

1 **What impact will climate change have on rural groundwater supplies in Africa?**

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11  
12 **Abstract** One of the key uncertainties surrounding the impacts of climate change in Africa is  
13 the effect on the sustainability of rural water supplies. Many of these water supplies abstract  
14 from shallow groundwater (<50 m) and are the sole source of safe drinking water for rural  
15 populations. Analysis of existing rainfall and recharge studies suggests that climate change is  
16 unlikely to lead to widespread catastrophic failure of improved rural groundwater supplies.  
17 These require only 10 mm of recharge annually per year to support a handpump, which  
18 should still be achievable for much of the continent, although up to 90 million people may be  
19 affected in marginal groundwater recharge areas (200-500 mm annual rainfall).

20  
21 Lessons learnt from groundwater source behaviour during recent droughts, substantiated by  
22 groundwater modelling, indicates that increased demand on dispersed water points, as shallow  
23 unimproved sources progressively fail, poses a much greater risk of individual source failure  
24 than regional resource depletion. Low yielding sources in poor aquifers are most at risk.  
25 Predicted increased rainfall intensity will also increase the risk of contamination of very  
26 shallow groundwater. Looking to the future, an increase in major groundwater-based  
27 irrigation systems, as food prices rise and surface water becomes more unreliable, may  
28 threaten long-term sustainability as competition for groundwater increases. To help prepare  
29 for increased climate variability it is essential to understand the balance between water  
30 availability, access to water, and use/demand. In practice this means increasing access to  
31 secure domestic water, understanding and mapping renewable and non-renewable  
32 groundwater resources, promoting small-scale irrigation and widening the scope of early  
33 warning systems and mapping to include access to water.

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35  
36 **Key Words** groundwater; climate; Africa; water supply; drought; agriculture

## 1 INTRODUCTION

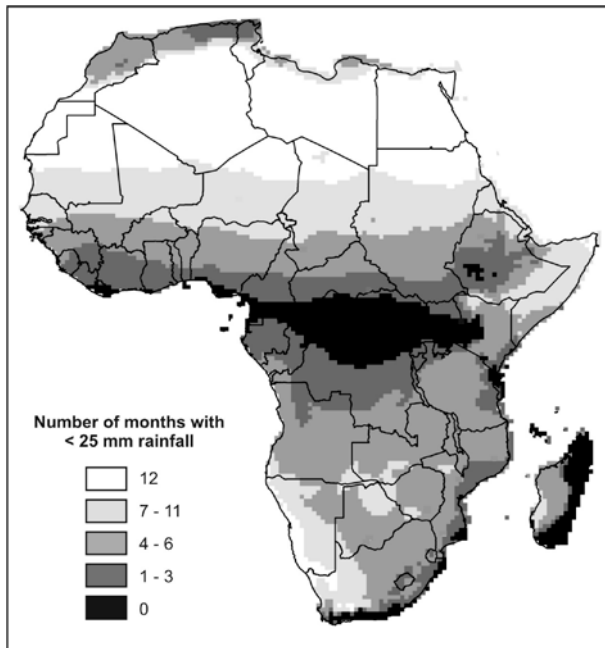
2 One of the key uncertainties surrounding the impacts of a changing climate in Africa is the  
 3 effect that it will have on the sustainability of rural water supplies. Of Africa's population of  
 4 900 million, roughly 60% live in rural areas and rely on small community or household  
 5 supplies (JMP, 2008). Less than half of the rural population currently have access to secure  
 6 water (e.g., improved boreholes, wells or treated surface water) – the majority still rely on  
 7 ponds, seepages or unprotected shallow wells.

8  
 9 The safety and reliability of water supplies are fundamental to the livelihood security of rural  
 10 communities. Continuing access to safe water generates major health benefits (Moore *et al.*,  
 11 1993); supports food production and consumption (directly or indirectly) and reduces poverty  
 12 (Carter & Bevan, 2008; Calow *et al.*, 2009). In a global study of the costs and benefits of  
 13 improved water supply and sanitation, WHO (2004) concluded that the wider socio-economic  
 14 benefits of safe water and adequate sanitation ranged from US\$3 to US\$34 per US\$ invested,  
 15 with the highest returns in Africa, hence the international community's commitment to reduce  
 16 by half those without safe water by 2015 (United Nations, 2000), as set out in the Millennium  
 17 Development Goals (MDGs). In Africa, however, progress towards meeting these goals has  
 18 been slow and patchy. At current rates of coverage improvement the target is not expected to  
 19 be met until 2050, at the earliest (United Nations, 2006).

