Groundwater Recharge and the Amplification of Rainfall Extremes under Climate Change

2015-16 El Niño flooding in Tanzania

Richard Taylor, University College London (UCL)

NERC SCIENCE OF THE ENVIRONMENT · ESRC ECONOMIC & SOCIAL RESEARCH COUNCIL · UKaid · UPGro Unlocking the Potential of Groundwater for the Poor · GroFutures · THE ROYAL SOCIETY · EPSRC Engineering and Physical Sciences Research Council

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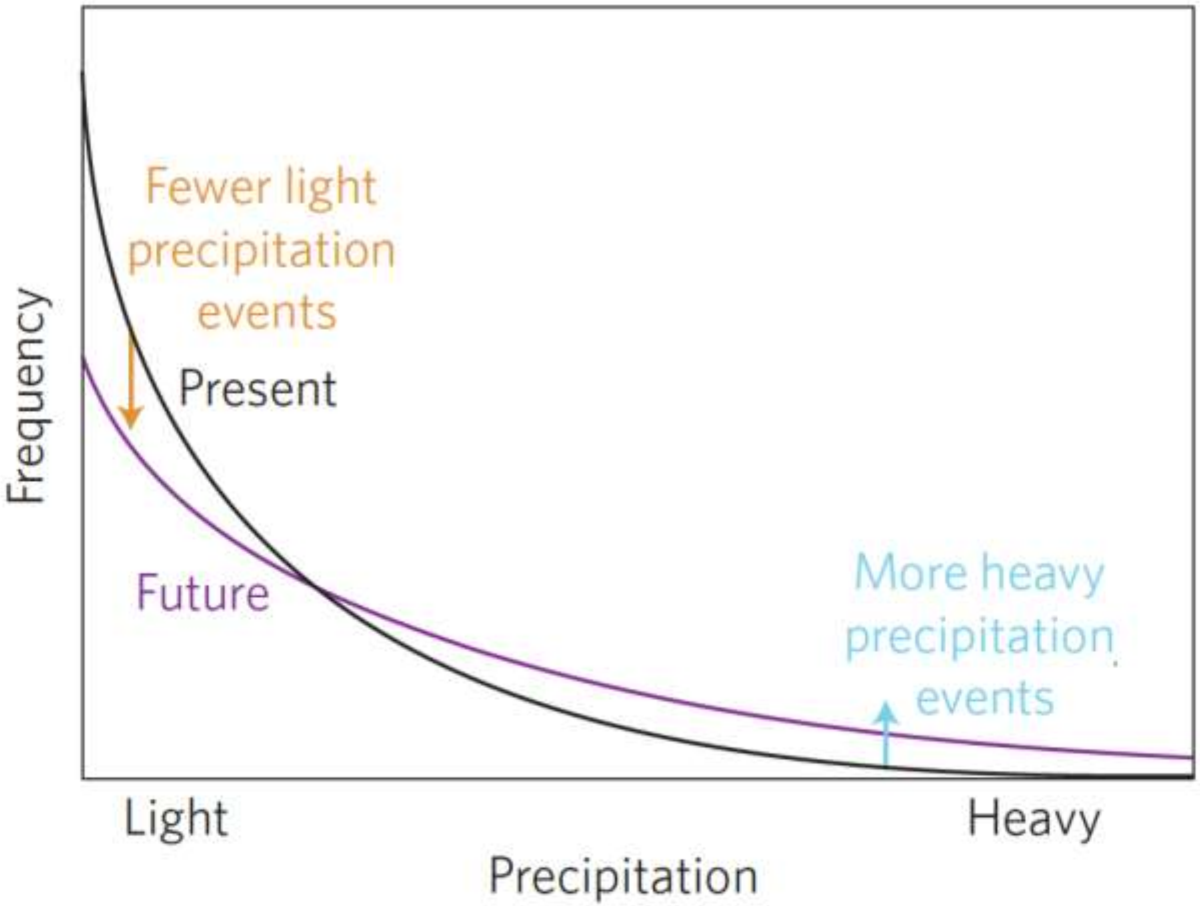
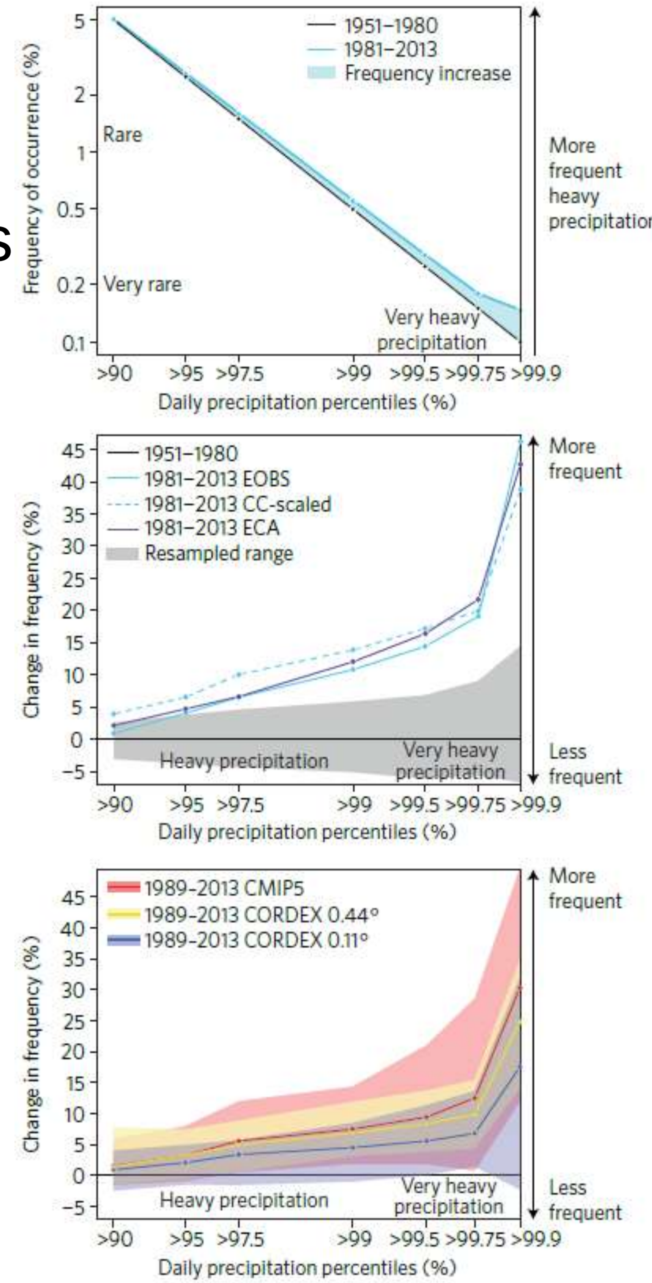
intensification of precipitation in a warming world

