Groundwater research issues in Africa

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Abstract

Poverty reduction and economic growth drive the development of groundwater resources across Africa. Due to the ephemeral nature of surface water, groundwater abstraction is often the only realistic and affordable means of providing reliable water supply for much of Africa's needs. However, the large variability in geological and hydrological conditions have a profound influence on the availability of groundwater across the continent, and the sustainable development of the resource depends on an accurate understanding of the hydrogeology and the availability of skilled people to make informed decisions. Despite the obvious need for data, little attention has been paid to the systematic gathering of information about groundwater resources, with the result that data are patchy, knowledge is limited and investment is often poorly targeted. Given the scale of groundwater development in Africa, there is now a pressing need to take groundwater resources seriously and provide a framework and funds for applied groundwater research across Africa to underpin current and future development and management of this precious resource. This framework must recognise the issues of particular concern to Africa, such as: the requirement to develop sustainable and cost effective community water supplies across all hydrogeological environments (even challenging ones); appropriately managing and protecting groundwater resources given the rate of rapid poorly planned urbanisation and the expansion in on-site sanitation and; the imperatives of water security, from household to national levels, with unpredictability of future climate, groundwater recharge and water demand.

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Introduction

Groundwater is Africa's most precious natural resource, providing reliable water supplies for more than 100 million people and, potentially, millions more. Groundwater has many advantages as a source of supply, particularly where populations are still largely rural and demand is dispersed over large areas. In particular, natural groundwater storage provides a buffer against climatic variability; quality is often good, and infrastructure is affordable to poor communities. Sustainable development of the resource is not a trivial task, however, and depends crucially on an understanding of groundwater availability in complex environments, and the processes through which groundwater is recharged and renewed.

Groundwater occurrence depends primarily on geology, geomorphology/weathering and rainfall (both current and historic). The interplay of these three factors gives rise to complex hydrogeological environments with countless variations in the quantity, quality, ease of access and renewability of groundwater resources. Development of the resource therefore depends on an accurate understanding of hydrogeology, and *people* with the skills to make informed decisions on how groundwater can best be developed and managed in a sustainable fashion. Despite these obvious needs, however, little attention has been paid to the systematic gathering of information about groundwater resources, with the result that data are patchy, knowledge is limited and investment is poorly targeted.

This volume highlights the complexity and variety of issues surrounding the development and management of groundwater resources across Africa, and provides a snapshot of groundwater research and application in the early 21st century. Chapters range from strategic discussions of the role of groundwater in development and poverty reduction, to case studies on techniques used to develop groundwater. Some of the issues surrounding the current status of research in Africa arising from the papers in this volume are summarized below, and a roadmap for future research is outlined.

African groundwater resources

Africa has huge diversity in geology, climate and hydrology. As a result, the hydrology of Africa is probably the most variable and challenging of all populated continents (Walling, 1996). For example, annual rainfall varies from negligible over parts of the Sahara, to almost 10,000 mm in the Gulf of Guinea; continent-wide runoff (153 mm) and rainfall/runoff coefficient (0.21) are considerably lower than for any other continent; and southern Africa has the highest variation in mean annual runoff, the greatest flood variability and the highest extreme flood index of any major region (McMahon *et al*., 1992). The great variability in rainfall, and in particular the long dry season (>5 months) over much of Africa, increases reliance on groundwater storage for water supply, providing security against dry season scarcity and longer-term drought.

Geological and hydrological variability have a profound influence on groundwater conditions. Roughly 34% of the land surface is underlain by heterogeneous Precambrian basement; 37% by consolidated sedimentary rocks; 25% by unconsolidated sediments; and 4% by volcanic rocks (MacDonald *et al*., 2008). Some rocks form highly productive aquifers, for example the large sedimentary basins of northern Africa where porosity can exceed 20%, and permeability is sufficient to allow development of high yielding boreholes. However, many other rocks types, such as the less weathered Precambrian basement, or mudstones, are poorly yielding and groundwater may be difficult to find, or non-existent. Figure 1 shows a simplified map of the groundwater resources of Africa.