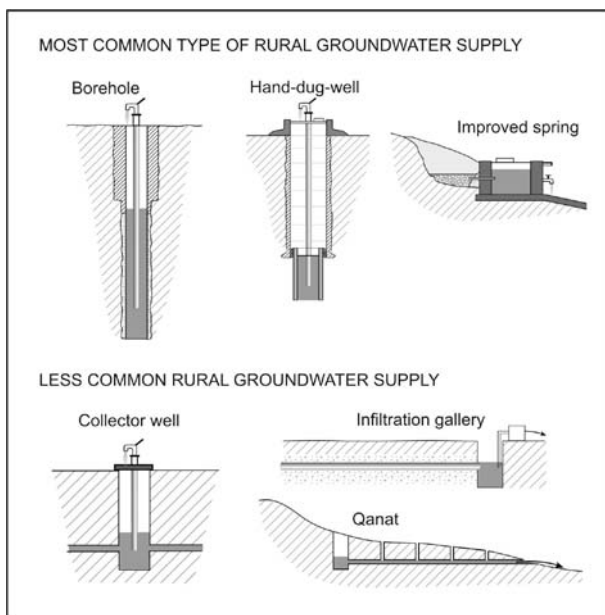
20  
 21 For a rural water supply to be safe and reliable, and to give the benefits of improved health,  
 22 livelihood security and poverty reduction, it must meet several basic requirements. For  
 23 example: water should be of sufficient quantity to meet all domestic needs; consumption  
 24 should not pose a health risk; it should be reliable across seasons and between years; it should  
 25 be accessible to all community members within a reasonable distance (usually within 1 km);  
 26 and the supply should be affordable and capable of being maintained by the user community.  
 27 At present, meeting these needs from rainwater or runoff is a challenge in Africa, not least  
 28 because of the long dry season experienced by much of the continent (Figure 1). As a  
 29 consequence, *groundwater* development is generally the preferred option for meeting  
 30 dispersed rural demand, with technologies that include boreholes, wells or springs, or more  
 31 rarely collector wells or infiltration galleries (Figure 2).

32  
 33 Groundwater has many advantages as a source of supply: natural groundwater storage  
 34 provides a buffer against short-term climatic variability; quality is often good; and  
 35 infrastructure is affordable to poor communities. However, resource development has to  
 36 occur within environmental limits, if degradation is to be avoided. Excessive pumping, the  
 37 risk of pollution from highly persistent contaminants and the long-term threat posed by  
 38 climate change all highlight the need for groundwater protection and careful management.

39  
 40 What will be the impact of climate change and drought on rural water supplies? In this paper  
 41 we review the nature of groundwater resources in relation to *improved* rural water supplies  
 42 and consider the impact of climate change on groundwater availability, access and use.  
 43



1  
2  
3 Figure 1 The average length of the dry season in Africa (1961-96) calculated using data  
4 from New *et al.* (1999).  
5



6  
7  
8 Figure 2. Different types of rural groundwater supplies (from MacDonald *et al.* 2005a).  
9

## 10 GROUNDWATER RESOURCES IN AFRICA

11 Groundwater occurrence depends primarily on geology, geomorphology/weathering and  
12 climate (both current and historic). The interplay of these three factors gives rise to complex  
13 hydrogeological environments, with countless variations in the quantity, quality, ease of  
14 access and renewability of groundwater resources.  
15

16 Mean annual rainfall is highly variable across Africa. It ranges from negligible over parts of  
17 the Sahara to almost 10,000 mm in the Gulf of Guinea (Figure 3). There are also substantial

1 seasonal, inter-annual and multi-decadal variations in rainfall (Hulme et al., 2000). There is  
 2 no simple direct relationship between average annual rainfall and recharge, because of the  
 3 many variables involved – principally temperature, intensity and seasonality of rainfall,  
 4 topography, vegetation cover and soil or rock type (e.g., Butterworth et al., 1999). While  
 5 recharge proportions in excess of 10% are possible in some areas with mean annual rainfall  
 6 below 500 mm, the proportion is generally less than this, typically falling to negligible for  
 7 areas with rainfall below 200 mm/a (Lerner *et al.*, 1990; Scanlon *et al.*, 2006; Eilers *et al.*,  
 8 2007; Edmunds *et al.*, 2008; WHYMAP, 2008).

9  
 10 Figure 4 shows a simplified groundwater resources map for Africa. The map is based on a  
 11 synthesis of studies (Foster, 1984; Guiraud, 1988; UNTCD, 1988; UNTCD, 1989;  
 12 MacDonald *et al.*, 2005a; MacDonald et al. 2008a) and uses the 1:5,000,000 scale geological  
 13 map of Africa as a base (UNESCO, 1991; Persits *et al.*, 1997). The four different  
 14 environments are: Precambrian basement rocks (covering approximately 34% of the land  
 15 surface); consolidated sedimentary rocks (37%); unconsolidated sediments (25%); and  
 16 volcanic rocks (4%).

17  
 18 *Precambrian basement rocks* comprise crystalline igneous and metamorphic rocks over 550  
 19 million years old. Unweathered and non-fractured basement rocks contain negligible  
 20 quantities of groundwater. However, significant aquifers can develop within the weathered  
 21 overburden and fractured bedrock (Chilton & Foster, 1995; Taylor & Howard, 2000).

22  
 23 *Consolidated sedimentary rocks*, particularly large sandstone basins, can store considerable  
 24 volumes of groundwater but in arid regions much of the groundwater is non-renewable,  
 25 having been recharged when the area received considerably more rainfall (Edmunds *et al.*,  
 26 2008). Also, sedimentary rocks are highly variable and can comprise low permeability  
 27 mudstone and shale as well as more permeable sandstones and limestones. However, despite  
 28 their low permeability, sufficient groundwater for rural water supply can often be found in  
 29 mudstones with careful investigations (MacDonald *et al.*, 2005b).

