Earth Perspectives
a SpringerOpen Journal

SYNTHESIS Open Access

Groundwater scarcity and conflict – managing hotspots

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Abstract

The link between water scarcity and public unrest is a close one. Groundwater is the only viable resource in most arid and semi-arid environments that can sustain rural and urban populations. Periodic drought forces people off the land who take refuge in the cities, taxing already stressed resources. Mining of groundwater places cities at risk; aquifers supplying both Yemen's capital city Sana'a and its major regional centre of Taiz are expected to run dry in the foreseeable future. In Somalia, al-Shabaab canvassed disfavour by mishandling the 2011 drought, which was partly self-inflicted through excessive tree-felling and their failure to repair broken infrastructure. Water scarcity was also a catalyst of the unrest in Syria, and has long been a critical factor in the tension between Israel and the Palestinians. Small island states and communities that live over transboundary aquifers are also vulnerable unless early technical investigation and collaborative interstate management are provided, while NGOs continue to drill boreholes in countries such as Malawi where the groundwater resource cannot keep up with demand. It is critical that the West helps these countries, particularly countries such as Yemen, Somalia and Syria, where the current instability partly stems from water scarcity issues, and where supply failure pushes people back towards competing tribal factions with implications for the security of the world. It is imperative that we switch our focus from fighting the symptoms of instability, such as insurgent terrorist groups, and start concentrating instead on the underlying causes such as poor governance and water resource scarcity. Given the continuing unrest in those countries affected by the so-called 'Arab Spring', the link between water scarcity and anarchy has become inarguable. The way to mitigate the ongoing threat to security must include technical advice on groundwater management and, where necessary, on preparing for the impacts of projected resource failure. The consequences of not taking this course of action are unthinkable.

Keywords: Groundwater; Aquifer; Water scarcity; Drought; Governance, groundwater management; 'Arab spring'

Background

The idea that 'water is the new oil,' and that the wars of the future will be fought over it, has been much derided in recent years. Water, say the objectors, is so essential to life that historically, inter-state disputes over the resource have been resolved without violence – even, in the case of the Iran-Iraq war of the 1980s, while fighting continued elsewhere (Bell 2009). The threat posed to global security by water scarcity, they say, has been exaggerated.

But while full-blown interstate wars over water remain unlikely, there can be little doubt, after the remarkable events of 2011, that the connection between civil conflict and groundwater scarcity is a close one. Civil conflicts, furthermore, can easily spill over into neighbouring states with potentially serious regional and international consequences, as events in 2012 along Syria's borders with Turkey and Lebanon proved.

In Somalia, al-Shabaab, an Islamic militant organisation affiliated to al-Qaida, was forced into retreat in large part because they mishandled the effects of a drought in the territories they controlled. This proved to be the turning point in a four-year, UN-backed military campaign against them. Meanwhile, upheavals in several of those countries touched by the so-called 'Arab Spring,' including Yemen and Syria, had one thing in common: the catalyst for violent change was water (Shank & Wirzb; Plumer).

Local conflicts are invariably driven by governance (or the lack of it), poverty and unsustainability, often

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with leverage from opportunist insurgent organisations – and water scarcity is often the key driver of such instability (Moench 2002).

It is groundwater that sustains rural communities wherever surface water is ephemeral, so keeping people on the land and retaining their livelihoods (Chopra & Gulati 2001). When the available supplies diminish due to cyclic drought events or to longer-term climate variability, hardship is exacerbated until wellbeing and livelihood are eroded. A regular water supply is essential for stock, for small-scale garden irrigation, for brick-making and other rural employment. Water scarcity affects one in six people on the planet (Evans 2010). A great many of these do not have an adequate supply of safe potable water for drinking and washing, and some spend an unacceptable proportion of their waking hours fetching water for the family dwelling.

Although some peoples are adept at 'drought proofing', others are more dependent on external support, but both are at risk should their groundwater supply diminish to the point that food security and sanitation are in jeopardy and post-drought recovery impossible (Calow et al. 2010). As the situation worsens, competition for resources inevitably leads to unrest and enhancement of tribal identity (Moench 2002). Should groundwater sources fail altogether, livelihoods are lost and a rural exodus becomes inevitable. Rural refugees tend to head for help to the cities, where basic services, including water provision, are often already badly over-stretched. Political instability all too often follows.