- consistent, observed impact of climate change is shift towards fewer light precipitation events & more frequent heavy precipitation, pronounced in tropics





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

piezometric & isotopic data: Uganda & Benin

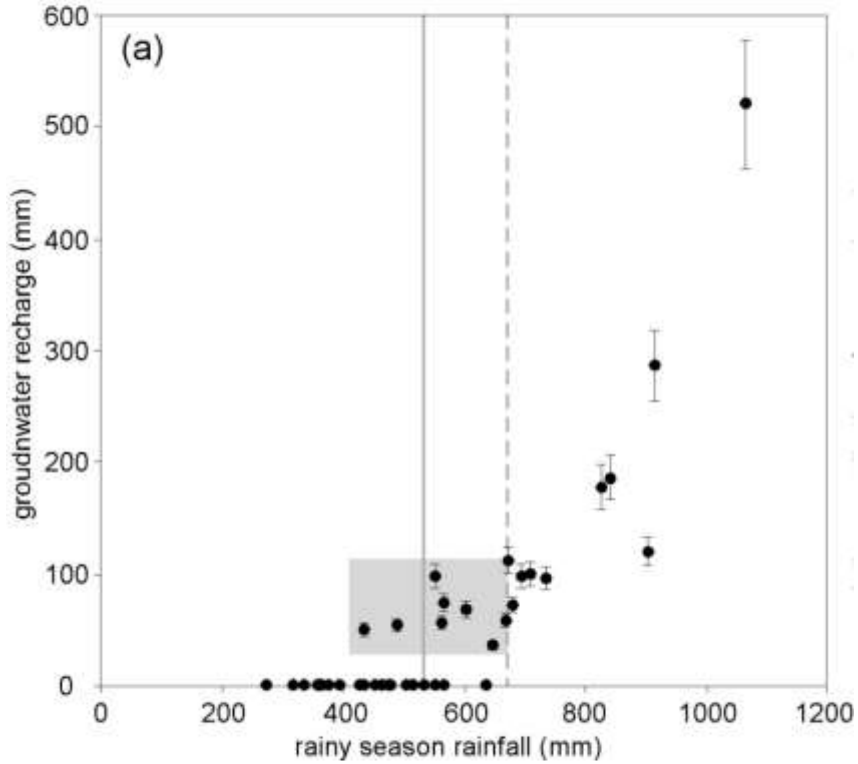
- in humid tropics, observed groundwater-level rises and stable-isotope ratios in groundwater traced to heavy rainfall events exceeding 10 mm·day^{-1}

