



XIX WORLD WATER CONGRESS
International Water Resources Association (IWRA)
Marrakech, Morocco | 1-5 December 2025

Establishing hydrological monitoring hubs to support the conceptual assessment and protection of Africa's natural water towers

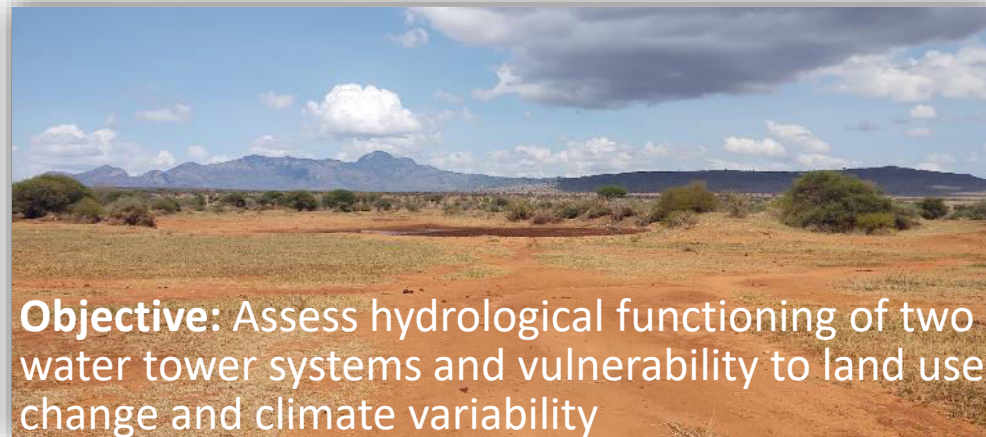
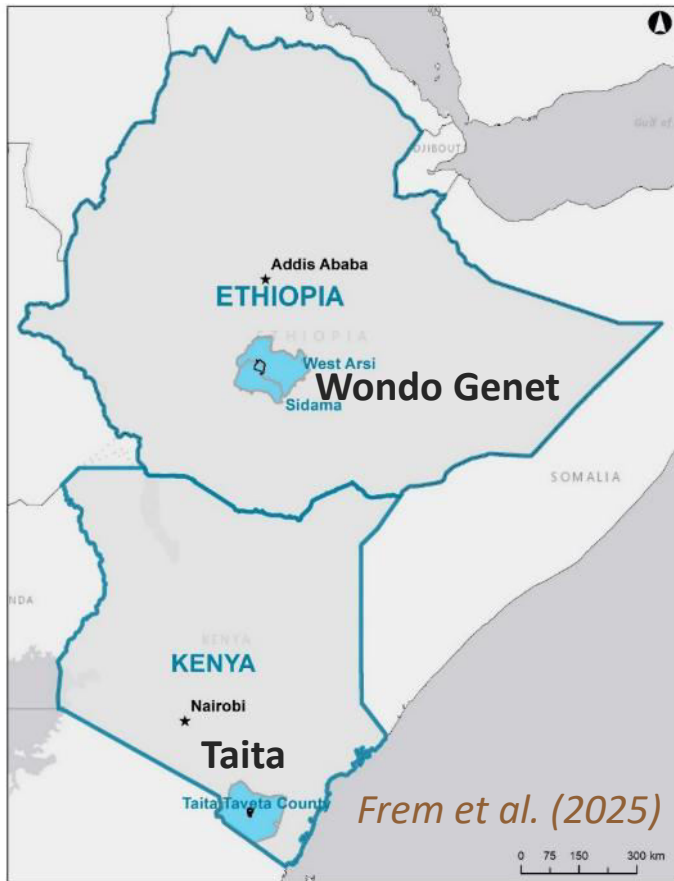
Tibor Stigter, Associate Professor
Michel Frem, PhD Researcher

IHE Delft Institute for Water Education
3 December 2025

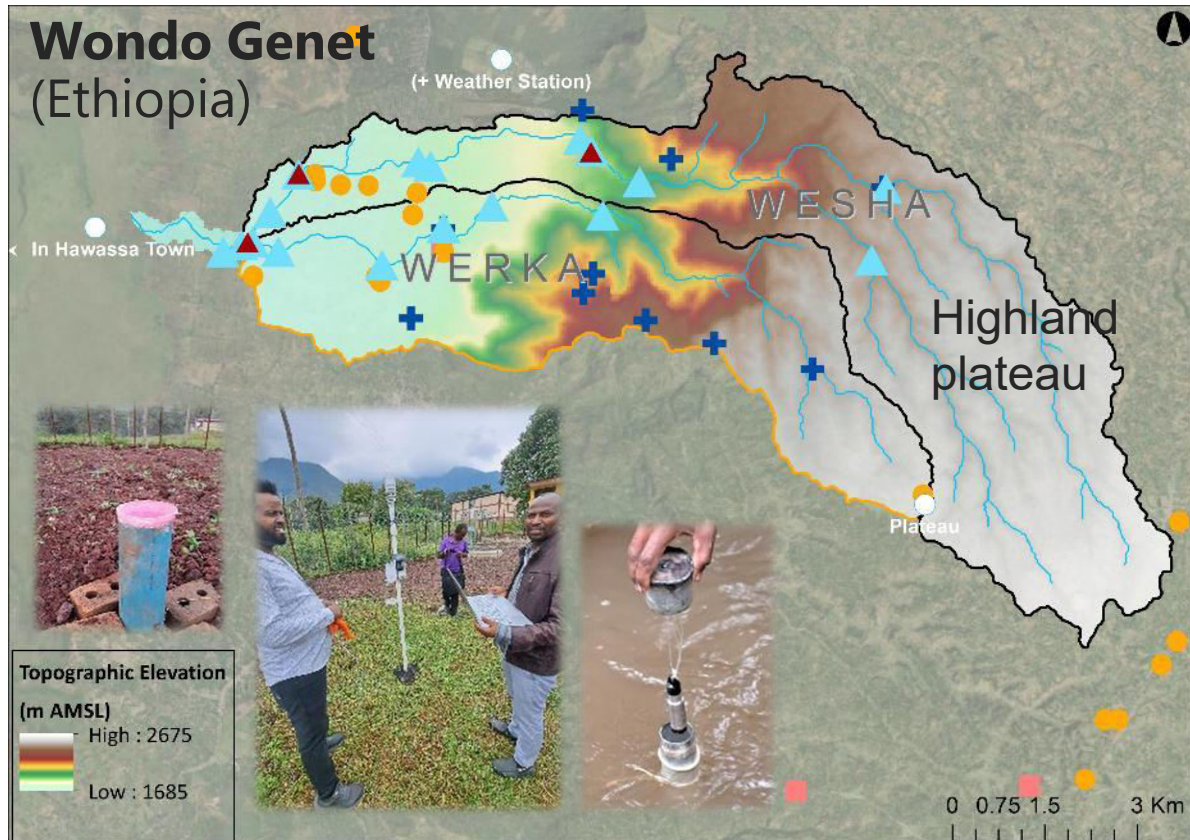
Co-authors:
Gretchen Gettel, Graham Jewitt, Benson Lombo,
Tilahun Azagegn, Binyam Hailu, Petri Pellikka

Tropical Mountains – Natural Water Towers

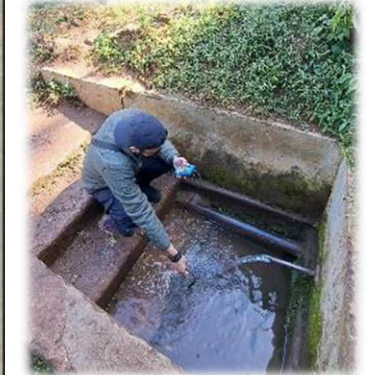
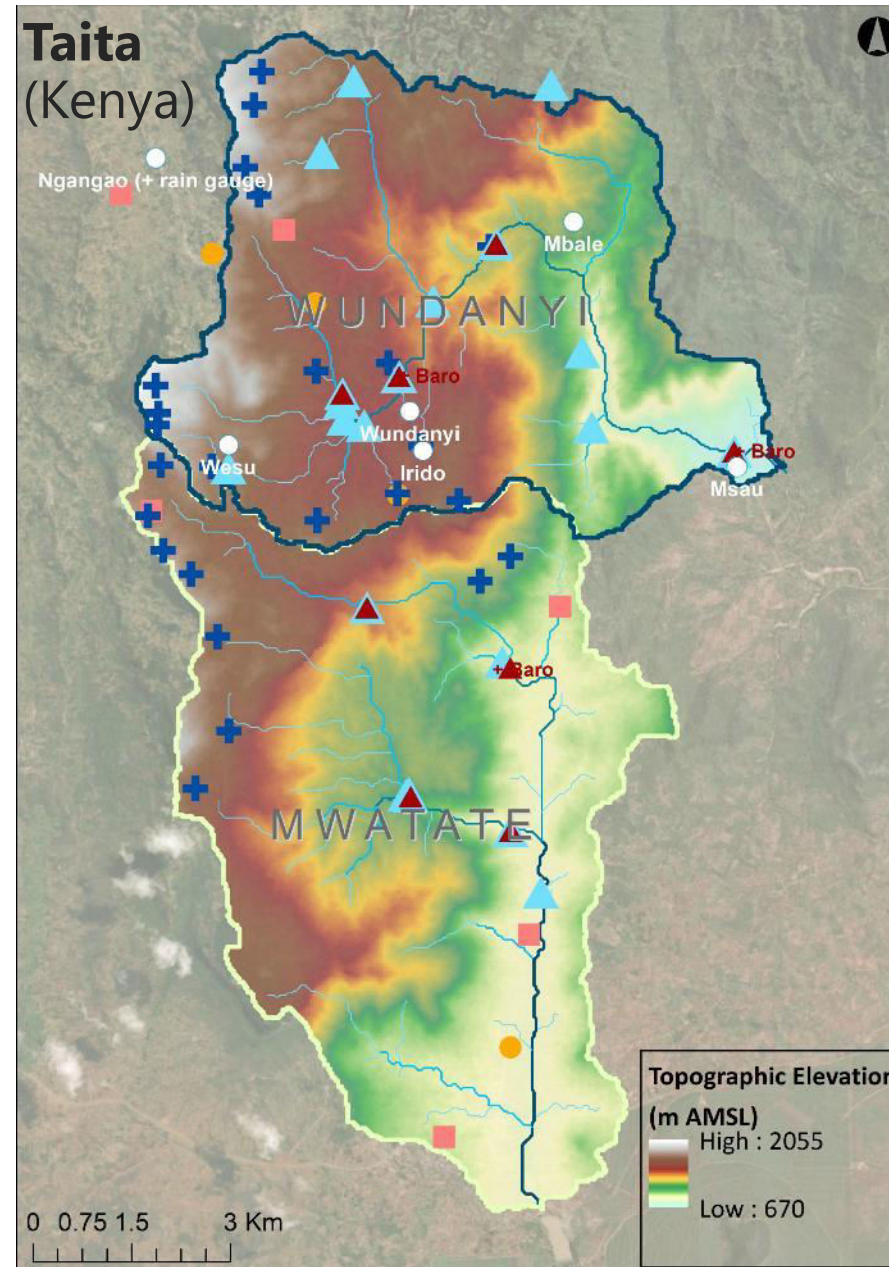
- EU project ESSA: IHE Delft responsible for hydrological study of two **natural water towers**: tropical mountain systems providing freshwater for household use and food production.