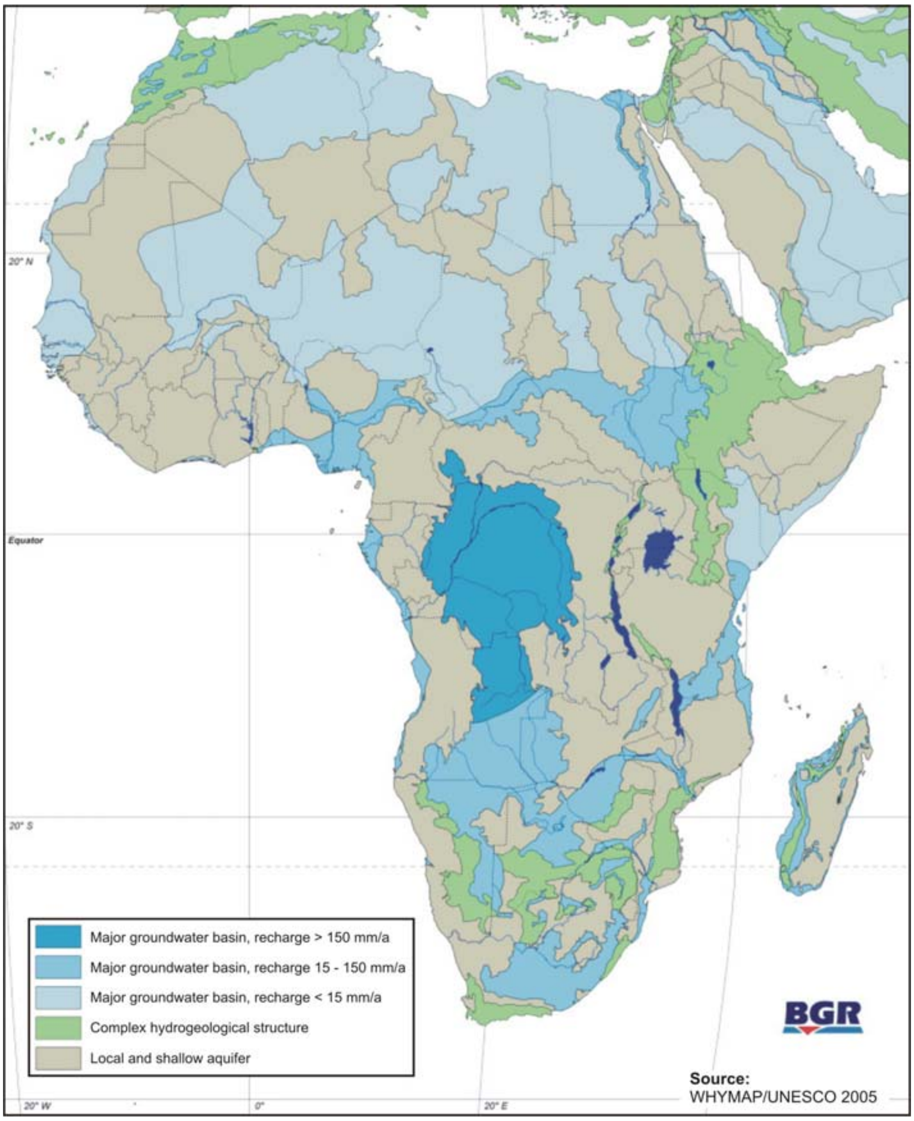

Figure 1. A simplified map of the groundwater resources of Africa (WHYMAP 2005). For more information see Struckmier (2008).

Goundwater is generally of good quality, and is largely protected from pathogenic contamination by the natural filtration of rocks and soil. However, little is known of the groundwater chemistry across much of the continent. The chemistry of the water is variable since it is largely determined by geochemical processes that take place as recharge infiltrates the ground and reacts with rock-forming minerals. In some environments, harmful concentrations of elements can occur, notably elevated concentrations of arsenic or fluoride.

Groundwater resources are often, but not always, renewable. Some of the major aquifers in the north of Africa do not receive significant present day recharge, but rely on rainfall from 5000-10,000 years ago (Edmunds, 2008). Active recharge does occur in many areas, however, and has been shown to occur in areas with annual rainfall as low as 200 mm. Recharge is a complex process and depends on many factors, including the intensity of rainfall events, and soil and aquifer conditions preceding such events. As a consequence, recharge is poorly constrained making it difficult to predict the effect of future climate scenarios.

Groundwater development

Economic development and poverty reduction imperatives drive the development of groundwater resources across Africa. At least 320 million people in the continent still have no access to safe water supplies, and at least 80% of these people live in rural areas (see Figure 2). In view of the ephemeral nature of many surface water bodies, and the need to develop water sources close to or within communities, groundwater development is often the only realistic and affordable means of meeting coverage targets.

How can these targets be met, and what are the main challenges in Africa? The chapters that follow (this volume) provide a number of insights, and can be summarised as follows:

1. In most areas, groundwater is the first option for water supply, and groundwater exploration and development have to take place in challenging environments – environments which many would write-off as non-aquifers. For example, 70 million people may need to rely on groundwater development in weakly permeable mudstone areas.
2. The rapid development of groundwater needed to achieve the Millennium Development Goals for water means that simple, yet fit for purpose techniques for groundwater exploration and development must be used. Ideally, such techniques should be reliable, cost-effective and capable of being applied by local government and project staff.