Taylor and Howard (1996) *J. Hydrol.* 180: 31-53.
Taylor and Howard (1999) *J. Hydrol*. 218: 44-71.
Owor et al. (2009) *Environ. Res. Lett*. 4: 035009.
Kotchoni et al. (2019) *Hydrogeol. J.* 27: 447-457.

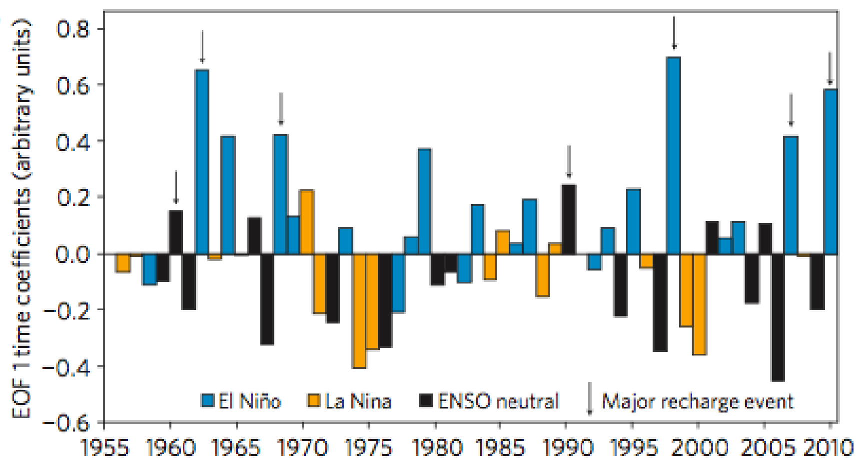
- heavy rainfall in the tropics is depleted with respect to the heavy isotopes of ^{18}O and ^{2}H, "*The Amount Effect*"

piezometric evidence from semi-arid Tanzania

- recharge occurs *episodically* and *disproportionately* from extreme (>80th percentile) seasonal rainfall generating ephemeral streamflow (*i.e.* focused recharge)



