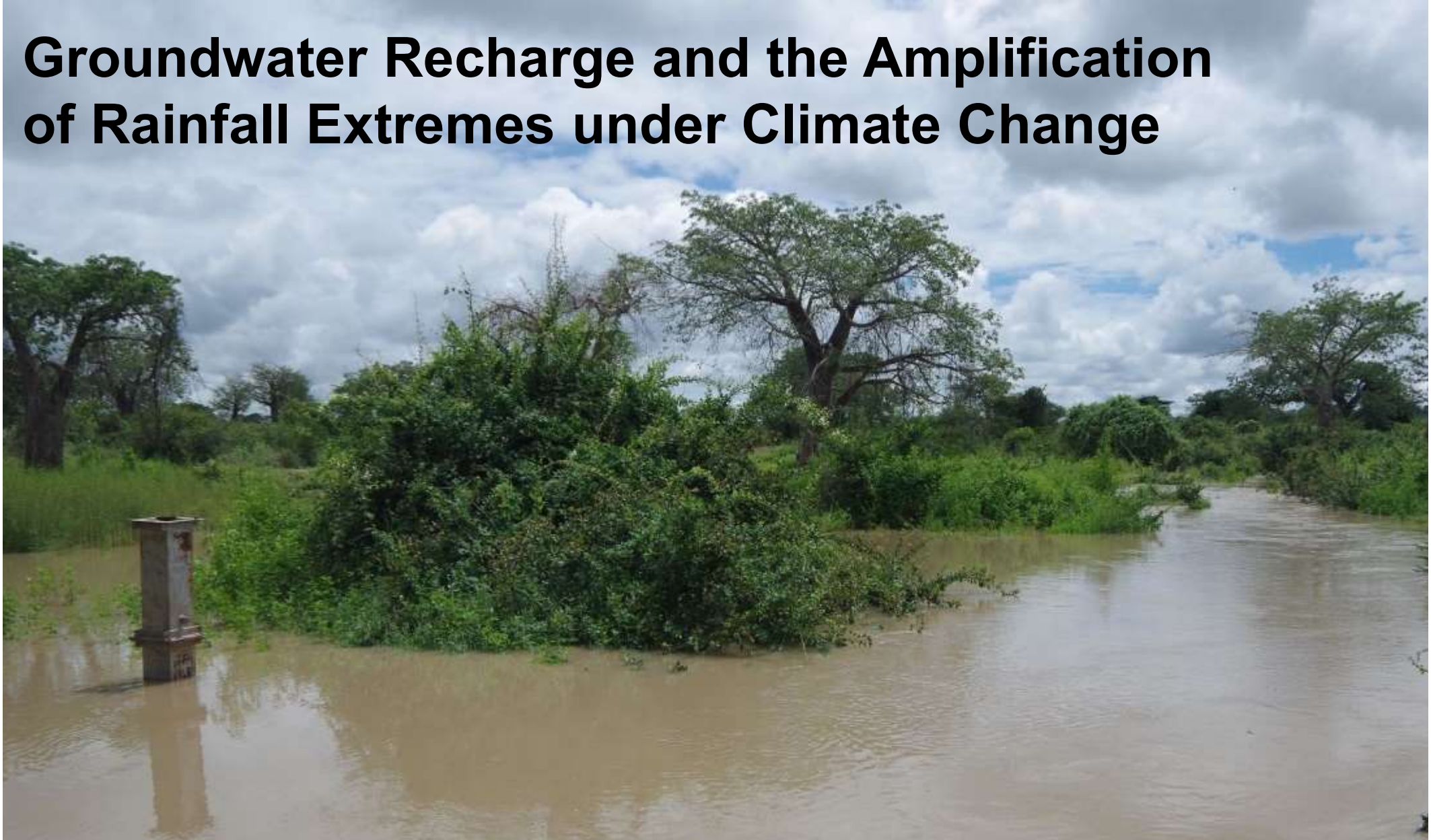
Groundwater Recharge and the Amplification of Rainfall Extremes under Climate Change



Richard Taylor, University College London (UCL)

Groundwater – Key to the Sustainable Development Goals, Paris (Sorbonne), 18 to 20 May, 2022
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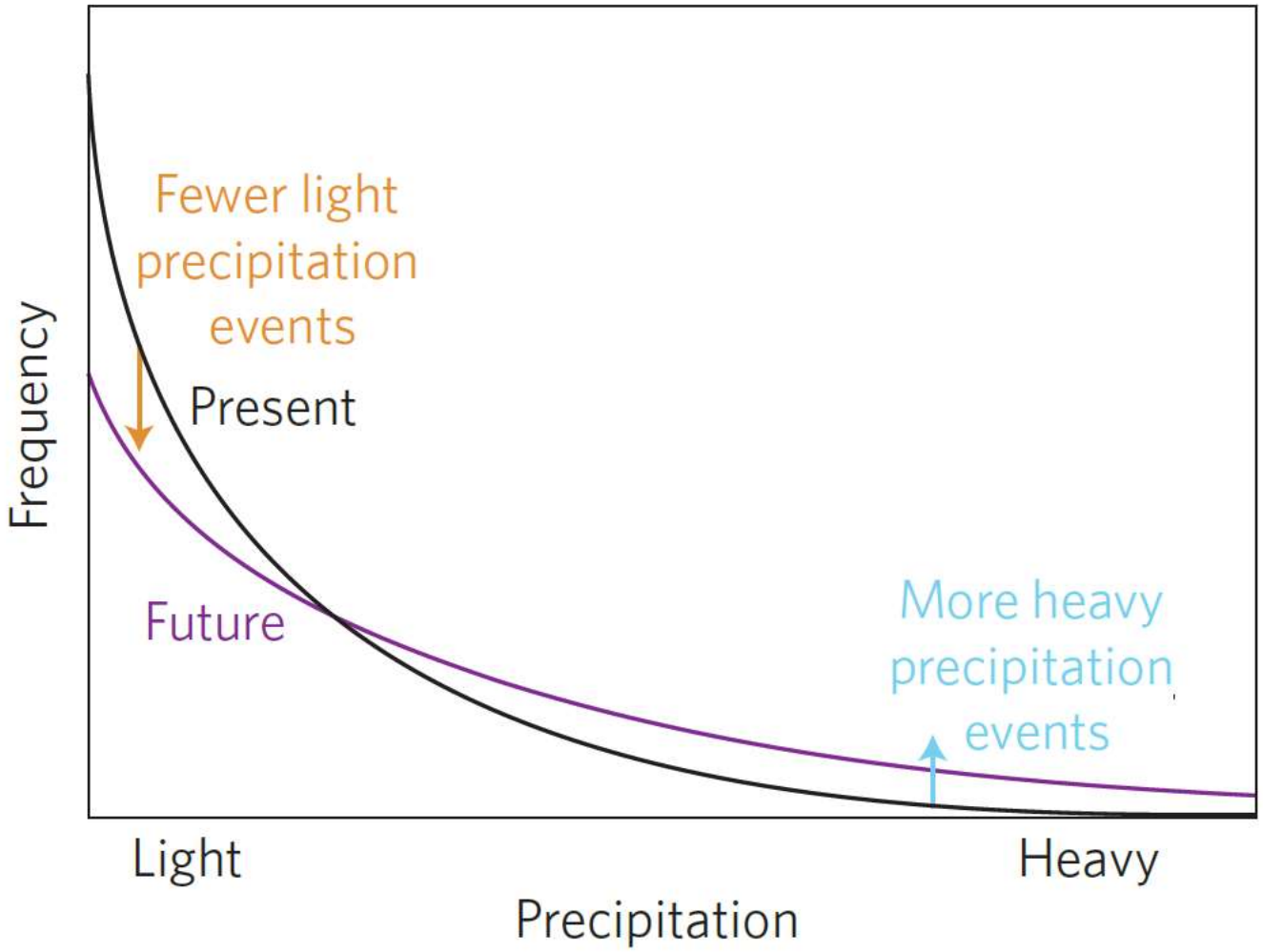
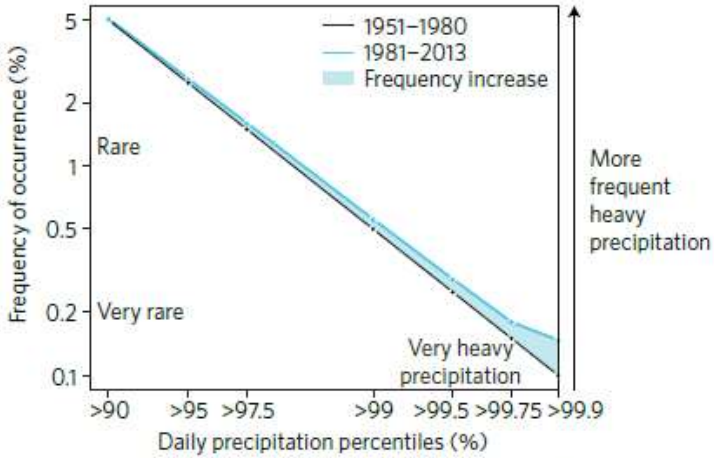
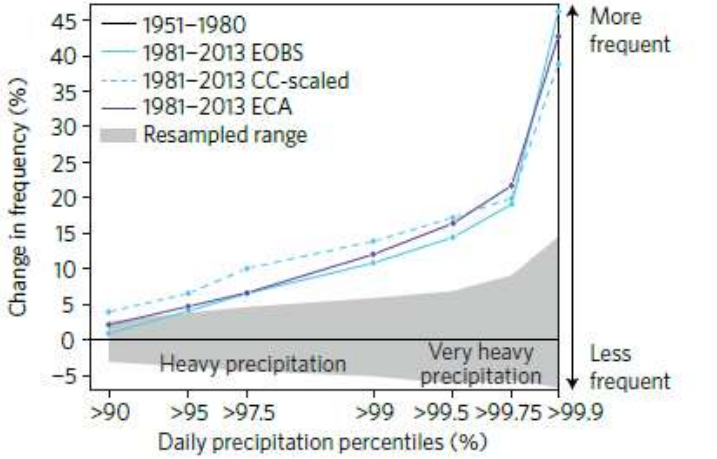
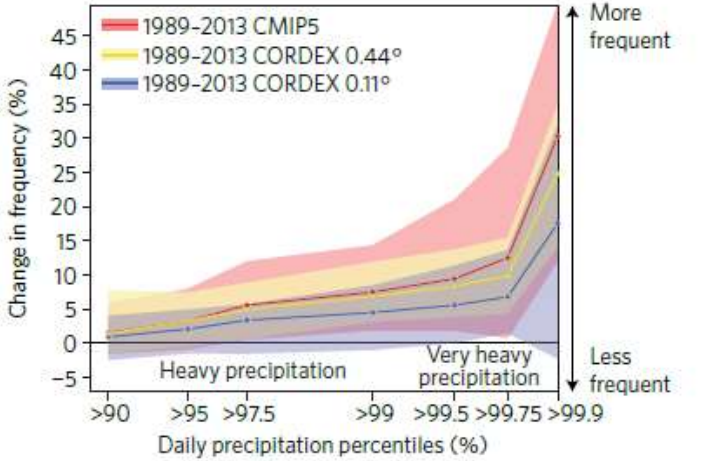
intensification of precipitation in a warming world