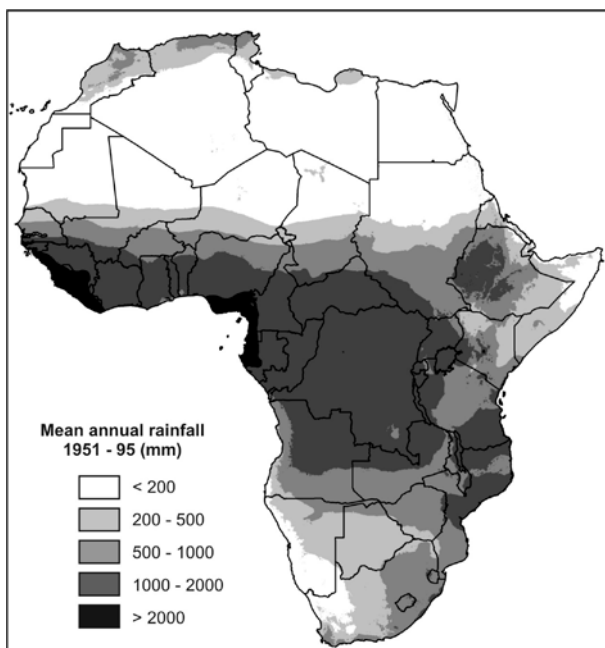
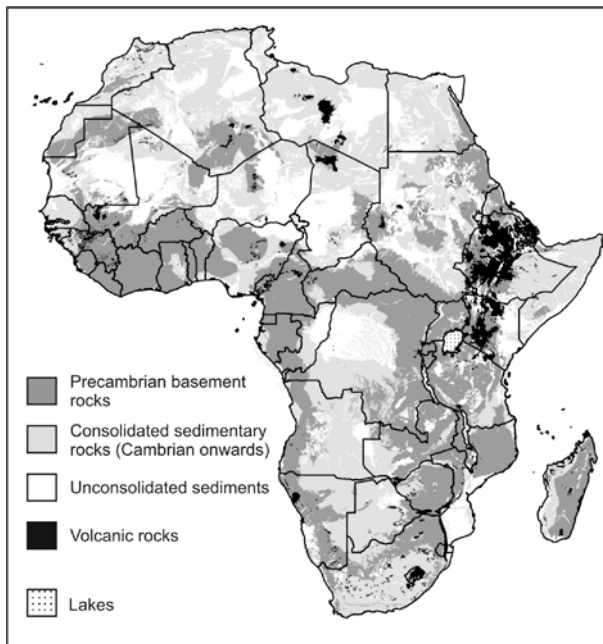


Figure 3 Average annual rainfall for Africa for the period 1951 – 1995 (New & Hulme 1997)

1  
2 *Unconsolidated sediments* form some of the most productive aquifers in Africa (Guiraud,  
3 1988). The estimate of their extent (approximately 25% of the land surface of Africa) is  
4 probably an underestimate of their true importance, since only the thickest and most extensive  
5 deposits are shown on the map. Unconsolidated sediments are also present in many river  
6 valleys, where they can form important local aquifers.

7  
8 *Volcanic rocks* are found in east and southern Africa where they can form important aquifer  
9 systems. Despite their limited extent, they are highly significant aquifers since they underlie  
10 many of the poorest and most drought vulnerable areas. The groundwater potential of  
11 volcanic rocks varies considerably, reflecting the complexity of the geology (Demlie, *et al.*,  
12 2007).



15  
16 Figure 4. The hydrogeological environments of Africa (adapted from MacDonald *et al.*,  
17 2008a)

## 18 19 20 **THE IMPACT OF CLIMATE CHANGE ON RURAL WATER SUPPLIES**

### 21 **Climate change scenarios**

22 There is considerable uncertainty surrounding the future of Africa's climate, as reported in the  
23 IPCC Fourth Assessment Report (Christensen *et al.*, 2007). The results of many of the  
24 different climate prediction models differ widely, and the models have difficulty in  
25 reproducing the observed climate patterns for the past 50 years. Despite these uncertainties,  
26 however, certain future scenarios are being predicted with greater confidence (Christensen *et al.*,  
27 2007): Africa is very likely to warm during the 21<sup>st</sup> century; annual rainfall is likely to  
28 reduce in the northern Sahara and southern Africa; and annual rainfall is likely to increase in  
29 the Ethiopian Highlands. However, there is still uncertainty as to how rainfall in the Sahel  
30 and West African coast will evolve. Other important aspects of the future climate in Africa,  
31 rarely discussed in detail, are changes in the unpredictability of rainfall and the increasing  
32 frequency of droughts and floods (Bates *et al.*, 2008).

1 Various researchers have discussed how these changes will impact on the African population  
2 (e.g. Boko *et al.*, 2007). In northern and southern Africa, a reduction in rainfall from existing  
3 low levels (Figure 3) will further increase scarcity. However, even in areas where *average*  
4 rainfall does not decrease, greater unpredictability may have serious consequences. Changes  
5 in the annual distribution of rainfall, and in particular the onset of the rainy season, may have  
6 devastating impacts on rain-fed agriculture in more marginal areas, such as in areas where the  
7 dry season is more than six months long, Figure 1 (Agoumi, 2003; Thornton *et al.*, 2006).

8  
9 Rainfall across Africa has been highly variable since records began in the early 1900s. The  
10 Sahel, for example, has shown large multi-decadal variability since 1900 and recent drying  
11 (Hulme *et al.*, 2000). Droughts are also endemic in Africa and the extent of drought-affected  
12 areas is increasing (Sheffield & Wood, 2008). Adapting to climate variability is therefore not  
13 new – and learning how water resources and people respond to existing variability is an  
14 important method for predicting possible future changes (Calow *et al.*, 2009).