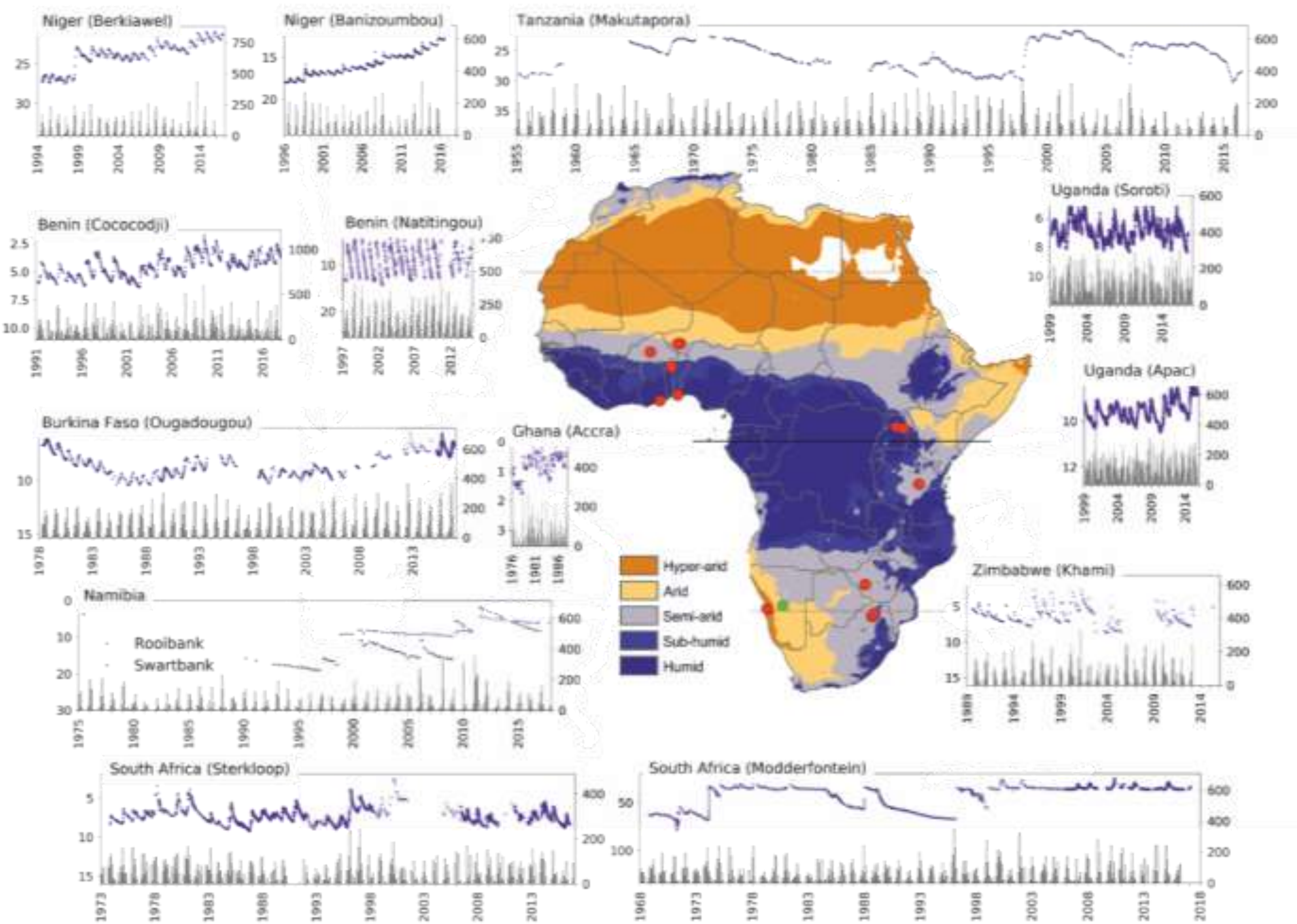
- episodic recharge results from heavy rainfall associated with ***El Niño Southern Oscillation***