Monitoring Networks

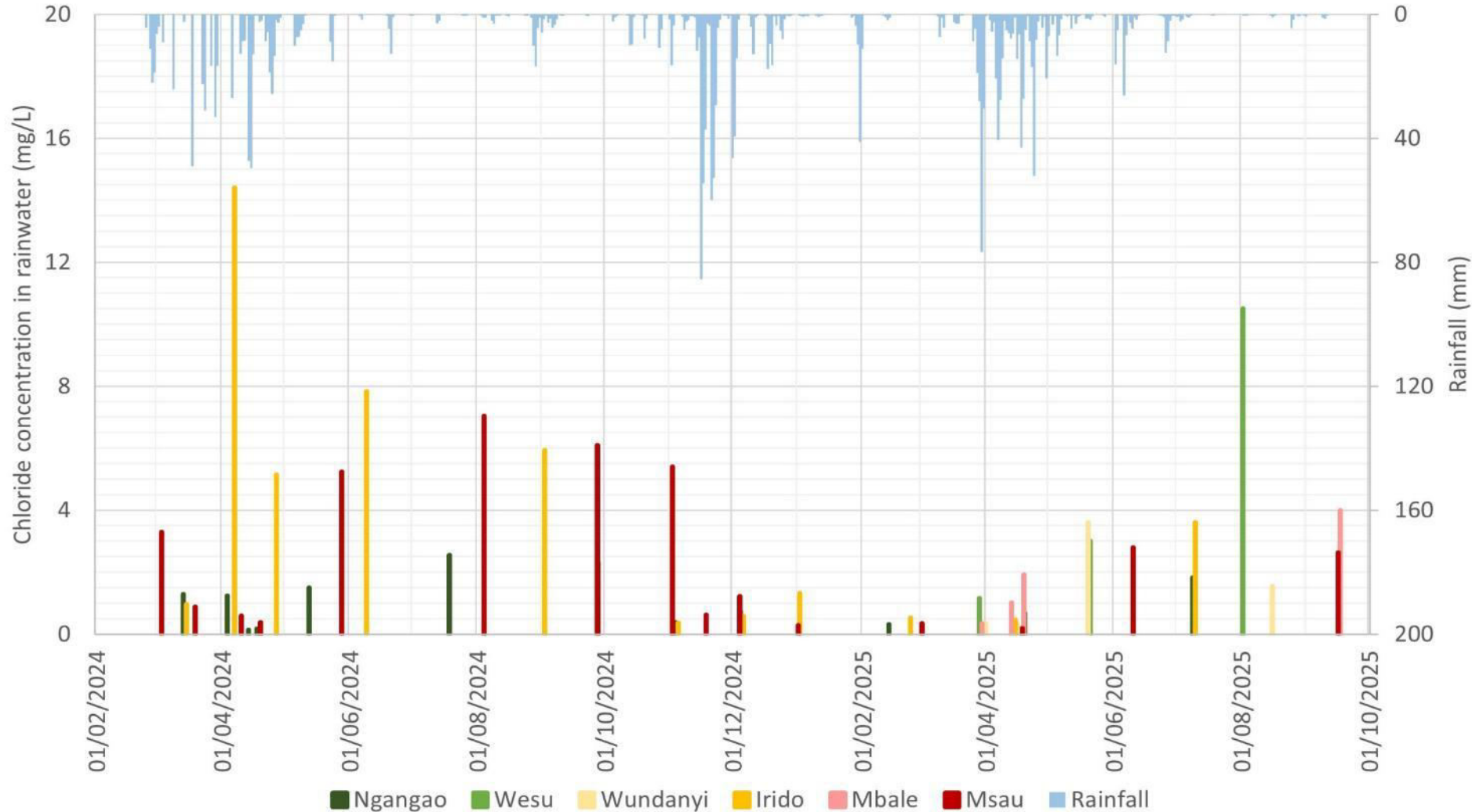


Frem et al. (2025)



- Rain Collector/Gauge
- Pressure Transducers
- Sampled Streams
- Sampled Springs
- Sampled Shallow Wells
- Sampled Deep Wells

Groundwater Recharge – Temporal variation of Cl in rainfall

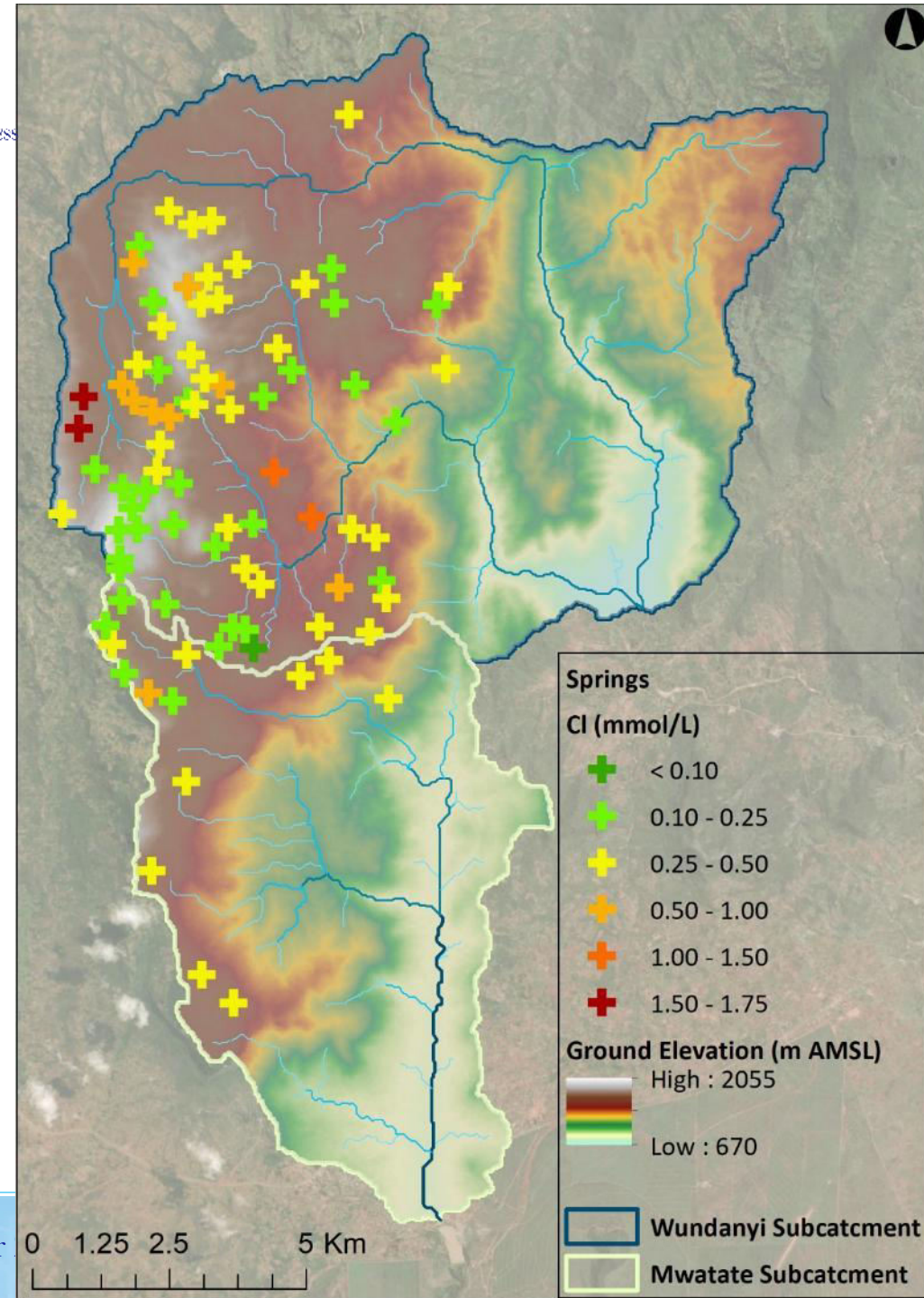


- **Ngangao forest** rainwater (highest elevation among the rain collectors): lowest Cl
- Wind direction and elevation influence deposition patterns
- Strange peak in wet season Cl in rainfall at **Irido**.
- Rainwater collectors installed at six locations and monitoring continues.



