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Yemen faces formidable freshwater management challenges. Devising policies for sustainable use and allocation of limited water resources is made difficult by substantial population growth, degrading environmental quality and uncertainty regarding possible changes in water availability due to climate change. We use the Water Resources Evaluation and Planning software to evaluate water needs and scarcity for three case study areas in Yemen representing different ecological conditions (Sana'a, Sadah, and Aden City) under a range of scenarios that include potential climate change and adaptation strategies. These management strategies, identified by stakeholder processes, have the potential to reduce vulnerability and build resilience. The modelled results suggest that current and predicted patterns of water consumption will soon fully deplete available supplies, and are a bigger driver of vulnerability than potential climate change for the region. In the absence of new strategies to bring into balance water supply and demand patterns, results for all three case studies suggest the pressing water crisis will only worsen. Timely interventions, designed to build resilience to scarcity, are urgently needed.

Keywords: climate change; Yemen; water scarcity; adaptation; vulnerability; decision support tools

Introduction

Potential impacts of climate change on water resource availability in Yemen could compound water scarcity and vulnerability in a country already burdened by troubling political, economic, and social concerns. Yemen is an arid, Middle Eastern country of 22.2 million people (2008 estimate) experiencing substantial population growth and persistently low levels of human development, two factors that exacerbate Yemen's water crisis and complicate efforts to build national and local resilience and adaptive capacity to any future climate challenges (Al-Ariqi 2006, MPIC 2006).

Although Yemen's United Nations' (UN) Human Development Index (HDI) has steadily risen over the last decade, low adult literacy and GDP *per capita* continue to keep Yemen near the bottom of the HDI rankings (140/182 countries) and near the bottom the UN's Human Poverty Index (111/135 countries) (UNDP 2009, World Bank 2009). Yemen was ranked 18th out of 177 countries on the 2009 Failed State Index in Foreign

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Policy (2009), which described the country as "a perfect storm of state failure" in the face of disappearing oil and water reserves.

Per capita water availability continues to fall steadily as the national population grows at 3.5% annually (RoY 2002, CIA 2009), with average annual growth of 4.9% in urban areas (UNSD 2011), where roughly one quarter of the population lives. Fifty years ago, Yemen's *per capita* water availability was around 1100 cubic metres (m^3), but had fallen to 460 m^3 per person per year by 1990 (World Bank 2002). The World Bank (2009) now estimates that the country has about 120 m^3 of renewable freshwater resources available *per capita* – a level just 2% of the global average *per capita* of 2500 m^3, almost 10-fold lower than the internationally recognised water "poverty line" of 1000 m^3 per person annually, and over four-fold lower than the level at which people face "acute scarcity" (Brown 2008).

In addition to population growth, unchecked extraction of groundwater for irrigated agriculture drives much of the scarcity, as it accounts for roughly 90% of total groundwater consumption (Al-Asbahi 2006). Yet 17.6% of the Yemeni population still subsists under the food poverty line (RoY 1998), due in no small part to the disproportionate allocation of the water resources to the production of Qat[1] rather than edible crops. Between 1970 and 2000, the area under Qat cultivation increased 13-fold (from 8000 to 103,000 ha), while grapes, for example, increased only 2-fold (from 10,000 to 23,000 ha) (MPIC 2003). Even though Qat makes up just 15% of Yemen's cultivated area, it consumes roughly 70% of the groundwater extracted, and this is anticipated to grow (MPIC 2003, Mcleod and Vidal 2010) as deep well drilling and pumping technology become more readily available (Zeitoun 2009). Combined with limited seasonal surface recharge and, until the recent creation of the Water and Environment Ministry, limited legal oversight of groundwater extraction (Boucek 2009), the result has been a 1–7 m annual decline in aquifer levels (Al-Asbahi 2006, Brown 2008).

The already precarious water scarcity conditions in Yemen may be worsened by future perturbations in climate. According to the Yemen's Initial National Communications to the UNFCCC, temperature across the country is expected to rise, while precipitation is expected to decrease, leading to increased pressures on the country's water resources (RoY 2001). Changes in the total amount of precipitation and in its frequency and intensity will directly affect the magnitude and timing of runoff and the intensity of future floods and droughts.

Research conducted under the Netherlands' Climate Assistance Programme (NCAP) from 2006 to 2008 sought to develop a better understanding of (1) the current water scarcity situation in urban and rural communities in Yemen and the impact of possible future climate variations on water availability, and (2) the efforts needed for Yemen to adapt and build resilience to water scarcity. This paper describes the processes, activities, results, and lessons learned from the NCAP efforts in three case study areas in Yemen: the rural highlands of the Sadah Basin, the urban highlands of the Sana'a basin where the Yemeni capital of Sana'a sits, and the urban and peri-urban areas of coastal Aden City. These basins represent the country's diverse ecological regions and development contexts and capture key rural and urban water supply-demand dynamics. In each of the case study areas, current and future vulnerability of water resources to climate change were assessed. In addition, potential adaptation strategies were identified within a stakeholder-driven process, and evaluated in a scenario-based water resource modelling framework in order to formulate pilot adaptation measures and integrate the results into national policy discussions.