- results in ***fewer but heavier rainfalls*** – this transformation of precipitation is **greatest in the tropics**









Fischer and Knutti (2019) Nature Climate Change 6: 986–991.


Migori and Homa Bay Counties
at Riat-Oria, Kenya
intensified rainfall
increases flood risk
15 May 2021 (Floodlist)

- **generates more frequent and prolonged droughts**

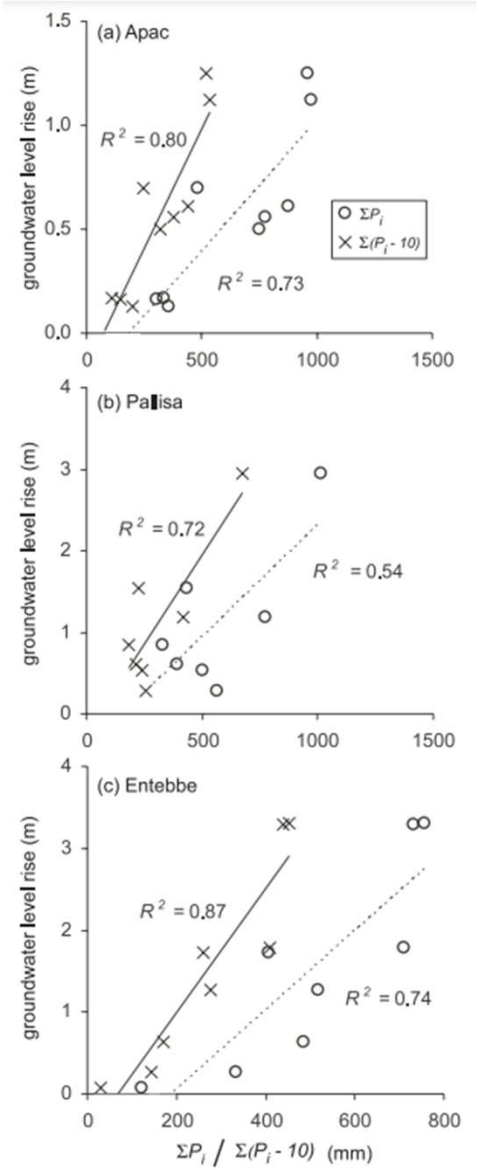
western Turkana, Kenya (The Guardian)

How does the intensification of rainfall impact the replenishment of groundwater?

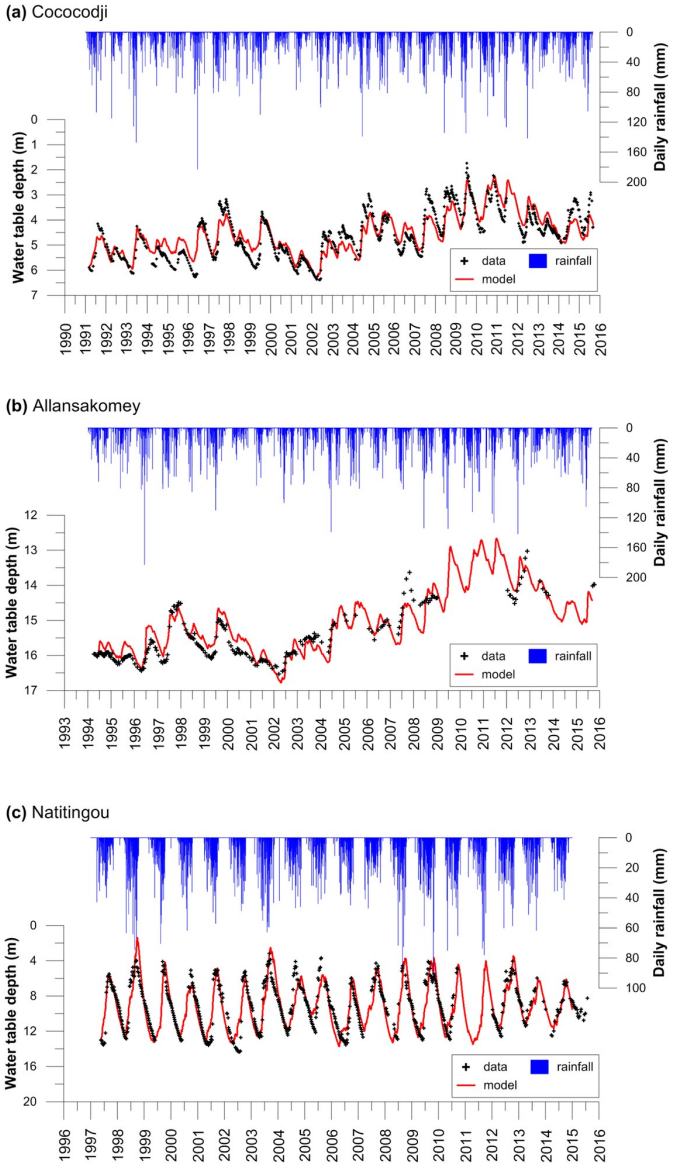
artesian borehole, Singida

piezometric records from Uganda and Benin

- in the humid tropics, observed groundwater-level rises trace recharge to “heavy rainfalls” >10 mm·day^{-1}



