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PIK

# Agroecological practices and the water planetary boundary

## Quantifying the limit of sustainable agricultural water use and the role of agroecological practices

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## Introduction

Increasing water withdrawal for irrigation purposes can put entire agro-ecosystems at risk. The central question in this context is: ***how can irrigation intensification take place without transgressing crucial boundaries of sustainable water use?*** Following the Planetary Boundary Concept[1,2], we assess meaningful indicators and tipping-points, which define and quantify sustainability limits at a local but also global level. In addition, we pose the question ***if and which agroecological measures can help to prevent a transgression of local water boundaries***?

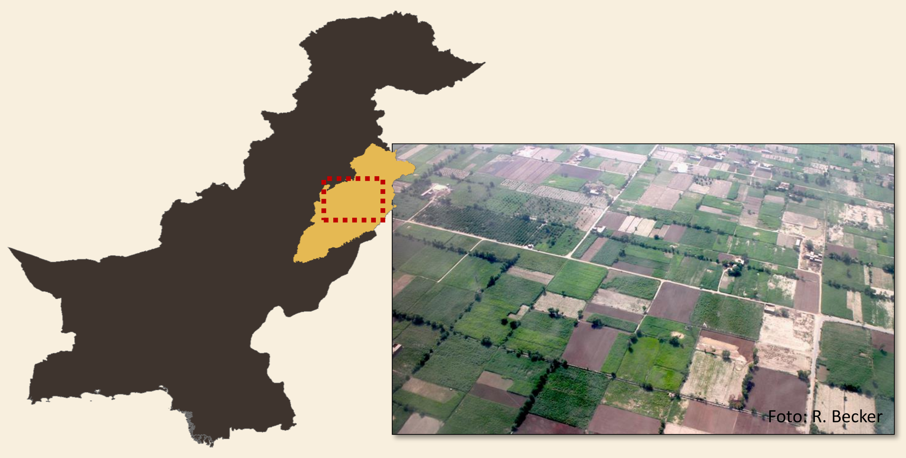
## Research Questions

- What are meaningful local control and response variables to define sustainability limits for water extraction?
- What are tipping-points of agricultural water use, which lead to irreversible degradation of a water and agricultural system?
- How can we quantify these limits and tipping-points?
- How can we quantify the role of agroecological measures in helping to stay within water sustainability limits?

## Methods (work in progress)

### 1

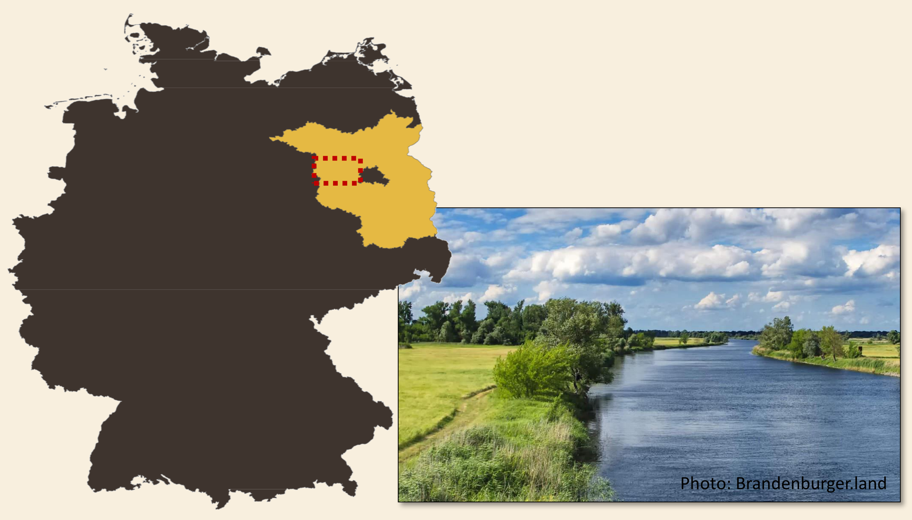
Selecting study sides and examining their environmental dynamics.
(*Review of literature and existing data bases*)




**Lower Chenab Canal System, Punjab, Pakistan**
**Approx. 16.000 km²**

- Semi-arid, monsoon climate
- Small-scale farming
- > 50% irrigated farmland
- Snow-melt dependent river flows
- Increasing water demand

➡ *Shrinking irrigation water resources*




**Havelland, Brandenburg, Germany**
**Approx. 1.700 km²**

- Temperate, continental climate
- Large-scale farming
- Low water holding capacity of soils
- Drought prone region
- Important wetland ecology

➡ *Increasing irrigation activities*

### 2

Definition of locally meaningful control and response variables. (*Expert discussion*)

