Vulnerability of shallow groundwater and surface water resources used for irrigation in rural communities in sub-Saharan Africa to climate variability and change

Geological Survey of Ethiopia

International Water Management Institute

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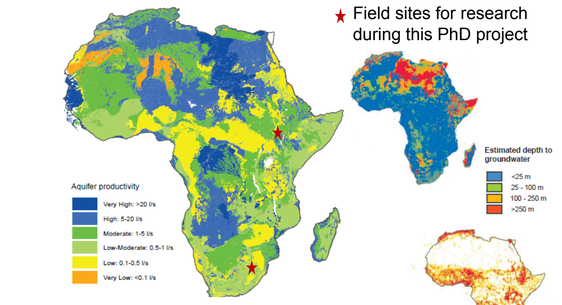
Background

Productive use of groundwater resources for irrigation in sub-Saharan Africa currently remains low but is expected to increase significantly in the near future, potentially providing a widespread poverty reduction. Their accessibility means shallow groundwater resources are most likely to be used by poorer communities, but they are also the most vulnerable to over-exploitation and climatic variability. Recent studies based on climate modelling and remote sensing data have demonstrated the abundance of groundwater resources at a broad scale, however, there is a scarcity of data to support its local management to reduce vulnerability.

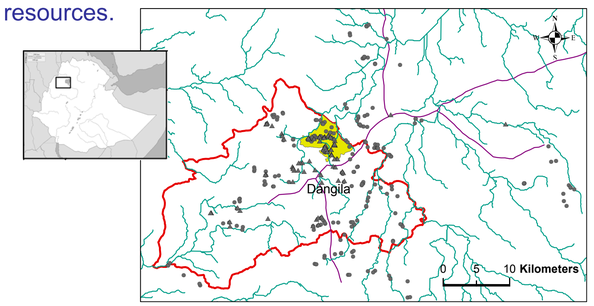


(From; MacDonald, A.M., Bonsor, H.C., Dochartaigh, B.E.O. and Taylor, R.G. (2012) 'Quantitative maps of groundwater resources in Africa', *Environmental Research Letters*, 7(2), p. 7)

Continental-scale hydrogeological assessment of Africa

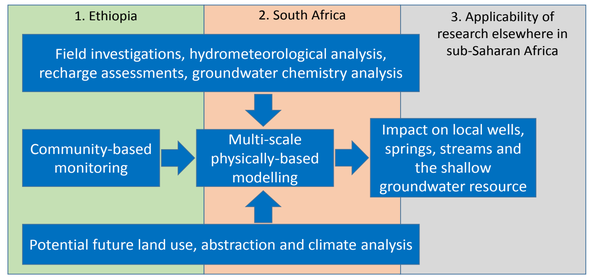
Aims and scope

The aim of the research is to assess the vulnerability of shallow groundwater resources. The project links local community monitored data to regional scale data to produce models used to simulate climatic and land use scenarios. The transferability of findings to more data-poor locations will be evaluated to determine the level of monitoring and modelling required for communities to manage their own resources.



Location of field site in northwest Ethiopia showing woreda boundary (red) and Dangesheta kebele which is the community of focus (yellow). Symbols indicate investigated hand-dug wells and springs.

Methodology



Field visit

A four-week field visit was conducted in March/April 2015 coinciding with the end of the dry season (period of greatest water scarcity). The hydrogeological assessment involved sampling, measuring and surveying wells, springs and rivers, plus ground-truthing satellite imagery and preliminary modelling outputs.

Groundwater sampling for laboratory major-ion and stable-isotope analysis from a developed spring (left) and a rope and washer pump

Conducting a pumping/recovery test on a hand-dug well (left) and a geological survey in the Gizani river in addition to surveying seasonal and perennial reaches

Geological surveys reveal a weathered regolith above variously massive, fractured or vesicular volcanic bedrock.

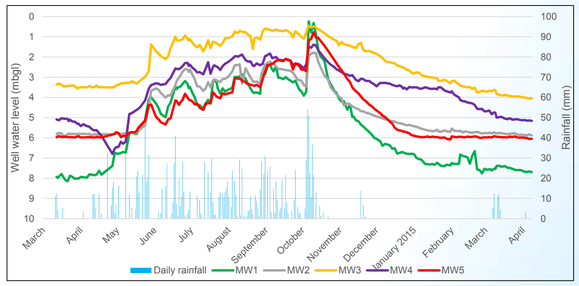
In-situ and laboratory analysis of groundwater chemistry imply a short residence time and consequent vulnerability to drought. Better water supplies are found in areas of high aquifer connectivity with expansive recharge areas.

Well tests indicate low hydraulic conductivity aquifers. Potential well yields could be increased (from a low level) by aiming to increase the saturated thickness penetrated, i.e. digging the wells deeper. Therefore, wells should be sited in areas of greatest regolith thickness.

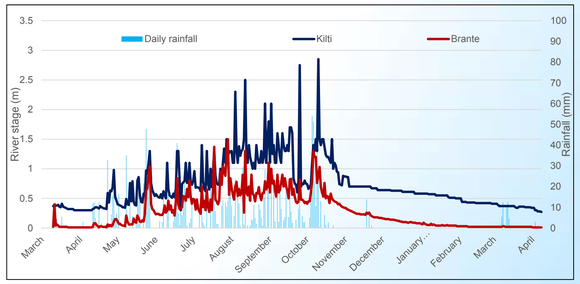
Community monitoring

After initial community workshops, locations were selected for groundwater monitoring, river gauge boards and a rain gauge. Local observers were trained to collect daily data.

Reconstruction of the Kilti river gauge board (left) following damage during wet season floods and measuring depth to groundwater in a monitoring well



Community monitored rainfall and groundwater level



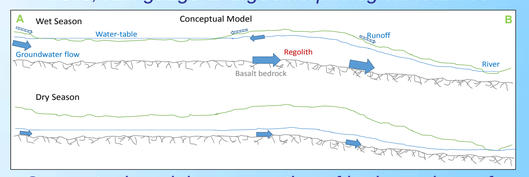
Community monitored rainfall and river stage

The community gathered data has been statistically validated against formal sources confirming its quality and value. In addition, the programme has increased the hydrological understanding of the local community, instilled a sense of ownership of their resources, and led to a feeling of partnership in the project.

Conceptual model

The floodplains with their constricted outlets become wetlands in the rainy season forming recharge basins. Water balance calculations using aquifer parameters obtained from well tests in combination with stable-isotope and major-ion chemistry data indicate that groundwater discharges from these basins with flow paths not necessarily coincident with the surface water discharge direction; i.e. groundwater flows laterally in accordance with larger scale topography. Recharge assessments suggest 500 mm/year: high enough for much greater groundwater irrigation.

Dangesheta kebele showing locations of monitoring wells, rain gauge and geomorphological features



Conceptual model cross-section of hydrogeology of Dangesheta kebele during wet and dry seasons showing a typical "hanging" floodplain with opposing groundwater and surface water discharge directions

Further investigation

- Modelling and deep groundwater chemistry analysis will reveal the interconnectivity between the shallow and deep aquifers.
- Well tests during the wet season will show the importance of saturated thickness on well yield.
- Wet season observations will identify; surface water flow paths and, with measurements of radon-222; aquifer recharge/discharge locations.
- An expanded measurement programme of well depths will allow inferral of shallow aquifer depth and thus areas of greatest thickness/potential.
- Modelling will enable simulation of the impacts of future climate and land-use change and increased abstraction.

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