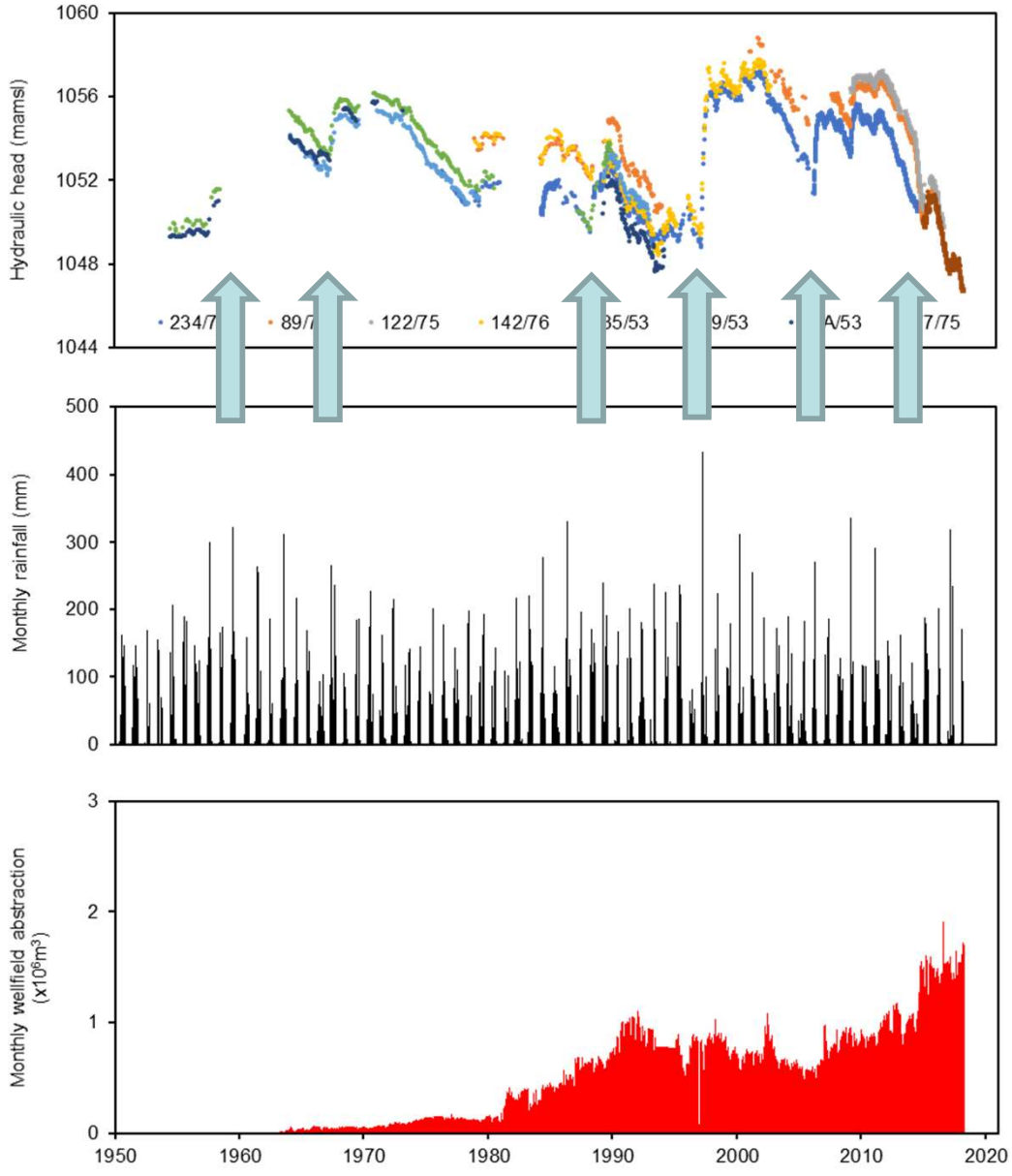
Owor et al. (2009) Environ. Res. Lett. 4: 035009.

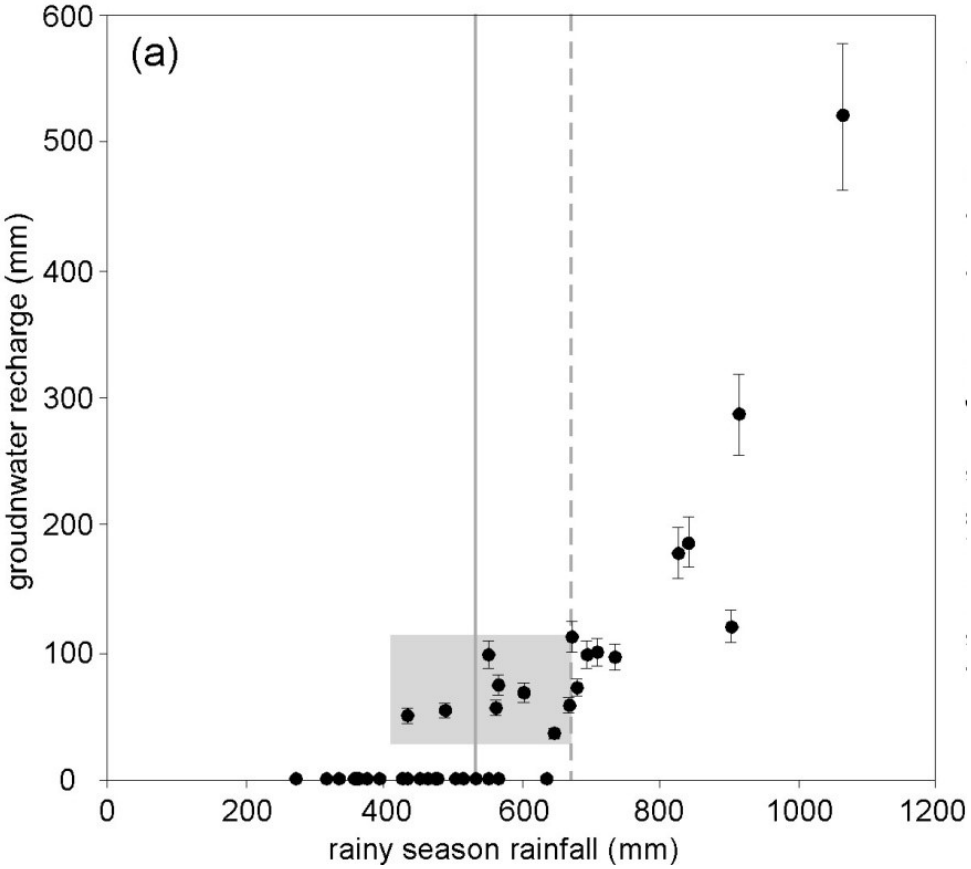


Kotchoni et al. (2019) Hydrogeol. J. 27: 447-457.