### 17 **Estimating the impact of changing groundwater recharge patterns**

18 As discussed above, groundwater recharge is a complex process, and most estimates of  
19 recharge are poorly constrained. Annual rainfall is clearly important, but other factors, such  
20 as the intensity of individual rainfall events, temperature, soil conditions, vegetation and land  
21 use are also significant. In addition, the permeability and porosity of underlying aquifers can  
22 limit the capacity for recharge to be stored. Nonetheless, for the purpose of making a general  
23 assessment for the whole of Africa, it is reasonable to assume that negligible recharge occurs  
24 in areas with annual rainfall of less than 200 mm (Eilers *et al.*, 2007), and that recharge in the  
25 up to approximately 50 mm can occur in areas with annual rainfall in the range of 200 – 500  
26 mm (De Vries & Simmers, 2002; Edmunds *et al.*, 2008), and greater in areas where rainfall  
27 exceeds 500 mm (e.g. Rueedi *et al.*, 2005).

28  
29 Domestic rural water supply is not a large user of water and the supplies are also limited by  
30 the yield of the hand pumps. Most hand pumps have a yield of 5 – 10 m<sup>3</sup>/d, which, if  
31 uniformly spread across Africa, would require recharge of less than 3 mm per year to supply  
32 secure water for all (Wright, 1992; Carter & Alkali, 1996). Even with a closer water supply  
33 spacing of 500 m (significantly greater than current averages), the recharge required to sustain  
34 the supplies is less than 10 mm per year (MacDonald *et al.*, 2008b).

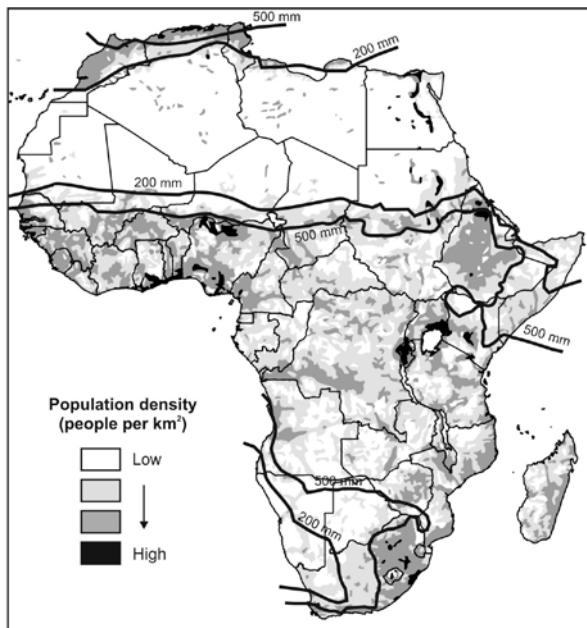
35  
36 In this context, and considering water for domestic supply only, people living within areas  
37 where rainfall is currently less than 200 mm are, in effect, mining groundwater that is not  
38 being actively recharged (Figure 5). In these sparsely populated areas, inhabitants have  
39 adapted to the lack of active groundwater recharge, and groundwater supplies are generally  
40 located in large sandstone aquifers, where there is sufficient groundwater storage to meet  
41 annual domestic needs. The groundwater is already managed as a finite non-renewable  
42 resource, and supplies are unlikely to be further affected by climate change.

43  
44 Community water supplies in areas where annual rainfall is between 200 and 500 mm per  
45 annum can generally sustain annual abstraction from ongoing irregular recharge. Boreholes  
46 are therefore drilled not only in aquifers with high storage, but also in poorer aquifers, where  
47 storage is limited and recharge is required annually (or at least every 2 or 3 years) to maintain  
48 reasonable yields. Therefore, any reduction in annual rainfall, changes in intensity or

1 seasonal variations; may cause problems for water supply, particularly in aquifers with low  
 2 storage capacity (Calow *et al.*, 1997; Calow *et al.*, 2009).

3  
 4 In areas where annual rainfall is currently greater than 500 mm per year, it is highly likely that  
 5 significant recharge ( $\gg 10$  mm, and more commonly  $> 50$  mm) occurs in most years (e.g.,  
 6 Rueedi *et al.* 2005). Even if rainfall were to fall substantially (e.g., by 20%) in these areas, it  
 7 is likely that there would be enough recharge to replenish aquifers sufficiently to supply the  
 8 modest requirements (3–10 mm) of hand pumps in rural areas.

9  
 10 Therefore, rural water supplies in areas where rainfall is between 500 and 200 mm are likely  
 11 to be most at risk from changes in rainfall caused by climate change. These supplies  
 12 generally rely on regular recharge, rather than large groundwater storage, but this regular  
 13 recharge often only barely meets demand and may not occur if rainfall were to reduce or  
 14 change in intensity. Figure 5 illustrates the relative population density in Africa in relation to  
 15 the mean annual rainfall for 1951-96. Using this population density distribution (UNEP  
 16 2000) and the JMP (2008) estimate of the total rural population, we calculate that  
 17 approximately 90 million people currently live in rural areas with rainfall between 200 and  
 18 500 mm, whose domestic water supply may therefore be vulnerable to decreases in recharge  
 19 due to climate change.



21  
 22 Figure 5 The relative population density of Africa relative to average annual rainfall  
 23 1951-96.