Groundwater Recharge – Spatial Distribution

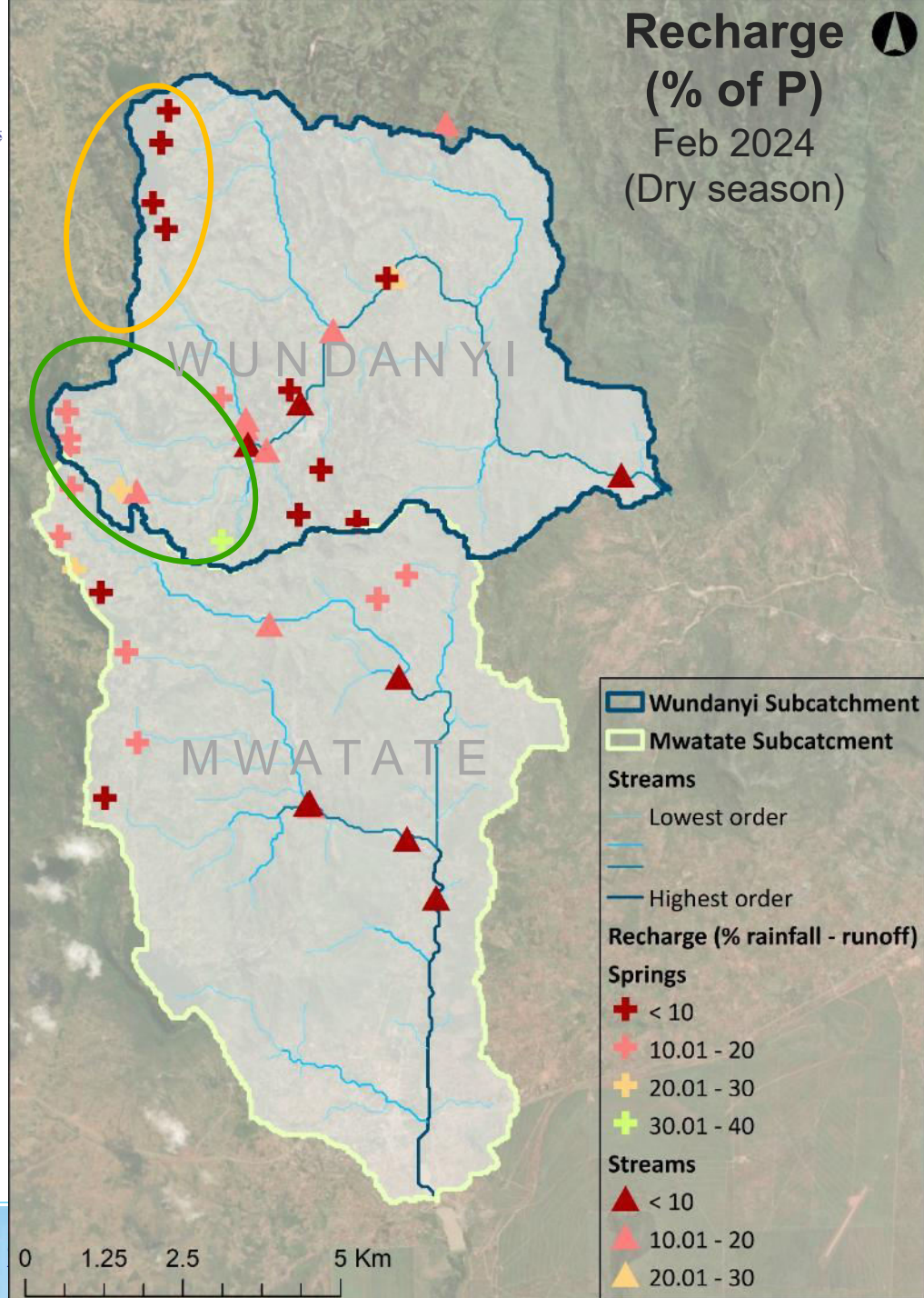
- 2022 campaign of spring sampling for Cl⁻ (and other major & minor elements) → flow system analysis (*Khan et al., in prep.*)
- Certain springs selected for longer-term monitoring, together with rain composition (Cl⁻ and stable isotopes)



Groundwater Recharge – Spatial Distribution

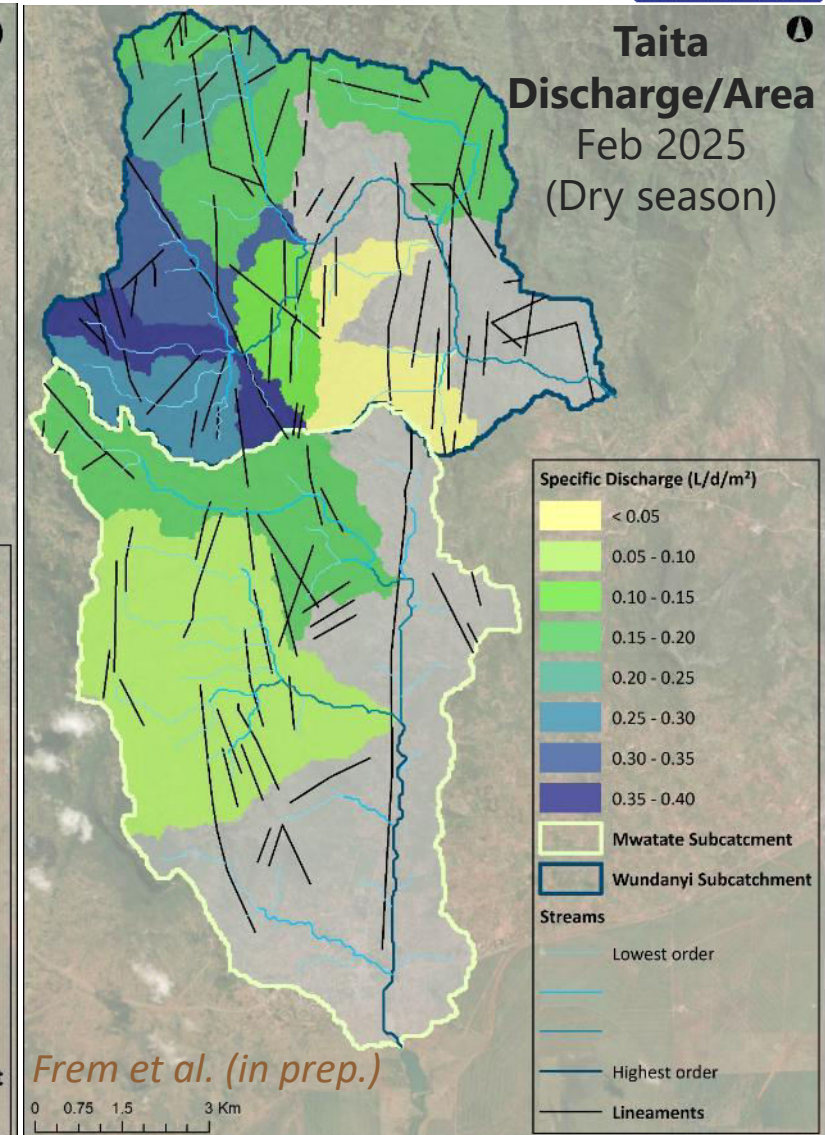
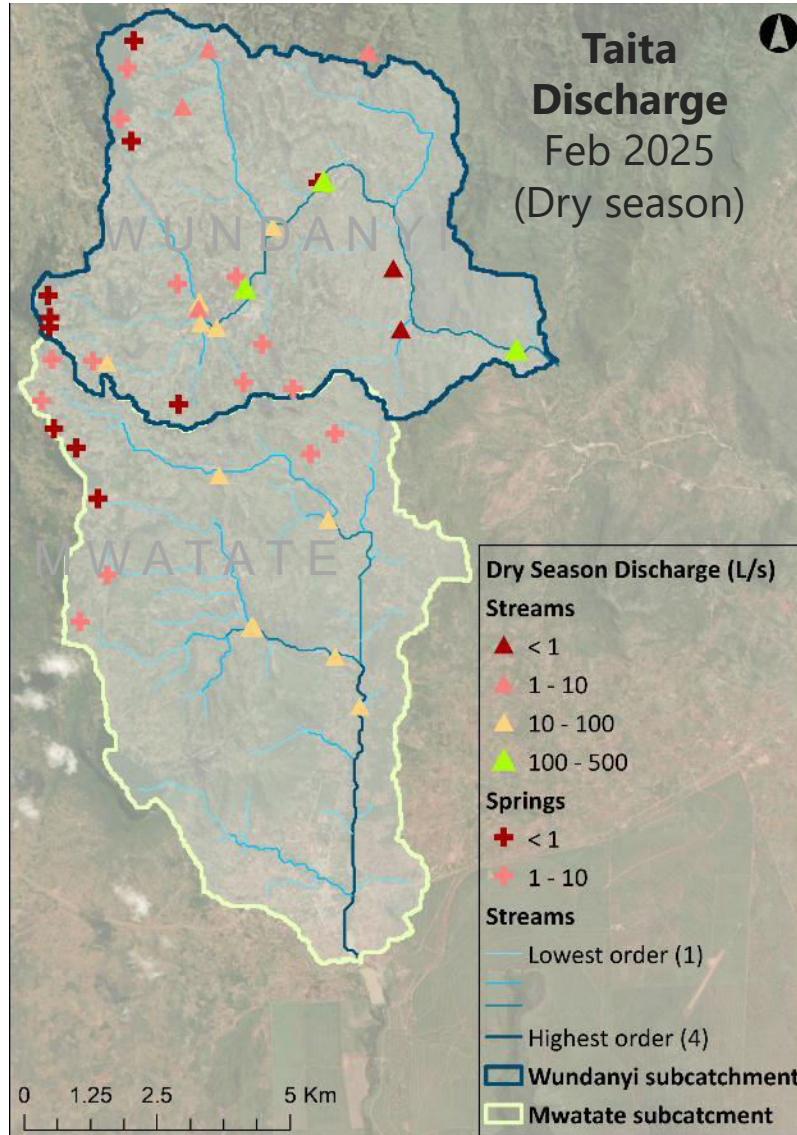
- 2022 campaign of spring sampling for Cl⁻ (and other major & minor elements) → flow system analysis (*Khan et al., in prep.*)
- Certain springs selected for longer-term monitoring, together with rain composition (Cl⁻ and stable isotopes)
- Groundwater recharge** (% rainfall) using the Cl⁻ mass balance for dry season of February 2024
- Includes springs and baseflow in rivers
- Based on spatially interpolated Cl⁻ concentrations in rainwater
- The springs in the north show lower recharge than the springs in the center → **Link to geology and land use**