piezometric evidence from a dryland in Tanzania

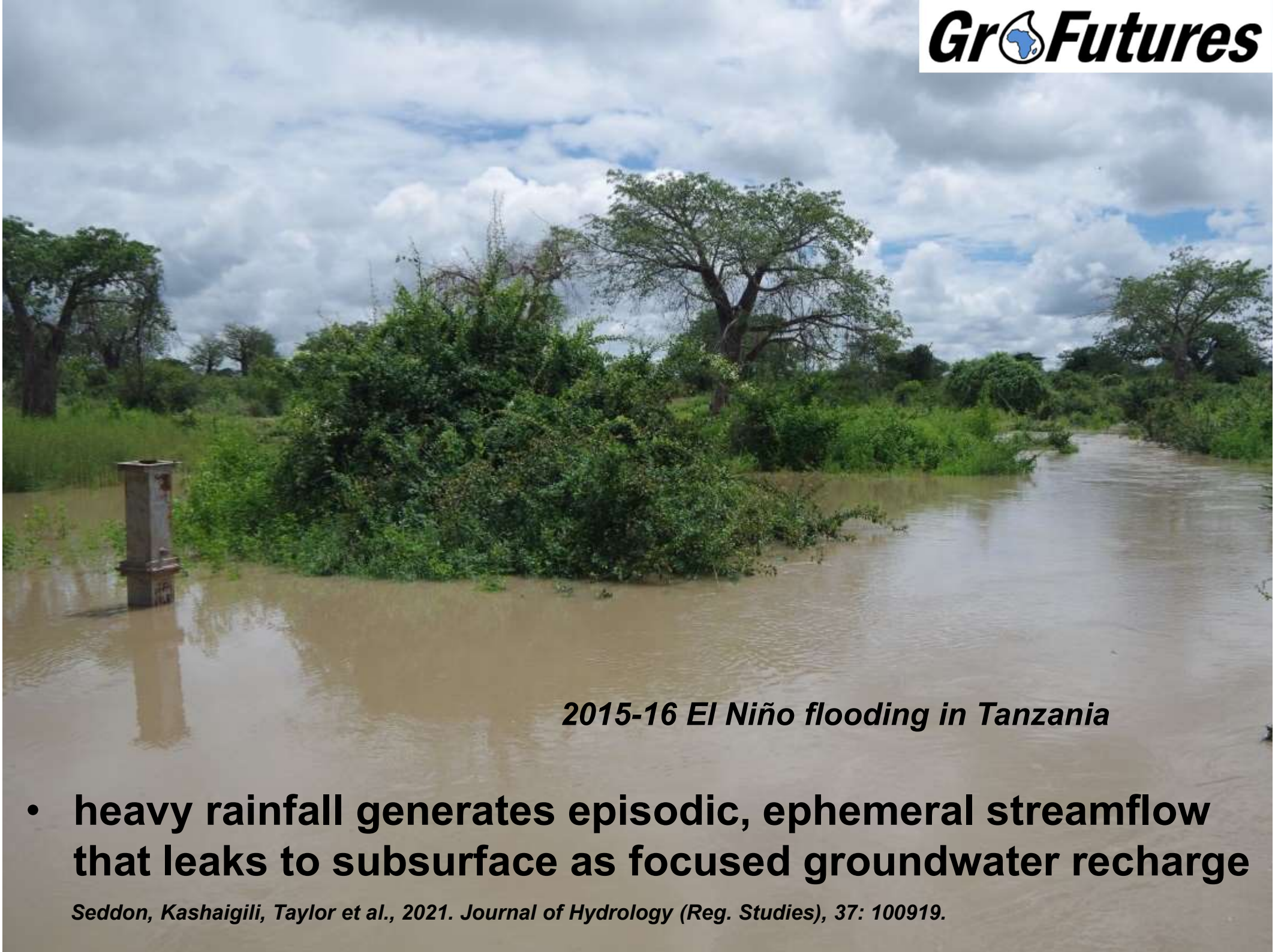
- multi-decadal record of groundwater levels reveals episodic replenishment associated with El Niño Southern Oscillation





- **recharge occurs *episodically* and *disproportionately* from extreme (>80th percentile) seasonal rainfall**

Taylor et al. (2013) Nature Climate Change 3: 374-378.