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

pan-African piezometric analysis

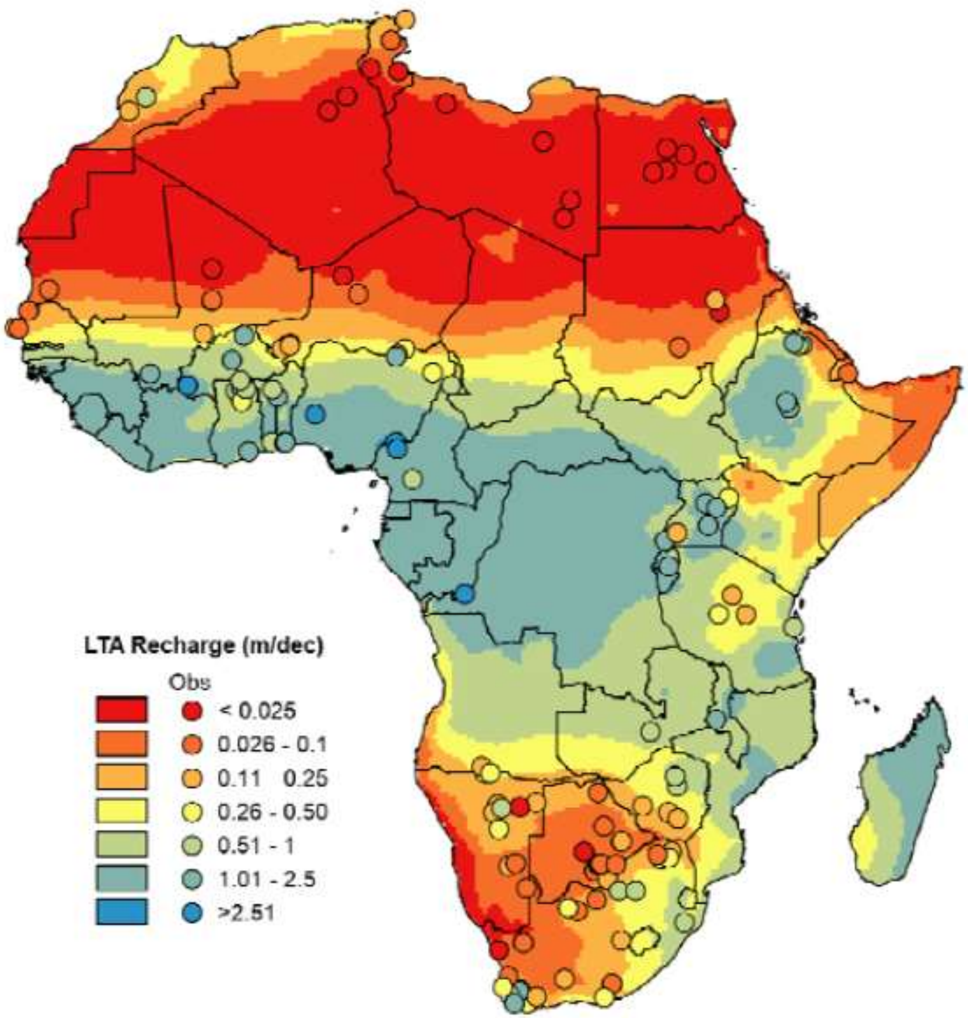
- confirms (1) bias in recharge to heavy rainfall; (2) episodicity of recharge in drylands and links to large-scale climate controls; and (3) importance of focused recharge in drylands

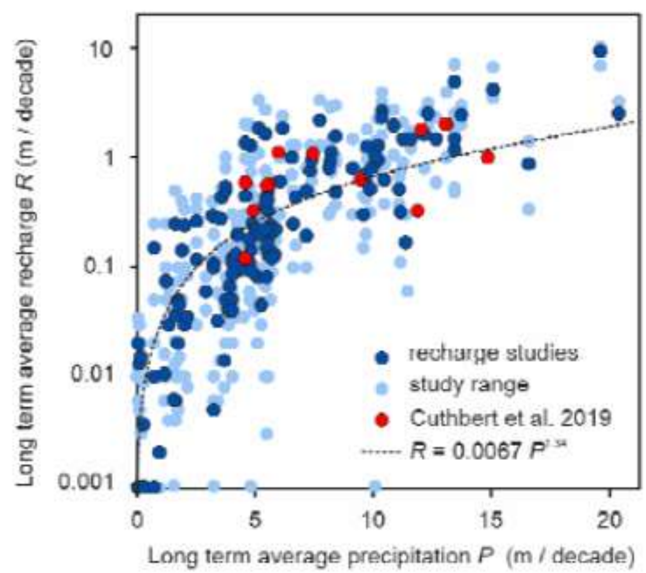


Cuthbert, Taylor et al. (2019) Nature 572: 230–234.

pan-African review of recharge studies

- **non-linearity** in relationship between long-term average (LTA) rainfall and recharge from systematic review of >200 studies