Study approach

In each of the case study areas (locations shown in Figure 1), extensive stakeholder consultations and data collection were conducted to characterise current water availability, future

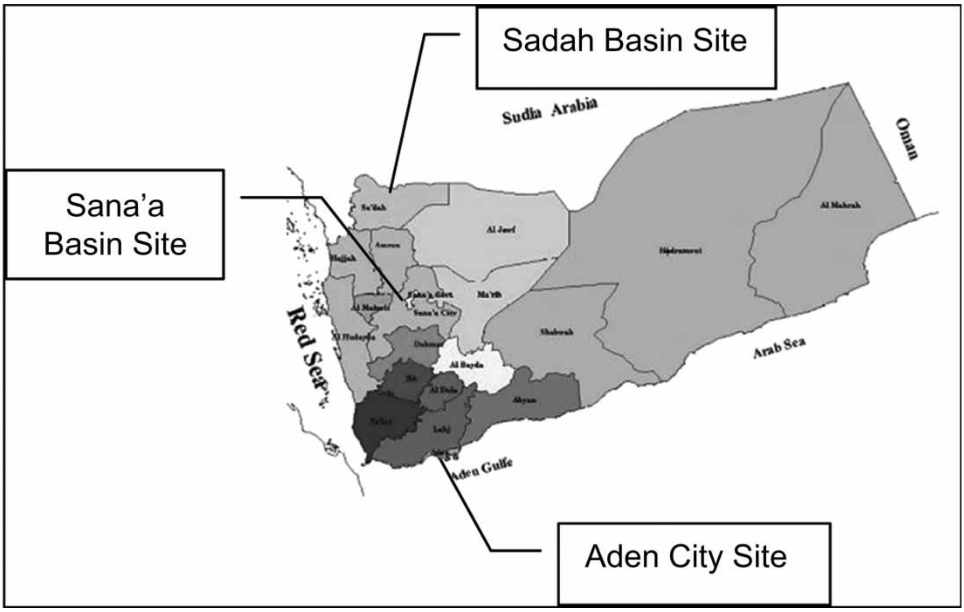

Figure 1. Case study site locations.

water resource vulnerability, and possible adaptation strategies to mitigate water scarcity. Stakeholder consultations were undertaken using rapid rural appraisal techniques and focused on local perceptions of water scarcity, climatic factors, and development challenges; overall strategy preferences of various interest groups (e.g. farmers, policy makers, water utilities officials) were collected based on perceived feasibility, cost, and value in terms of water savings. These structured stakeholder discussions were then synthesised into a set of inputs for water resource modelling and prioritising adaptation initiatives.

Current water demand and supply data and estimated future trends in water use, obtained from a number of Yemeni and international data sources, were incorporated into a scenario-driven water balance modelling platform – the Water Resources Evaluation and Planning (WEAP) software (Yates *et al.* 2005). WEAP was used for each case study to analyse water availability for a number of adaptation and climate scenarios, including a reference scenario (herein referred to as “Reference”) that projected existing trends in water supply and demand into the future (2025) in the absence of adaptation options. In the Reference scenario, for all case studies, the climate sequence for future years was developed by repeating the sequence of available historical data and assuming a similar periodicity into the future (2007–2025) (see NCAP final report for details: Noaman *et al.* 2009).

In addition, two different climate change scenarios incorporated changes in precipitation and temperature through 2025, as predicted by the Oregon State University model (OSU Core) and UK Meteorological Office High Resolution General Circulation model (UKHI), developed during the Netherlands Climate Change Studies Assistance Program (NCCSAP: 1996–2000). The OSU Core model represented an “expected” climate trajectory, whereas the UKHI model represented a “worse case”, drier trajectory. The assumptions for OSU Core and UKHI climate trajectories are based on previous climate modelling work that was undertaken during the Netherlands Climate Change Studies Assistance Programme (NCCSAP) (NCAP 2008), and the trajectories are summarised in

Table 1. Climate change scenarios for each case study.

Scenario	Annual change by 2025	
	Precipitation	Temperature
Sana'a		
OSU Core	+2%	+1.0°C
UKHI Dry	−10%	+ 1.3°C
Sadah		
OSU Core	+10%	+1.8°C
UKHI Dry	−32%	+2.2°C
Aden City		
OSU Core	+10%	NA
UKHI Dry	−16%	NA

Table 1. As noted recently by the World Bank (2010), limited meteorological data collection and uncertainty make difficult the detailed downscaling of climate trajectories for Yemen from the number of existing global climate model sources. Like that study, the intent here is to explore the impact of selected adaptation strategies in the context of several possible simplified future climate trajectories, and is certainly not meant to be a comprehensive analysis that considers the broad range of possible future climate patterns.