Figure 2. At least 320 million people in Africa lack access to safe water supplies. Developing groundwater resources is the only realistic way of meeting this need across Africa.

3. Unchecked development of groundwater and lack of testing may mean that water quality problems remain undetected until health problems emerge. For example, quality issues associated with elevated natural fluoride concentrations have caused widespread problems in the East African rift valley.

4. In the absence of government regulation and enforcement, particularly in rural areas, communities have to devise and monitor their own rules governing groundwater use and source protection. This is likely to become increasingly problematic with the rapid increase in the use of latrines for on-site sanitation.

5. Government is unable, or unwilling, to meet the full costs of developing groundwater and maintaining infrastructure. Groundwater users – both urban and rural – now have to meet more of the costs of service provision, so supplies need to be sustainable and affordable.

6. Climate change, and the predictions of less reliable, more extreme rainfall across parts of Africa is likely to impact groundwater resources as people seek more predictable water supplies. Demand for groundwater resources is likely to increase markedly, and in some marginal areas, recharge to groundwater may decline.

Groundwater development may also underpin urban and industrial development. However, developing and managing groundwater resources in urban Africa presents its own challenges:

1. Rapid, unplanned urbanisation can lead to the contamination of groundwater resources. There are many examples of well fields being abandoned and groundwater resources being grossly contaminated by rapid urbanisation and poor sewerage (Adelana *et al*., 2008).

2. Increased demand for groundwater from urban centres has led to overexploitation within urban areas, and in the peri-urban or rural areas beyond them. Symptoms include rapid water-level decline, declining yields and a deterioration in water quality due to salt water intrusion.

3. Industrial sites (including those associated with oil exploration and production) can also threaten groundwater quality. Poor environmental regulation and control can lead to contamination of important aquifers, which may threaten the water supply of people in nearby communities.

4. The use of groundwater to supply rapidly growing small town supplies brings with it a new set of issues. Higher yielding, well protected boreholes are necessary, but require a greater level of expertise and exploration to site and develop, and effective methods to manage.

5. Groundwater is not yet used extensively for large scale irrigation in Africa, though small 'garden' irrigation is not accounted for in irrigation statistics. Foster et al. (2008) cite hydrogeological reasons (the crystalline basement will not support high yielding irrigation boreholes) and socio-economic factors (high capital cost, low levels of rural electrification, and lack of social tradition in irrigated crop cultivation). The challenge for Africa is to develop its irrigation potential – at a range of scales – and avoid the pitfalls of widespread groundwater degradation found in south-east Asia.

A way forward for groundwater research

It is clear that although groundwater supports social and economic development in Africa (particularly in rural areas), the resource is not properly understood. The papers within this volume consistently highlight the lack of systematic data and information on groundwater across Africa. This needs to be rectified. Groundwater studies have occurred on an *ad hoc* basis where resources have allowed researchers to follow an issue of interest. Data are scarce and to a large extent have not been gathered with any rigour over the last two decades. The reasons behind this change are complex (Robins *et al.*, 2006) and include unwanted impacts from decentralisation and rationalisation of government tasks, and the lack of clear demarcation of responsibilities among the various institutions involved in service delivery.

There is a pressing need for international donors and research funding bodies to take groundwater seriously, and provide a framework and funds for future research. The papers in this volume point a way forward:

- For rural water supply, identify how groundwater resources exist in difficult areas not normally taken to be aquifers and develop appropriate but effective techniques for the widespread development of groundwater.
- Groundwater quality must also be taken seriously. There is a critical need for research into the widespread contamination of groundwater resources from sanitation practices, and also more information required on the distribution of harmful substances (such as arsenic and fluoride) in groundwater.
- There must be systematic collection of information on the quality and quantity of groundwater resources to underpin groundwater management, particularly in a changing future. Groundwater models should be developed to test our understanding of the systems, where data allow.
- Management strategies must be developed that are appropriate for Africa, and which leave room for community management, while recognising the larger scale issues such as transboundary and shared aquifers.
- The current recharge and replenishment of groundwater must be known in detail across different aquifer types and climate zones. Only then can it be possible to predict how groundwater may be affected by future climates.
- Interdisciplinary research is needed that will inform understanding of the wider issues of sustainability and in particular the role that reliable groundwater sources will play in providing water security and improving livelihoods.

By learning the lessons of research in other continents, and by developing new research topics appropriate to Africa and African issues, the groundwater resources can be better understood and better managed for the benefit of all people throughout Africa.

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