British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Analysis of confidence in continental-scale groundwater recharge estimates for Africa using a distributed water balance model

Mackay, J D, Mansour, M, Bonsor, H C, Pachocka, M, Wang, L, MacDonald, A M, Macdonald, D M J and Bloomfield, J P

1 Introduction

Recent studies suggest that, if exploited, groundwater could help to meet the increasing demand for fresh water in Africa with an estimated total groundwater storage between 0.36–1.75 million km^3 (MacDonald *et al.*, 2012). Quantifying groundwater recharge is vital as it forms a primary indicator of the sustainability of underlying groundwater resources. The complexity of recharge processes in Africa means that simulating these processes is often highly uncertain. This study is an initial exploration of the uncertainty of recharge simulations over Africa based on a preliminary sensitivity analysis using the ZOODRM distributed hydrological model code developed by the British Geological Survey.

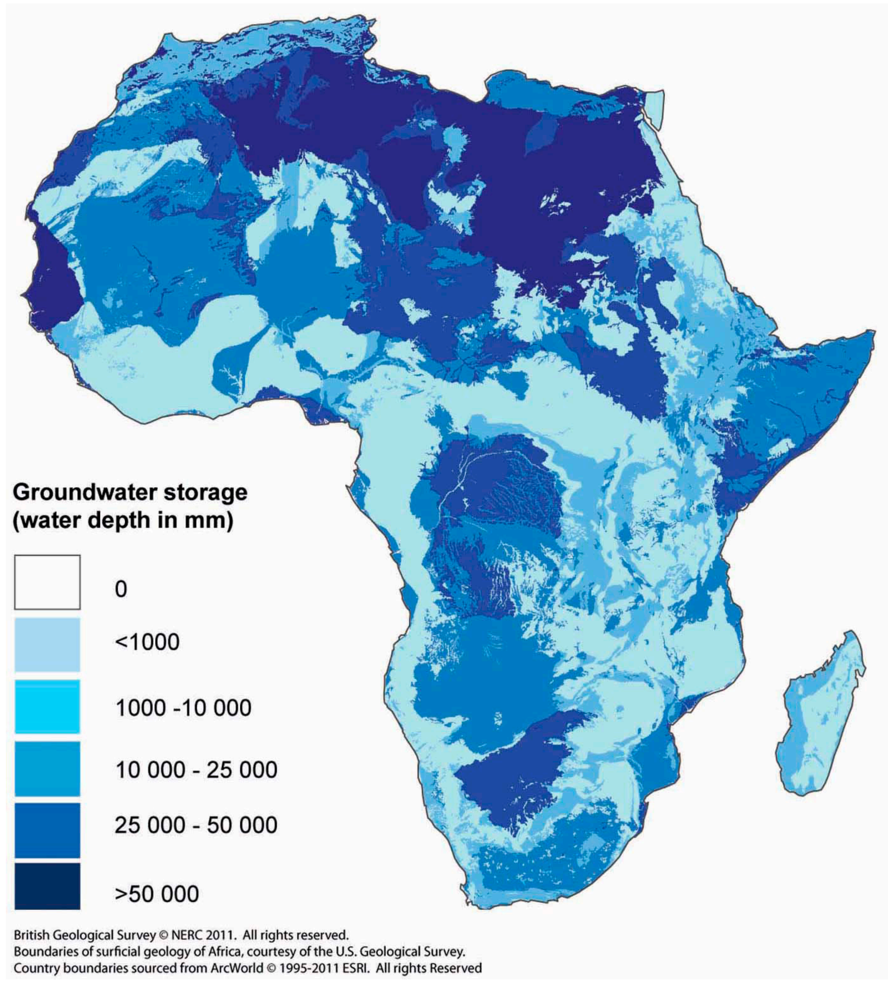

Figure 1 Estimated distribution of groundwater resources in Africa (MacDonald *et al.*, 2012).

2 Water balance model of Africa

ZOODRM is a distributed water balance model that implements simple conceptual representations of hydrological processes over the vegetation canopy, land surface, river network, soil zone and aquifer (Figure 2). Using readily available global datasets of surface topography, vegetation, soil and the underlying bedrock, a ZOODRM water balance of Africa was constructed. The aquifer storage and discharge parameters were drawn from the recent quantitative groundwater maps of Africa (MacDonald *et al.*, 2012). National Oceanic and Atmospheric Administration rainfall and potential evapotranspiration (PET) products were used in conjunction with MODIS leaf area index (LAI) data to drive the model.