Case study contexts and WEAP framework details

Sana'a basin

The Sana'a basin is an intermountain basin situated in the western highlands of Yemen, where Sana'a, Yemen's capital city, is located. The 2004 national population census reported 1.71 million people living in Sana'a city – quadruple the number in the 1980s. The average growth rate continues at approximately 5% annually. Water consumption is growing concomitantly at an annual average rate of 4.2% due to this large population expansion, as well as illegal drilling, technological advancements in drilling (allowing for deeper wells), the enormous quantity of water diverted for Qat production in the peri-urban areas, and largely unenforced conservation rules. The result is that groundwater wells serving Sana'a are expected to go dry in the coming decade, as overdraft exceeds annual recharge by a factor of four to five (Hellegers *et al.* 2008, Kasinof 2009). Yet, existing government plans call for expansion of irrigated agriculture over the 2016–2020 period, implying a continued over-abstraction of groundwater.

Stakeholder consultations identified the following strategies to help improve water availability in the Sana'a basin:

- *Drip irrigation*: improve irrigation efficiency through the introduction of drip irrigation techniques; modelled by changing irrigation efficiency.
- *Improved indigenous methods for wadi flow use/infiltration*: introduce small dam construction as a means to improve wadi flow infiltration and decrease losses to evaporation.
- *Alternative crop production*: shift production from Qat to a less water intensive crop that enhances local food security; modelled by a 3% per year decrease in the areas cultivated with Qat starting in 2008, replaced with wheat.

- *Improved water distribution systems*: reduce high losses in the municipal water distribution system and introduce water saving domestic fixtures; modelled by reducing the annual water use rate in Sana'a by 1% per year starting in 2008 and reducing losses in the distribution system from an initial value of 30–10% over the study period.
- *Promotion of lower population growth in Sana'a city*: modelled by simulating population growth rate as 2%, compared to 5% in the Reference scenario.
- *Wastewater reuse*: use wastewater treatment plant (WWTP) effluent for irrigated agriculture requirements in a key peri-urban sub-basin; modelled by diverting treated wastewater to irrigation areas rather than letting it flowing into a nearby wadi.

Note that several of these options have localised, rather than basin-wide, impacts on water resource availability. For example, an improved water distribution system will benefit the urban area of Sana'a city and diminish groundwater abstraction from the Central Plains aquifer from which Sana'a City derives its water.

The WEAP model of Sana'a represents 22 hydrologic sub-basins and five major aquifer systems identified by studies by Sana'a University's Water and Environment Centre (WEC 2001a, 2001b, 2002); explicitly representing the Central Plain, Southwestern, Southeastern, Northeastern, Northwestern, Eastern and Western aquifers enabled modelling of regional differences in groundwater storage and availability across the Basin to be analysed. Hydrologic simulation in WEAP included partitioning of rainfall between runoff, infiltration, and evapotranspiration in the 22 sub-basins using a semi-distributed, lumped parameter hydrologic model embedded in WEAP (Yates *et al.* 2005). Each of these 22 sub-basins was linked to one of the five aquifers for purposes of simulating groundwater recharge. Irrigated, rainfed, and inactive land cover areas obtained from the National Water Resources Authority were included in this parameterisation. Crop types delineated included Qat, grapes, mixed crops, and orchards. Domestic demand was simulated using population projections for each of the sub-basins.

In the Reference scenario, the climate sequence for future years was developed by repeating historical data for the period 1932–2000 and assuming a similar periodicity through 2025 (Noaman *et al.* 2009). To gauge the impact of climate change on the Basin's water resources, the OSU Core and UKHI Dry precipitation and temperature trajectories (Table 1) were superimposed on the Reference sequence. Note that while this methodology incorporates possible changes in temperature and the magnitude of precipitation in the analyses, it does not address probable changes in the periodicity of precipitation due to climate change.

Sadah basin

The Sadah basin is an intermountain area situated in the western highlands of Yemen about 250 km north of Sana'a. The basin is characterised by sparse rainfall and high evapotranspiration rates, with no permanent or seasonal streams; only after heavy rains will surface water runoff discharge into Wadi Marwan, the main surface drainage channel in the basin.

Since the late 1970s, socioeconomic development in the region has emphasised irrigated agriculture reliant on groundwater abstraction. Between 1983 and 2001, a period during which total groundwater abstraction grew from 45 to 90 Million (M) m^3 per year, net aquifer recharge dropped to just 7 Mm^3 per year, an approximate 30% decline from previous levels. Indeed, by the end of 1998, the active zone of the aquifer had been exhausted.

