5 Sub-Saharan Africa: Opportunistic Exploitation

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Introduction

Better control of water is often cited as one of the most important elements for improving agricultural performance and the livelihood of the rural poor in sub-Saharan Africa (SSA). A key reason for this contention is the high variability in the region's natural water supplies. In fact, the spatial and temporal unevenness of the area's water resources (rainfall, river flows and groundwater) is perhaps the greatest of any major region of the world and is of concern in both low and high rainfall areas. While the construction of surface water storage and irrigation could help to even out water distribution – making it easier to take advantage of the Green Revolution and other technologies that revolutionized agricultural landscapes and food supplies in much of Asia – physical, economic and political factors have often hindered their development in SSA. In such circumstances, groundwater would seem to have great potential for a variety of reasons.

Groundwater has been described as a perennial source of water (Calow *et al.*, 1997), a much needed buffer during times of drought (Carter, 1988, in Carter, 2003), and a resource that can be developed for localized use (Butterworth *et al.*, 2001). Carter (2003) even describes groundwater as the ultimate resource for use at local scale, both because it lends itself to incremental development at relatively low cost and because it is more resilient to interannual variability than surface water is. With reference to groundwater, availability where it is needed reduces the need for large-scale infrastructure investments and low variability obviously counters fluctuations in surface supplies – two key issues in the region. Despite these positive and potential attributes, especially in the SSA context, groundwater plays only a relatively limited role.

The reason for the modest groundwater use across all sectors is partly because the hydrogeologic formations underlying most of SSA are not of the type necessary to supply large-scale water resources development. However, the lack of

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similarity to traditional groundwater regions can lead to an underappreciation of the use that does exist in SSA. At the extreme, an estimated 80% of human (mostly rural) and livestock populations in Botswana depend entirely on groundwater (Chenje and Johnson, 1996, in Nicol, 2002), with groundwater contributing up to 65% of all water consumed (Noble *et al.*, 2002). Groundwater is also critical for livestock production in large parts of the Sahel and East Africa. Similarly it plays a critical role in supplying water for small-scale but highly valuable irrigation as well as in stabilizing water supplies in times of drought. Numerous reports highlight the major role groundwater plays in rural domestic supply (BGS, 2000; Carter, 2003). The data on groundwater use are often found distributed among many agencies – donor offices, central government departments and local governments. Other abstraction points are unknown as they are privately installed. It is therefore difficult to estimate actual numbers involved, but the majority of poor rural households depend on groundwater for domestic supply, livestock, crop production and other purposes. Thus an appreciation of the impact of groundwater use in SSA agriculture goes beyond simple calculations of irrigated area to include livestock maintenance, drought mitigation and broader rural livelihood support.

In the past, there have been few attempts at broad-scale research on the role of groundwater in agricultural livelihood in the SSA context and even fewer attempts to quantify that role. As knowledge on this subject is relatively poor, the goal of this paper is to develop as full a picture as possible based generally on published information so as to consolidate known information, highlight critical gaps and inform further research on groundwater and its potential role in solving Africa's water and poverty problems. The paper is divided into four parts: an overview of the known groundwater resources of SSA and their relationship to human population; an overview of agricultural groundwater use and extent, highlighting groundwater's various roles and their possible contribution to rural livelihoods; the state of groundwater governance; and a set of recommendations for development of, and research on, groundwater in SSA.

Groundwater Resources of Sub-Saharan Africa

Understanding the general distribution of water resources in SSA is made difficult by the paucity of data. According to the FAO (2003b, p. 51): 'The information available is uneven and very poor for some of the African countries.' In addition to basic data problems, the distribution of water within Africa is not equal and the continent has the greatest spatial, and temporal, supply variability of any region in the world (Walling, 1996), thus making broad overviews difficult. In general, though, rainfall is greatest on the Guinea coast and in the west-central regions, and drops as one moves east and away from the equator. Low rainfall regions also tend to have irregular rainfall, often leading to crop failures. The unequal rainfall distribution is offset to some degree by the prevalence of exotic rivers such as the Niger, Nile and Okovango. The rainfall and surface water patterns, along with underlying geology, determine groundwater availability, accessibility and its utility for agricultural use.

SSA is generally divided into four main hydrogeological provinces: crystalline basement complex, volcanic rock, consolidated sedimentary rock and unconsolidated sediments (Fig. 5.1). Of the four provinces, the basement complex is largest and occupies over 40% of the area including most of West Africa as well as Zambia, Zimbabwe, the northern belt of South Africa and northern