### 25 **Increased demand for reliable domestic supply**

26 As rainfall and surface water become less reliable, as is predicted for much of Africa, there is  
 27 likely to be an increased demand for groundwater. This increased demand is already observed  
 28 in current climate variability, for example during droughts in southern Africa in the early  
 29 1990s (Calow *et al.*, 1997) and more recently in the droughts in the Horn of Africa  
 30 (MacDonald & Calow, 2007; Calow *et al.*, 2009). In addition to these stresses, the ever-  
 31 growing population across Africa puts considerable extra demands on individual sources.  
 32 During a prolonged dry season or drought, surface water and shallow unimproved  
 33 groundwater sources (shallow wells and small springs) often fail, leaving only water points

1 abstracting from larger groundwater bodies operational. Therefore, often only the larger  
2 springs, deep hand-dug-wells or boreholes are reliable across seasons and in drought years.

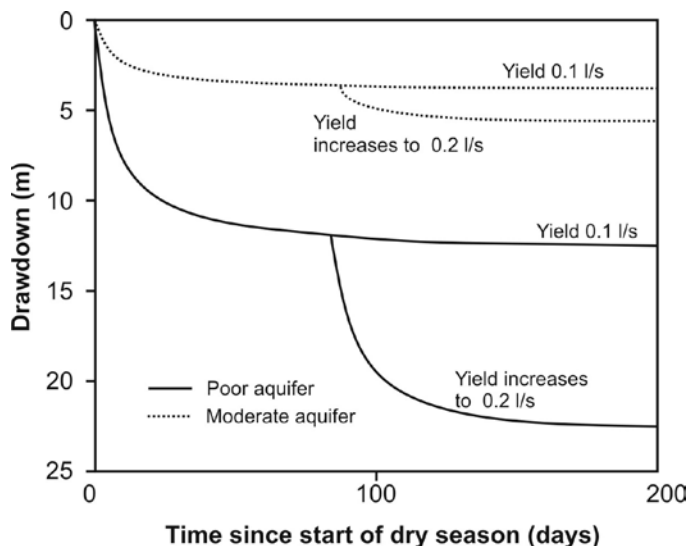
3  
4 However, these 'reliable' sources are also prone to failure during drought. The primary  
5 reason for this is the increased demand put on the source as others fail. This increased  
6 demand can cause two common failures:

7  
8 *Mechanical breakdown due to increased stress on individual sources as other sources run*  
9 *dry.* Prolonged pumping throughout the day can put considerable strain on the pump  
10 mechanism, leading to breakdowns. This is exacerbated if borehole water levels are falling,  
11 and pumping lifts are therefore increasing. The problem may be further exacerbated if  
12 maintenance activities on existing sources are reduced or stopped, because relief drilling  
13 programmes are given priority during drought.

14  
15 *Localised depletion of the groundwater resource as groundwater levels fall in the immediate*  
16 *vicinity of a well or borehole, or group of sources.* This is most likely to occur where high  
17 demands on a groundwater source are combined with low aquifer permeability. For example,  
18 in a basement aquifer, which often has a low transmissivity of around  $1 \text{ m}^2/\text{d}$  (Wright, 1992),  
19 pumping rates of higher than approximately  $0.1 \text{ l/s}$  (enough to provide domestic supply for  
20 about 250 people) can lead to excessive drawdowns and reduce borehole efficiency.

21  
22 Modelling of borehole behaviour in two aquifers using BGSPT (Barker & Macdonald, 2000)  
23 indicates the impact on groundwater levels from increased demand in the dry season (Figure  
24 6). The first is a poor aquifer with transmissivity  $1 \text{ m}^2/\text{d}$ , which would under normal usage  
25 sustain a handpump used by 250 people (MacDonald *et al.*, 2008b). The second represents a  
26 higher yielding aquifer with transmissivity of  $10 \text{ m}^2/\text{d}$ . More information on the model setup  
27 is given in MacDonald *et al.* (2008b)

28  
29 The results (Figure 6) demonstrate that in poor aquifers an increase in demand towards the  
30 end of the dry season can lead to greatly increased drawdowns, and therefore an increased risk  
31 of source failure. This is a problem of *accessing* the available groundwater resources, not a  
32 failure in the absolute groundwater availability. Different strategies can be used to help  
33 overcome this problem – for example, siting boreholes in more productive parts of the aquifer  
34 (Calow *et al.* 2009), adopting two phase pumping (Holt and Rushton, 1984) and appropriate  
35 choice of technology (e.g., MacDonald *et al.*, 2005a). This is discussed further below.





1 Figure 6 Maximum daily drawdown in a borehole for a poor aquifer ( $T = 1 \text{ m}^2/\text{d}$ ) and  
 2 moderate aquifer ( $T = 10 \text{ m}^2/\text{d}$ ) modelled using BGSPT (Barker & Macdonald, 2000). Two  
 3 scenarios are modelled: yield at 0.1 l/s for 12 hours per day, and yield doubling to 0.2 l/s for  
 4 12 hours per day after 90 days. The model is relatively insensitive to storage (MacDonald *et*  
 5 *al.* 2008b).

## 7 **Increased demand for groundwater for agriculture**

8 Many of the impacts of climate change described in the IPCC Fourth Assessment Report  
 9 (Boko *et al.*, 2007) relate to agriculture. The report presents a bleak picture for developing  
 10 countries (and Africa in particular) with projections that between 75 and 250 million people in  
 11 Africa will be exposed to increased water stress by 2050, and that rain-fed cereal yields will  
 12 be reduced in some areas by up to 50% within the same time frame. Rising food prices have  
 13 already raised serious concerns about impacts on poor people (who spend most of their  
 14 income on food), and whether food production from rain-fed and irrigated systems can be  
 15 increased to meet growing demand within the constraints imposed by already limited land and  
 16 water.