The Basin's water vulnerability, as understood through stakeholder consultations, is due largely to the decision to mine groundwater unchecked – which has resulted in rapid depletion of groundwater, low efficiency of water use, and low coverage of water and sanitation services. Stakeholders identified the following adaptation scenarios to mitigate groundwater depletion in the Sadah Basin:

- *Improved irrigation efficiency*: aggressively introduce drip irrigation techniques to dramatically increase irrigation efficiency.
- *Increase storage capacity*: introduce five new dams in 2010, each with a 0.5 Mm^3 storage capacity, coupled with rain harvesting technologies and enhance groundwater recharge and increase rainfall runoff collection during dry months.
- *Greywater use*: construct and operate a WWTP with a capacity of 50,000 m^3 per day for Sadah city; effluent from the plant being diverted for agriculture irrigation and reuse in the city beginning in 2008.

The WEAP model for Sadah basin represents groundwater in one primary aquifer and surface water resources in seven major hydrologic sub-basins. Current groundwater storage for the entire basin was calculated to be 3728 Mm^3 based on available statistics for the basin (WEC 2002). Four existing surface storage structures (i.e. dams to capture flash flood waters) with a combined annual capacity of 1.7 Mm^3 were also included in the model.

Water demand was disaggregated between agricultural and household (domestic) uses. Domestic water demand was projected through 2025 using historical population growth rates for the urban population of Sadah city and the disbursed rural population surrounding the city. Agricultural water demand associated with irrigated areas was further divided among the three major crop types: grapes (40%), cereals (30%), and wheat (30%). As with the Sana'a basin, the lumped parameter hydrologic model embedded within WEAP was used to partition rainfall among runoff, recharge, and evapotranspiration.

The Reference climate was developed by repeating available historical precipitation and temperature values from the 1996–2006 period into 2007–2025 (Noaman *et al.* 2009). Again, two climate change scenarios employed the precipitation and temperature trajectories from the OSU Core and UKHI Dry models (Table 1) superimposed onto the Reference climate sequence.

Aden City

Aden City is the chief port for Yemen and one of the largest natural harbours in the world. Nearly 600,000 people lived in Aden in 2004, approximately 3% of the national population. Population growth is approximately 3.8% annually. As a growing urban centre and regional hub of commerce, Aden is plagued by consumption far in excess of available supply, and entrenched poverty, low distribution efficiencies, and failing physical infrastructure compound the situation.

Unlike Sana'a, there are no perennial rivers to meet this growing demand for water. The city depends entirely on groundwater well fields located in the Tuban and Abyan Delta basins located outside Aden in the Lahej and Abyan governorates – a source of acute political tension for the city that further complicates Aden's water scarcity vulnerability. The only surface water available is found in wadis near the Gulf of Aden, originating from rainfall in the southern part of the country. Seasonal flash flooding allows for limited groundwater recharge of the Tuban (Lahej) and Abyan Delta aquifers.

Stakeholder consultations identified the following adaptation strategies for Aden basin:

- *Desalinisation*: Supply Aden City with desalinated water from the Alhiswa hydropower plant at a capacity of approximately 22,000 m^3/day;

- *Improved irrigation efficiency*: Enhance irrigation efficiency via implementing drip irrigation technology, conveying irrigation water through plastic piping, and rehabilitation of traditional earthen irrigation channels combined with spate irrigation methods to transfer water to fields;
- *Use of greywater for recharge*: Treated effluent from the Aden WWTPs is injected into the Lahej, Abyan, and Tuban aquifers.
- *Use of greywater for irrigation*: Direct use of treated effluent from WWTPs for irrigation in the Lahej and Abyan Basins.
- *Improved water distribution systems*: Reduce distribution system losses for the urban centres of Aden, Abyan, and Lahej by 2.5% annually from initial loss rates of 34.2%, 33.1%, and 33.8% for Aden, Abyan, and Lahej, respectively (Komex 2002).

The WEAP model for the Aden Governate divides the system into two major sub-basins representing the Abyan and Tuban deltaic systems upstream of the city of Aden. These sub-basins comprise the ephemeral Tuban and Abyan wadis that convey flash floods during the rainy season from uplands located outside of the model boundaries. A groundwater aquifer for each of these two sub-basins was included in the model. Data for wadi flows and extraction from and recharge into the Abyan and Tuban aquifers were derived from earlier studies (Sogreah 1981, Negenman 1995, Saif 1998, Komex 2002).

Because of limited data regarding the hydrologic features of the Tuban and Abyan sub-basins, a more simplified hydrologic simulation within WEAP was used for Aden. With this construct, the percentage of rainfall available to land cover for evapotranspirative purposes was specified explicitly; the remainder of rainfall went to runoff in the Tuban and Abyan wadi systems. Groundwater recharge was accomplished with infiltrative losses from the wadis. Because temperature is not used as a parameter in this simplified hydrologic representation, only precipitation sequences needed to be developed for the Reference and climate change scenarios for the Aden model. The Reference precipitation was developed by replicating the sequence of available historical data (1952–1980) into the future (2007–2025), as was done for Sana'a and Sadah. Again, the OSU Core and UKH1 climate trajectories were superimposed on this Reference sequence to develop the two climate change scenarios (Table 1).