Focus by the international community to date has been on countries such as the Palestinian West Bank, Yemen and, of course, Somalia. But many other countries are equally at risk: large parts of the Middle East, Zimbabwe, Malawi, many small island states such as Anguilla in the West Indies, and the numerous densely populated islands of the Indian and Pacific oceans.

The current international response is to fight the symptoms of water scarcity rather than the causes. In Somalia, for example, the symptoms are al-Shabaab and the war lords, while the causes are lack of representative governance, drought, poverty and loss of livelihood. As a consequence, 'water wars' periodically bubble to the surface and will likely cost the international community dear unless timely technical intervention is provided.

This paper presents the causes and likelihood of future 'water wars,' as illustrated by events in Somalia in 2011, and which could soon be repeated in, particularly, Yemen, as boreholes that supply the capital city of Sana'a and Ta'iz (a city in central Yemen with a water shortage arguably even more severe than Sana'a's) begin to run dry. The objective is to review the hypothesis advocated by, for example, Van der Molen and Hildering (Van der Molen & Hildering 2005), that technical intervention from the international community to attempt to maintain basic water supplies (or if all else fails, to manage the relocation of people) is an essential component of peace.

Water scarcity and the role of groundwater

Water scarcity is an increasing and irreversible problem that derives from a diverse set of causes. The more obvious of these are (Pereira et al. 2009):

- Land use change and desertification
- Climate cycles and variability
- Demography and occupation of marginal lands
- Interception and diversion of surface water
- Groundwater mining
- Pollution

Poor maintenance of water points in many rural and peri-urban communities also leads to hardship, sometimes severe. Surface waters are essentially ephemeral in semi-arid areas. Even the mighty 'grey green' Limpopo now runs dry for much of the time, since a number of tributary catchments have been dammed. Groundwater, however, tends to be slower to react to rainfall and drought cycles (Calow et al. 1997), and can provide a sustainable source of safe water in times of shortage (Figure 1). It is in fact essential to many impoverished rural communities, as well as to many towns and cities that are poorly served by surface water. Conjunctive use of surface and groundwater is often feasible for some of the time, but it can seldom be relied upon, so that surface water is generally regarded as a bonus whenever it is available.

Although groundwater is perceived as a universal panacea, particularly by many aid agencies, it is a renewable resource that in some areas is finely balanced by demand. Aquifers are often slow to recover once the rains have arrived, and may never be able to fully recover after a drought if demand continues to rise (Figure 1). Effective rainfall, which is precipitation minus actual evaporation, provides runoff to surface waters and recharge to groundwater. Recharge – which is not easy to quantify without detailed measurement and flow modelling – is the rate at

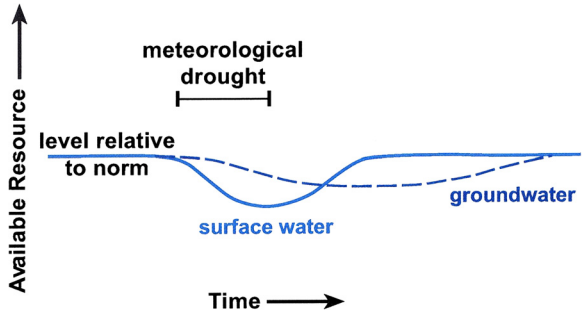

Figure 1 Reaction of groundwater and surface water to meteorological drought.

which water enters the aquifer as a result of percolation of rainwater through the soil and unsaturated rock downwards to the water table.

This renewal process contributes in turn to natural discharge from the aquifer, as springs and as baseflow to surface waters, which also maintain groundwater-dependent ecosystems. Renewal also contributes to any shortfall in storage within the aquifer. However, Sophocleous (Sophocleous 1997) warns that 'safe yield' – the balance between withdrawal and recharge – is not the same thing as 'long-term sustainable yield', and may lead to depletion of the resource without careful management.

Storage is the volume of water contained in an aquifer, and varies as the water table rises in response to periodic recharge events, and recedes with loss to baseflow and abstraction (Figure 2). If baseflow and abstraction exceed recharge then storage makes up the shortfall. Conversely, if recharge exceeds baseflow and abstraction, any shortfall in storage is made up, with the remainder contributing to enhanced baseflow discharge. If recovery is incomplete in the long-term the resource potential diminishes and the aquifer fails to meet demand.