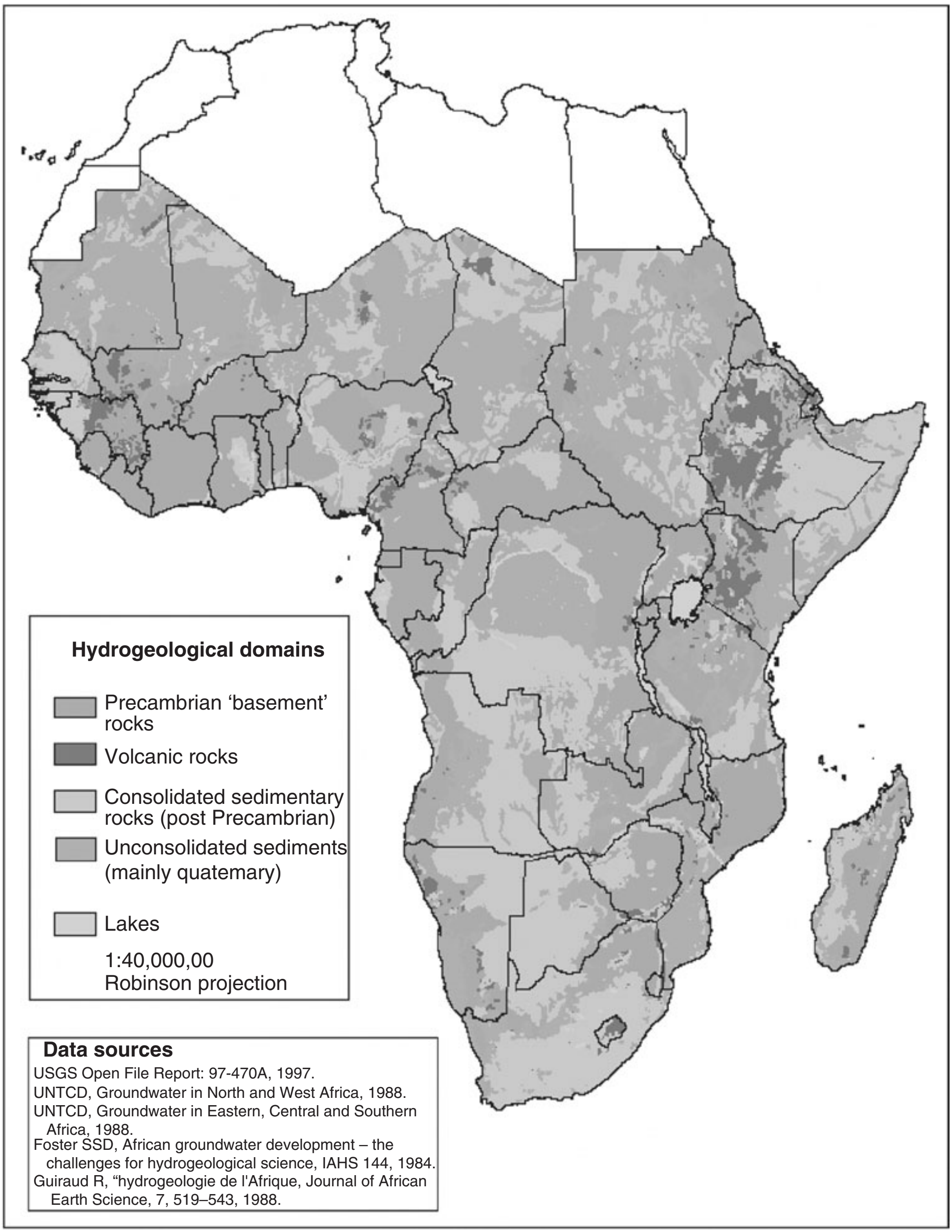

Fig. 5.1. Hydrogeological provinces of Sub-Saharan Africa. (From BGS, 2000.)

Mozambique. Basement complex aquifers have very little or no primary porosity and the groundwater in them is held in the weathered mantle and in fissure zones. These aquifers are characterized by poor storage and low yields, typically less than 1 l/s (Field and Collier, 1998; UNEP, 2003, p. 17).

The second largest aquifer complex, consolidated sedimentary rock, underlies 32% of the area and can hold substantial groundwater reserves (Walling, 1996). However, mudstone areas, which make up approximately two-thirds of this variety, store little groundwater. Most of South Africa, Botswana, southern Angola, eastern Namibia, eastern Democratic Republic of Congo, north-west Zimbabwe and western Zambia are underlain by this aquifer type with limited groundwater occurrence.

Unconsolidated sediments make up 22% of the region's area and often hold groundwater in unconfined conditions within sands and gravels. These aquifers are often found in river beds, and so their groundwater may be especially important for human use due to potential ease of access (MacDonald and Davies, 2000). Unconsolidated sediments are found along the Limpopo River and several of its tributaries, and also in coastal areas, such as the Cape Flats aquifer in South Africa and the coastal zones of the countries at the horn of Africa (Fig. 5.1). However, Purkey and Vermillion (1995) note that many African river systems are typified by fine to very fine sediments, rather than coarse sand and gravel, thus reducing extraction possibilities.

Volcanic rocks cover only about 6% of SSA. In paleosoils and fractures between lava flows they can produce high groundwater yields and supply springs (MacDonald and Davies, 2000). In Djibouti, where groundwater represents 98% of all water used, volcanic aquifers are an important source of water (Jalludin and Razack, 2004). However, in other volcanic areas, groundwater storage can be highly limited (Walling, 1996).

To exemplify the low-yielding aquifers in many parts of SSA, Table 5.1 shows the typical yields in the main aquifers found in South Africa where groundwater studies have been more rigorous than elsewhere in SSA. In Botswana, yields of up to 27 l/s (Table 5.2) have been reported, but generally yields are less than 5 l/s. Where high yields have been found, these have been unsustainable in the long term as they decline rapidly due to limited storage in lower layers of the aquifers (Water Surveys Botswana, Colombo, 2003, unpublished data). In

Table 5.1. Examples of favourable yield characteristics for major aquifers, South Africa (the hydrogeological provinces indicated here are the authors' inferences).

Aquifer type	Hydrogeological province	Typical yield[a] (l/s)
Alluvial deposits	Unconsolidated sediments	3–8
Coastal sands	Unconsolidated sediments	3–16
Karoo sediments	Unconsolidated sediments	1–3
Table mountain sandstone	Consolidated sediments	1–10
Dolomite (Karst)	Consolidated sediment	20–50
Granite (weathered)	Basement complex	5–10

[a]From DWAF (1998, p. 33).