Results

Sana'a basin

Under the Reference climate, groundwater abstraction appears sustainable when the change in groundwater storage is viewed from a basin-wide perspective; storage levels off at approximately 65% of initial storage in the year 2020 (Figure 2(a)). However, when results for each of the five aquifers are represented individually, regional disparities are dramatically apparent (Figure 2(b)). Groundwater storage in the North Eastern, South Eastern and South Western aquifers appears to be sustainable under the conditions simulated in the Reference scenario, whereas groundwater drops precipitously and becomes *fully depleted* in the Central Plains, Eastern and North Western aquifers before 2020 (Figure 2(b)).

The impact of climate change on this system is observable, but not substantial. The OSU Core and UKHI trajectories result in an increase in irrigation demand by 1% and 2.8%, respectively, so that groundwater depletion occurs several months sooner in the Central Plains aquifer, for example (Figure 3). Thus, the model suggests that *existing* patterns in water use and availability themselves coincide to produce a potentially devastating

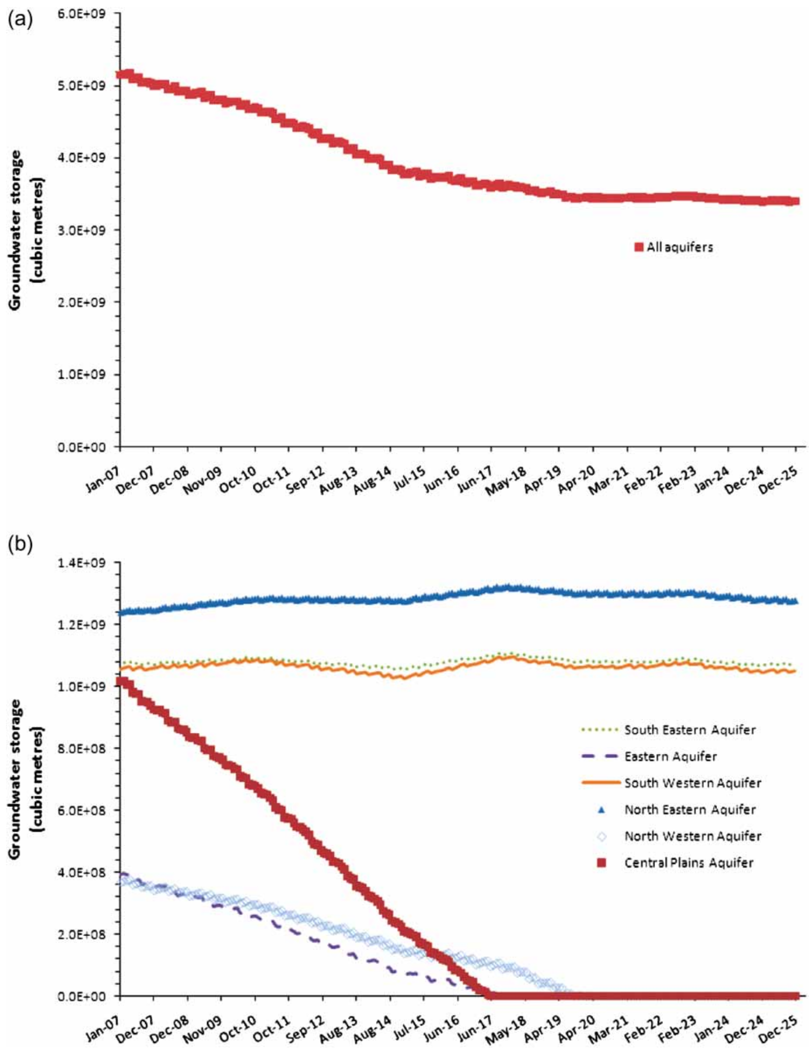

Figure 2. Groundwater storage in the six aquifers of the Sana'a basin under the Reference scenario represented (a) in total, and (b) individually.

depletion of groundwater resources within the next decade, with only minimal additional exacerbation of the situation due to expected climate change trajectories.

The adaptation strategies identified for Sana'a, when modelled individually to assess the potential for each to stabilise water demand and groundwater abstraction, failed to substantially curb groundwater depletion in the already greatly stressed Central Plains aquifer which serves the urban and peri-urban areas of Sana'a (Figure 4(a)). Note that the three strategies providing the greatest water savings over the study period (i.e. shifting the curves further to the right) are improving irrigation efficiency, improving urban efficiency, and wastewater re-use for agriculture. However, even the adaptation strategy providing the most dramatic water savings (i.e. using WWTP effluent for irrigation) only delays full depletion by three years compared to the Reference Scenario (Figure 4(a)). When *all* six adaptation strategies are initiated simultaneously, the rate of decline in groundwater

