Impacts of climate change on groundwater resources in sub-Saharan Africa: evidence from Uganda

R. Taylor¹, L. Mileham¹, C. Tindimugaya¹,²

¹ UCL Geography, UK
² Ministry of Water & Environment, Uganda
• in sub-Saharan Africa, basin storage (soil water, groundwater) provide enormous potential to mitigate and adapt to forecasted “water scarcity”
• groundwater enables communities to overcome intermittent water scarcity associated with seasonal and inter-annual climate variability
low-cost water supplies

- groundwater-fed water supplies avoid the high costs of treatment required to make surface water sources potable
- majority of all improved rural water supplies and town water supplies are fed by groundwater

- collecting water from a spring in Kampala
- groundwater-fed town reservoir, Wobulenzi, Uganda
• food production derives almost entirely from soil water ("green water") obviating the need to withdraw freshwater ("blue water") for agriculture
  - *a sector responsible for ~70% of global freshwater withdrawals*
4% of arable land in Africa is under irrigation – most (75%) of this occurs in Egypt, Sudan, and Madagascar\(^1\)

- \(~0.8\%\) of the arable land is irrigated with groundwater in sub-Saharan Africa,
- sub-Saharan Africa has more groundwater available (1500 km\(^3\)·year\(^{-1}\)) than China (800 km\(^3\)·year\(^{-1}\)) or India (400 km\(^3\)·year\(^{-1}\))\(^1\)

---

Climate change and groundwater?

key challenges to understanding this relationship:

• reduced reliability (convergence) of climate predictions over continental areas (land-climate coupling) where soil infiltration and recharge takes place

• uncertain impacts of climate change on recharge regimes and storage (e.g. weathered crystalline rock aquifers)

• impacts of climate change on groundwater demand and aquifers at risk (e.g. urban & coastal aquifers)
weathered crystalline rock aquifer systems

- weathered crystalline rock aquifer systems underlie over 40% of sub-Saharan Africa & all of the Great Lakes Region of Africa

- low yielding and subject of very limited research
research in Uganda

• long (17 year) relationship with research partners:
  - Water Management
  - Meteorology
  - Health

• high density of meteorological, epidemiological and hydrological data (including groundwater!)
climate change & recharge regimes

- According to IPCC 4AR (Chapter 3), predicted increase in the incidence of heavy precipitation events will decrease groundwater recharge as soil infiltration capacities are exceeded more frequently - 70% in NE Brazil  
  (Döll and Flörke, 2005)

- In contrast, research in Uganda shows the timing and magnitude of groundwater recharge depends upon the number of heavy rainfall events  

- Increases in the intensity (and volume) of precipitation lead to a 66% rise in recharge  
• curiously strong relationship ($r^2 = 0.57$) between mean storage anomalies in satellite (GRACE) datasets & borehole hydrographs

- mean (total) equivalent water thicknesses in Uganda estimated to range from 800 to 3600 mm
  - based on mean groundwater residence times of 8 to 18 years (CFCs, $^3$H) and basin recharge / baseflow of 100 to 200 mm·year$^{-1}$
groundwater – surface water interactions?

- groundwater levels and lake stage in Lake Victoria Basin respond to seasonal precipitation
- hydraulic gradients suggest groundwater contributes to lake water balance; degree to which groundwater storage regulates the level of Lake Victoria remains unclear

(1) data from WRMD Monitoring Network
localised impacts of intensive groundwater abstraction from weathered crystalline rock aquifer systems:

*Rukungiri:* $\sim 3 \text{ m}\cdot\text{year}^{-1}$ decline in water table since 1998

*Wobulenzi:* $\sim 0.3 \text{ m}\cdot\text{year}^{-1}$ decline in water table since 1999
climate change and human health

- heavy rainfall events associated with loading of faecal pathogens (TTCs) in shallow groundwater-fed springs\(^1\) and incidence of diarrhoeal disease\(^2\)

greater frequency of heavy rainfall events as a result of climate change increases the risk of diarrhoeal disease

- as faecal contamination is related to observed sanitary risks¹, improved community hygiene will reduce the risk diarrhoeal disease from climate change.

1. To assess uncertainty in climate change impacts on terrestrial hydrology using multi-model ensembles of future climate* and hydrological model ensembles (see HEPEX)

   * based on scaled increases in global mean temperature (CLIMGEN) & SRES time slices

2. To assess changes in basin storage from river discharge data (trends in baseflow contributions using Boussinesq / Maillet algorithms) - extending current research constrained by limited availability of borehole & satellite data
Groundwater & Climate in Africa

- international conference: June 24-28th, 2008 Kampala, Uganda

- www.gwclim.org

- papers to be published in special issue of HSJ and IAHS Red Book