Table 5.2. Borehole yields in selected well fields in Botswana. (From Department of Water Affairs, 2000.)

Wellfield	Hydrogeological province[a]	Average borehole yield 1998–2000[b] (l/s)
Palla Road	Unconsolidated sediments	11.11
Kanye	Unconsolidated sediments	10.47
Serowe	Unconsolidated sediments	1.75
Palapye	Basement complex	5.92
Gaotlhobogwe	Basement complex	27.78
Molepolole	Basement complex	6.47
Thamaga	Basement complex	4.17
Malotwane	Basement complex	3.39
Letlhakane	Unconsolidated sediments	6.22
Lecheng	Basement complex	2.53
Shoshong	Basement complex	1.75
Moshupa	Basement complex	1.58
Metsimotlhabe	Basement complex	1.53
Mochudi	Basement complex	1.39
Chadibe	Basement complex	0.94
Sefhare	Basement complex	2.67
Pitsanyane	Unconsolidated sediments	1.66

[a]From WMA Report to IWMI (2003).
[b]From Department of Water Affairs (2000).

the basement complex aquifer in Burkina Faso, yields are typically less than 1 l/s, whereas in the sedimentary aquifers yields reach 27 l/s (Obuobie and Barry, forthcoming). Planning for the use of groundwater in basement complex aquifers is further complicated by large seasonal variation in groundwater levels. These have been observed to range from 1 to 5 m in basement complex aquifers (Chilton and Foster, 1995). Depth to extractable groundwater appears to be another limiting factor for its use in SSA. In the Limpopo basin in South Africa depth to groundwater is highly variable, and borehole depths range from 50 to more than 100 m. In Lesotho, groundwater occurs mostly at depths of more than 50 m; in Zambia most boreholes are drilled to 44 m depth (Wurzel, 2001); in Zimbabwe borehole depths range from 25 to more than 100 m (Interconsult, 1986). In Mozambique, depth to extractable groundwater is up to 35 m in some areas, but can be up to 100 m in others. The high costs of abstraction associated with groundwater use including costs of unsuccessful drilling are seen as a major drawback to the use of groundwater in SSA.

The relationship between population distribution and SSA's groundwater provinces provides some insights into current agricultural groundwater use patterns and potential future development. Around three quarters of the SSA population lives in areas of poor groundwater availability, with 220 million people in low-yielding crystalline basement complex areas and about 110 million in areas of consolidated sediment. In these areas dwell most of the rural population, the socio-economic group often affected by problems of water access and who could potentially benefit from groundwater use. But because of the limiting factors alluded to above, there is a limit to how much groundwater they can use and the extent to which groundwater can impact their livelihood. Another 15% (60 million) of the population lives in areas with unconsolidated sediment, though most are not near areas with easy access to productive alluvial aquifers. The remaining 10% of the population (45 million) lives in volcanic rock zones with high but variable groundwater potential.

The most comprehensive water resource availability and use database for SSA to date is the FAO AQUASTAT. Although this database was originally designed with reference to agricultural use, it remains the most complete source of data for SSA. This database shows that for many of the SSA countries, groundwater is a small component of overall renewable water resources, suggesting limited contribution of groundwater to overall water requirements. Only 11 out of the 45 SSA countries listed in the AQUASTAT database have at least 10% of their renewable water resources made up of groundwater (Table 5.3),[1] and only 6 of these countries have per capita groundwater availability above 1000 m^3. Per capita water availability of surface water in Africa is generally much higher than the groundwater availability indicated here (see Savenije and van der Zaag, 2000),

Table 5.3. Groundwater availability and use in sub-Saharan Africa. Source: AQUASTAT, literature.

Country	Groundwater produced internally[a] (km^3/year)	Groundwater/ total renewable water resources[a]	Per capita groundwater availability[b] (m^3/year)	Information on use available[c]
Angola	2	0.01	179	No
Benin	0.3	0.03	40	No
Botswana	1.2	0.41	732	Yes
Burkina Faso	4.5	0.36	323	Yes
Burundi	0.1	0.03	16	No
Cameroon	5	0.02	305	No
Cape Verde	0.1	0.33	239	No
Central African Republic	0	0.00		No
Chad	1.5	0.10	153	No
Comoros	1	0.83	1490	No
Congo	0	0.00	–	No
Democratic Republic of Congo	1	0.00	17	No
Cote d'Ivoire	2.7	0.04	156	No
Djibouti	0	0.00	–	Yes
Equatorial Guinea	1	0.04	1866	No
Eritrea		0.00	–	No
Ethiopia	0	0.00	–	Yes
Gabon	2	0.01	1440	No
Gambia	0	0.00	–	No