In semi-arid climates, water stored in the aquifer is often 'mined' during the dry cycle years in the hope that the shortfall will be made up in the wet cycle years (Robins et al. 2013). It is also feasible to knowingly mine the aquifer for short-term financial gain in anticipation of planned alternative supplies coming on stream before the aquifer runs dry (Younger 2007). A typical example might be a decision to open an opencast coal mine, perhaps combined with a coal-fired power station, both of which depend on water pumped from aquifer storage. It might well be calculated that the social and financial benefit derived from the facility over, say, 25 years will outweigh the risk of failing to find an alternative supply when the aquifer runs dry at the start of year 26.

Groundwater mining also takes place out of necessity – in order to sustain whole communities, for example – in the certain knowledge that the supply will one day run out (that is, when abstraction + diminishing baseflow exceed long-term potential recharge). The assumption, again, is that a viable alternative source will be found in the intervening period.

The risk, of course, is that no alternative can be found. It is communities forced to live with this risk that can benefit most from help and advice on how best to manage their finite resource, through, for example, selective water pricing, conservation and the re-use of waste water. Should such tactics prove insufficient, early warning of a failing water supply can still help avert civic chaos by buying time to organise a staged transfer of businesses, essential service-providers, government institutions and even people and their homes to alternative, better-watered locations.

All groundwater needs managing towards the goal of sustainability of supply. To attain this goal, and indeed to reach any properly informed groundwater management decision, the resource needs to be regularly monitored (Taylor & Alley 2001). The prevailing meteorology, variations in surface water run-off and baseflow discharge, groundwater abstraction rates as well as simple groundwater levels all need to be closely watched. The data collected can then be used to construct and validate groundwater flow models, allowing a variety of 'what if' scenarios to be formulated, and giving policy-makers

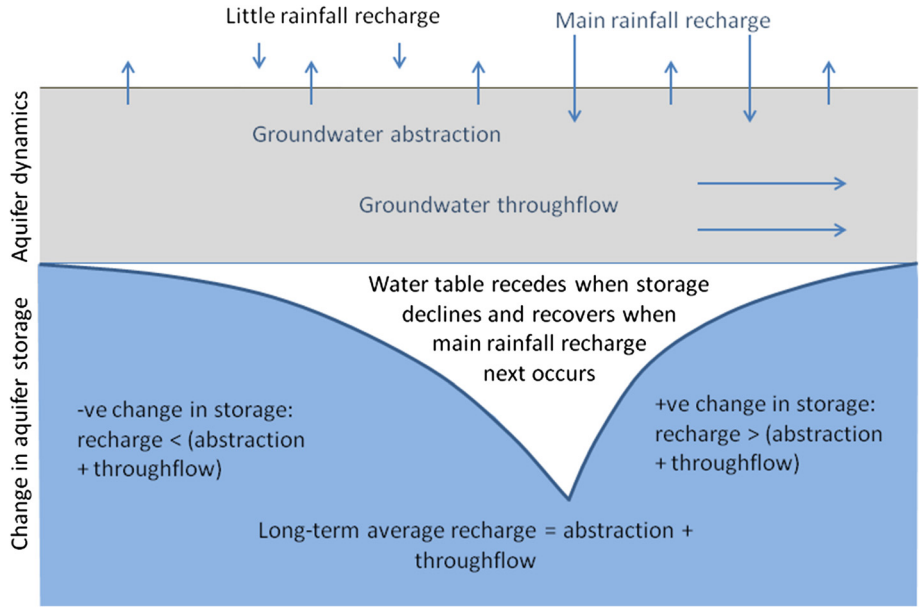

Figure 2 Temporal relationship of groundwater storage to ongoing discharge (baseflow and abstraction) and periodic recharge.

essential insight into the likely performance and productivity of their local aquifer. However, monitoring is often inadequate or even absent in many poorer countries, rendering validated modelling impossible. It is these countries that are most at risk of mismanaging groundwater resources, and where the possibility of groundwater ceasing to flow is greatest.

At risk communities

United Nations Environment Programme (United Nations Environment Programme 2009) reported: 'Since 1990 at least eighteen violent conflicts have been fuelled by the exploitation of natural resources. In fact, recent research suggests that over the last sixty years at least 40% of all intrastate conflicts have a link to natural resources. Civil wars such as those in Liberia, Angola and the Democratic Republic of Congo have centred on 'high-value' resources like timber, diamonds, gold, minerals and oil. Other conflicts, including those in Darfur and the Middle East, have involved control of scarce resources such as fertile land and water.' The report continued: 'Environmental factors are rarely, if ever, the sole cause of violent conflict. Ethnicity, adverse economic conditions, low levels of international trade and conflict in neighbouring countries are all significant drivers of violence'.