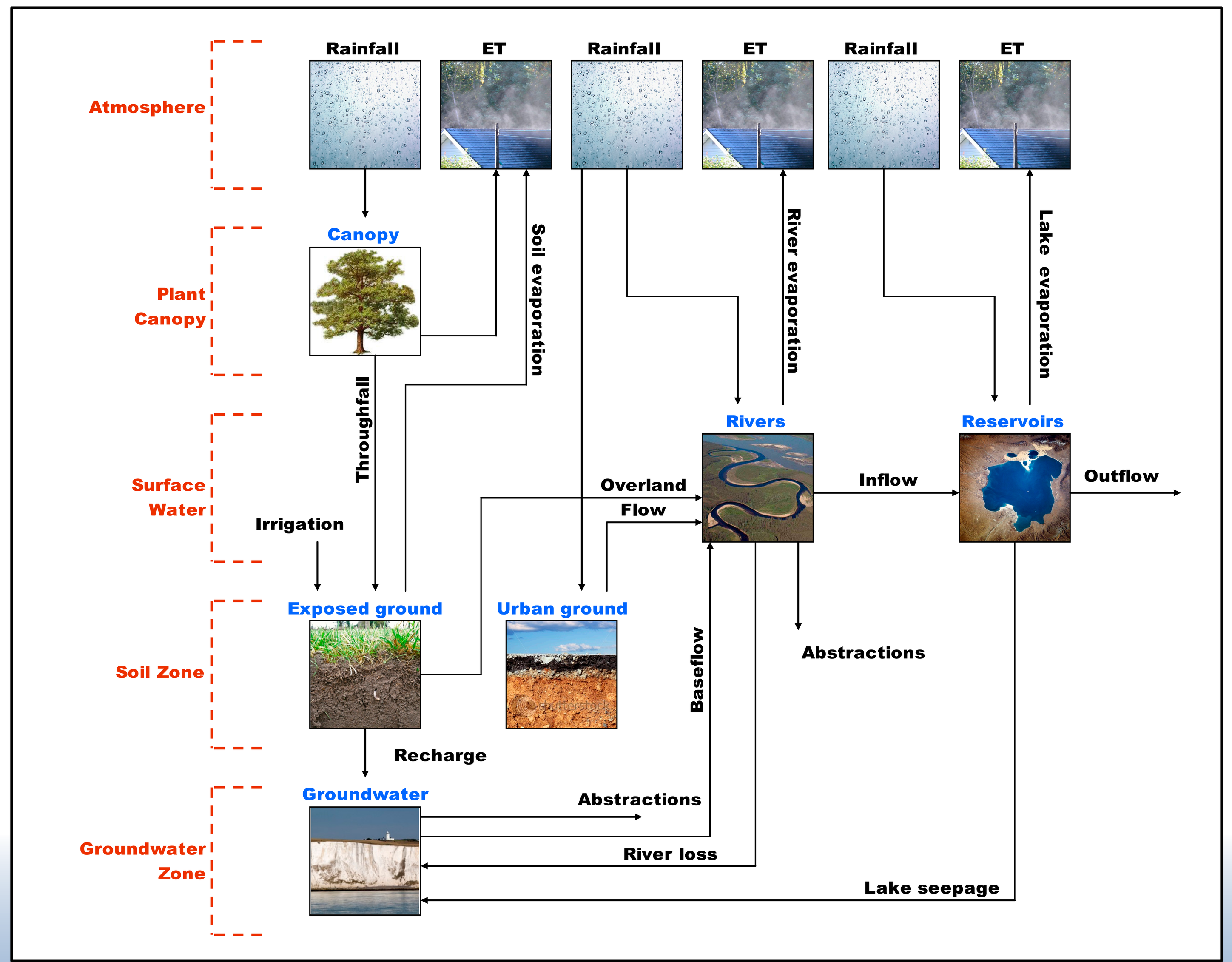

Figure 2 ZOODRM model structure.

3 Model configuration

The model uses a 50x50 km Cartesian grid of equally spaced nodes. The model has been calibrated to available river flow data from the Global Runoff Data Centre (http://www.bafg.de/). Sensitivity has been explored by perturbing model parameters and weather data by ±10%. Different recharge calculation methods including a 'wetting threshold' method and two modified FAO methods with different representations of vegetation root distribution (Figure 3) were also used to assess their relative influence on the simulated recharge.