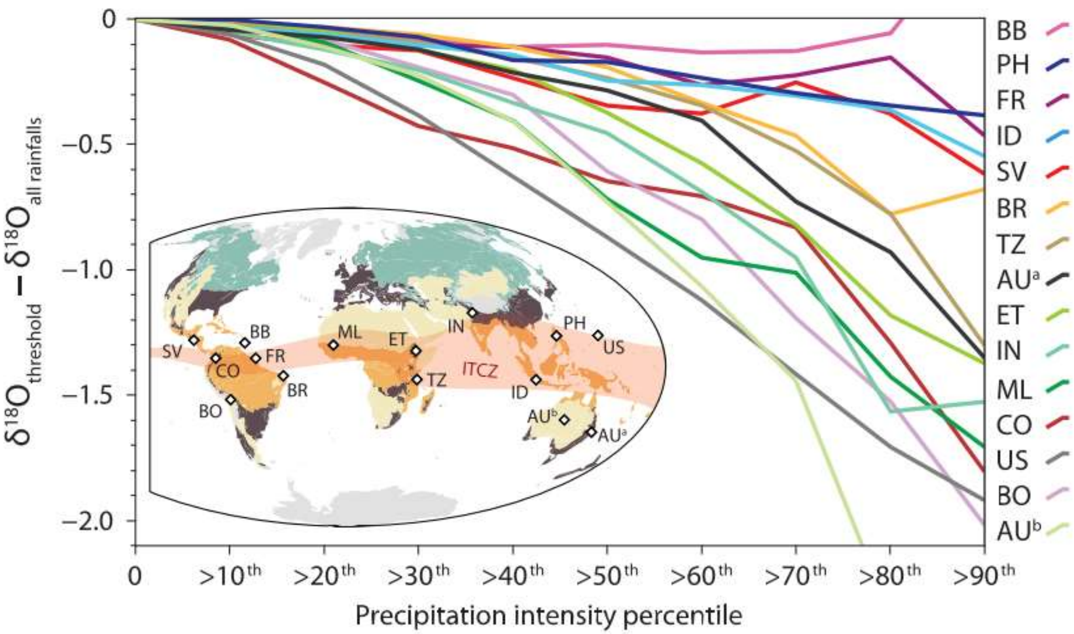


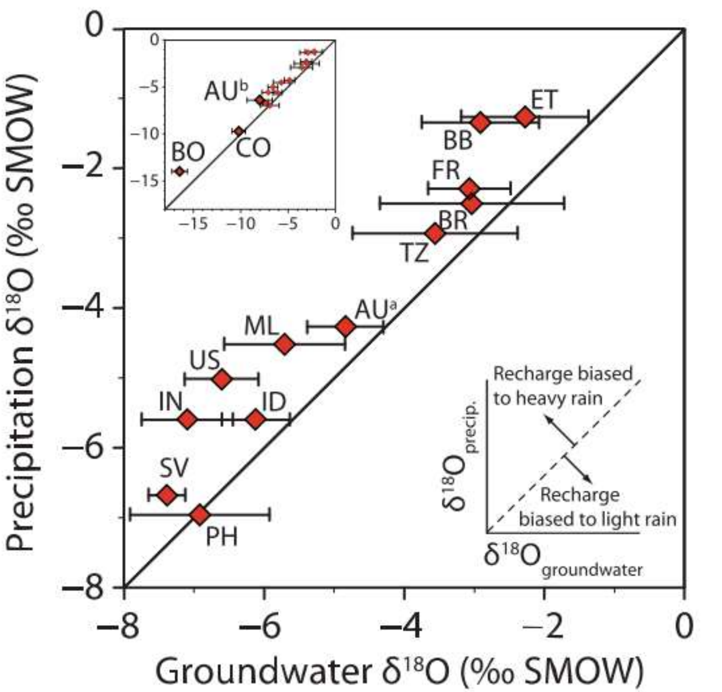


MacDonald et al. (in review) Environ. Res. Lett.

pan-tropical evidence from stable isotopes

- isotopic composition of tropical groundwater is biased to heavy monthly rainfalls exceeding 70th percentile