17  
 18 In this context, developing groundwater for smallholder irrigation holds promise for  
 19 strengthening livelihoods and improving food security (IWMI, 2007). Away from the Nile,  
 20 however, there is little irrigation in Africa. Currently, groundwater is estimated to be used to  
 21 irrigate less than 2 million hectares (Giordana, 2006), contributing to the livelihoods of only  
 22 1.5 to 3% of the rural population. A comparison with the widespread use of groundwater for  
 23 irrigation in Asia indicates room for growth (Foster *et al.*, 2008), although the groundwater  
 24 boom experienced in parts of south-east Asia was only made possible through access to cheap  
 25 energy, credit and market integration, catalysing private investment in productive aquifers,  
 26 such as the deep sedimentary aquifer in Gujarat and the extensive moderately productive  
 27 basaltic aquifers of the Deccan (Kulkarni *et al.* 2000). Comparisons between Africa and Asia  
 28 should therefore be treated with caution.

29  
 30 A key question is whether groundwater-based irrigation can be promoted as a sustainable  
 31 Africa-wide strategy for reducing poverty and increasing food production. The answer to this  
 32 question is probably 'no'. Increasing abstraction from groundwater by ten-fold to help sustain  
 33 irrigated agriculture could lead to more widespread over-exploitation problems and threaten  
 34 the sustainability of domestic water sources. That said, groundwater resources in lower  
 35 yielding, more complex hydrogeological environments are to some extent self regulating: it is  
 36 difficult to over-abtract from low yielding aquifers, since drawdowns in individual boreholes  
 37 become excessive at high yields (Figure 6). The groundwater resources most at risk from  
 38 over-exploitation, therefore, are arguably those in higher yielding aquifers such as sandstones,  
 39 unconsolidated sediments, and the more productive areas of basement or volcanic rocks,  
 40 where regional drawdowns are more likely.

## 42 **The impact of climate change on groundwater quality**

43 Even without climate change, there are significant pressures on the quality of shallow  
 44 groundwater across Africa. Poor sanitation and increased urbanisation have caused shallow  
 45 groundwater to become polluted in many cities and peri-urban areas (Adelana *et al.*, 2008).  
 46 Even in rural areas, higher population densities and the widespread use of latrines, or absence  
 47 of sanitation, can lead to shallow groundwater to become grossly contaminated. Intense  
 48 rainfall events, and the elevated water table during the wet season can enable pathogens (and

1 other suspended contaminants) to enter the shallow groundwater directly and travel tens or  
 2 hundreds of metres whilst still potent (e.g. Pritchard et al., 2008, Taylor *et al.*, 2009).

3  
 4 Increasing intensity of rainfall events across Africa may then lead to increased contamination  
 5 of shallow groundwater. Rural water supplies, which depend on very shallow groundwater,  
 6 or are poorly constructed so that shallow groundwater is not excluded, may be particularly  
 7 vulnerable.  
 8

## 9 **PREPARING FOR CLIMATE CHANGE**

10 A key conclusion from the above is that increasing the resilience of rural water supplies to  
 11 climate variability will generally require actions already identified for improving water  
 12 security for communities. This means understanding the balance between water availability,  
 13 access and use/demand (MacDonald & Calow, 2007; Calow *et al.*, 2009). For those reliant on  
 14 groundwater in areas where rainfall is currently in the range 200-500 mm/a, absolute water  
 15 availability for domestic needs may become the main constraint. However, for the majority,  
 16 the main issues are likely to be access to existing groundwater through reliable water points,  
 17 or increased demand for groundwater due to irrigation.  
 18

19 Here, we discuss actions that will help to increase the resilience of rural communities to  
 20 climate variability: (1) improving access to reliable rural water supply as part of efforts to  
 21 achieve the MDGs; (2) developing and improving access to groundwater for small-scale  
 22 irrigation; and (3) strengthening links between water and food security programmes,  
 23 particularly in relation to drought planning and emergency responses.  
 24

### 25 **Improving access to reliable water supplies**

26 Getting water to poor people remains a major investment challenge. An obvious need,  
 27 therefore, is to ensure that the financial commitments made by the international community  
 28 are actually met, since improving access to safe and secure water remains key to reducing  
 29 long-term vulnerability. Investment alone is clearly not enough, however. Funds also need to  
 30 be targeted at poorer areas, and to poorer communities, in such a way that sustainable and  
 31 affordable infrastructure is embedded in local communities. How can this be achieved?  
 32 Looking specifically at future ‘drought-proofing’ of rural water supplies, Calow *et al.* (2009)  
 33 offer the following recommendations:  
 34

- 35 • Ensure that the service options offered to communities under demand-responsive policies  
 36 are based on a sound understanding of hydrological and hydrogeological conditions and  
 37 trends. MacDonald *et al.* (2005a) describes in more detail how this can be done, and how  
 38 government, private sector and civil society stakeholders have a role to play in making  
 39 this happen.  
 40
- 41 • Ensure that wells or boreholes are located in the most productive parts of the aquifer.  
 42 Modest investment in resource assessment and siting techniques can pay dividends in  
 43 terms of higher drilling success rates and higher yielding (more reliable) sources (van  
 44 Dongen & Woodhouse, 1994; Reedman *et al.*, 2002; MacDonald *et al.*, 2005a; Carter,  
 45 2006). Simple tests can also be carried out to assess the performance of a well or borehole,  
 46 once it has been constructed, providing valuable information on how the source will  
 47 behave during drought (e.g. MacDonald *et al.*, 2008b). If a single source cannot meet peak  
 48 dry season or drought demand, further village sources may need to be developed.