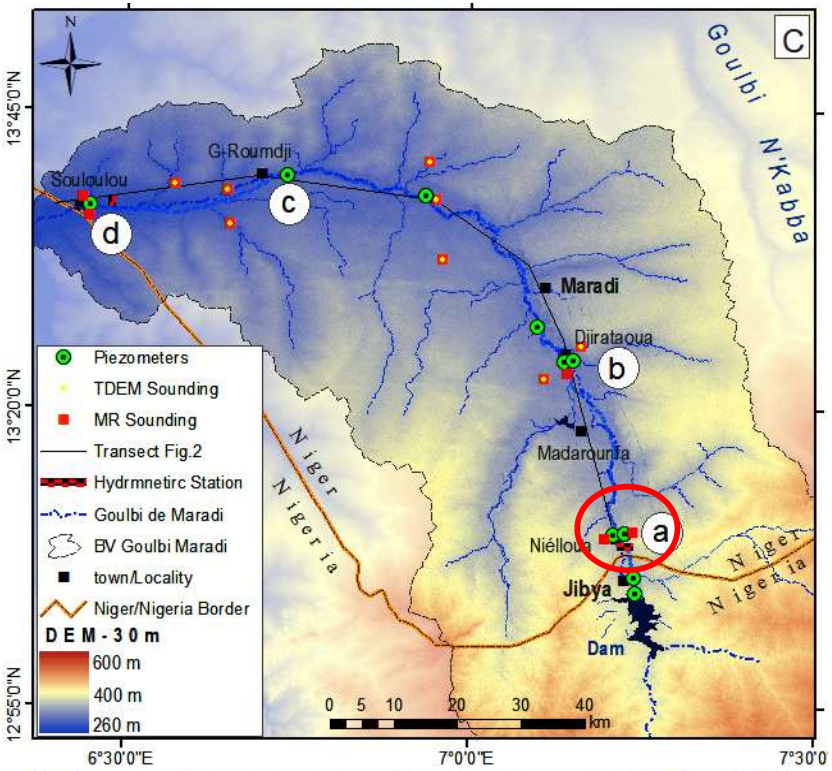


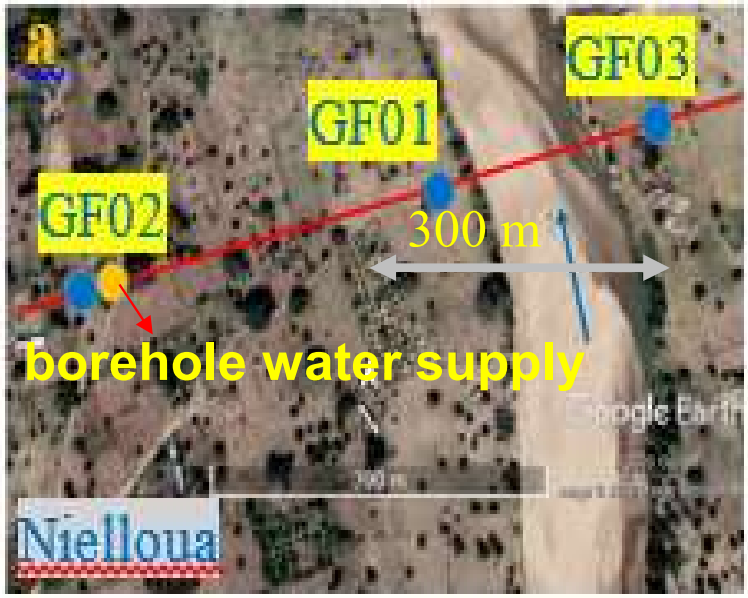
2015-16 El Niño flooding in Tanzania

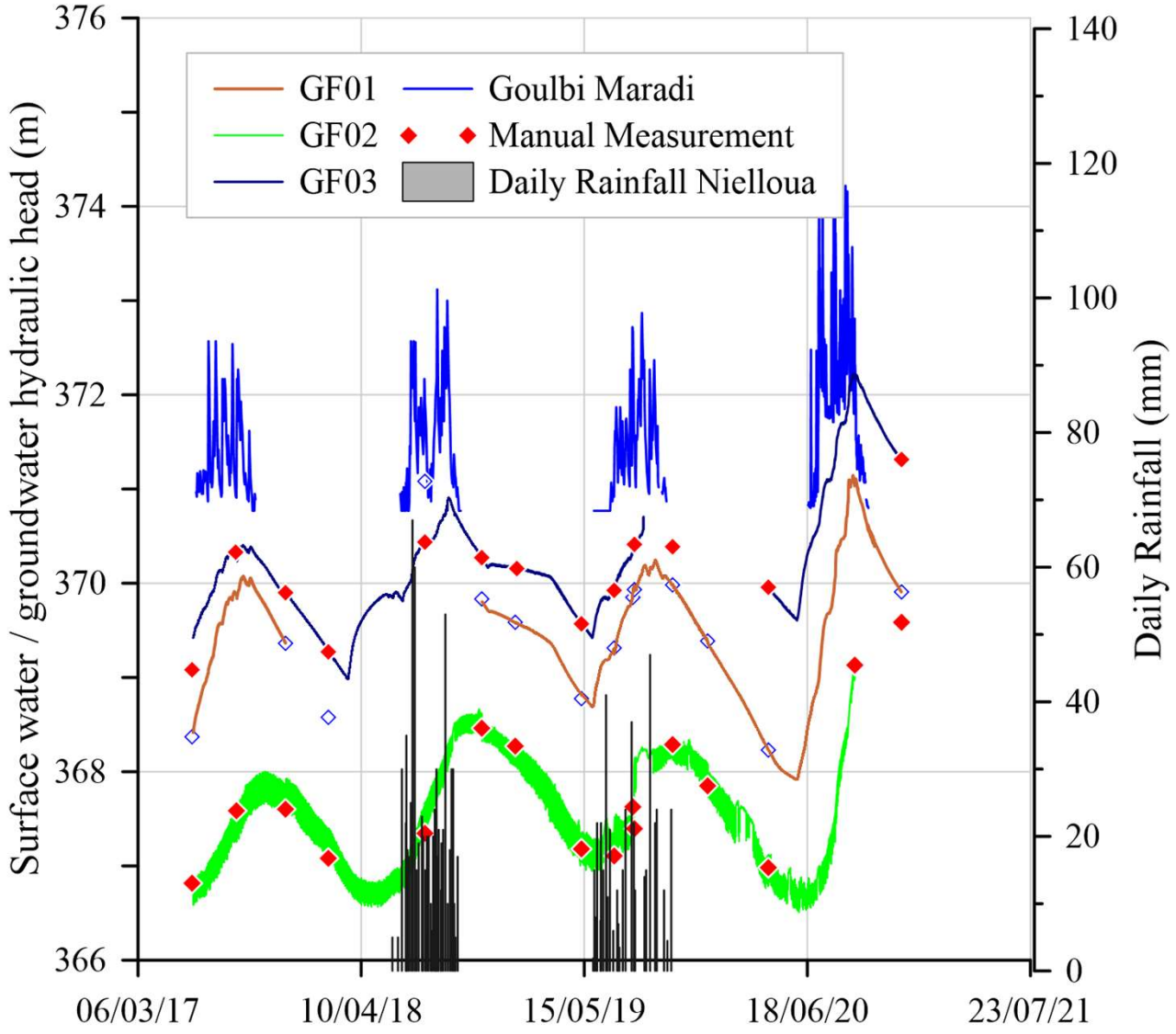
- **heavy rainfall generates episodic, ephemeral streamflow that leaks to subsurface as focused groundwater recharge**

Seddon, Kashaigili, Taylor et al., 2021. Journal of Hydrology (Reg. Studies), 37: 100919.

recent piezometric evidence from Niger



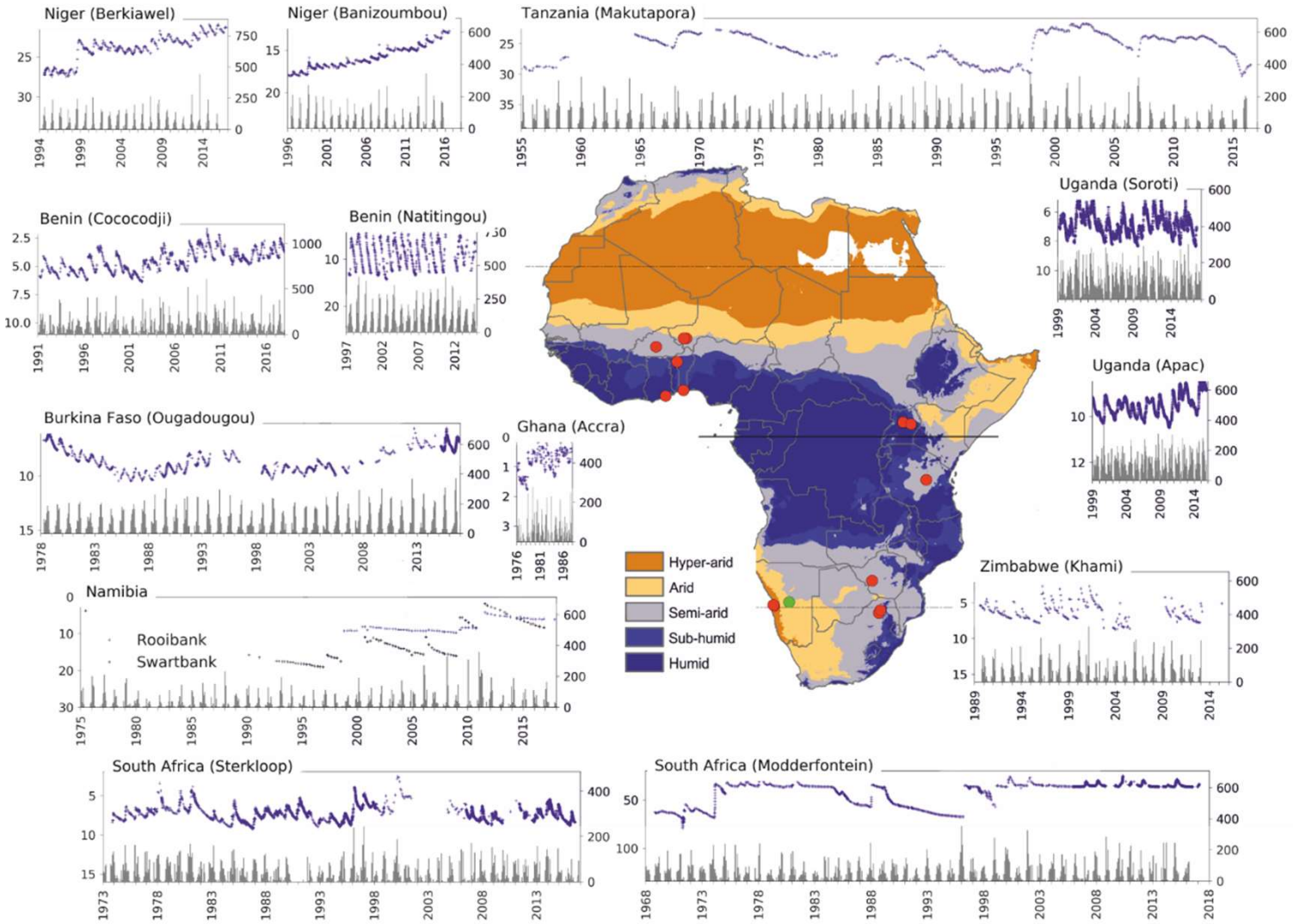




- **focused recharge observed from episodic, ephemeral transboundary streamflow in Niger** ***Issoufou et al.*** **(Abstract 148)**