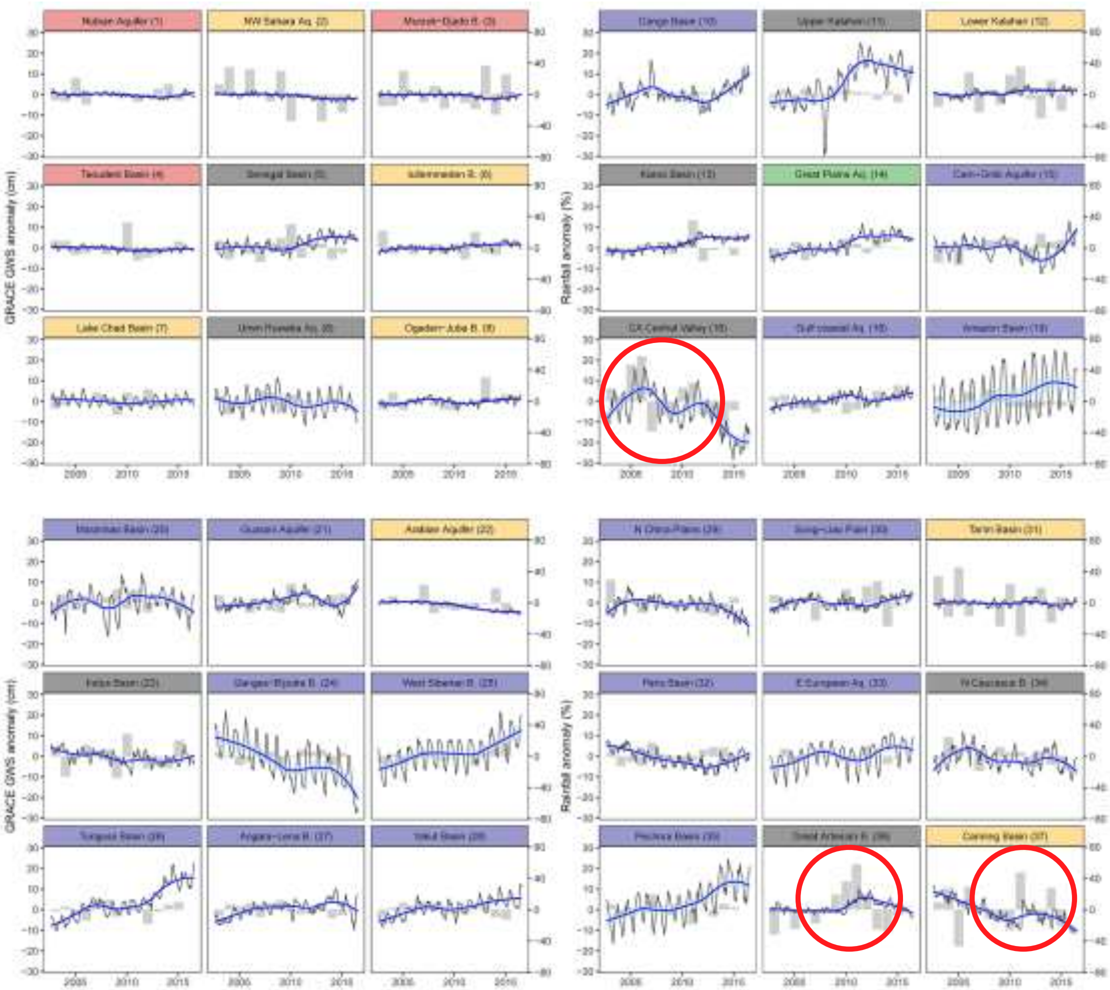




Jasechko & Taylor (2015) Environ. Res. Lett. 10: 124015.

evidence from GRACE satellite data

- non-linearity in trends in groundwater storage ΔGWS associated with episodic nature of groundwater replenishment from extreme annual (>90th percentile, 1901–2016) precipitation