Communities that are at most risk are those in poor rural, peri-urban and even urban settings in arid and semi-arid environments, where government is weak and resource management inadequate (Evans 2010; Calow et al. 1997). Residents of small island states may also be at risk, as demands from growing populations overtake resource potential (Watson et al. 1998). Even in richer countries such as the United States, groundwater-fed cities such as Orlando, Florida and Tuscon, Arizona are at risk of failing supply, although here strong governance will help alleviate stress and avoid the potential for conflict.

In many poorer countries, the risk of supply failure, as well as the possibility of conflict, are increased by inadequate monitoring and a lack of understanding of the groundwater resource, coupled with poor governance and the optimistic administrative perception that there is enough water for all comers (Figure 3). The paradigm is that the risk of supply failure is greatly enhanced by conflict, be it local, national or regional, while water scarcity is also of itself a recognised cause of conflict (United Nations Environment Programme 2009).

Problems with groundwater scarcity are continually being reported in new parts of the world. (Robins et al. 2013) demonstrate that demand has now outstripped resource potential in four of the fifteen administrative water management units in Malawi. All four already have relatively high-density rural populations. Yet further mining of the available groundwater resource is not viable in Malawi – whose population, growing by almost 3 per cent a year (CIA World Fact Book), is expected to almost triple to over 45 m by 2050 – because the aquifer is a shallow weathered zone in ancient crystalline rocks with little storage potential, barely capable of providing enough to support existing communities through five or six consecutive dry cycle years within a recognised overall eleven-year climate cycle (Mwafulirwa 1999).

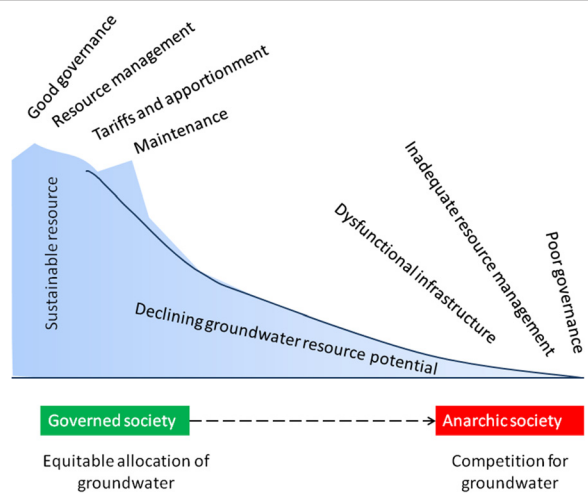

Figure 3 Groundwater resource potential and governance.

Work in South Africa supports the concept that resource potential is inadequate to sustain demand in some areas. (Van Wyk et al. 2011) have determined recharge rate potentials in the Western Cape that are negligible. Here the wet and dry cycle is slightly less distinct than in Malawi, and lasts an average of 18 years (Taljaard 1996). When the water finally runs out for the local aquifer-dependent communities, the unfortunate people will inevitably leave their land and head to the towns and cities as dispossessed citizens, placing an additional burden of provision on an already overstretched government.

Groundwater mining has long been advocated for short-term gain in the hope that it may pay for some long-term remedy of supply. The Great Man-Made River Project, first conceived in the late 1960s and funded by Libya, set about mining the Nubian Sandstone aquifer (Salem 1992), with an original design life of 1000 years – although the project is likely to run dry in 60 to 100 years (Christian Science Monitor). Water first came on stream in 1989 and is now used for urban water supply as well as irrigation. The Nubian sandstone aquifer, which last received recharge in the Pleistocene era, will not recover unless pluvial conditions reoccur.

The income and wellbeing derived from irrigating farmland and supplying towns and cities has been considerable, although everything could be in jeopardy as a consequence of recent civil conflict associated with the 'Arab Spring.' Egypt, north-eastern Chad and north-western

Sudan also have trans-boundary interests in the fossil water that need to be addressed if future conflict with those countries is to be avoided.