- 1
- 2 • Construct sufficient sources in a village to meet existing and future demand in both
- 3 drought and non-drought years. In the longer term, this is more cost-effective than
- 4 attempting to develop extra capacity during a crisis. Such an approach is standard
- 5 practice in designing urban schemes, and the same rigour should be applied to rural water
- 6 supply. However, creating excess capacity may be considered contentious, particularly if
- 7 is done at the expense of other communities.
- 8
- 9 • Sink deep relief boreholes in the most favourable hydrogeological locations – perhaps
- 10 away from villages - which can be uncapped and used in emergency situations. Such
- 11 boreholes could be used by households from different villages should local sources dry
- 12 up, could be used to provide water for tankering operations, or could be used as
- 13 emergency watering points in pastoral areas, with complementary livestock interventions
- 14 (e.g., de-stocking).
- 15
- 16 • Explore methods of increasing groundwater recharge and reducing evapotranspiration, for
- 17 example, the use of managed aquifer recharge (Gale, 2005) to enhance recharge or the use
- 18 of sand dams.
- 19

## 20 **Developing groundwater for irrigation**

21 Smallholder agricultural systems are an important intervention point for measures aimed at

22 reducing poverty and increasing agricultural production. Moreover, strengthening agricultural

23 livelihoods in Africa through water management approaches, including groundwater-based

24 smallholder irrigation, has been identified as a key priority in the recent Comprehensive

25 Assessment report (IWMI, 2007). The report recommends small-scale, divisible and

26 affordable water technologies for Africa (treadle pumps, low cost drip, low cost pumps and

27 small storage tanks), and notes the major benefits these could bring, if resource development

28 and management/protection needs are considered in tandem.

29

30 Key questions here relate to how investment in local groundwater irrigation is delivered (and

31 by whom), how to ensure it occurs within safe (sustainable) limits in light of the discussion

32 above, and how (and by whom) such interventions are managed. These are significant

33 questions, and we do not go into detail here. However, it is worth emphasising again that data

34 on local hydrological and hydrogeological conditions are often limited or non-existent

35 (Robins *et al.*, 2006; Calow *et al.*, 2009). This makes identifying suitable areas and

36 appropriate technologies difficult.

37

38 Additionally, promotion of low volume, multi-purpose systems, rather than dedicated

39 domestic and irrigation infrastructure, has advantages. Several authors (e.g., Nicol, 2001;

40 Moriarty & Butterworth, 2003; Calow *et al.*, 2009) note that ‘domestic’ water is often used as

41 a production input in garden irrigation and livestock watering, as well as activities like

42 brewing and brick-making, even though water points are generally not designed with multiple

43 uses in mind. One reason why greater flexibility has not been designed in to most existing

44 systems is that rural water supply and agriculture remain institutionally and functionally

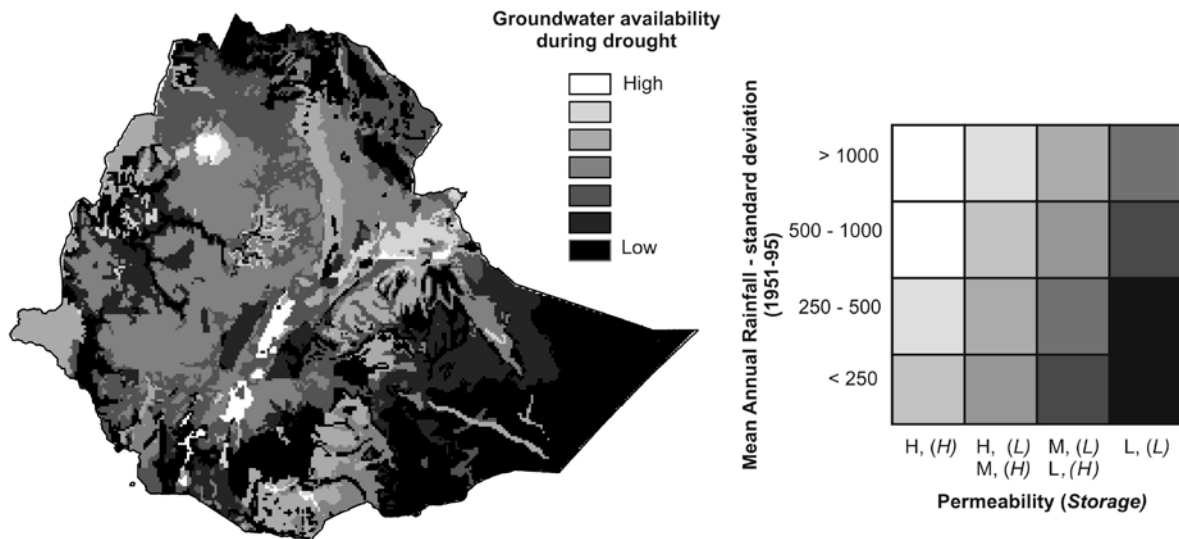
45 separate.