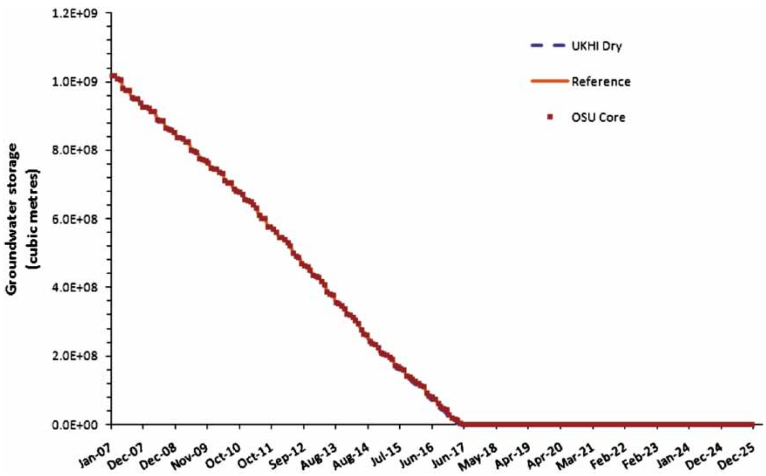

Figure 3. Sana'a basin's Central Plains aquifer storage under the Reference and climate scenarios.

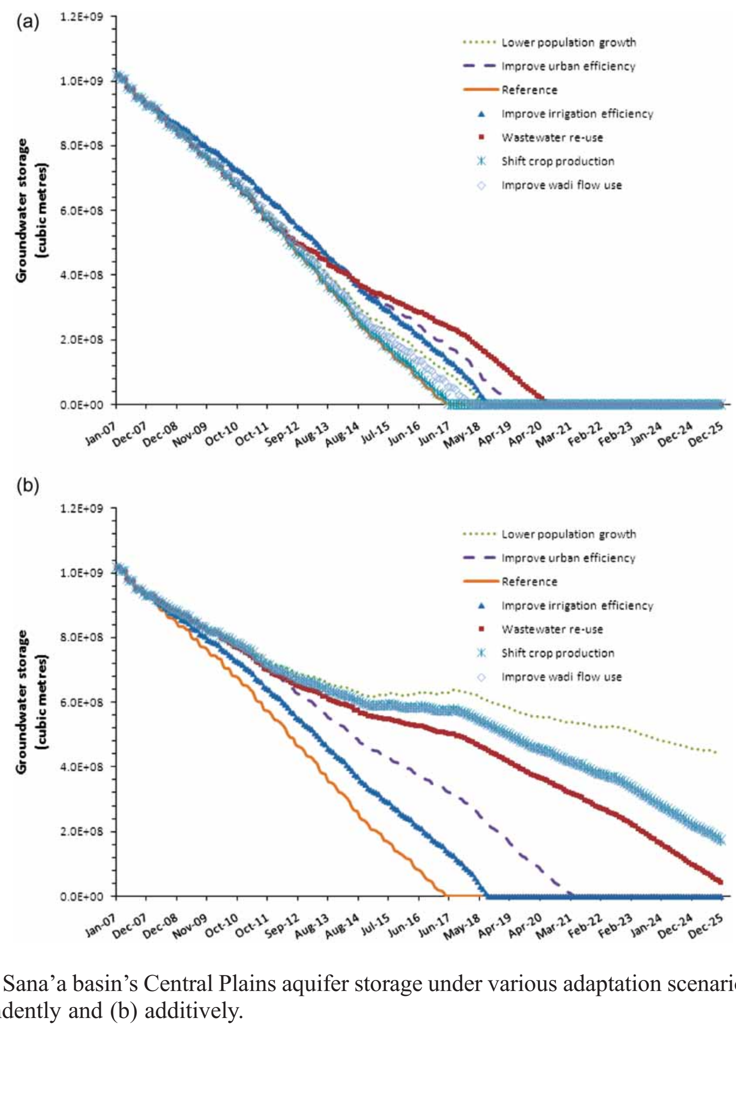

Figure 4. Sana'a basin's Central Plains aquifer storage under various adaptation scenarios simulated (a) independently and (b) additively.

storage in the Central Plains aquifer drops substantially, and depletion is avoided within the timeframe analysed as shown in Figure 4(b). The Eastern and North Western aquifers follow similar trajectories (results not shown).

Sadah basin

Under Reference conditions, the model suggests that groundwater depletion in the Sadah Basin will occur around 2024 (Figure 5). As with the Sana'a basin, the differential impacts of the two climate change scenarios on simulated groundwater storage trajectories in the Sadah Basin were minor (Figure 5). The predicted timing of aquifer depletion is roughly consistent with earlier studies by Al-Sakkaf (1996), which showed full depletion by 2032, and with Yemen National Water Authority study that showed full depletion by 2030.