Recharge (% of P)
Feb 2024
(Dry season)

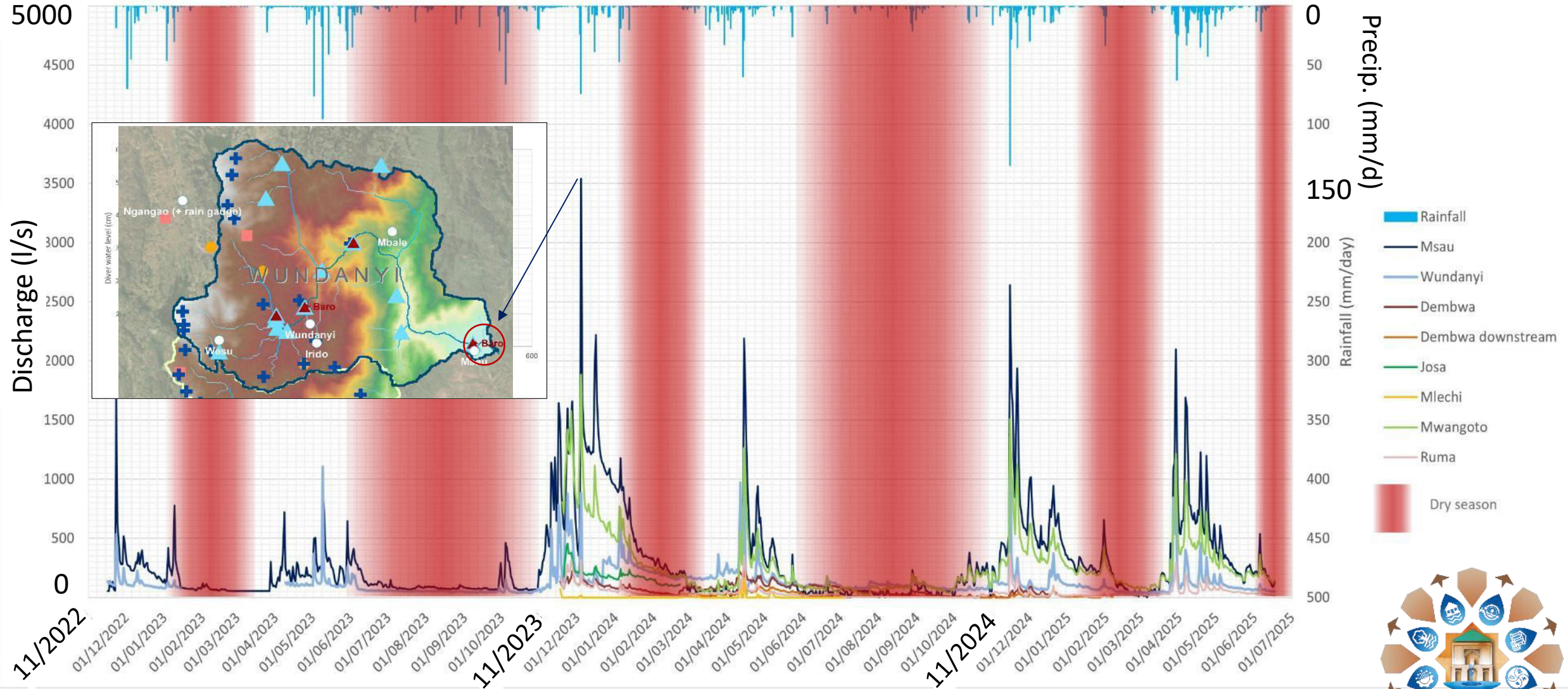


Groundwater Discharge – Spatial Distribution

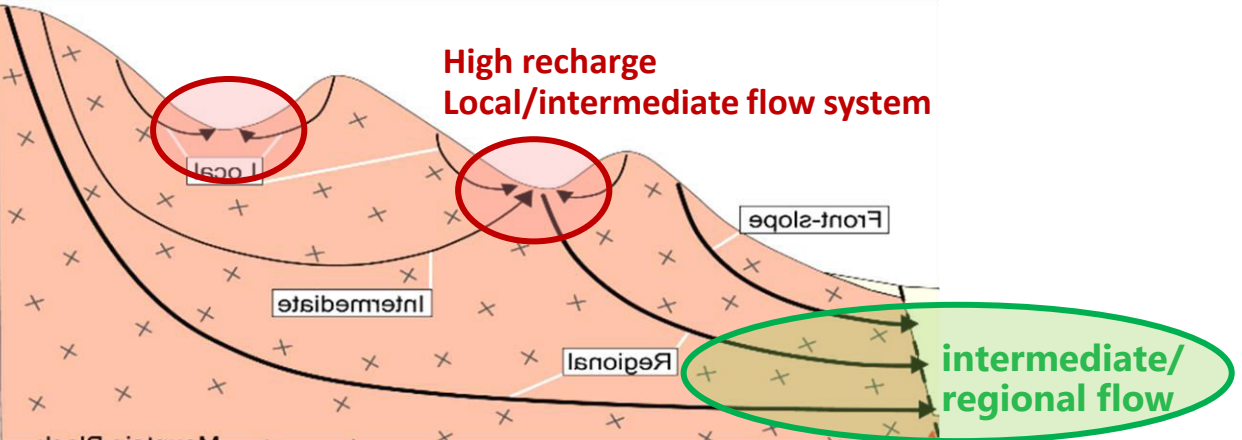
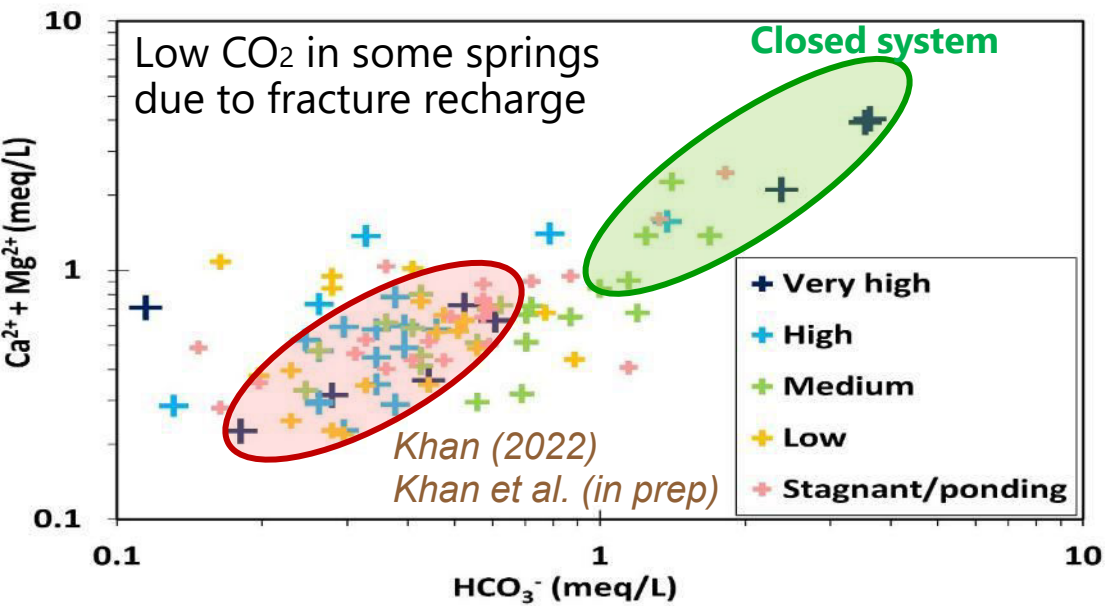
- Dry season total river flow is larger than the sum of spring discharge → **Geological faults** provide **important contribution to baseflow**.
- **Geological faults** cause **subsurface transfer** between subcatchments.
- Highland currently provides **moderate to low** contributions to lowland during dry season.