Table 5.3. *Continued*

Country	Groundwater produced internally[a] (km^3/year)	Groundwater/ total renewable water resources[a]	Per capita groundwater availability[b] (m^3/year)	Information on use available[c]
Ghana	1.3	0.04	62	Yes
Guinea	0	0.00	–	No
Guinea-Bissau	4	0.25	2825	No
Kenya	3	0.15	89	Yes
Lesotho	0	0.00	–	No
Liberia	0	0.00	–	No
Madagascar	5	0.01	277	No
Malawi	0	0.00	–	No
Mali	10	0.17	814	Yes
Mauritius	0.2	0.09	163	No
Mozambique	2	0.02	103	No
Namibia	2.1	0.34	1034	Yes
Niger	2.5	0.71	214	Yes
Nigeria	7	0.03	54	Yes – limited
Rwanda	0	0.00	–	No
Senegal	2.6	0.10	234	No
Sierra Leone	10	0.06	1662	No
Somalia	0.3	0.05	35	No
South Africa	1.8	0.04	41	Yes
Sudan	2	0.07	50	Yes – limited
Swaziland	–	0.00	–	No
Tanzania	2	0.02	54	No
Togo	0.7	0.06	123	No
Uganda	0	0.00	–	No
Zambia	0	0.00	–	Yes
Zimbabwe	1	0.07	78	Yes

[a]Derived from AQUASTAT.
[b]From http://www.geohive.com
[c]From literature.

though in regions without surface water, groundwater becomes the only source available. Thus, to the region as a whole, groundwater will only play a relatively small role in agriculture because of the absolute levels of resource availability and the size of the resource relative to surface water. However, such generalizations can be misleading in national or even subnational contexts because of the great spatial and temporal variability in both ground and surface supplies.

Agricultural Groundwater Use in SSA

As shown in Table 5.3, national statistics on water use are not readily available for most countries. As such it is clear that one must consult multiple and often inconsistent data sources to paint even a rudimentary picture of its use at a continental scale. This approach is of course fraught with problems. For example, most use appears to be in small rural villages, where boreholes and wells have been installed by multiple agencies: government, individuals, non-governmental organizations (NGOs) and relief agencies. This use is scattered and individually quite small and therefore both difficult to measure and seemingly inconsequential. As a result, it frequently goes unreported (UNEP, 2003, p. 2), and total use tends to be underestimated. The cumulative impact of even small-scale uses of groundwater can be significant as the many scattered boreholes in Burkina Faso (Fig. 5.2) or the many shallow wells and deep tube wells in wadi systems (alluvial aquifers) in Djibouti (Jalludin and Razack, 2004) illustrate.

Examining the history of groundwater development in the region also highlights the difficulties in collecting meaningful statistics for groundwater use. For example, in southern Africa some of the literature relating to groundwater use is project-based or localized. Often, one has to consult multiple sources (government, consultants, NGOs and even individual water users) to construct a meaningful database relating to use. Here, an attempt is made at classifying groundwater use according to development objective and the agents responsible for installation of boreholes or wells (Table 5.4). One of the challenges arising from such a model of groundwater development is poor coordination of agents and the difficulty in trying to establish the actual extent of groundwater use or the number of boreholes drilled and used. In this scenario, it is also very difficult to capture the extent of groundwater use for livelihood and other purposes and its overall contribution to the economy.

Despite the problems associated with lack of data or incomplete data, some of the data available do present a picture that agricultural groundwater use is important at local scales in parts of SSA. For example, in the Limpopo province in northern South Africa there are reportedly more than 35,000 boreholes mostly used for domestic water and irrigation of small gardens, and Asian-style growth rates (see Wang *et al.*, Chapter 3, and Sakthivadivel, Chapter 10, this volume) in development have been documented (Tewari, forthcoming). In semi-arid Botswana, water supply is largely groundwater-based (Brunner *et al.*, 2004). Groundwater in Botswana is mostly used for rural, domestic and livestock purposes and this has steadily increased over the last 30 years, as shown by the number of registered boreholes in the country (Fig. 5.3). The increase in groundwater use in Botswana has been accompanied by overdraft as the abstraction is presumably greater than recharge (Kgathi, 1999). Such use of groundwater is mirrored in several other countries. Pockets of small-scale groundwater irrigation are found in Tanzania where reportedly 200 ha are irrigated using diesel and electric pumps; and in Malawi and Zimbabwe where collector wells are used to abstract water from weathered basement complex aquifers (FAO, 1997). In Cameroon, groundwater makes up only 2% of renewable water resources (Table 5.3). Yet, in the north of the country, where reservoirs are limited and precipitation is lower than the national average, groundwater is the most widely available water resource and is used for domestic, agricultural and industrial purposes (Njitchoua *et al.*, 1997). Similarly, in Borno and Yobe of Nigeria's Lake Chad basin, groundwater is the predominant source of domestic