When the mitigating effects of adaptation strategies are considered individually, as in Figure 6(a), the drip irrigation scenario avoids total groundwater depletion by only an additional two years relative to Reference conditions; building new dams delays depletion by only one year, and the option using greywater for agriculture has a negligible impact (due to the limited volume of water produced and stakeholders benefited). Even the additive effect of initiating all adaptation strategies together, an aggressive approach, does not stabilise annual groundwater demand relative to annual groundwater supply, and serves to delay the inevitable groundwater depletion by only a few more years (Figure 6(b)), with depletion not quite fully realised by the end of 2025.

Aden City

Under Reference conditions, both the Abyan and Tuban aquifers are essentially depleted by 2025 (Figure 7(a) and (b)), although depletion of the Tuban aquifer (Figure 7(b)) is more rapid (2015 versus 2019 for Abyan) because of a greater reliance on groundwater relative to wadi flow in the Tuban sub-basin. As with the two other case studies, climate change trajectories shifts the groundwater depletion curves in Aden very little (Figure 7(a) and (b)).

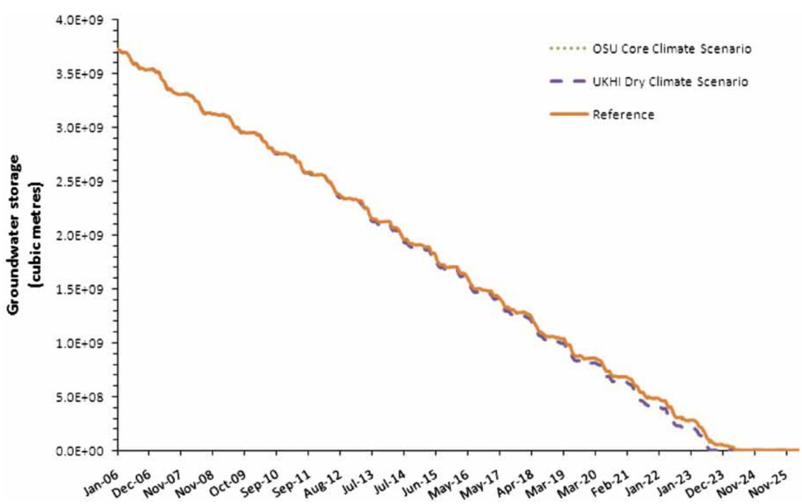

Figure 5. Groundwater storage in Sadah basin under the Reference and climate scenarios.

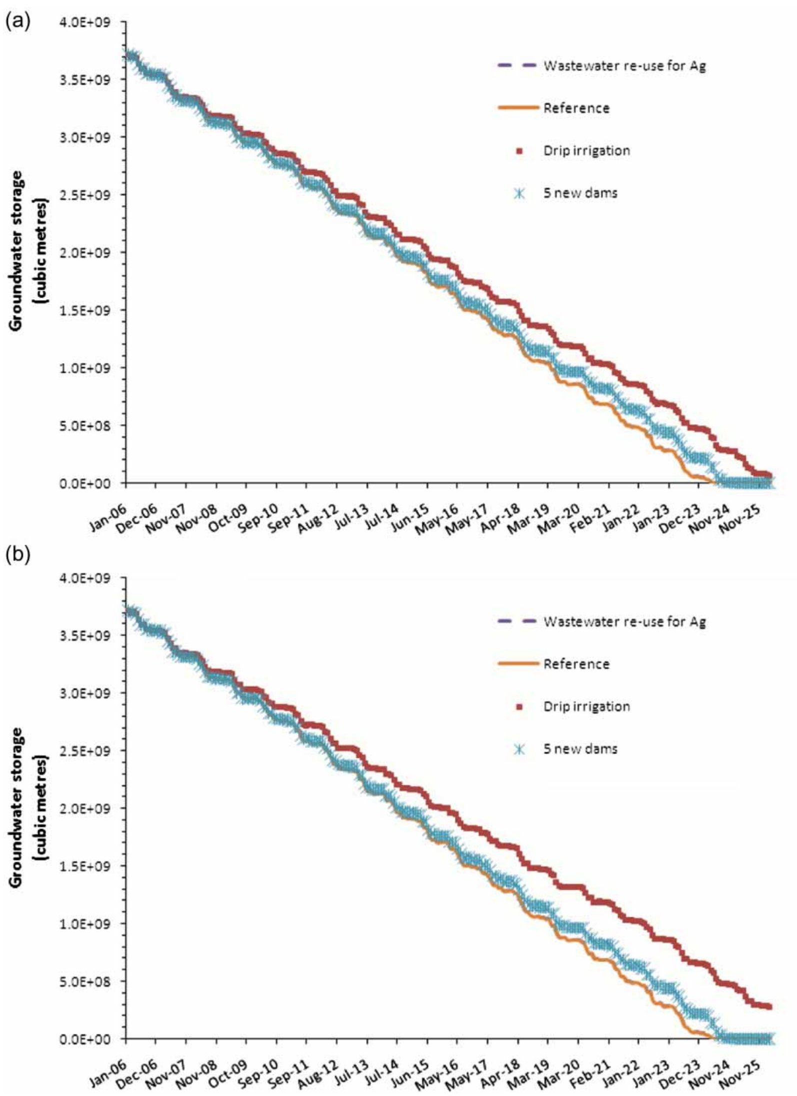

Figure 6. Groundwater storage in the Sadah basin under various adaptation scenarios simulated (a) independently and (b) additively.