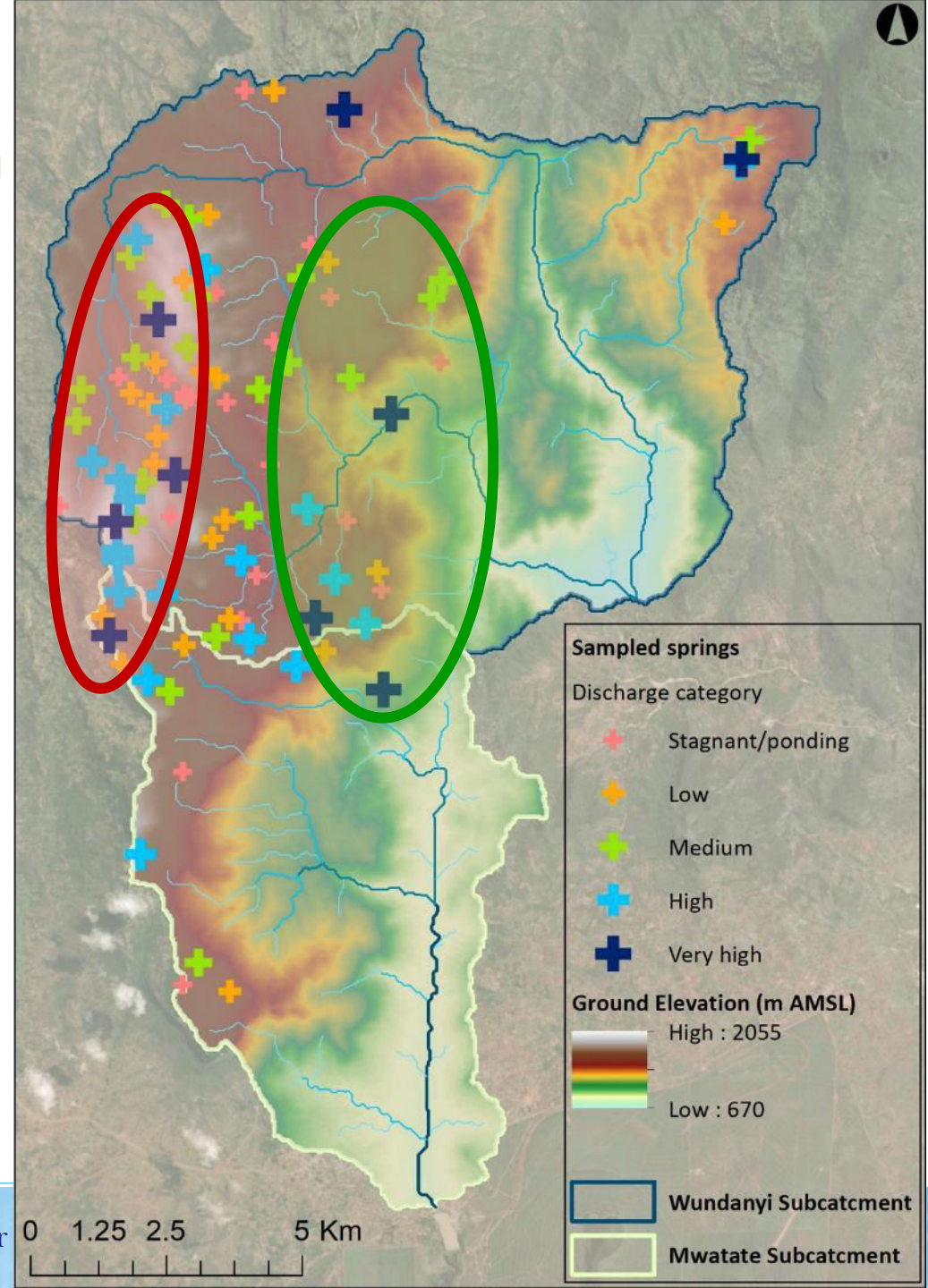
Groundwater Discharge – Temporal variation



Groundwater Composition – Flow system

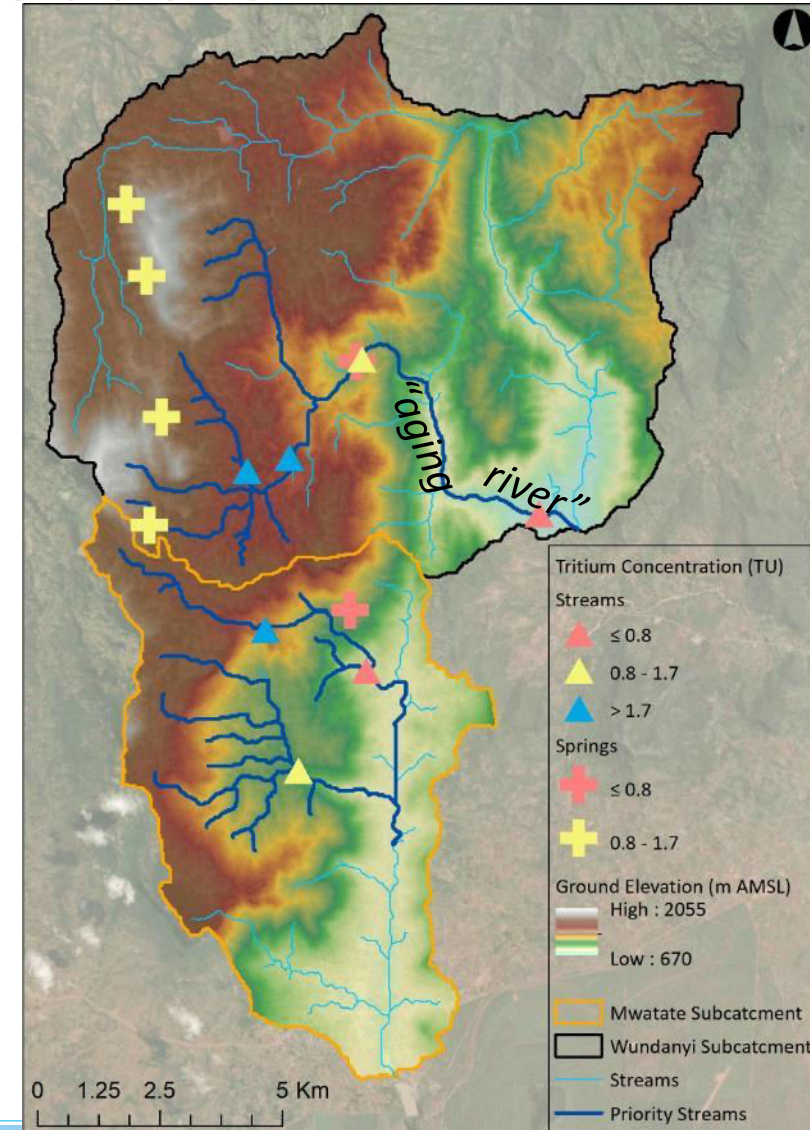
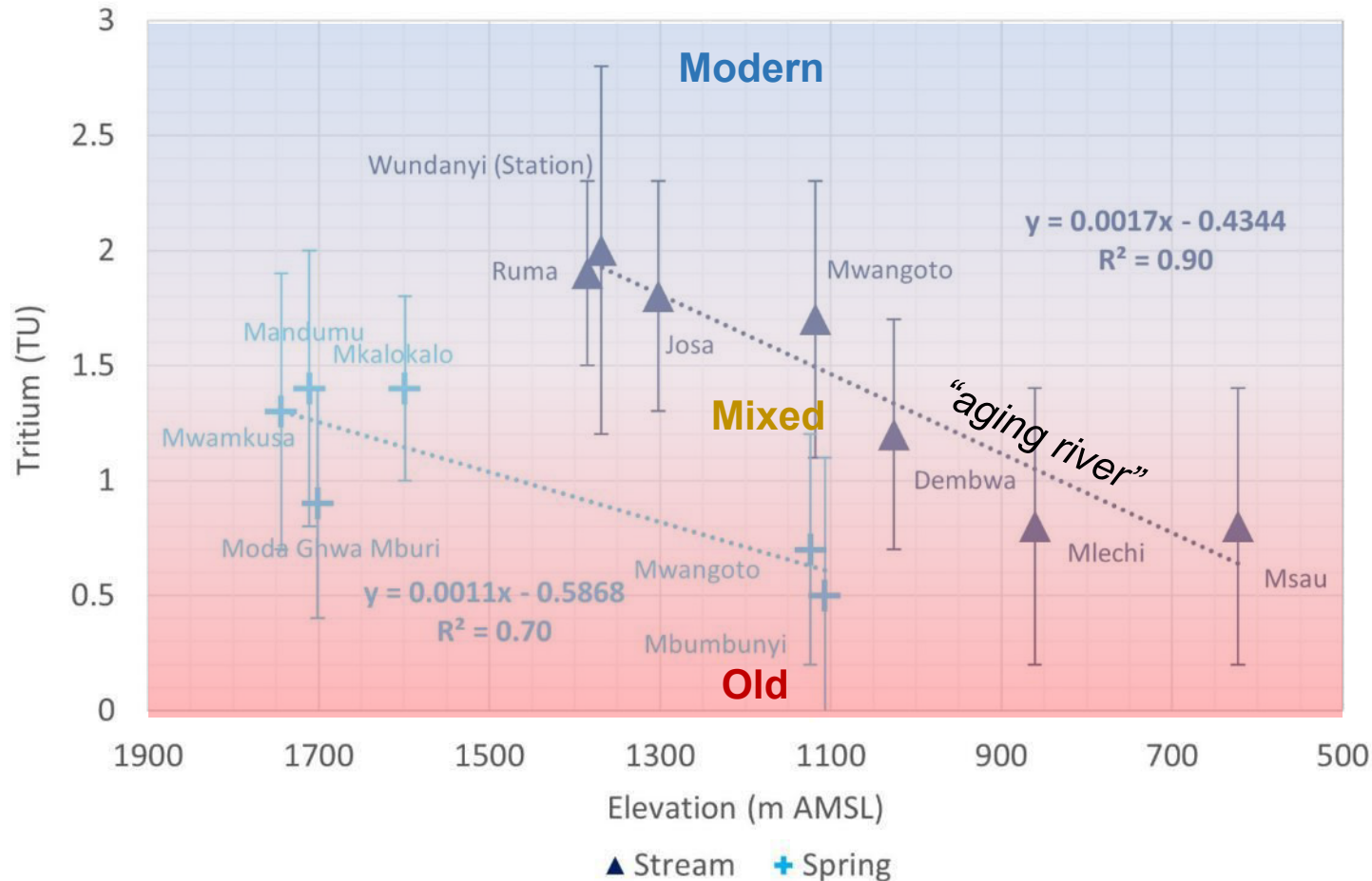


adapted from Markovich et al. (2019)