pan-African piezometric analysis

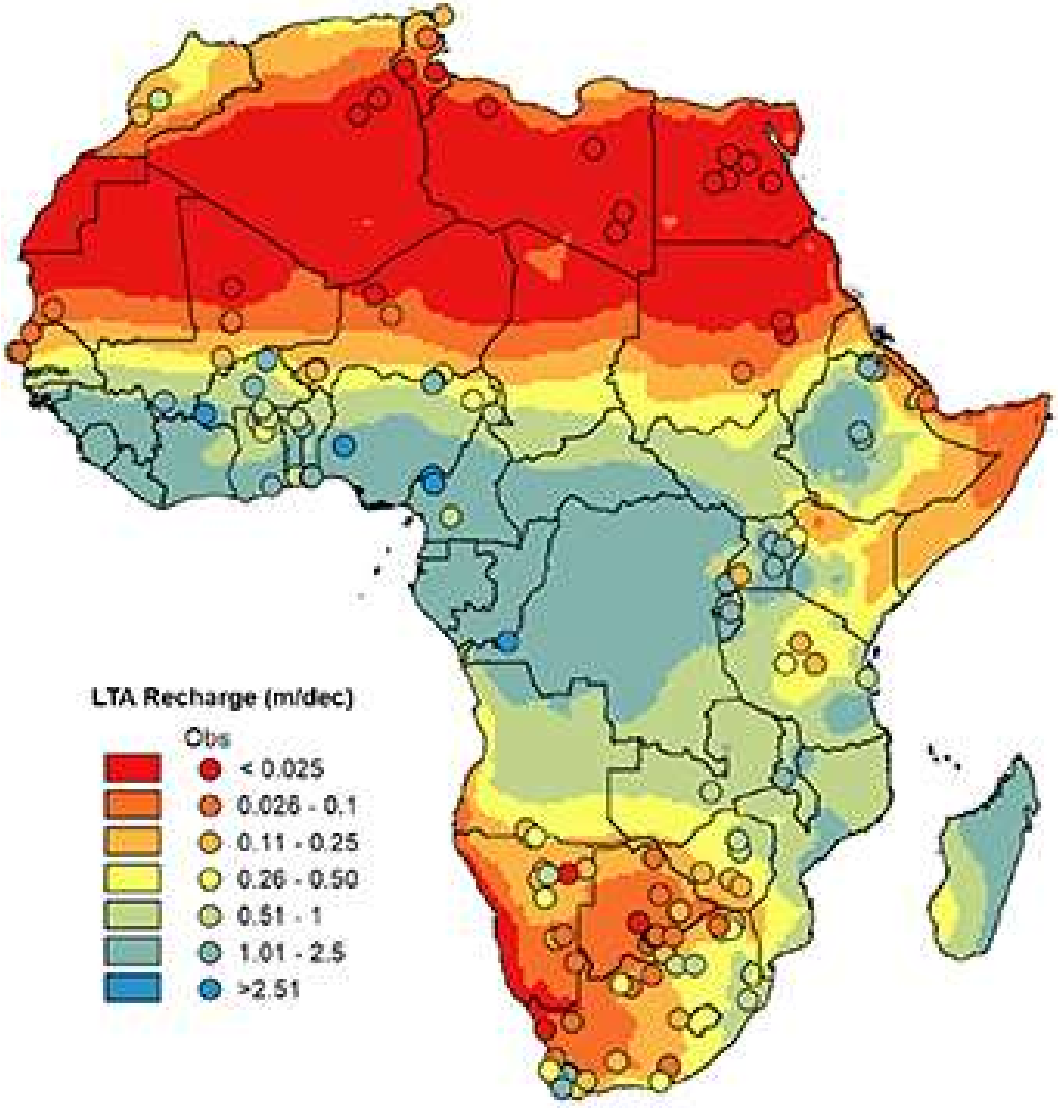
- confirms (1) bias in recharge to heavy rainfall; (2) episodicity of recharge in drylands and its link to large-scale climate controls; and (3) importance of focused recharge in drylands



Cuthbert, Taylor… Kotchoni, Vouillamoz, Lawson et al. (2019) Nature 572: 230–234.

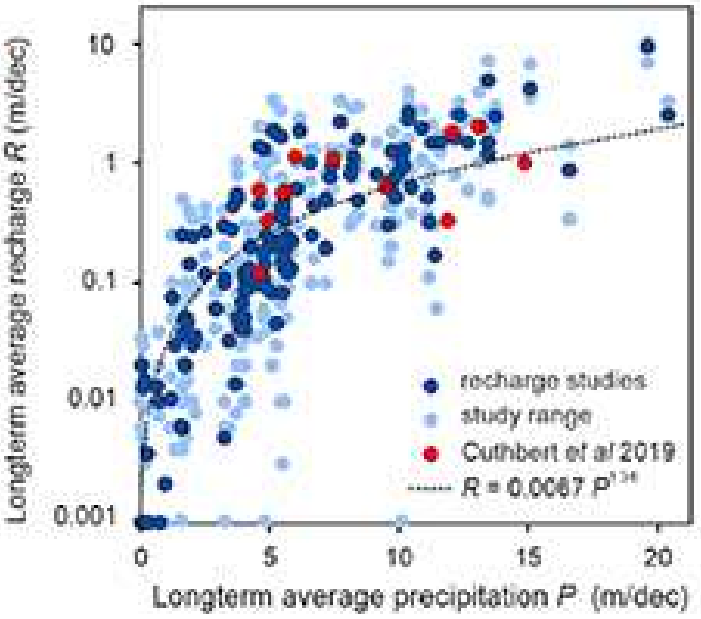
pan-African review of recharge studies

- relationship between long-term average rainfall and recharge from 134 studies reveals a bias to heavy rainfall



Power Law relationship:

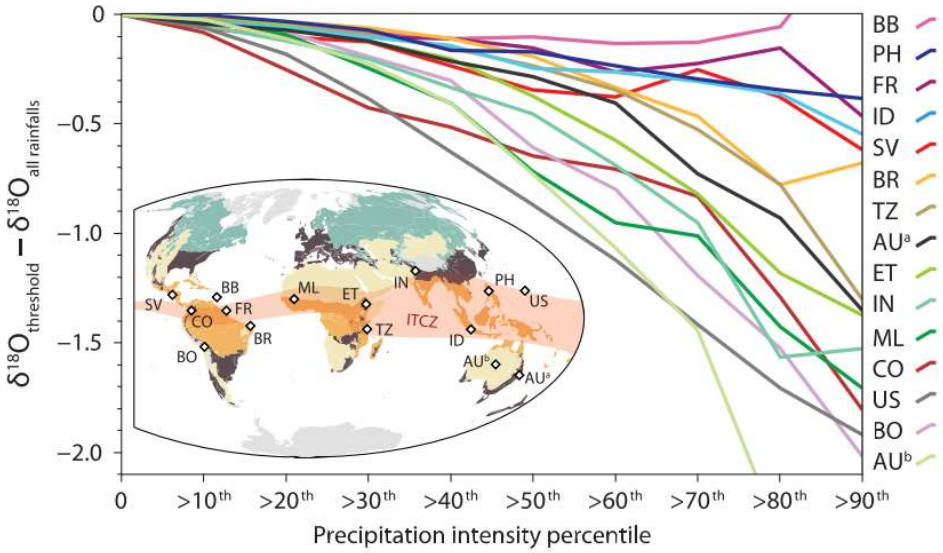
$$R = 0.0067 \cdot P^{1.34}$$

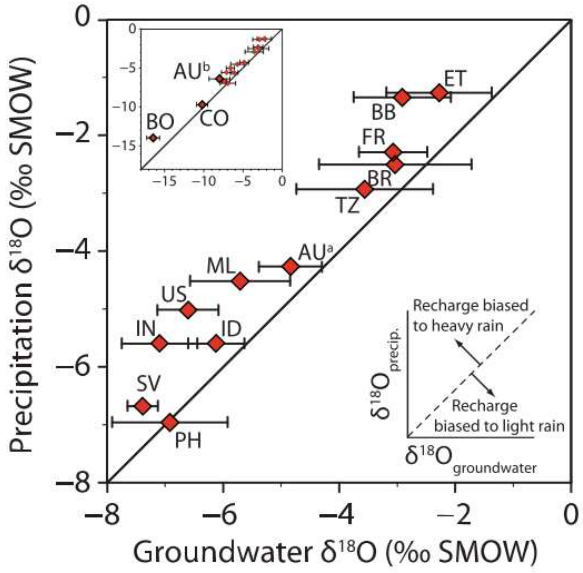


MacDonald, Lark, Taylor, Abiye et al. (2021) Environmental Research Letters 16: 034012.