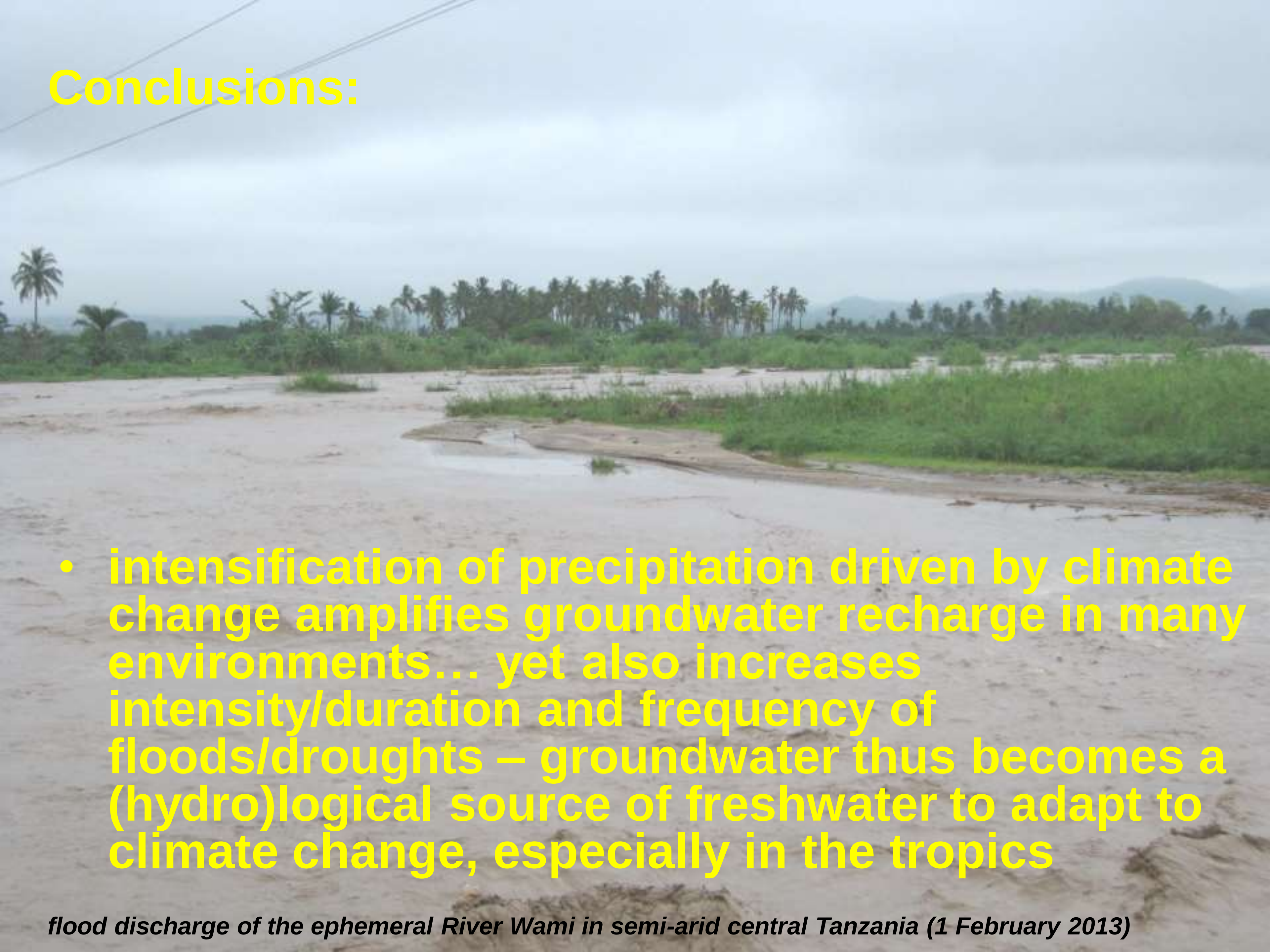


- clearest examples observed in dryland environments (*e.g.* California Central Valley, Great Artesian Basin)

Shamsudduha & Taylor (2020) Earth. Syst. Dyn. 11: 757-774.
Opie et al. (2020) Earth. Syst. Dyn. 11: 775-791.

Conclusions:

- **intensification of precipitation driven by climate change amplifies groundwater recharge in many environments… yet also increases intensity/duration and frequency of floods/droughts – groundwater thus becomes a (hydro)logical source of freshwater to adapt to climate change, especially in the tropics**



flood discharge of the ephemeral River Wami in semi-arid central Tanzania (1 February 2013)

- rapid transmission of extreme-heavy rainfalls through soils as recharge is inconsistent with models employing matrix-defined infiltration capacities and Richards equation – and reflects presence of structures (e.g. macropores) making groundwater more vulnerable to contamination than previously considered
- most large-scale models of recharge do not represent focused recharge, a dominant recharge pathway in drylands, undermining the validity of recharge projections

Makgadikgadi Salt Pan, Botswana