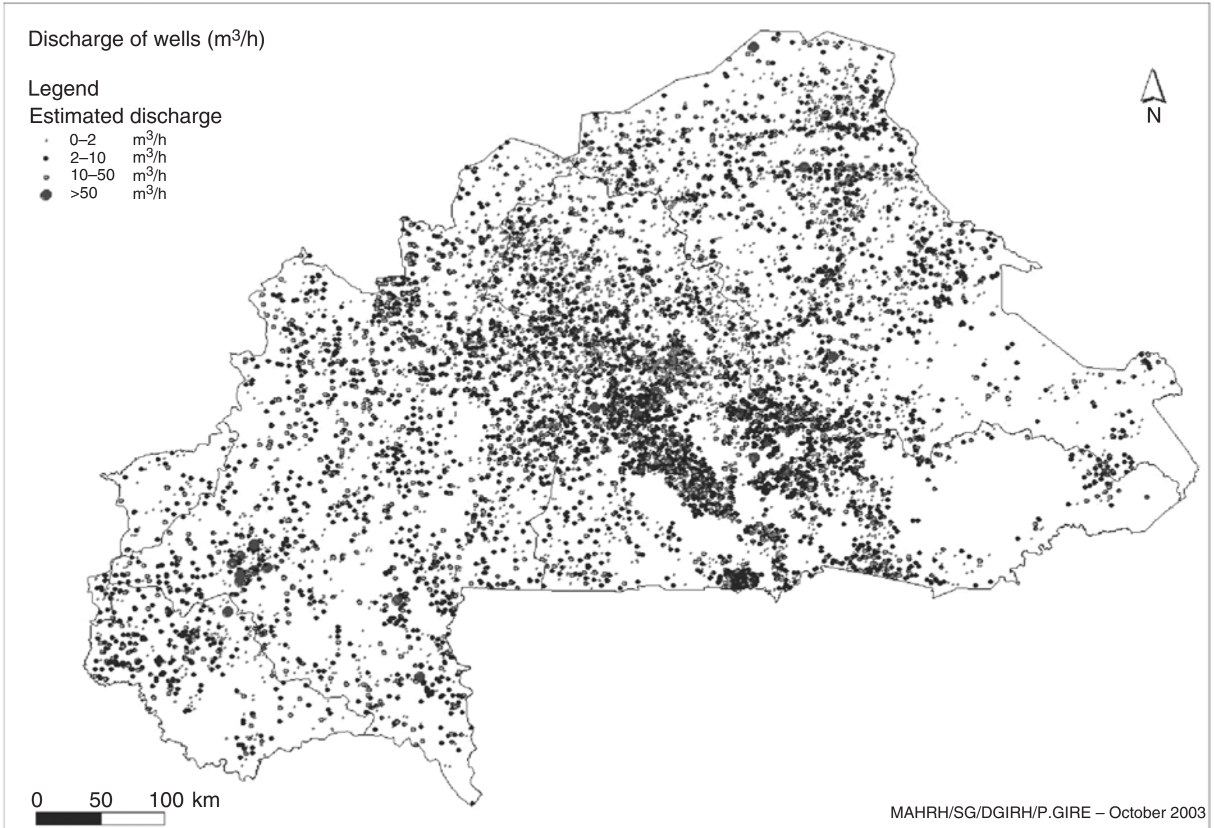

Fig. 5.2. Wells across Burkina Faso. (From Obuobie and Barry, forthcoming.)

Table 5.4. Types of groundwater use in SSA.

Type of groundwater use	Purpose	Responsible agent for borehole/well installation
Drought mitigation	Livestock watering Agriculture (crops)– bridging mechanism so that crops do not fail to mature Domestic water supply	Individuals Government
Normal supply	Domestic water Commercial irrigation	Individuals NGOs Municipalities Government in the case of rural communities (both central and local)
Emergency relief	Domestic water during drought years Stock water	NGOs CBOs Governments Churches
Social responsibility activities	Boreholes installed as part of ongoing aid and development activities	NGOs CBOs Governments Churches

NGO – non-governmental organization.
CBO – community-based organization.

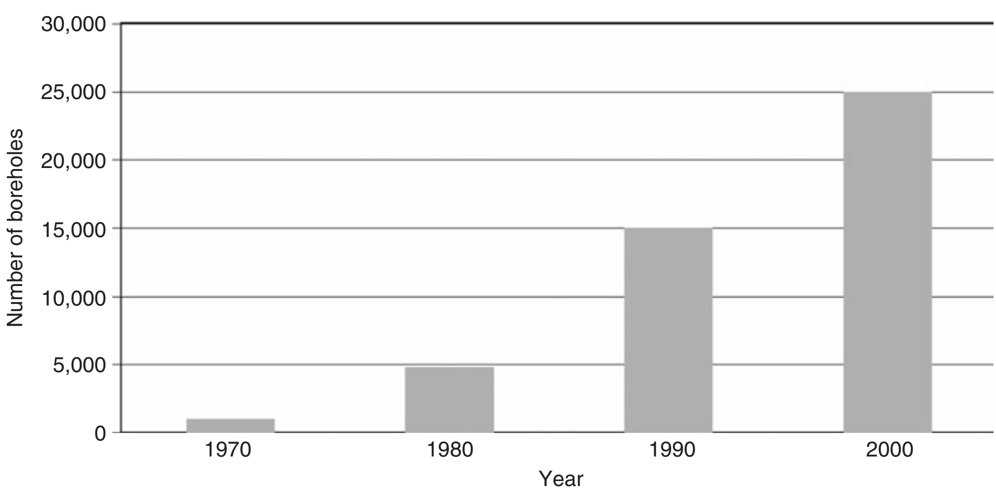

Fig. 5.3. Number of boreholes drilled over time in Botswana. (From DWA, 2002.)

water and for other non-irrigation uses, and more than 2000 boreholes are used in the two states alone (Bunu, 1999).

In addition to the numerous small-scale groundwater uses in SSA such as those mentioned above, large-scale commercial irrigation occupies the largest usage of groundwater, especially in South Africa in the Karst aquifer region of the upper Limpopo River basin in the north-west province where about 77 million cubic metres are abstracted annually for irrigation (IUCN, 2004), and in the wider Limpopo Water Management Area where about 850 million cubic metres are abstracted annually for irrigation (Basson *et al.*, 1997). Also, the Karst aquifers in the Lomagundi area (central Zimbabwe) and the Nyamandhlovu aquifer (western Zimbabwe) are exploited for commercial irrigation (Masiyandima, forthcoming). Irrigation officials in Zimbabwe estimate that more than 17,000 ha are irrigated commercially using groundwater.