evidence from stable isotope ratios of O and H

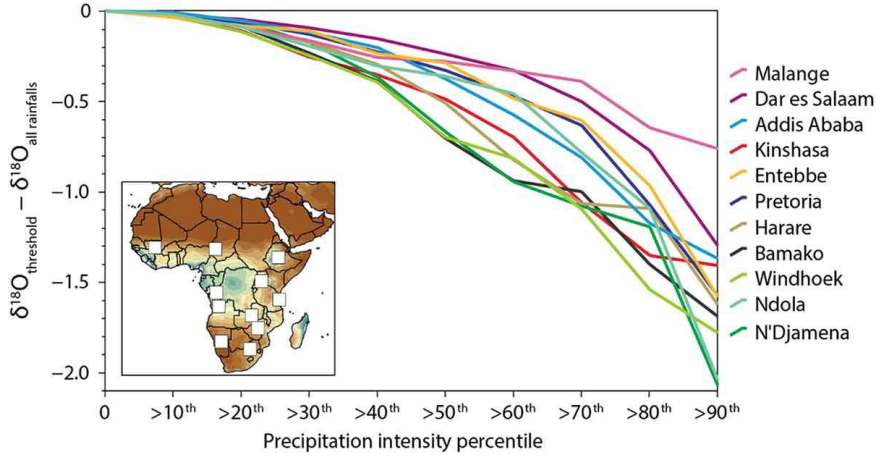
- **isotopic composition of groundwater at 14 of 15 sites across the tropics is biased to heavy monthly rainfalls exceeding 70th percentile**

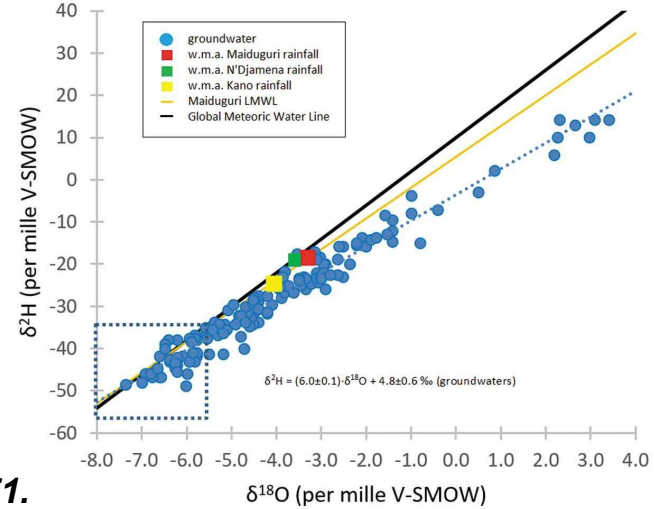




Jasechko & Taylor (2015) Environ. Res. Lett. 10: 124015.

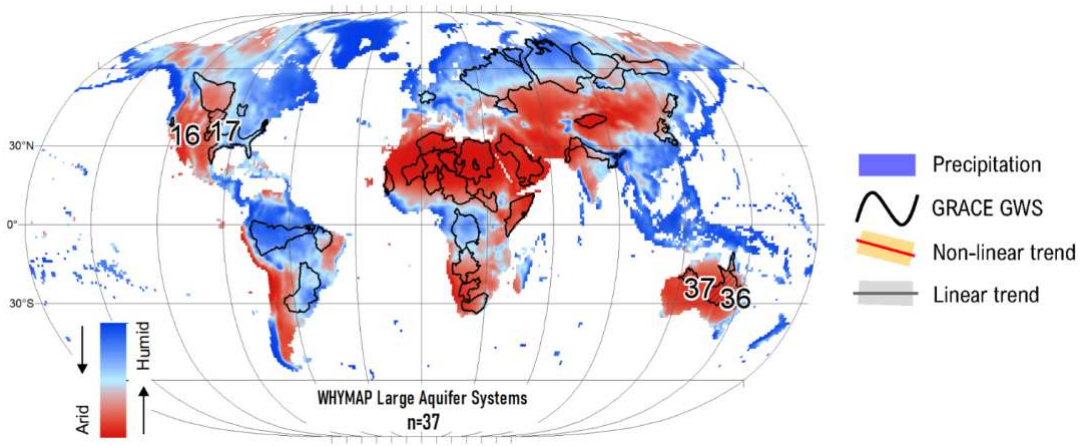
- **in drylands of the SW Chad Basin and central Tanzania, groundwater is traced to heavy, isotopically depleted monthly rainfalls**

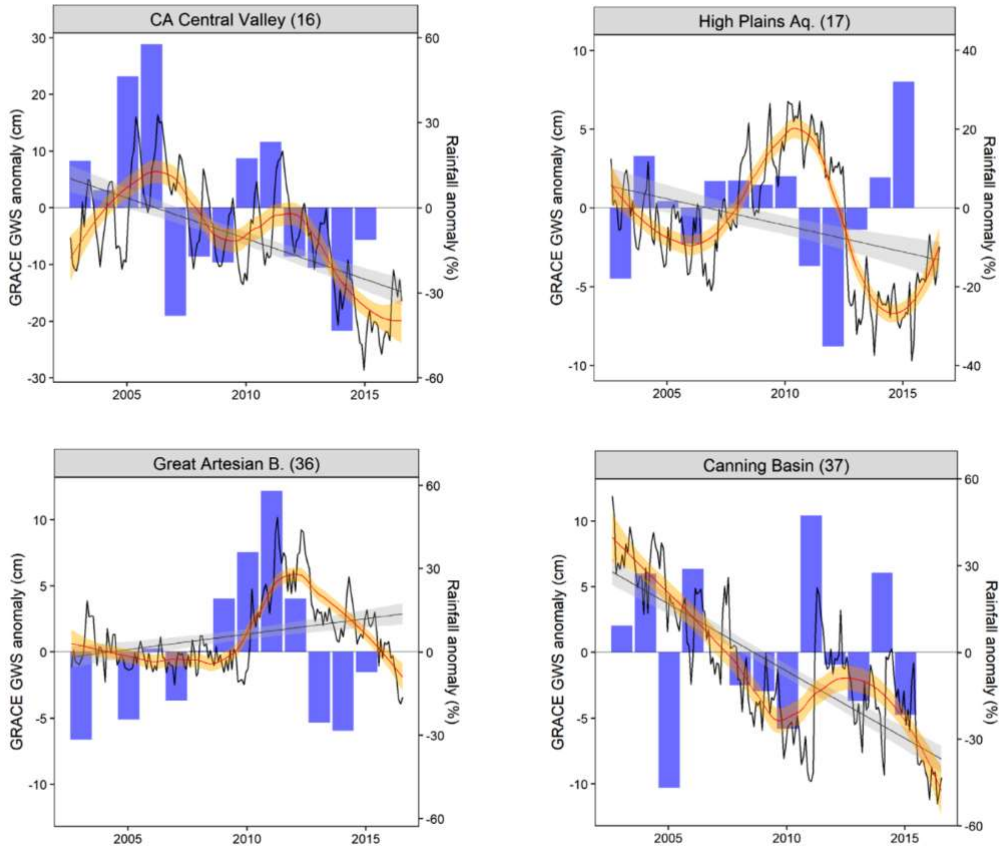




Goni et al. (2013) Hydrology Science Journal 66(8): 1359-1371.

evidence from GRACE satellite data globally





- non-linearity trends in groundwater storage in drylands associated with episodic nature of groundwater replenishment from extreme heavy (90th percentile) annual precipitation

Shamsudduha & Taylor (2020) Earth System Dynamics 11: 757-774.