46

## 1 Water and food security – making the link

2 The impact of drought and climate variability on food security in Africa has received much  
3 attention over the last 30 years. One outcome is the establishment of numerous (and  
4 sometimes competing) early warning systems. These have moved beyond the simple food  
5 balance models that dominated in the 1980s and 1990s to include much more localised  
6 information on household ‘entitlements’ and income. Major gaps and deficiencies remain  
7 however, particularly in relation to the narrow focus on food rather than food and water  
8 security.

9  
10 There are various ways in which water security can be included in these analyses. One  
11 example is vulnerability mapping that combines data on rainfall with hydrogeology to identify  
12 areas of varying groundwater development potential and drought reliability (Figure 7 gives an  
13 example for Ethiopia). However, national and regional maps tell us nothing about local  
14 relationships between water availability, access and use. This information, beyond coverage  
15 data, is vital to an understanding of water insecurity, as insecurity may vary greatly over short  
16 distances.



17  
18 Figure 7 A map of groundwater availability during drought for Ethiopia calculated  
19 using hydrogeological and climate data (MacDonald *et al.*, 2001).

20  
21 To identify the most vulnerable areas and communities, water security data can be combined  
22 with data on rural poverty and food security. The rural poor, for example, may include  
23 marginal and undiversified resource-poor farmers, female-headed households, landless  
24 labourers, pastoralists and displaced people, with the particular manifestation of insecurity  
25 varying between groups. From a food security perspective, information about access to  
26 production and exchange capabilities is required, and the impact this has on access to food.  
27 Combining indicators from all three data sets can then provide a much clearer understanding  
28 of livelihood insecurity and the interventions needed to support it. Interventions may include  
29 pump repair and maintenance in the early stages of drought, or assistance with water transport  
30 and tankering in later stages, combined with actions such as cash transfer and food for work.

31

## 32 CONCLUSIONS

33 Rural water supplies in Africa are overwhelmingly dependent on groundwater. Groundwater  
34 has many advantages over surface water sources, including reliability, ease and low cost of

1 development, and generally good quality. Achieving the MDGs in Africa therefore depends  
2 crucially on accelerating groundwater development within sustainable limits. Growing  
3 concern over climate change and rainfall variability, however, raises questions about how  
4 much development potential there is, whether existing supplies may be threatened in future,  
5 and how to mainstream climate scenarios into rural water policy and practice. Below are  
6 several issues that should be considered for improved groundwater sources.  
7

- 8 1. It is important to emphasise that climate change is unlikely to lead to the widespread  
9 catastrophic failure of improved groundwater rural water sources. Domestic supply  
10 requires only 3 – 10 mm of recharge annually per year, which should still be  
11 achievable for much of the continent. However, although widespread failure is very  
12 unlikely, a sizable minority could still be directly affected if rainfall, and thus  
13 groundwater recharge, significantly diminishes. Those currently living in low rainfall  
14 areas (200 – 500 mm) are most at risk of recharge reducing to the point of  
15 groundwater resources becoming non-renewable. Up to 90 million may be directly  
16 affected.  
17
- 18 2. In most areas, the main determinants of water insecurity will continue to be *access*  
19 rather than *availability* related, with source failure occurring when there is  
20 overwhelming demand on too few sources. Increasing rural water supply coverage to  
21 meet the MDGs, and ensuring that targeting and technology decisions are informed by  
22 an understanding of environmental conditions, remain essential.  
23
- 24 3. Matching the technology to the groundwater conditions, and siting sources in the most  
25 productive parts of the aquifer will improve the security of groundwater supplies.  
26 Other options, such as increasing the number of sources in a community, managed  
27 aquifer recharge, or relief boreholes may all have benefits.  
28
- 29 4. Developing groundwater further for small-scale irrigation could help increase  
30 agricultural productivity and increase farm incomes. However, *ad hoc* development  
31 could threaten domestic supplies and, in some areas, lead to groundwater depletion as  
32 abstraction increases significantly beyond domestic use. Promotion of low volume,  
33 multi-purpose systems holds promise, but questions remain about how such systems  
34 are financed and managed, and the role government, private sector and civil society  
35 stakeholders should play.  
36
- 37 5. Increased rainfall intensity predicted by most climate models is likely to lead to  
38 greater contamination of shallow groundwater as water-tables rise and flood latrines,  
39 or surface flooding washes pathogens into boreholes, or through the soil. The  
40 construction of sources should be improved to ensure that shallow layers are sealed  
41 out.  
42
- 43 6. With respect to drought planning and responses, much more could be done to protect  
44 livelihoods before lives are threatened. The prevailing ‘food-first’ culture that  
45 dominates vulnerability assessment and emergency response in most African countries  
46 ignores the impact of water insecurity on livelihoods, and the role water interventions  
47 can play in reducing immediate and longer-term vulnerability. There is therefore a  
48 pressing need to broaden assessment and response systems to include non-food needs,  
49 develop monitoring systems with defined water indicators and incorporate such  
50 systems into existing early warning and response structures.

1  
2 Finally, it is important to emphasise that the discussions in this paper refer only to *improved*  
3 water sources. Those who still rely on shallow unprotect shallow wells and ponds are likely  
4 to become increasingly insecure with climate change. Therefore, every effort should be made  
5 to extend reliable access to secure water for all throughout Africa  
6

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10

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