Combining AQUASTAT figures with the results of a set of county surveys and some assumptions, Giordano (2006) estimated that there were perhaps 1 million hectares of groundwater irrigation in SSA. Although this is a rough estimate, it gives some indication of the possible direct role of groundwater in agricultural production in SSA. In an effort to measure the value of groundwater in other regions where use is more widespread and forms part of broader irrigated settings, irrigated area or the volume of water applied can be a reasonable measure of agricultural impact. By such measures, the value of groundwater in SSA is clearly small given the region's physical size and rural population. Yet groundwater is still considered the resource of choice in many, particularly rural, areas. The importance accorded to groundwater in parts of SSA is reflected by the number of site-specific studies on certain aspects of groundwater use such as recharge (Taylor and Howard, 1996; Njitchoua *et al.*, 1997; Brunner *et al.*, 2004). There have been many other groundwater recharge studies: in the Kalahari in Botswana (de Vries *et al.*, 2000), Ghana (Asomaning, 1992), Kenya (Singh *et al.*, 1984), Uganda (Howard and Karundu, 1992), Zambia (Houston, 1982) and Zimbabwe (Houston, 1990). Most studies try to quantify available groundwater resource from recharge.

Given the general belief that groundwater has been relatively undeveloped in SSA, it is not surprising that most studies focus on increased use. Yet, there are indications from a number of regions that the 'development' stage discussed by Shah and Kemper (respectively Chapter 2 and Chapter 8, this volume) has already been passed and overabstraction is now the issue. For example, farmers in the Dendron area in the Limpopo province of South Africa have experienced declining water levels over the last two decades in the aquifers that supply all of their irrigation (Masiyandima *et al.,* 2001). Similar problems have been reported in the Nubian aquifer system (which is admittedly a fossil system with no recharge) in northern SSA (Ulf and Manfred, 2002) and in other arid and semi-arid environments such as in Botswana. Abstraction of groundwater from Botswana's aquifers generally exceeds annual recharge (Kgathi, 1999). This is manifested by the declining water levels in several well fields. According to the Department of Water Affairs (Botswana), in some well fields groundwater levels are declining by as much as 2.6 m/year. Clearly there is little scope of additional groundwater development in such areas.

Livestock production

Large areas of savannah, semi-desert and desert areas in SSA are typified by livestock, rather than crop, production. While cattle tend to dominate the livestock economy, sheep, goats and, especially in deserts or near-desert environments, camels can also play important roles. In general, cattle density is highest in the Sahel region and roughly along the line from Ethiopia along the rift valley to South Africa and Lesotho (Thornton *et al.*, 2002). Livestock production is also pronounced in the drier areas of southern and eastern Africa, particularly in Botswana and Kenya.

In these arid areas, groundwater plays a critical role in the maintenance of the livestock economy, which is itself the basis of human survival of the poorest segments. In Somalia, for example, the only agricultural use of groundwater is for livestock watering (Ndiritu, 2004, unpublished data). In Botswana, a major livestock-producing country in southern Africa, groundwater is the main source of stock water. For Ghana, it is estimated that 70% of cattle and 40% of other livestock production account for 4.5% of agricultural gross domestic product (GDP) and all depend entirely on groundwater use (Obuobie and Barry, forthcoming). As a general indication of the role of livestock in rural livelihood and the role of groundwater in sustaining those livelihoods, the FAO (1986, p. 137) states that 'groundwater is more widespread than surface water in the Sahel, although it is at present exploited mainly for domestic and livestock purposes, from traditional wells with yields too low for irrigation'. As with irrigation, quantification of the contribution of groundwater to SSA's total livestock economy, based on published sources, is problematic. The World Bank has estimated that 10% of SSA's population is directly dependent on livestock production (McIntire *et al.*, 1992). Thornton *et al.* (2002) estimated that there are more than 160 million poor in SSA, and roughly one-third of the total population keep livestock. Given that a large share of livestock production is likely groundwater-dependent, the value of groundwater in SSA's overall livestock economy and in the livelihood of its poorest residents is clearly substantial.

Drought mitigation

Since groundwater supplies are less correlated with rainfall than surface supplies, one of groundwater's key functions can be its ability to mitigate the effects of erratic rainfall or drought on agricultural production. While this function is of global importance, it may be especially so in SSA where temporal rainfall variability, as outlined earlier, is amongst the highest in the world. In fact, African pastoral societies have taken advantage of groundwater to mitigate the impact of temporal variation in rainfall supply for centuries. The focus is now on the role of groundwater in moderating the impacts of drought on domestic water supply to rural communities (Gillham, 1997) and on crops. A case in point is the considerable expansion of irrigation in general, including wells, following the 1968–1973 droughts in Sahel (Morris *et al.*, 1984, p. 14). There are also numerous papers that highlight that role (Amad, 1988; Calow *et al.*, 1997).

In contrast to valuations of groundwater supply in crop and livestock production where relatively straightforward estimates can be made based on total area, number of animals or value of output (if data are available), estimating the drought mitigation value of groundwater is complicated by two primary reasons. First, the knowledge that groundwater is available as an alternative to surface or rainwater reduces risk and makes farming and livestock production possible in areas where it would otherwise not occur. Thus the value of some production based on non-groundwater sources, especially in marginal lands, can in fact be attributed to groundwater. Second, the role of groundwater in drought mitigation highlights the issue of *marginal*, as opposed to average, valuation of water resources.