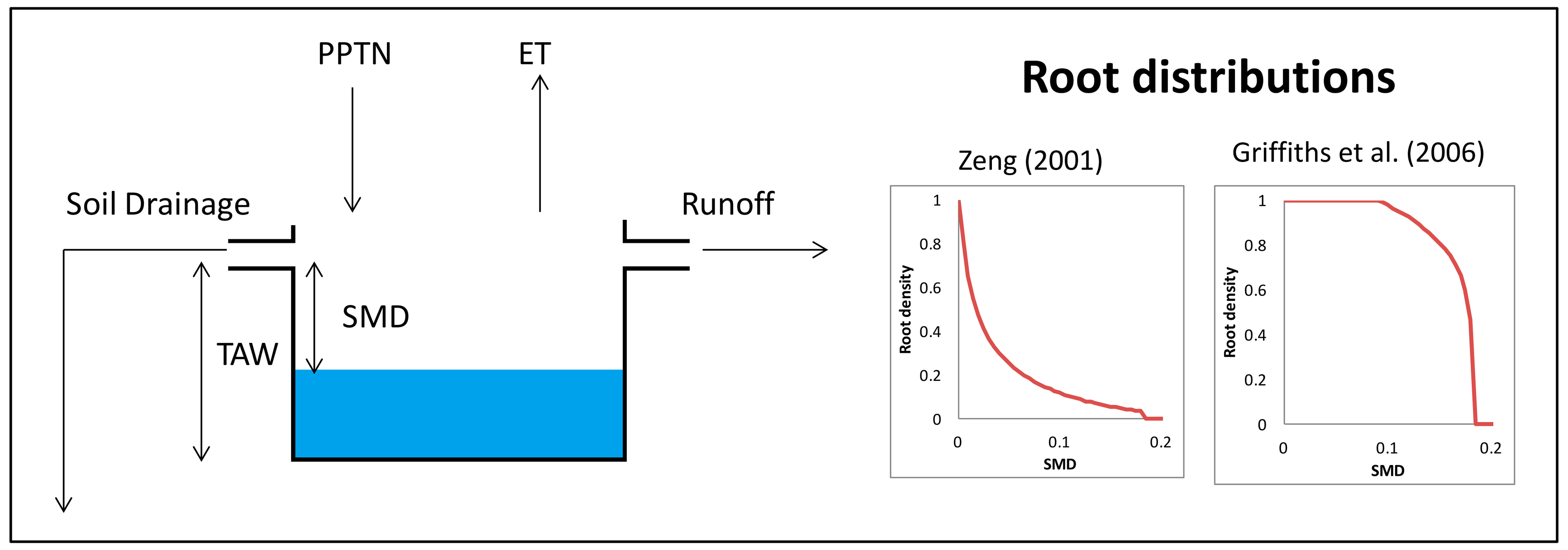

Figure 3 Soil moisture allocation recharge methods.

4 Groundwater recharge simulations

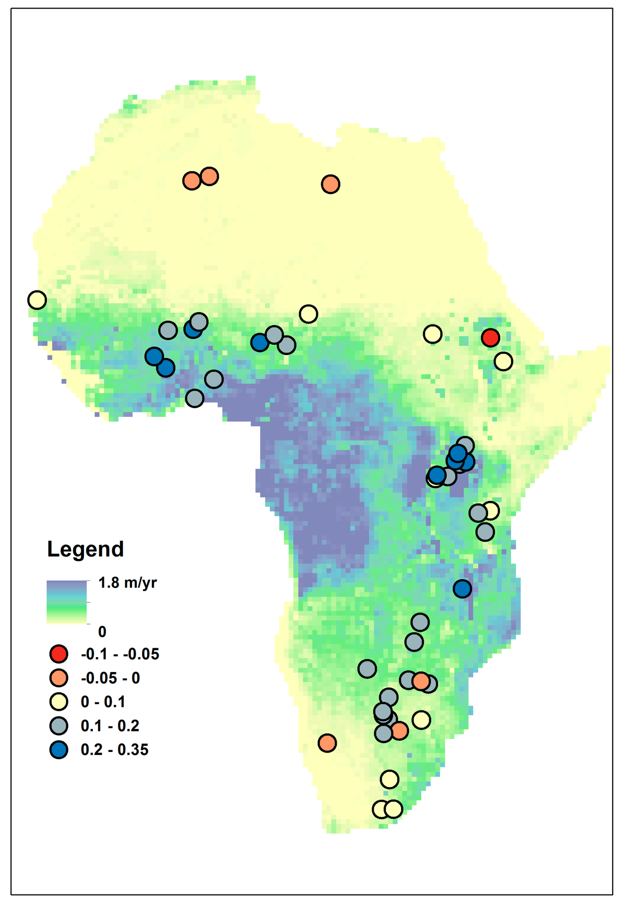

Figure 4 Groundwater recharge simulation using the control model setup. Dots show difference between observations in m/day.