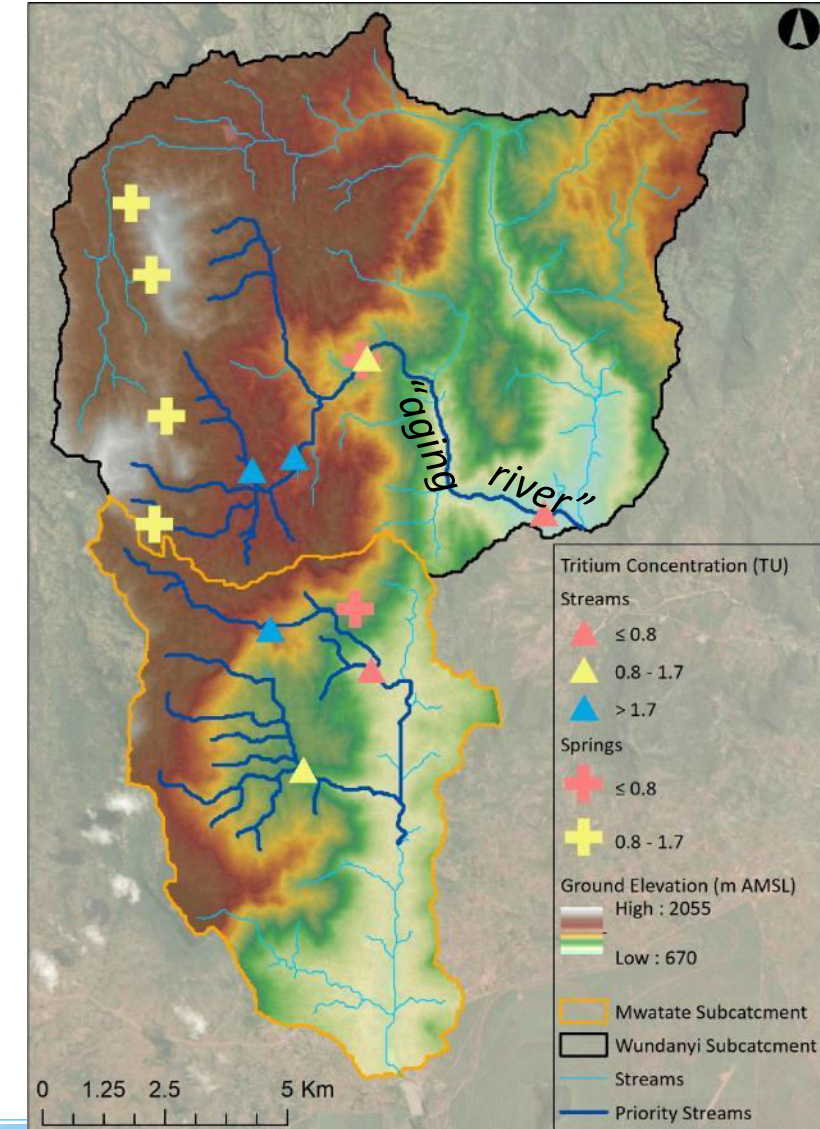
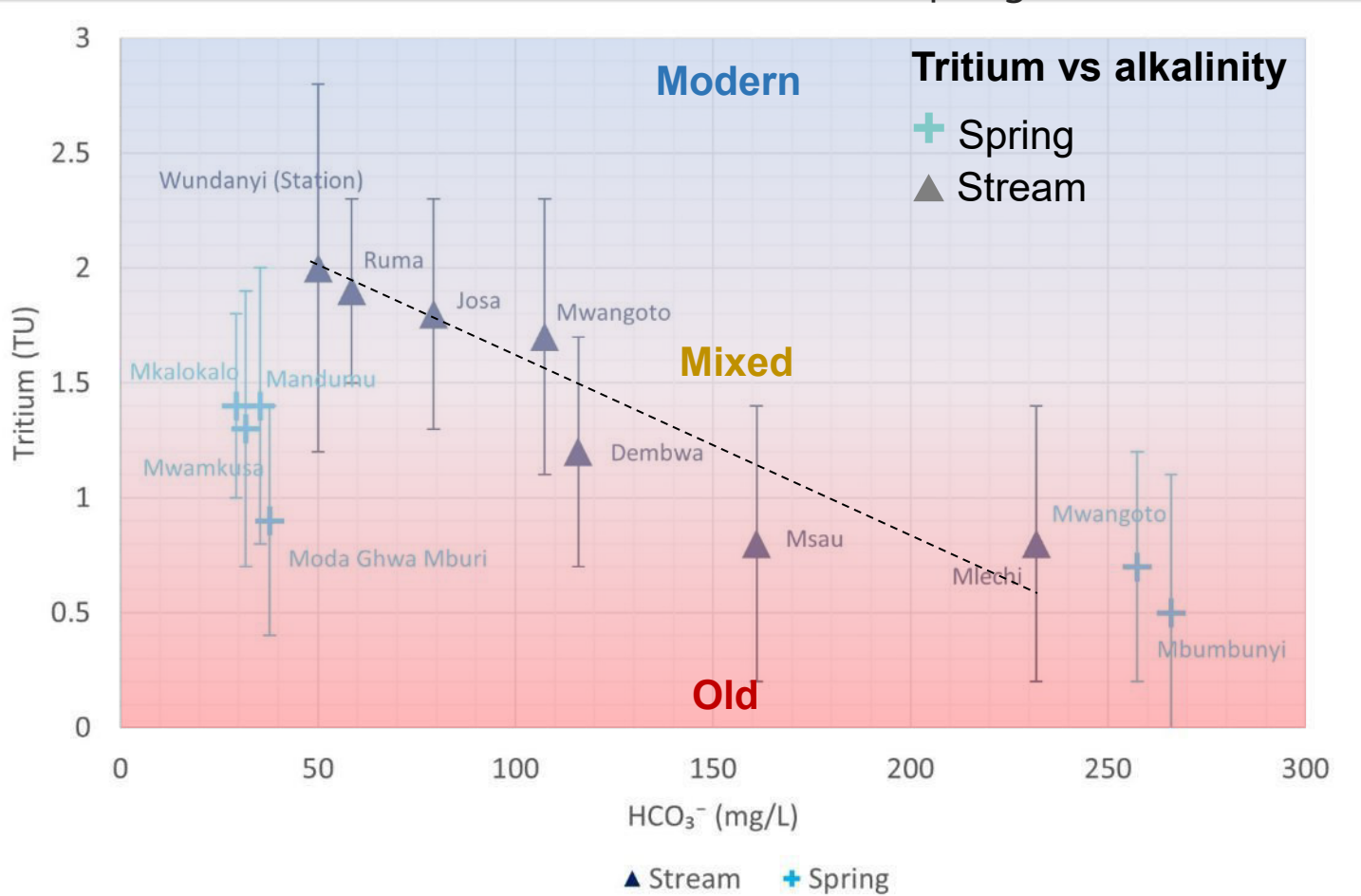
Conceptual model of highland-lowland interrelations

- Streams at higher elevations more influenced by rainfall;
- Springs at higher elevations mixed response;
- Lower tritium at lower elevations in both springs and rivers.