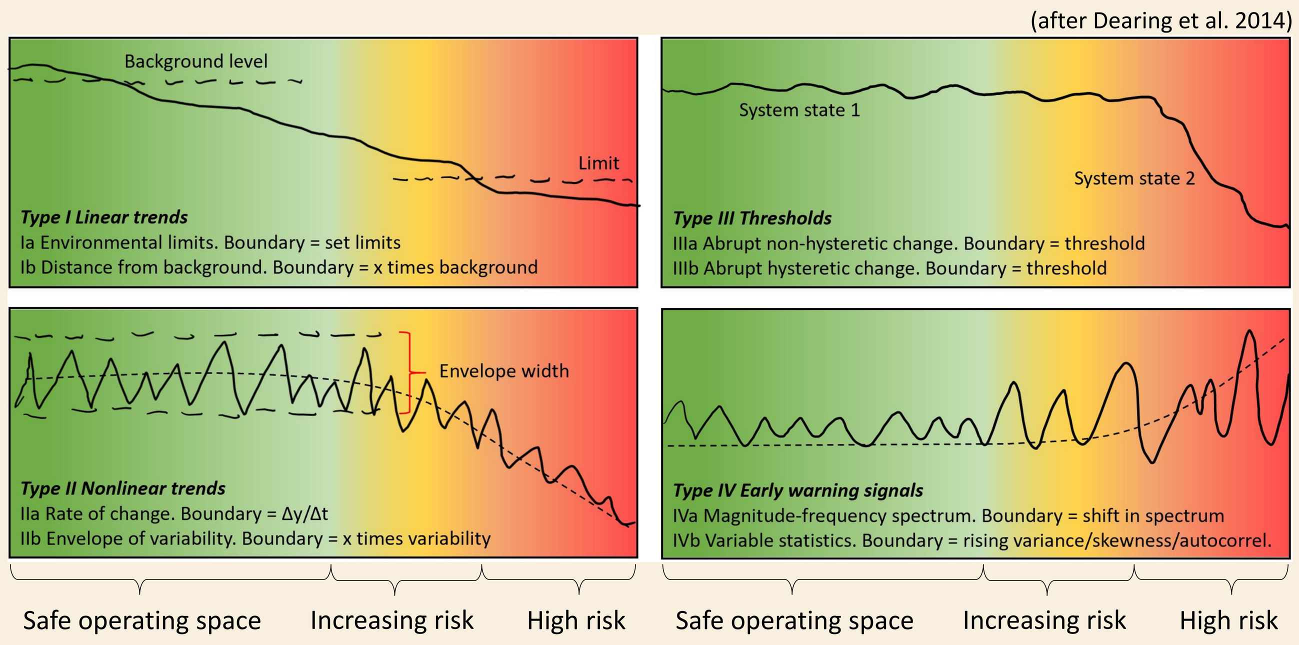
**Examples for control and response variable and potential tipping-points:**

| Potential (local) control variables | Potential response variables | Potential tipping-points indicating boundary transgression |
|---|---|---|
| Minimum flow requirements | Loss of wetlands, reduced water resources for irrigation | River discharge < min. flow requirements |
| Glacier melt | River runoff | Reduction in melt water |
| Groundwater quality (nitrate concentration > threshold) | Loss of aquatic life, reduced fertilizer requirements (if re-use of water for irrigation) | Eutrophication, toxicity of GW too high for irrigation |
| Bare soil evaporation vs. plant evaporation | ? | ? |
| Soil moisture content | Drought stress, increase of irrigation demands, yield losses | ? |
| Groundwater extraction rates (> threshold) | Increased yields, higher soil moisture, higher evapotranspiration rates, drop of ground water levels < threshold | Drop of GW tables below root zone access |
| Surface water extraction rates (> threshold) | Reduced river runoff | Flow regime shift |
| Increased water temperature | Loss of aquatic life | Threshold for algae bloom |
| Salt concentration in groundwater | Salt concentration in soil and plants, yield losses | Irreversible salt concentration |
| Irrigation water applied | Drop of GW levels, river flows, change in moisture fluxes, nutrient uptake by plant | Drop of GW tables below root zone access |
| Soil stability, erosion, sediment loads | Sediment load in streams | ? |

### 3

Exploring and understanding (non-)linear systemic changes[3] and dangerous effects.
(*Quantitative analysis using statistical and process-based models*)

(after Dearing et al. 2014)




### 4

Setting local (sub-)boundary[4] values and harmonizing them with global boundaries[5].
(*Quantitative analysis using statistical and process-based models*)


**Examples**

Minimum glacier melt leading to long-term reduction in water availability.