There are numerous smaller-scale groundwater-mining projects around the world that have proved just as controversial. A halt was recently called to a proposed coalmine and power station in eastern Botswana, a scheme designed to sell electricity to South Africa using water mined from the Karroo sandstone aquifer at Mmamabula. Environmentalists were concerned about the impact on groundwater-dependent ecosystems, although the ultimate reason for shelving the scheme was the unacceptable business risk associated with international economic and political uncertainty over the lifetime of the project.

Another area of potential conflict concerns transboundary aquifers (TBAs), defined as a groundwater unit shared by two or more nations (International Groundwater Resources Assessment Centre 2012). The evaluation of TBAs is often difficult due to scarcity of data.

At the last count, 273 TBAs had been mapped around the world (United Nations Educational, Scientific and Cultural Organisation 2009), a number that is still growing as hydrogeological knowledge advances. Of the 273, just four are currently managed in a genuinely collaborative way – two in Africa, the Genevese aquifer straddling the border between France and Switzerland, and the Guarani aquifer shared by Brazil, Argentina, Paraguay and Uruguay. The UN has been seeking to codify international rules on the management of TBAs for over 15 years. Until it succeeds, the management of TBAs and the allocation of resources between neighbouring political entities will generally go on depending on *ad hoc* bilateral agreements between the states involved.

For a TBA agreement to succeed, due attention must always be paid to the social and political impact on either side of the affected border. Not all TBAs require such careful handling – for example, when population density and demand on both sides of the border are low – but many others that are not properly managed have the potential to generate considerable socio-political friction (Davies et al. 2012).

Among the best known examples is the West Bank Mountain Aquifer, which is recharged in Palestine but with groundwater that discharges in springs in neighbouring Israel (Mansour et al. 2012). The Jewish state, founded on the principal of 'making the desert bloom,' regards irrigation as essential to its existence. Some 60% of the water it consumes in this water-scarce land is used for irrigation. In a water-scarce land, however, many Palestinians consider this unconscionable when agriculture accounts for just 1.6% of Israel's GDP (Deconinck 2006).

Israel's continuing occupation of the Golan Heights – historically Syrian territory, annexed by Israel following the Six-Day War of 1967 – is largely about retaining control of the water produced on the high ground. The Golan Heights may provide as much as 15% of Israel's water, whether as surface water or indirectly through local aquifer recharge (Dafny et al. 2006). The control of groundwater has also been a key strategy in Israel's physical and economic blockade of Palestinian Gaza, which again flared into violence – including the first ever exchange of long-range missile fire – in November 2012. Israel controls the upstream parts of the shallow coastal aquifer on which the Gaza Strip depends. In 2008, Israeli authorities reportedly constructed trap wells along the Strip's northern borders in a deliberate attempt to divert the abstracted water to recharge its own aquifers (Kishawi 2011).

Consideration also needs to be given to water stress in small island states. The latest island to 'go critical' is Anguilla in the West Indies. Anguilla is a low-lying limestone island with a shallow lens of renewable fresh water overlying a saline interface with seawater below. Careful monitoring and management of abstraction used to ensure continuity of supply to 'The Valley' and the outlying rural areas, albeit a supply with a slight brackish taste. However, recent systemic failures have led to the destruction of the fresh water lens, and the island's water supply has now gone saline. Alternative means of supply urgently need to be found if the island is to remain tenable for many of its 15 000 inhabitants: a remedy that will inevitably cost far more than timely intervention and advice on water conservation and management techniques would have done. Although conflict is unlikely in Anguilla, the prospect of mass displacement of the population is real.

Perhaps the most critical groundwater issue of modern times concerns the Sana'a sandstone basin aquifer that supplies the capital city of Yemen with its drinking water. Media reports consistently state that this ancient city – a UNESCO World Heritage site and one of the oldest inhabited places on earth, said to have been founded by Shem, the son of Noah – will run dry in 2017.

The accuracy of this unusually specific date, however, is suspect. Hydrogeological evaluation of the aquifer yielding such a precise prognosis is not forthcoming. Although some investigation has been carried out, and a small body of literature exists e.g. (Alderwish 1995; Alderwish & Dottridge 1998; Handley & Dottridge 1997; Al Hamdi 2000), adequate monitoring of the resource has not taken place and there are few historical data with which to calibrate a workable groundwater flow model. Prognoses of how much water remains in store in the aquifer cannot, therefore, be made with any degree of certainty.

