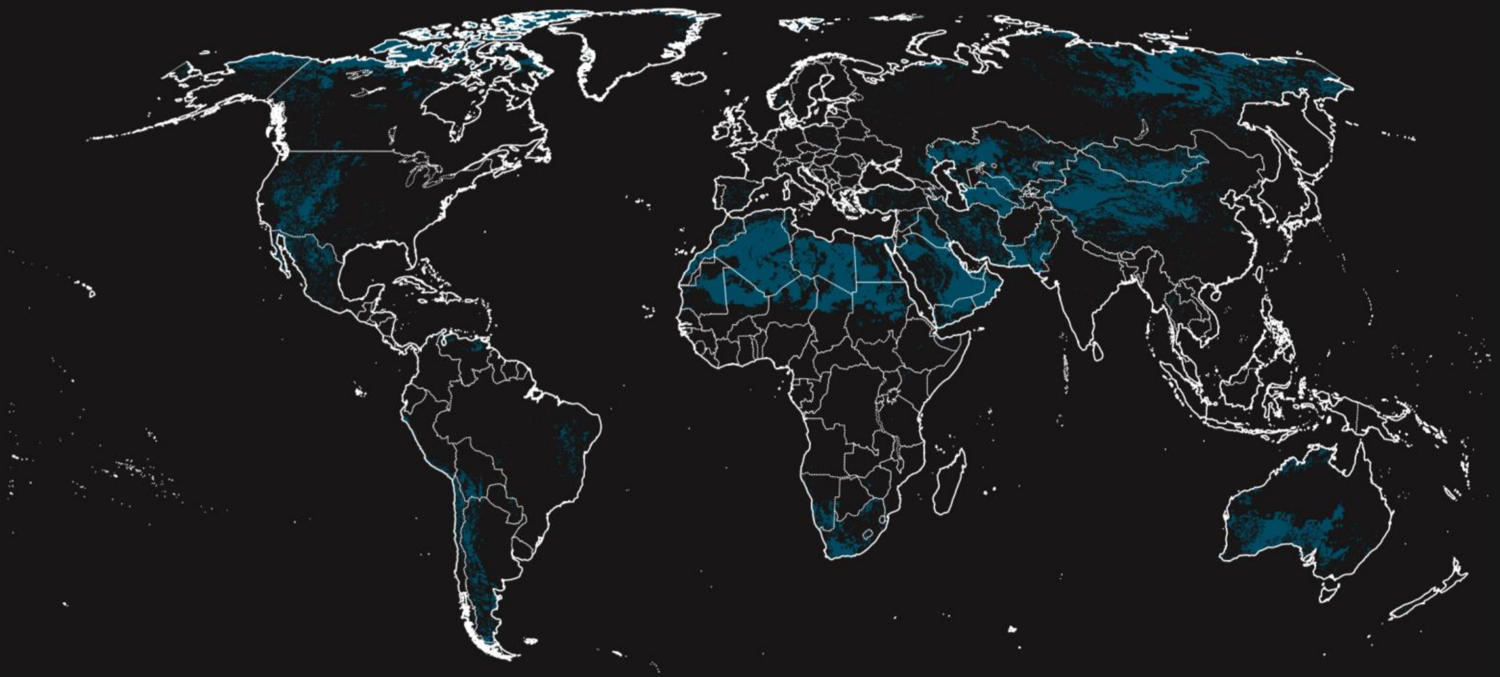


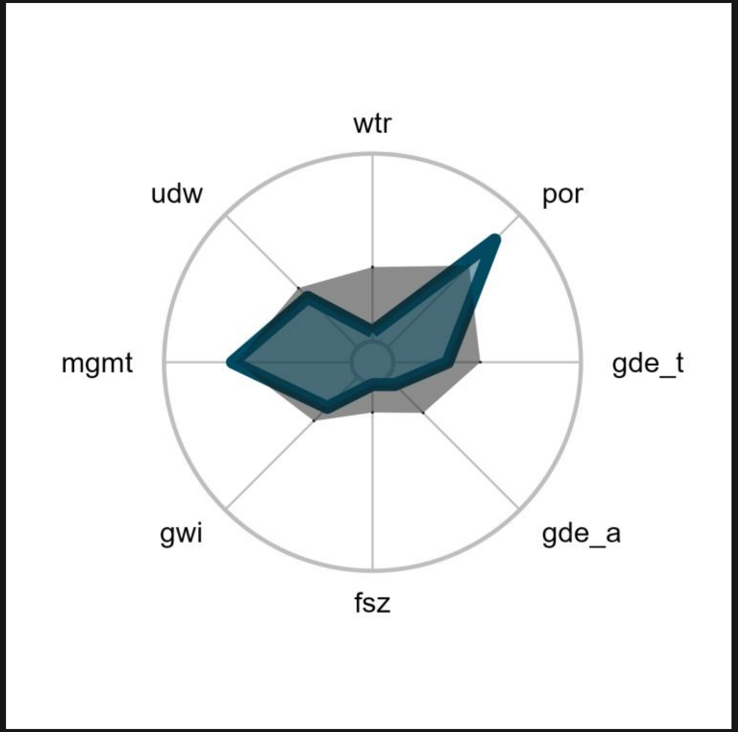
## **8:** Underserviced areas with limited agricultural production or groundwater mgmt.





# 9: Arid areas with important Earth system storage functions





# **10:** Deep groundwater systems with little storage capacity or social functions