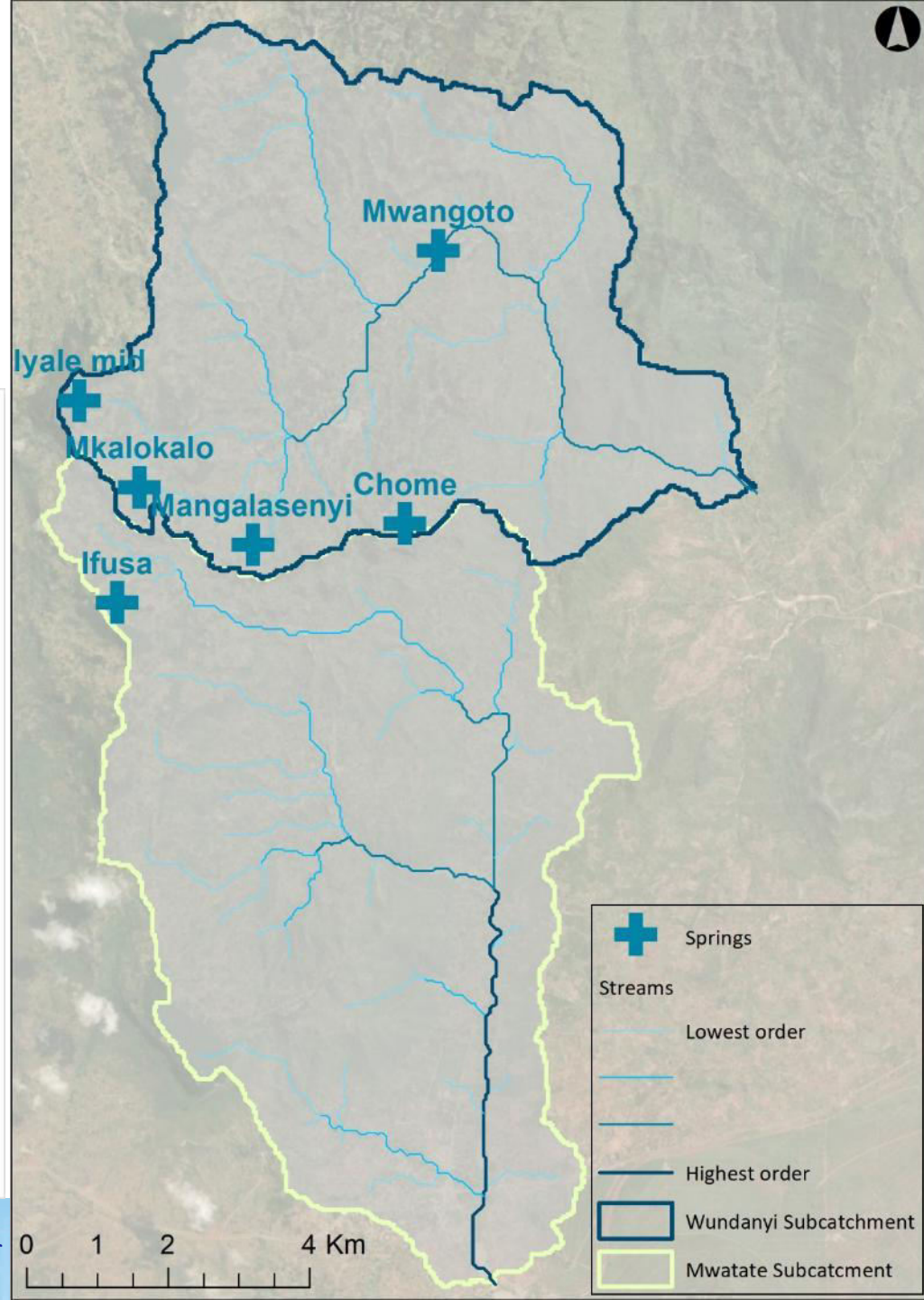
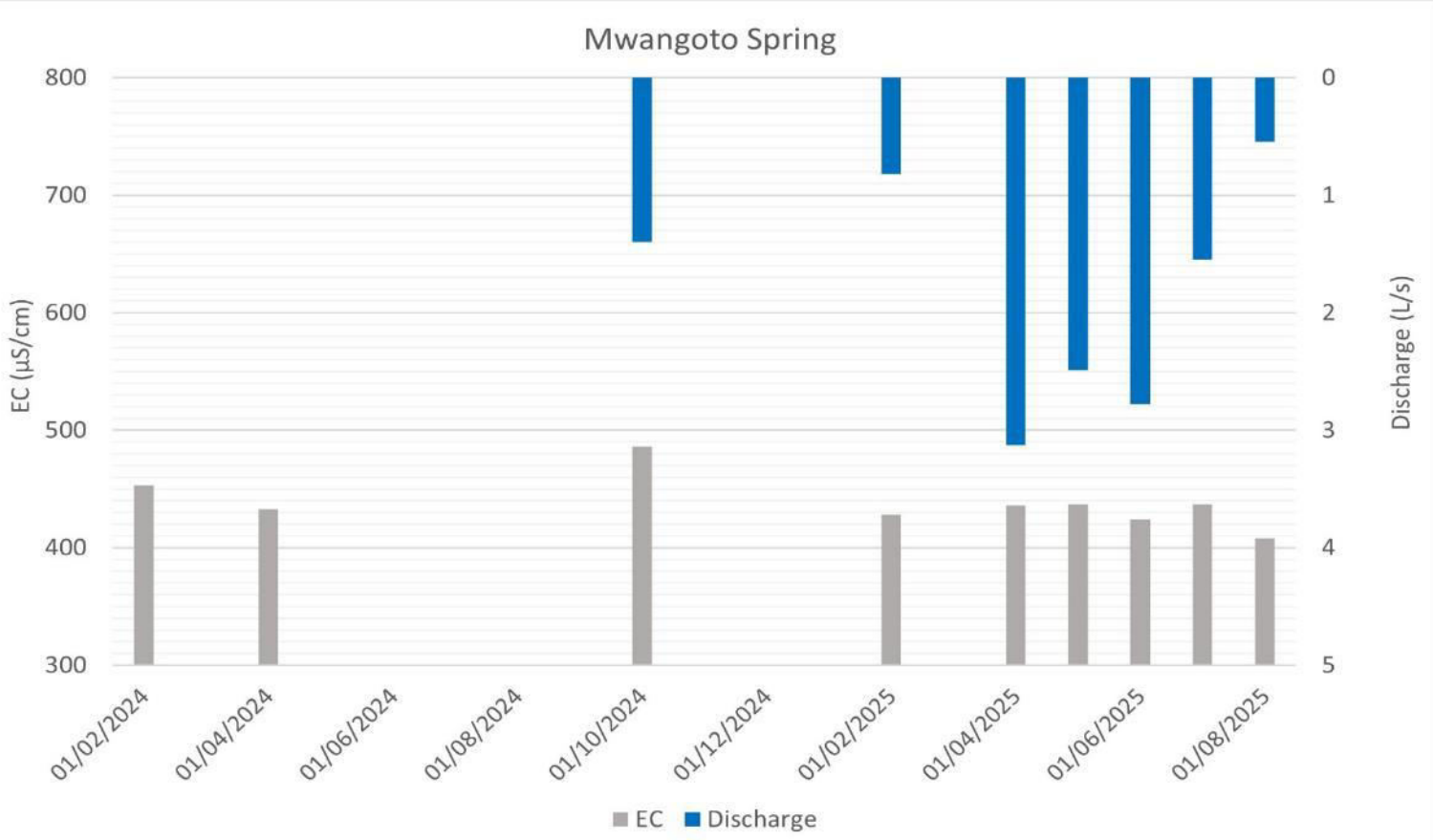
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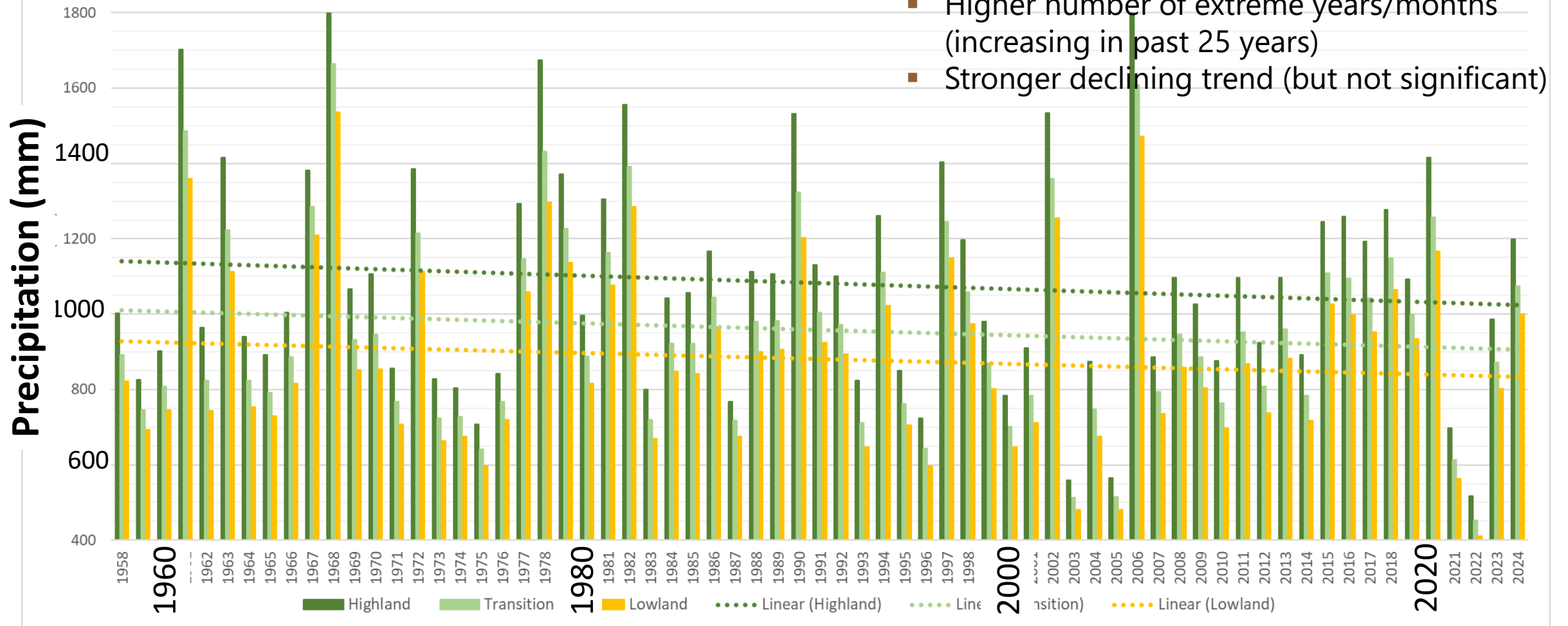
Water Chemistry

- Mwangoto Spring:
 - Higher EC in the dry season (on average)
 - Higher discharge in the wet season (on average)



Drivers of variability and change in highland/lowland hydrology

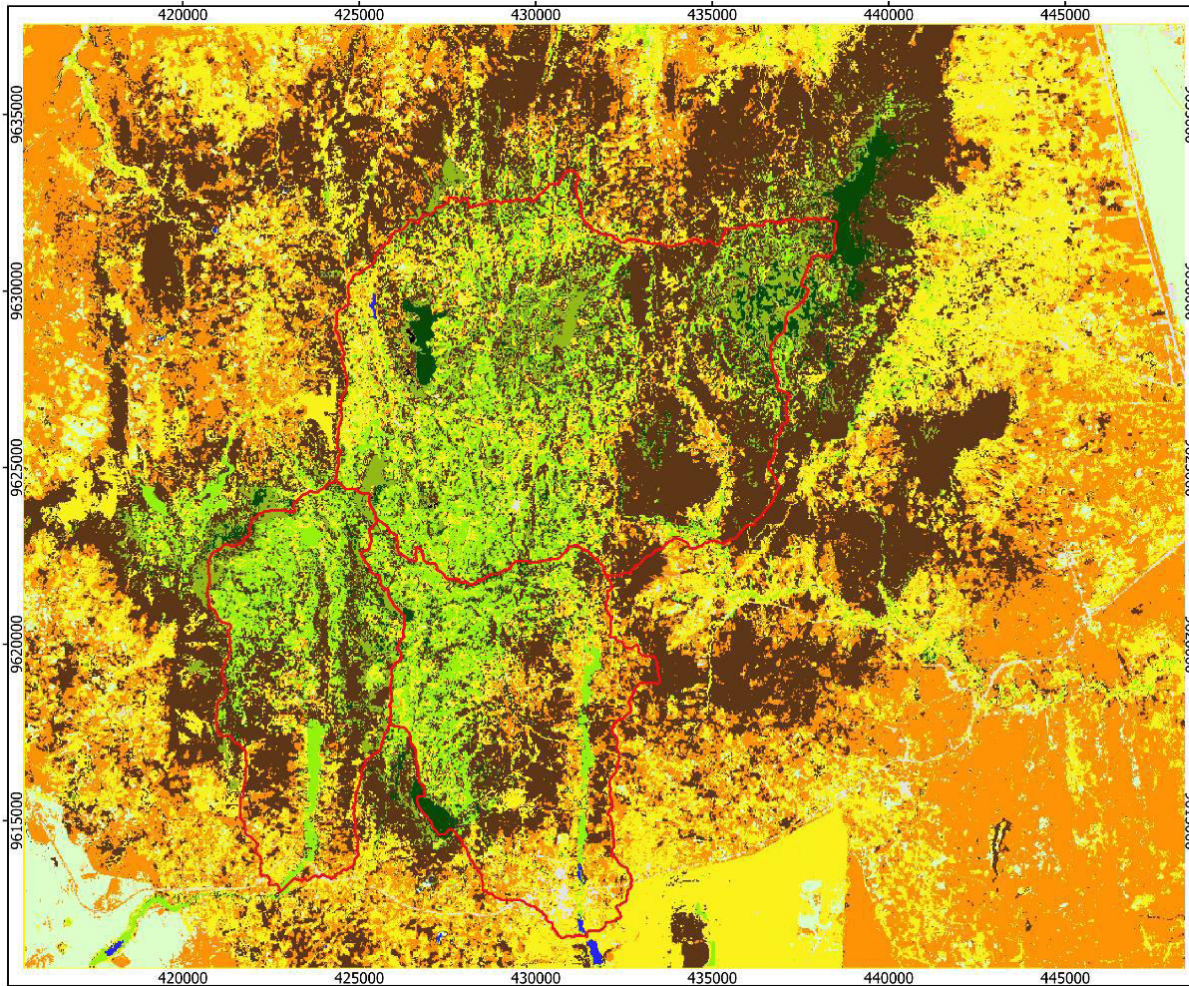
1. Precipitation: Taita Hills 1958 - 2024