The Canadian engineering consultancy, Hydrosult Inc, along with the North Carolina-based RTP International, continue to collect data on behalf of the World Bank, which in turn has attempted to put forward various policy options for and in co-operation with the Yemeni government (Research Triangle Park International 2012;

Hydrosult Inc 2010). The World Bank acknowledges, however, that their advice is based on results that are 'only indicative and not definitive, mainly because, under the difficult political situation in Yemen during the preparation of the study, [our engineering consultants] were not in a position to assess either the social impacts of their options or the scope for implementation' (Garduño 2012).

That Sana'a's aquifer is running dry is not in doubt. It is when and how it runs dry that needs evaluating so that an ameliorating strategy can be put in place. Sana'a is one of the few capital cities in the region to be situated in the semi-arid inland mountainous part of the country. Others, such as Mogadishu in Somalia, are on the coast where some groundwater is available in wadi fan deposits, and where desalination of seawater could be viable in a richer society. Many of the social options available in Sana'a are drastic. The government of Ali Abdullah Saleh (1990–2012) contemplated relocating the entire population to the coast: effectively an abandonment of a city that has been inhabited for thousands of years.

According to another scenario, as the aquifer fails, private suppliers will for a time attempt to meet demand using water tankers – in fact, an already thriving business in many parts of Yemen. But the cost of privately supplied water would soon rise too high for Sana'a's poorer classes, who would likely lead an exodus from the city voluntarily. Without the street-cleaners, the hospital workers, the tradesmen and all those others who keep the engine of any modern city running, life would soon become intolerable even for those who could afford expensive privately imported water, who would then follow the working classes out, leading to the same outcome as the forced relocation mooted by the Saleh government.

The possibility of social chaos in Yemen has long been foreshadowed across the Gulf of Aden in Somalia, which in 2011 was afflicted by the region's worst drought for 60 years. Somalia has had no properly functioning central government since the downfall of Siad Barre in 1991. For the last five years, the administration in Mogadishu has been battling al-Shabaab, an al-Qaida-affiliated Islamist insurgency that still controls much of the south of the country. And it was the south of the country that was worst affected by the drought, in large part because of al-Shabaab's mismanagement of the environment. This was despite the fact that Somalia's only permanent river, the Juba, is located in the south.

For several years, al-Shabaab did nothing to rein in a boom in the production of charcoal, the sale of which was critical to the funding of their insurgency. Uncontrolled tree-felling has left swathes of their territory barren and open to desertification. For over five years, al-Shabaab also did nothing to maintain or repair irrigation systems around the Juba, or even the south's network of wells, an estimated 95% of which were filled in with rocks or otherwise destroyed during the inter-clan violence of the 1990s (Fergusson 2013).

The consequence was an official famine, and huge numbers of people fleeing the land. US officials estimate that 29 000 children under the age of five died over three months in summer 2011. The suffering was exacerbated when al-Shabaab responded to the famine by calling it 'infidel propaganda' and denying its existence. Foreign aid agencies were prevented from operating in the areas controlled by the militants, while fleeing refugees were ordered to return home and instructed to 'pray for rain.' This was a disastrous piece of public relations in a nation of nomad pastoralists, whose survival has long depended on the ability to move to greener pastures when the rains fail. Historians may well judge the consequent collapse of public support for al-Shabaab as the turning point in the UN-backed war against them.

Somalia's civil conflict has been sustained by rivalry between clans, who have always competed over scant water resources in a dry land. Disputes over water used to be settled by the application of *xeer*, the country's ancient customary law, traditionally administered by elders from the rival clans gathered at a neutral location, out in the open beneath a tree. Somalia's problems mostly stem from the 1980s when the dictator Siad Barre ran down the xeer system in favour of scientific socialism. The old social structures were then further destroyed in the 1990s by civil war and the massive displacement of the population that followed. The collapse of central government forced Somalis to fall back on the only social organisations that survived that chaos: their tribes.

The Somali experience may have important lessons for Yemen, where society is organised on comparable tribal lines. If Yemen's aquifers were to start running dry, it is not difficult to imagine how tribesmen might resort to filling up the wells of rivals to prevent the abstraction of groundwater needed for the survival of their tribal kin. The UN-backed military campaign against al-Shabaab continues, amid ongoing speculation by security analysts that the insurgents are closely linked to al-Qaida's Yemen-based franchise, AQAP (al-Qaida in the Arab Peninsula). In 2011 AQAP, profiting from the power vacuum that followed the ousting of President Saleh, gained control of several cities in the southern Yemeni province of Abyan.