Concluding thoughts - synthesis & some caveats:

- *climate injustice is structural*: amplification of drought and flood risks highest in tropical low-income countries
- groundwater recharge observed to result preferentially from heavy, often extreme rainfall in drylands and humid environments across tropical Africa and beyond

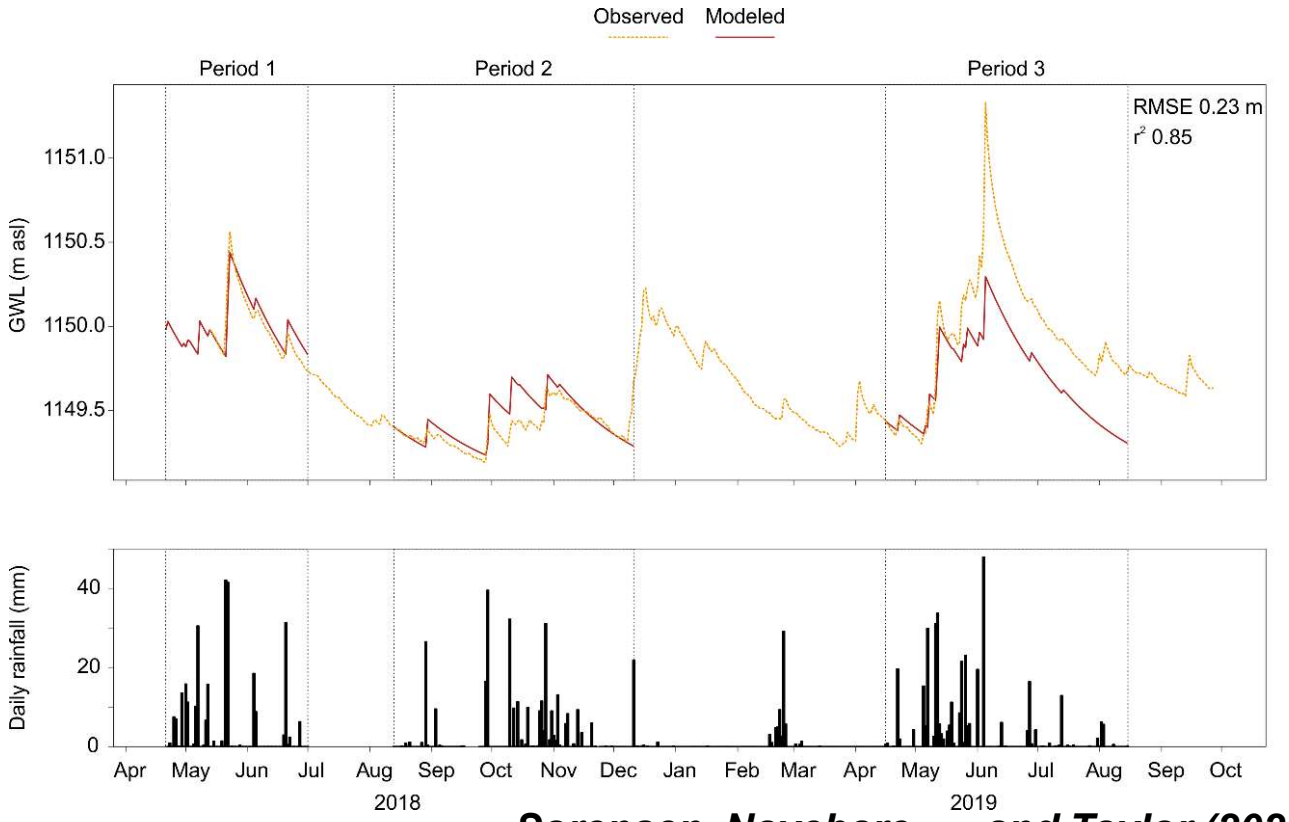
Makgadikgadi Salt Pan, Botswana

- **groundwater is thus a logical source to supplement soil moisture (reduced by the intensification of rainfall and amplified ET by climate change) and improve food security and access to safe water**

large-scale groundwater-fed irrigation (Zambia)

vulnerability of groundwater to contamination

- rapid piezometric responses to heavy (>10 mm/day) rainfalls highlight rapid infiltration of rainfall and the vulnerability of groundwater to contamination from these events



Sorensen, Nayebare, … and Taylor (2021) Water Research 206: 117734.

- NOTE: role of ***fast flow**** in the transmission of recharge is inconsistent with models employing the Richards equation

Hartmann et al. (2021). PNAS 118: e2024492118.

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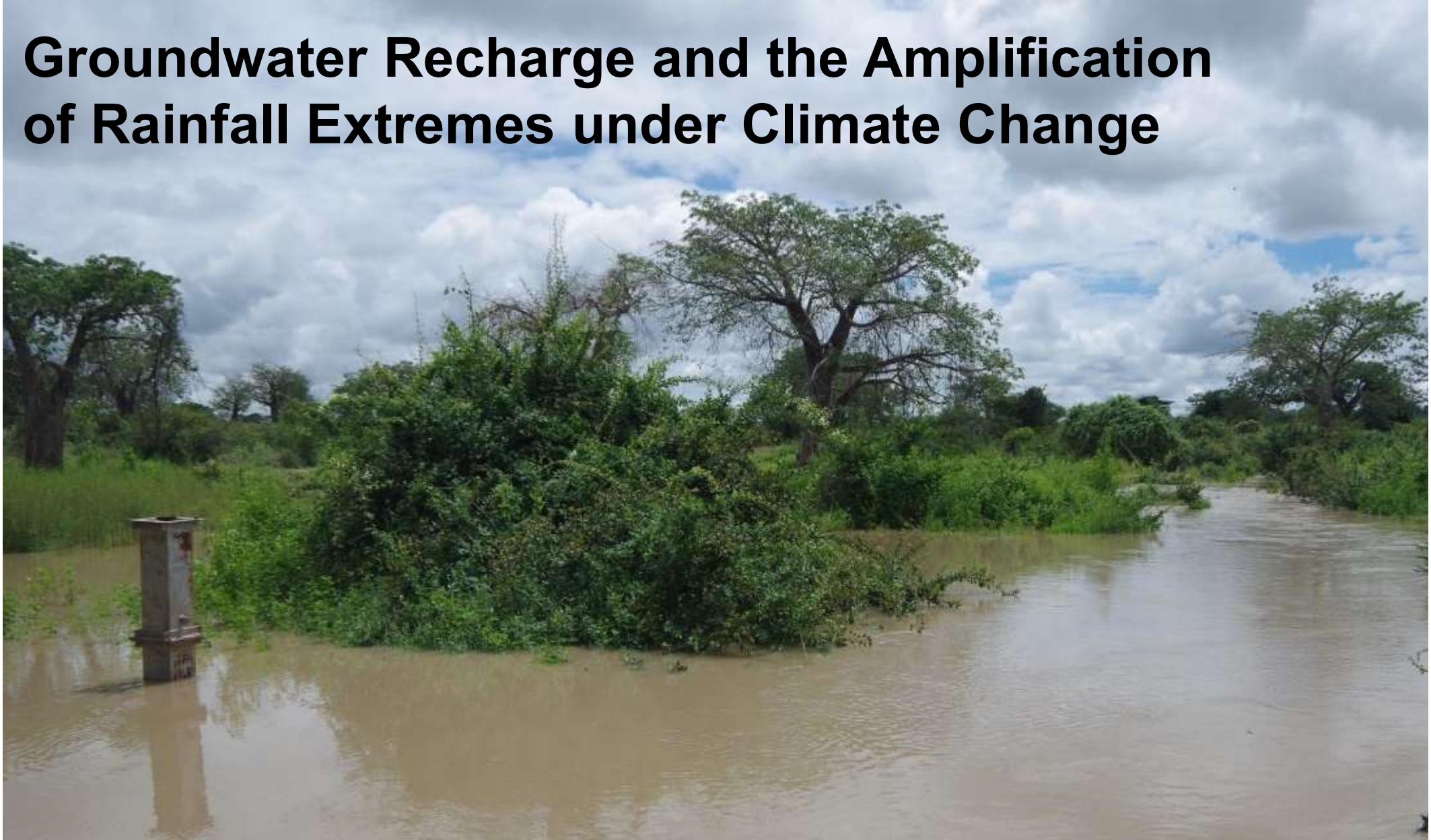

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