For the control run, a soil moisture accounting recharge method was used with root distributions defined by Zeng (2001). The mean annual recharge was calculated as 3629 km^{3}yr^{-1}. A comparison with available field data shows that the model has an overall positive bias which is most pronounced in the tropics (Figure 4). The simulated annual recharge changes by >18% when using a perturbed rainfall input (Figure 5). Recharge simulations are also sensitive to the soil field capacity and runoff coefficient parameters while the rooting depth, LAI and river bed hydraulic conductivity have a negligible impact on groundwater recharge.

Switching the root distribution to that proposed by Griffiths et al. (2006) and using the wetting threshold method reduced the simulated annual recharge by -2098 (-58%) and -1143 (-31%) km^{3}yr^{-1} respectively indicating that proper understanding and representation of recharge processes is vital to quantify groundwater recharge over Africa.

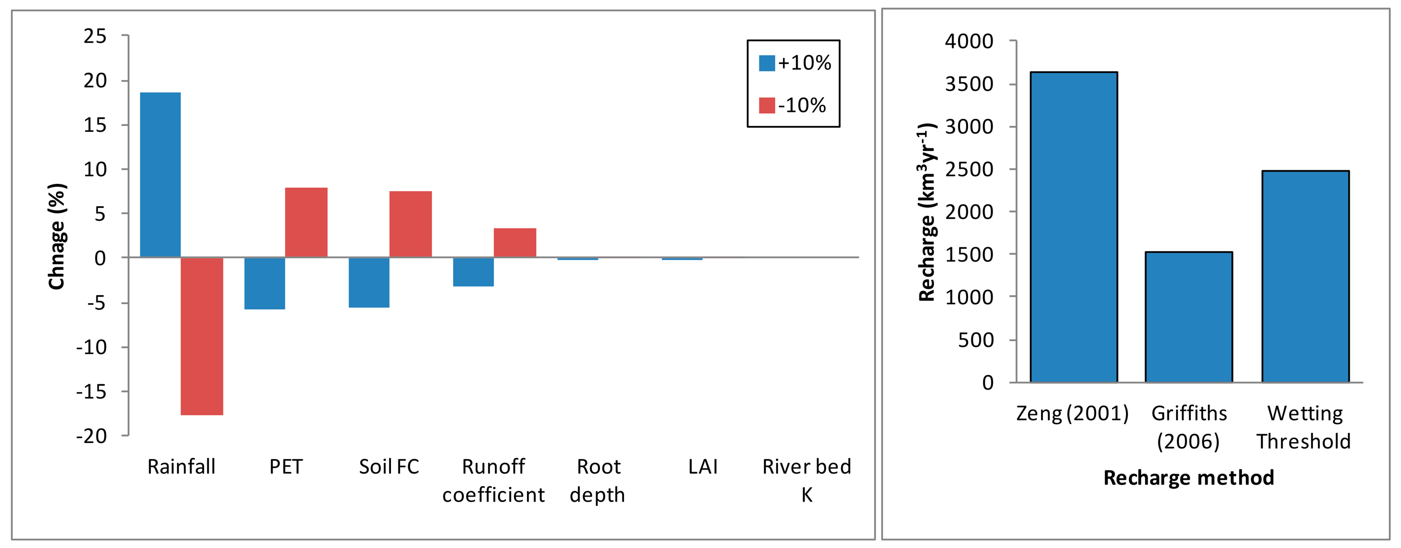

Figure 5 Simulated annual recharge using different model parameters (left) and recharge modelling methods (right).

5 Future work

This preliminary sensitivity analysis indicates that large-scale simulations of groundwater recharge in Africa are likely to be subject to considerable uncertainty. Further research needs to be conducted to quantify this uncertainty through proper examination of model parameter and structure uncertainties. Furthermore, there is still little understanding of which recharge estimation techniques are most suited to contrasting environments over the African continent.

References

Griffiths, J, Keller, V, Morris, D and Young, A R. 2006. Continuous Estimation of River Flows (CERF)—Technical Report: Task 1.3: Model scheme for representing rainfall interception and soil moisture. Environment Agency R & D Project W6-101. Centre for Ecology and Hydrology, Wallingford, UK.

MacDonald, A M, Bonsor, H C, Dochartaigh, B É Ó and Taylor, R G, 2012. Quantitative maps of groundwater resources in Africa. Environmental Research Letters, 7(2), 024009.

Zeng, X. 2001. Global Vegetation Root Distribution for Land Modeling. Journal of Hydrometerology, 2(5), 525–530.

Contact information

Jonathan Mackay email: joncka@bgs.ac.uk tel: +44 (0)115 9363236