Yemen itself remains perilously unstable, and the revolution promised by the popular 'Arab Spring' is still incomplete. That upheaval began in May 2011 in Ta'iz, Yemen's former capital, where demonstrators protesting the lack of water provision had occupied a central city square. Ta'iz's water supply is poor even by Yemen's low standards. Householders have long been forced to go without running water for periods as long as 40 days e.g. (El-Sharabi 2006). The protest turned violent, and quickly spread to the rest

of the country, when Saleh's troops used extreme force to clear the square.

The spark that ignited the ongoing conflagration in Syria was similar. Here it began in the southern city of Daraa near the Jordanian border, a region that had suffered severe water shortages for months previously. The hardship in rural areas was exacerbated by the local governor, an Assad regime placeman, whose system of water allocation, including drilling rights, was notoriously corrupt. The flashpoint came when several schoolchildren, all members of the same Al-Abazeed family, were arrested for writing anti-Assad graffiti on the walls of their school. The ensuing public protest was met with regime gunfire, and the unrest soon escalated. It is telling that the regime then tried to bring Daraa back into line by cutting off the city's water supply altogether. In autumn 2012, there were reports that they had even tried to poison a local reservoir. The shortage of groundwater played a central catalytic role in both Yemen and Syria; and as we have seen, the destabilising influence of groundwater scarcity in these countries is far from played out yet (Arnold; Famiglietti; Gleick).

Groundwater management and policy making

The current preference of most national governments is to tackle the most immediate symptoms of a water-stressed society, when experience shows that sustainable solutions are almost always found only when the underlying causes are addressed.

In Malawi, NGOs are focused on repairing wells and increasing the number of new ones from 35 000 to 40 000, while failing to address or in some cases even to acknowledge the underlying problem that the resource itself may be inadequate. This policy, too, could lead in the end to increased poverty, hardship and refugee displacement: almost the exact opposite of the UN's Millennium Development Goals under which Malawi's water provision programme was adopted in the first place.

In island states like Anguilla, it is primary resource inadequacy that could force the displacement of populations. In the case of some transboundary aquifers, it may be no more than the reluctance of neighbouring states to work towards co-operative resource management through the simple sharing of data.

In Yemen, the new government of President Abd Rabbuh Mansur Hadi is focused on fighting local insurgencies in both the north and south of the country. The US-backed campaign against AQAP is seen as essential to the survival of his government. In Washington, it is considered a vital cog in the ongoing War on Terrorism, and essential to the security of the West. (With the Yemeni government's approval, the US has recently expanded its programme of assassinating Islamist leaders with missiles launched from drones – a programme unpopular with many Yemenis, whose nickname these days for their president is 'Abdu Drone Hadi' (Alwazir)). And yet this Western policy of trying to 'contain' the Islamist threat does nothing to avert the looming water crisis in central Yemen. The exhaustion of the Sana'a basin aquifer will likely make the country's capital untenable both for the government and for many if not all of its 1.9 m inhabitants, forcing an unprecedented (for Yemen) mass displacement of the population.

The destabilising effect this could have on the Hadi regime is difficult to predict, but would seem to be at least as great as the threat posed by AQAP, if not greater. Yemenis do not need reminding that it was a dispute over water rights, in Ta'iz in 2011, that sparked the popular unrest that led eventually to the overthrow of President Hadi's predecessor, Abdullah Saleh, who had held the reins of power in Yemen for over 30 years. And yet dealing with water scarcity in Yemen continues to be treated as an issue of second-order importance, both by the Hadi government and their allies abroad.

In Somalia, al-Shabaab – which controlled most of the country until mid-2011, and was the *de facto* government in those areas – accelerated the mass movement of refugees, and hastened their own political demise, by favouring the short-term gains from the charcoal industry over the long-term maintenance and repair of essential water infrastructure, and then by stubbornly refusing to recognise the severity of the ensuing drought.

The goal of better water management, which in arid and semi-arid regions means better groundwater management, needs to be placed much higher up the international community's agenda. If the social and financial advantages of early technical intervention are not self-evident, the case for increasing Western security by helping to prevent local conflict or war over the long-term is surely compelling. al-Qaida and its local franchises thrive only where governments cannot provide basic services to their people – and the provision of water is, of course, the most basic service of all.