Rural domestic supplies

Groundwater plays a role in providing domestic supplies to the rural population in many countries in SSA. According to the Southern African Development Community (SADC) statistics, groundwater is the primary source of drinking water for both humans and livestock in the driest areas of SADC, and it is estimated that about 60% of the population depends on groundwater resources for domestic water. In the Limpopo River water management area in South Africa rural domestic supply accounts for 55 million cubic metres of groundwater abstracted, or just more than 20% of all groundwater abstracted. Admittedly, groundwater resources in SSA are modest, but are sufficient and important at local levels as they are the main resource for water supply for rural populations, e.g. in parts of rural Zimbabwe, Mozambique (Juizo, 2005), Zambia and Botswana). Although precise numbers are lacking, it is likely that most domestic water supply in rural SSA is currently from groundwater and that expansion in rural supplies in the near future will likely be from groundwater sources. Further, within the rural sector, domestic use, rather than agriculture or livestock, appears to account for the vast majority of demand. This was true, for example, in all cases examined in SSA with the exception of South Africa (Obuobie and Giordano, forthcoming). Groundwater thus provides the foundation for rural livelihood whether or not it is directly used in agricultural or livestock production.

Mining

In Botswana and South Africa, groundwater is particularly important for mining. In Botswana, mining accounted for more than 60% of all abstractions at the turn of the century. In South Africa, the mining operations for platinum, diamond, tin, chrome, fluorspar, graphite, granite, silicon, vanadium, copper, manganese and coal in the Limpopo province depend largely on groundwater. In 2002, more than 70% of the water used for mining in the province was groundwater. In South Africa, the mining demand is overshadowed by both irrigation and domestic water demand but is expected to grow as the mining sector promises to remain a strong economic driver in the Limpopo province. The problem with groundwater use for mining may not be related as much to the volumes extracted as to the contamination of both surface and groundwater resources associated with it.

Urban use

In addition to small-scale use of groundwater in rural areas, there is pronounced use in many urban centres. The large cities that are groundwater-dependent in SSA are shown in Fig. 5.4. Even in cases in which groundwater is a small fraction of total water use, it represents a stable source of water, which is one of its important characteristics, particularly in dry years. In addition to the large

Fig. 5.4. Groundwater-dependent cities in SSA. (From UNEP, 2003.)

cities shown in Fig. 5.4, there are several urban centres that depend on groundwater which are not included in this map. Many small towns are dependent on groundwater for water supply. This is the case in Burkina Faso (Obuobie and Barry, forthcoming) and in Botswana's so-called minor villages. In South Africa about 105 towns depend entirely on groundwater (Tewari, 2002). It is generally accepted that many people in SSA depend on groundwater for drinking water supply. However, the actual number of people using groundwater for this purpose is unknown (see UNEP, 2003, p. 3). The fact that urban use is widespread shows that it is not as much a question of availability and accessibility and economic feasibility as it is of economic means and political decision and will to develop it.

Groundwater, livelihood and poverty

Groundwater use in SSA clearly contributes to livelihood through agricultural production – in the form of irrigation supply, livestock support and drought mitigation and in domestic supplies as outlined above. In the context of SSA, the benefits of groundwater use likely accrue primarily to the poor, because they make up the vast majority of rural agricultural producers. While the general connections between groundwater, livelihood and poverty in SSA are clear, quantifying the role that agricultural groundwater use plays in poverty alleviation and livelihood support is difficult.

Small rural communities in many southern and east African countries make use of groundwater from shallow aquifer systems associated with wetlands to produce crops both for household consumption and sale. In surveys carried out in about 20 communities across the southern African region,[2] wetland crop production contributed up to 50% of household food, and more than 50% of total annual household income (Masiyandima *et al*., 2004). If we assume that 20% of the wetland systems in Zambia and Malawi are cultivated for such uses, about 600,000 ha are under cultivation. At an average annual household gross income of about $200/ha, the total gross income from such groundwater use is estimated to be well over $100 million. This can be compared to a value of $50–55 billion for the irrigation economy of India (Shah, Chapter 2, this volume).

While recognition of groundwater use in SSA wetlands is generally low, it is in fact better recognized than other small-scale uses of groundwater. In general, data on this sector are often limited and data on groundwater use, in particular that related to small-scale uses by poor farmers, are often non-existent as already discussed. Even government departments responsible for groundwater sometimes do not seem to have accurate information regarding the groundwater situation. While information from some government agencies indicates that the area under smallholder irrigation in South Africa is quite small (Nel, 2004, Pretoria, South Africa personal communication),[3] Busari and Sotsaka (2001) found that there is at least one community garden in each of the 70 villages around the Giyani area in the Limpopo basin, with gardens ranging in area from 1 to 25 ha. Community gardens are also to be found in many other villages across the Limpopo province. In 2001, the Limpopo province Department of Agriculture had a database with some of the community gardens irrigated with groundwater.[4] On the basis of pumping hours and pump discharges detailed in the database, abstraction for irrigating community gardens is estimated at about 3 million cubic metres annually, less than 2% of the reported groundwater abstraction for irrigation in the Limpopo water management area.[5] While this use may appear extremely modest from a water-accounting standpoint, it plays a significant role in the lives of the farmers who use it, enabling them to produce food and reduce their dependence on government and donor agencies for food.