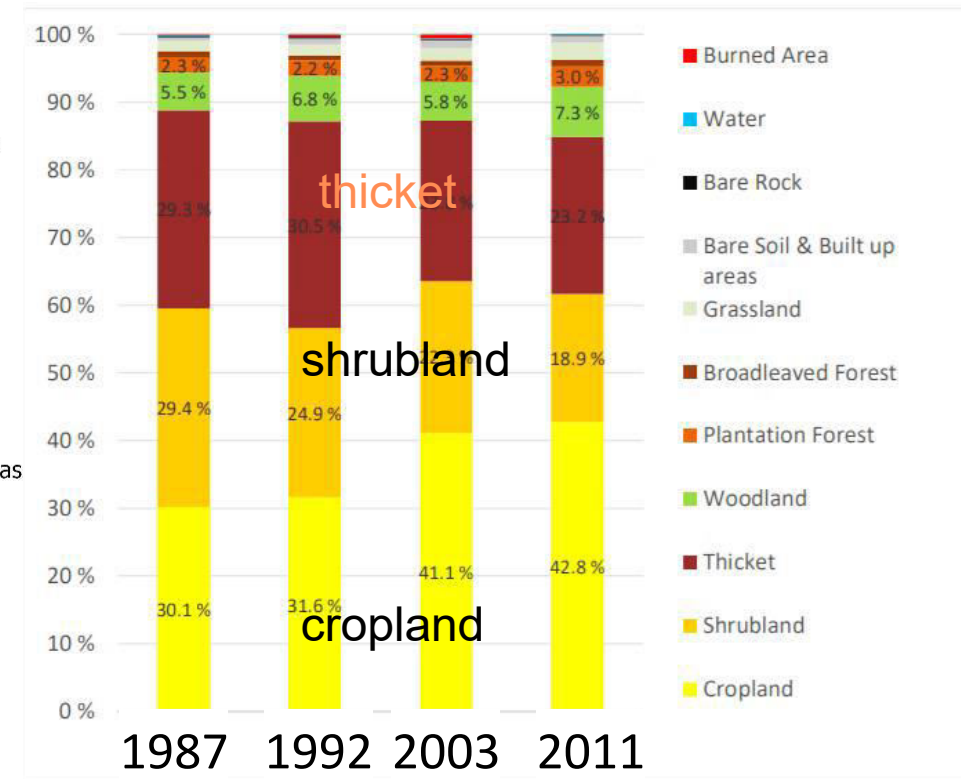
Drivers of variability and change in highland/lowland hydrology

2. Land use: Taita Hills 2021

- Increase in cropland up to 2011 (at the cost of shrubland and thicket), then reduces again (woodland)



Mwende (2022)



Heikinheimo (2015)

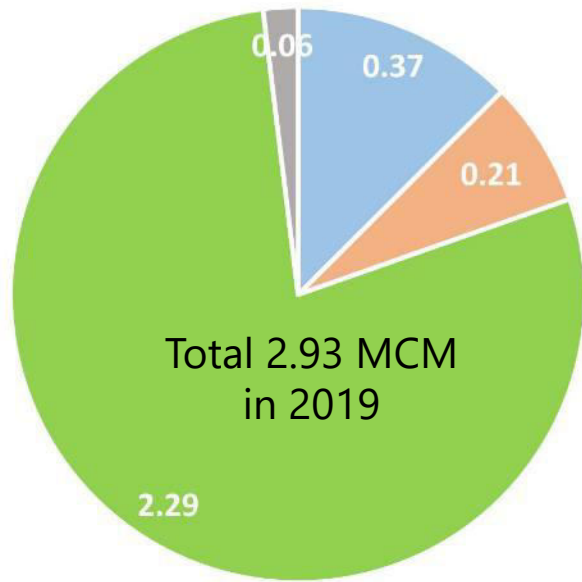
Drivers of variability and change in highland/lowland hydrology

3. Water use: Taita Hills 2003-2024

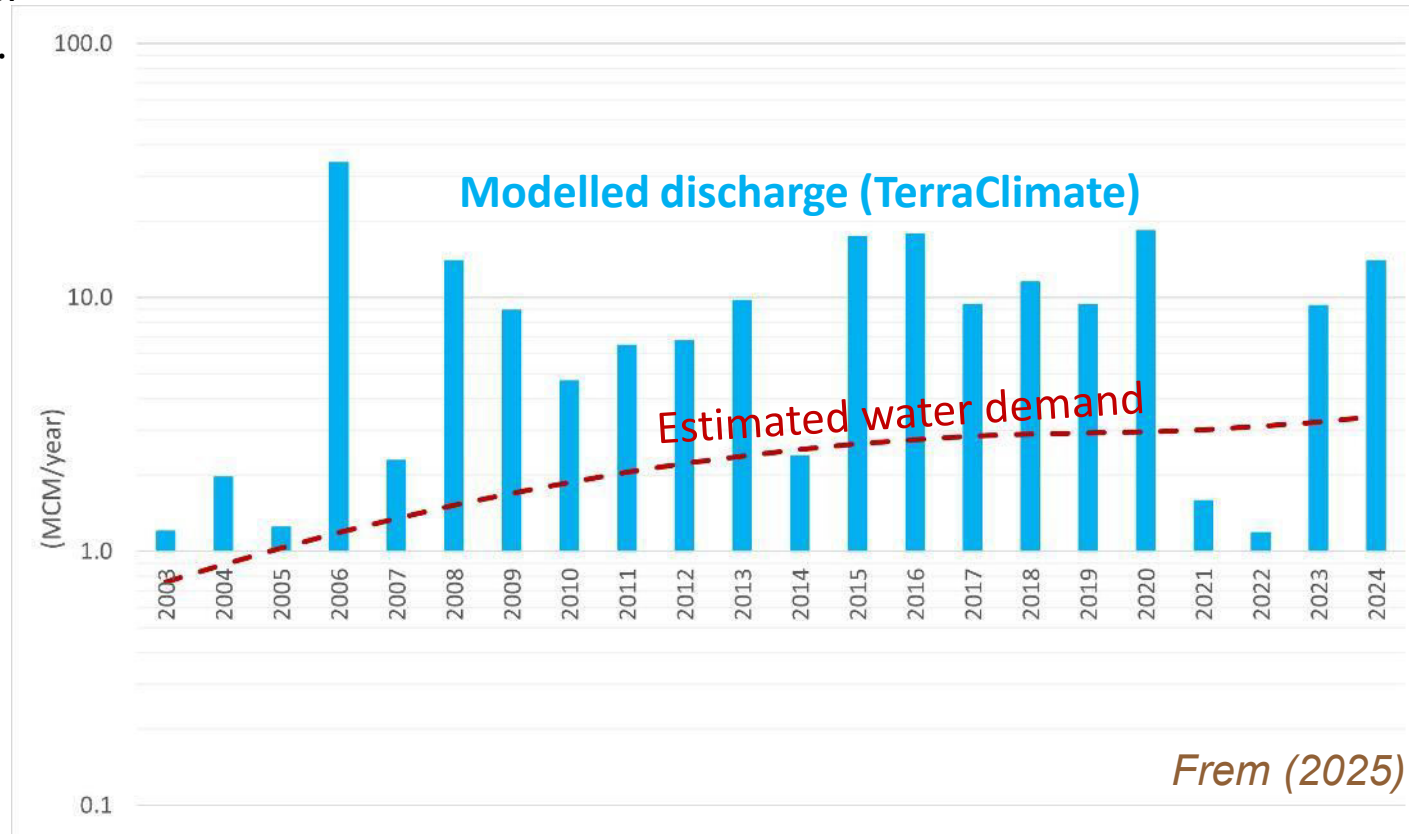
- Irrigation (assumed rate 5,000 m³/ha/year) considered within 250m buffer zone of rivers
- Result consistent with reported agricultural water demand of 85% of total demand (UNECA, 2003).

- As water demand increases, prolonged drought periods (such as 2021–2022) pose a critical challenge.

Water Demand in Wundanyi (MCM/year)



■ Domestic ■ Livestock ■ Irrigation ■ Industrial/other



Frem (2025)

Final considerations

- Evidence from recharge, discharge and hydrochemistry observations shows that geological faults play an important role in highland – lowland water transmissions.
- The main river of Taita Hills changes its behavior along its course, also due to offtake for consumption, becoming “older” and with a stronger lowland signature.
- Land use change, in particular increasing cropland area and plantation forest, has decreased the water retention potential of the catchment.
- Increased water use is an additional major driver of reduced flow in the dry season, where demand exceeds available flow in dry years.
- Strategies for adaptation, including control of water use, reduction of runoff and increase of recharge, will be further evaluated with the model.



Final considerations

- Establishing Taita Hills and Wondo Genet as ecohydrological observatories ensures the preservation of these critical water tower systems and provides valuable insights for communities, NGOs, governments and research organisation worldwide.



Under the High Patronage of His Majesty King Mohammed VI



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Thank you!

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www.worldwatercongress.com



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