It costs little to give technical advice, and the impact of even basic conservation measures can be dramatic. The West can and should share its long experience of, for example, the setting up and management of wastewater recycling projects; or schemes designed to promote and assist the conjunctive use of water; or of tariff systems which can quickly establish a community's priorities in the way scarce water is used, often an essential first step in bringing over-consumption under control. Technical advice should be part of an overall package which also includes advice on institutional and policy innovations and dissemination of results of programmes of work that have and have not worked in similar situations elsewhere.

Some technical solutions, such as replacing leaky infrastructure, introducing desalination plants, perhaps even the re-locating of water intensive industry, obviously cost more,

and may not be suitable for many poorer nations. Certain rich states in the Middle East have explored the possibility of importing groundwater by sea from the Balkans or South America, a venture unlikely to be of much help to impoverished Yemen if that water is to be sold on a commercial basis.

Identifying the hotspots and ensuring their management to lessen the likelihood of conflict is a major step forward in managing risk rather than dealing with crisis. Prediction of future hotspots has also been advocated (Khaleq et al. 2012) whereby a model-based analysis of current exposure to water scarcity and water stress could be applied to predict future hotspots so that effort can be appropriately focussed to reduce that likelihood. This becomes even more important in the light of a recent report by the Organisation for Economic Co-operation and Development (OECD 2008) that predicts that 47% of the world's population will be living in areas of high water stress by the year 2030.

Yet whatever the cost of such solutions, it will be small compared to that of failing to intervene at all, and allowing nations to slide into a state of anarchy – a process of 'undevelopment' that leads to impoverishment and suffering for millions.

Conclusions and recommendations

The evidence derived from the hotspots that have developed over the past few years suggests that the hypothesis mooted by Van der Molen and Hildering (Van der Molen & Hildering 2005) would appear to be valid, and that the international community should attempt to help maintain basic water supplies in communities and countries that are at risk, as an essential component of peace. Water scarcity was an underlying catalyst to the 'Arab Spring' in a number of countries. In some cases, firm intervention by the international community to help maintain basic supply infrastructure could have made it much harder for insurgents to gain a foothold. In poor arid and semi-arid states, water failure encourages migration to cities, increasing stress on basic utilities that ultimately leads to unrest; technical intervention and reinstatement of rural water points can help arrest this transfer of people. Maintenance of a basic water supply is fundamental to community wellbeing, and without such a supply, communities tend to break down into tribal factions that are prepared to fight over any remaining resources.

There are several different types of groundwater scarcity hotspot. These are illustrated by:

- *Malawi* and *Zimbabwe* - a milder version of the situation in Yemen where infrastructure projects are failing as demand is slowly outstripping the renewable capacity of the resource.
- *Anguilla* – a delicate groundwater system supplying increasing demand.
- *Yemen* – over exploitation of a limited resource which is driving failing domestic supply and livelihoods which will lead to the collapse of entire regions.
- *Somalia* – drought combined with a breakdown of traditional coping and sharing mechanisms caused by prolonged civil war.
- *Palestine West Bank* – a classic externality problem with a transboundary aquifer shared with Israel; the recharge areas lie in the West Bank but Israel enjoys much of the benefits.

It is one thing to identify and acknowledge the world's groundwater hotspots. Bringing about the cultural shift in thinking necessary to deal with them as they should be dealt with – through exported technical assistance rather than weapons technology – is a challenge of a different order. Analysis of the events of 2011, however, is persuasive: water scarcity played, as it continues to play, a critically destabilising role in the countries affected by the 'Arab Spring.' The correlation between water scarcity and anarchy is inarguable. It follows that the best way to mitigate the security threat implicit in the Arab Spring is to address its underlying causes rather than its the symptoms; and one of the most important and obvious of these causes is the mismanagement of scarce water resources. Equally important, however, is transfer of knowledge in institutional and policy innovations and dissemination of results of evidence-based research on what has worked in similar situations, and on what has not worked. Finding ways to correct this should lie at the heart of Western foreign policy; the science of water management needs to be put brought back to the centre of debate. Failing to do so will threaten the future security of us all.

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
The authors took equal responsibility in preparing the paper. Both authors read and approved the final manuscript.

Acknowledgement
Responsible editor: Michael Piasecki

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Received: 23 January 2013 Accepted: 6 November 2013
Published: 12 February 2014

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doi:10.1186/2194-6434-1-6
Cite this article as: Robins and Fergusson: **Groundwater scarcity and conflict – managing hotspots.** *Earth Perspectives* 2014 **1**:6.