Minimum required precipitation – evaporation to guarantee minimum river flow.

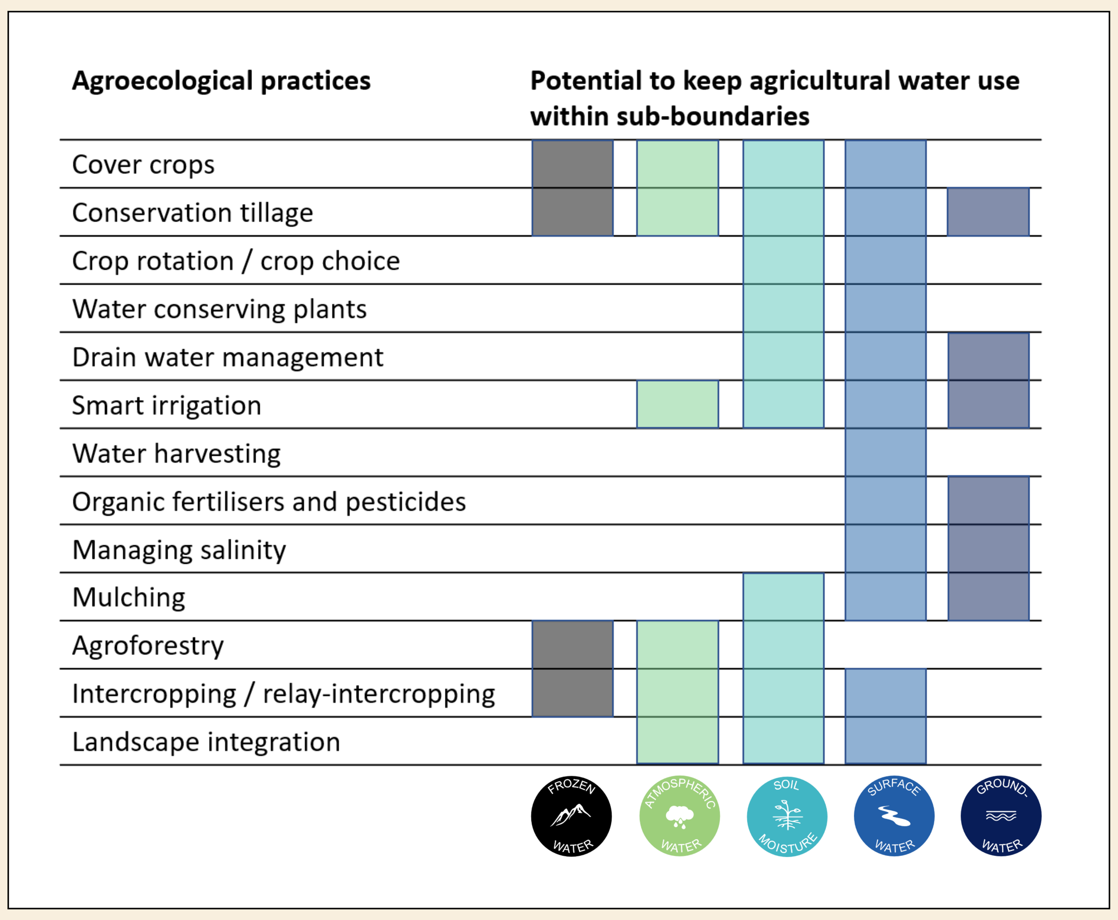
Minimum required soil moisture content for crop/plant growth *or* maximum soil moisture content to not alter local or global moisture fluxes.

Minimum river flow to maintain wetlands and aquatic life.

Minimum GW recharge to replenish aquifers.

### 5

Quantifying the potential of agroecological practices for keeping agricultural water use within sustainability limits.
(*Quantitative analysis using statistical and process-based models*)




## Expected results

The study will help to define locally meaningful sustainability limits, which indicate if the agroecological system under study is still operating within boundaries of sustainable water use. Furthermore it will help to highlight the potential of agroecological measures to expand agricultural activities within these limits.

## References


[1] Rockström et al. (2009): A safe operating space for humanity.
[2] Steffen et al. (2015): Planetary Boundaries: Guiding human development on a changing planet.
[3] Dearing et al. (2014): Safe and just operating spaces for regional social-ecological systems.
[4] Gleeson et al. (2020): The Water Planetary Boundary: Interrogation and Revision.
[5] Zipper et al. (2020): Integrating the Water Planetary Boundary with water management from local to global scale.
Photo Havelland: https://brandenburger.land/landkreise/havelland.html
Water Planetary Boundary Symbols by Miina Porkka (Thank you Miina).



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