In considering the impact of groundwater on livelihood and poverty in SSA, it is important to consider the costs associated with the use of groundwater, particularly drilling and operation and maintenance of equipment. In comparison with India, and perhaps other regions, such costs are high in SSA. Drilling costs, though variable across the continent, are still largely prohibitive. Wurzel (2001) estimated the average drilling cost in Africa to be $100/m, more than tenfold that in India. In 1996, borehole drilling costs were approximately $37/m in Mozambique while in Lesotho it was $23/m (Wurzel, 2001). In Zimbabwe drilling costs were estimated to be about $40/m in 2004 (Masiyandima, forthcoming). Combining these costs with the poor drilling success rate for boreholes (common in hard-rock areas), the cost of development of groundwater may still be difficult to justify in many places, even for targeted use such as rural domestic water supply.

Groundwater Governance

In SSA, there are customary or traditional mechanisms to regulate groundwater use in some areas. However, there have been relatively few efforts to develop formal groundwater governance mechanisms in most of the continent. This may be in part because of the general belief that groundwater potential has not been fully exploited and so the need for governance has not generally arisen. The lack of formal groundwater governance mechanisms may also be related to the fact that formal water policy in general has not received much emphasis until recently. Examples of this can be observed in Burkina Faso and Ghana where national water policies are still to be put into practice. Whatever the case, in many countries in SSA, the mechanisms for water governance in general, at least formally, were weak or non-existent prior to the recent set of water policy reforms that sprouted across Africa since the late 1990s. If the situation for surface water is bad, mechanisms for groundwater governance are as bad or worse.

However, the past few years have been marked by significant reforms in the water sectors in a number of countries in SSA. The aims of the reforms are numerous and these are summarized by Van Koppen (2002) as:

- Better integrate the management of water resources (multiple-use sectors; quantitative and qualitative; beneficial and non-beneficial uses; surface and groundwaters; hydrological, legal and institutional aspects; water and other sectors; governments and other stakeholders).

- (Further) prioritize domestic water supply in rural areas usually through local government and in urban areas sometimes through new public–private partnerships for water supplies (Mozambique, South Africa, Uganda, Zambia).
- Harmonize fragmented pieces of formal legislation into new policy and legislation.
- Specify the role of the government – invariably the custodian of the nation's water resources – complementary to newly established decentralized basin authorities and in some cases national bodies, such as the Water Resources Commission in Ghana or parastatals like the Zimbabwe National Water Authority.
- Shift and decentralize the boundaries of lower-level water management institutions to basins in order to better match hydrological reality.
- Design and implement national water right systems, accompanied by water charges and taxing.
- Stimulate users' participation, especially in basin-level and lower-tier water management institutions.
- Protect water quality and environmental needs.
- Improve hydrological assessments and monitoring for surface and groundwaters and ensure public availability of data.
- Promote international cooperation in trans-boundary basins.
- Redress the race, gender and class inequities of the colonial past (in Zimbabwe and South Africa).

The limited use of groundwater has perhaps meant little need for governance structures in the past. The situation has changed in some areas, with problems of overabstraction arising. Potentially, such cases will benefit from some form of regulation, and the reforms in the water sector offer opportunities for better control and regulation.

Conclusions

Given the impacts of groundwater utilization on agriculture and livelihood in Asia and the many advantages of using groundwater, it is not surprising that groundwater is considered as an option for water supply for various uses and also as having an impact on poverty in SSA. However, this chapter has highlighted some of the reasons why agricultural groundwater use is, and will likely remain, relatively limited.

The main reason for the limited contribution of groundwater to overall water resources in SSA is the hydrogeology – low-yielding aquifers and depth of occurrence of the groundwater. This is compounded by the fact that the rural population that could benefit from the groundwater is located in areas with aquifers not suitable for large-scale abstraction of groundwater or with their supply not prioritized by national agents. However, groundwater has its role – for mitigating the impacts of drought, rural domestic supplies, stock water and irrigation at local scale. To obtain a better picture of current and potential future contribution in these areas, there is need for a shift from the traditional analyses focusing on national and regional scales to more local levels where the limited opportunities exist.

Even where groundwater is available, most of the rural poor who could benefit most from it are not in a position to pay the capital costs associated with developing the resource. We have seen in the case of South Africa that development costs are higher than in many other regions. Combining this with the fact that farmers are poorer than in many other regions means that groundwater does not lend itself to the fast development that has been seen elsewhere.

We will likely continue to see the benefits of groundwater for rural domestic use and livestock watering, as well as small-scale irrigation in SSA. Increase in use beyond these sectors is highly unlikely due to resource limitations and high costs associated with the use of groundwater. Groundwater use is best explored where such factors working against its use are minimal. This has happened in some cases – in Botswana and in agricultural regions in South Africa (where incomes are also relatively high) where groundwater has continued to expand despite the associated overdraft. Cases need to be evaluated on an individual basis, and opportunities exploited in the best possible way.

While it is likely that the groundwater resources of SSA can provide solutions to the problems of water accessibility faced by some of the region's agricultural and rural communities, the limitations highlighted in this report suggest that this role should be seen as strategic. Opportunistic use of groundwater should be followed. The major challenge in following strategic and opportunistic approaches is limited information. The focus of the effort on groundwater research in many of the SSA countries should be to consolidate available knowledge and begin to construct adequate data on availability and how then to foster finance to develop use in those strategic locations.

Notes

1 Derived from AQUASTAT statistics (FAO, 2003a,b).
2 Communities in South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.
3 Jaco Nel is a geohydrologist with the Department of Water Affairs, Pretoria, South Africa.
4 Data obtained from Engineer Martinus Gouws, Limpopo Province Department of Agriculture (2001).
5 From the Limpopo Province Department of Agriculture (South Africa) community garden database.

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