Adaptation to changing water demand & climates in Sub-Saharan Africa: the role of groundwater

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groundwater-fed irrigation of maize (Zambia)
Rukungiri Town, Uganda

overview:

• projected changes in freshwater withdrawals and resources
• rethinking freshwater availability - groundwater storage
• groundwater and people
• substantial rises in freshwater demand for irrigation are projected to improve food security and resilience to climate variability & change
domestic water withdrawals

- increased freshwater withdrawals are required to increase access to “safe water” under rapid population growth and urbanisation.

outside Iganga Town, Uganda
per capita water use is projected to rise as access to piped water supplies increases
warming in Africa: 1.5 x global mean

* 2080-2099 relative to 1980-1990
“It is likely that the frequency of heavy precipitation... will increase in the 20th century over many areas of the globe. This is particularly the case in... tropical regions.” IPCC SREX (2011)

warming intensifies precipitation

• **fewer**, low and medium intensity precipitation events
• **more**, very heavy precipitation events (*i.e.*, “extreme events”)

Allan and Soden (2008); Allan et al. (2010)

rainstorm in Namibia (NASA)
more frequent and intense flood events
• longer droughts
• lower crop yields from rain-fed agriculture due to more variable and lower soil moisture

Challinor et al. (2006)

1975
Total rainfall: 394mm
Yield = 1360 kg/ha

1981
Total rainfall 389mm
Yield = 901 kg/ha
rainfall intensity and recharge?

seasonally humid Uganda

semi-arid Tanzania

Owor et al. (2009)

Taylor et al. (2013)
recharge & rainfall extremes

- recharge in East Africa results disproportionately from heavy rainfall - 
  annually (humid) episodically (semi-arid)

Taylor et al. (2013)

- projected intensification of rainfall under climate change favours recharge
Groundwater in Sub-Saharan Africa is a climate resilient source of freshwater. Can it meet increasing demand?
rethinking freshwater availability:
currently defined by the ratio between mean annual river flow to estimated human demand for freshwater
African water crisis – “scarcity paradigm”
• metric unrelated to access/delivery (infrastructure)
• based on a gross exaggeration of per capita usage: 840 m$^3$ per year vs. 20 to 25 m$^3$ per year observed in Uganda, Ethiopia, Tanzania
groundwater storage in Africa

- disregards distributed groundwater storage - 10 to 100 times mean annual river flow

MacDonald et al. (2012)
• groundwater storage can sustain freshwater withdrawals under conditions of substantial intra- and inter-annual variability in river discharge
• natural and constructed storage required to meet imbalances in freshwater supply/demand

Taylor (2009)
• Sub-Saharan Africa has sufficient water.

• The infrastructure to access groundwater storage, to store peak flows, and to deliver safe water to users is inadequate.
>40% of SSA underlain by weathered / fractured rock aquifers with low bulk transmissivity (T).

Low hydraulic diffusivity (T/S) restricts both the magnitude of well yields and... their impact.

MacDonald et al. (2012)
“localised aquifers”

- The impact of low pumping rates is localised – constrained by geology.

- Localised groundwater storage (~0.5 x 10^6 m^3 per km^2) able to sustain hand-pump abstraction <0.003 x 10^6 m^3 per year.

Figure 3. Flowpath simulation of a shallow well pumping under a uniform hydraulic gradient of 0.001. The hydraulic head contour interval is 0.05m. Taylor and Howard (1995)
despite ambitions of some... this is not the future of irrigated agriculture across Sub-Saharan Africa – the hydrogeology does not permit it
‘Small is beautiful.’

- distributed, low-intensity groundwater abstraction by smallholder farmers
small-holder farms in Sub-Saharan Africa

- account for over half of most country’s GDP and up to two-thirds of the labour force  
  FAO (2001)

- 80% of all farms and account over 90% of the agricultural production in many countries  
  IFAD (2011)

- distributed, low-intensity groundwater use complements existing land-tenure systems in Sub-Saharan Africa

Kenya (AGRA)
localised nature of groundwater supply & demand alleviates the "Tragedy of the (aquifer) Commons" that characterises productive, regional aquifers (USA, China, India)
2 key physical challenges to unlocking the potential of groundwater in Sub-Saharan Africa:

- reducing the high cost of drilling that currently impedes groundwater development by small landholders
sustainability

• sustaining groundwater discharges (baseflow) to surface waters and their associated ecosystem services under increased use of groundwater
Thanks for listening!