Note that the UKH1 climate projection, for example, actually shifts the point of depletion several months earlier in Abyan (Figure 7(a)), consistent with the decrease in precipitation this climate model predicts.

Implementation of most of the adaptation strategies individually only slightly mitigates depletion of the Abyan and Tuban aquifers (Figure 8(a) and (b)). Only improved irrigation techniques (drip irrigation represented) provides for substantial water savings (25% in the Abyan sub-basin; Figure 8(a)), preventing depletion of that aquifer within the study timeframe. The Tuban aquifer avoids full depletion only approximately three years later than the Reference under the enhanced irrigation scenario conditions. Implementing all strategies together benefits the Abyan aquifer more dramatically than the Tuban aquifer (Figure 9(a) and (b)). For the Abyan aquifer, the cumulative impact of all strategies

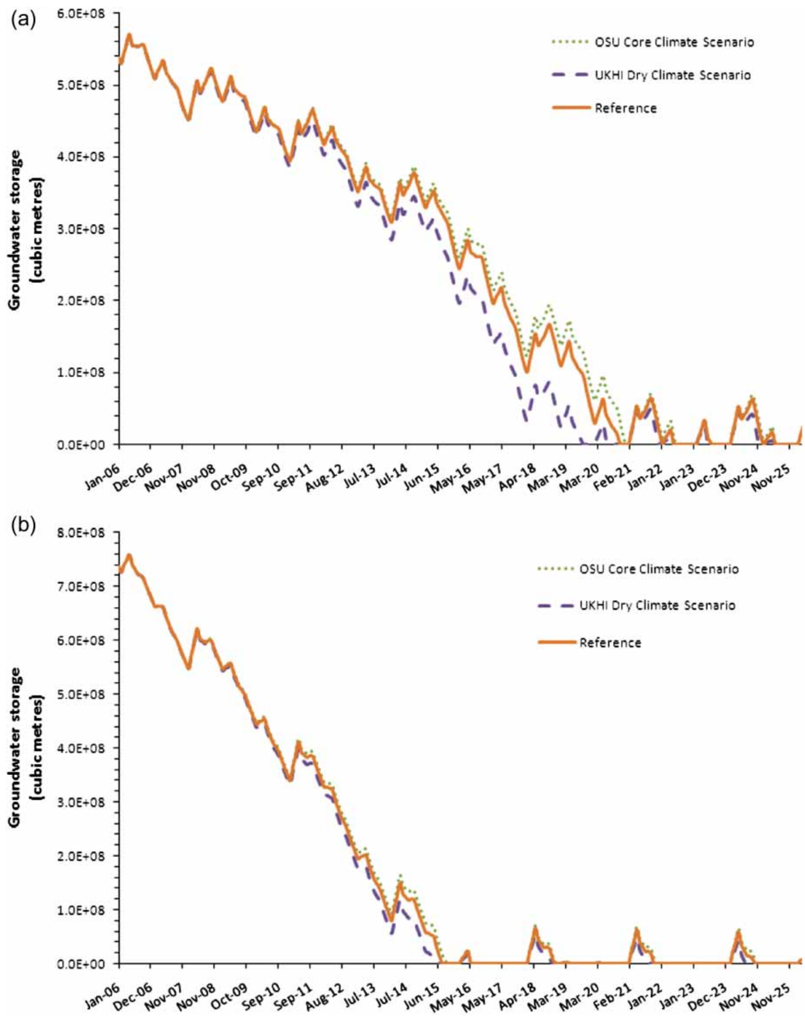

Figure 7. Groundwater storage in the Aden basin for (a) Abyan and (b) Tuban aquifers, under the Reference and climate scenarios.

appears to result in a sustainable trajectory, with groundwater storage levelling off and even rising somewhat (Figure 9(a)). For the Tuban aquifer, storage continues to decline, although much less dramatically compared to the Reference condition (Figure 9(b)).

Conclusions

Water balance modelling conducted in this study suggests that existing imbalances in water demand and water supply in three representative case study areas in Yemen greatly eclipse any additional impact that predicted climate change may exert on the water resource systems. These analyses also indicated that implementation of any single, stakeholder-identified, adaptation strategy does not appear to be able to fully reverse, or at least stop, further expected declines in groundwater resources over the next decade. However, a combination of multiple targeted strategies does appear to be sufficient to create a sustainable

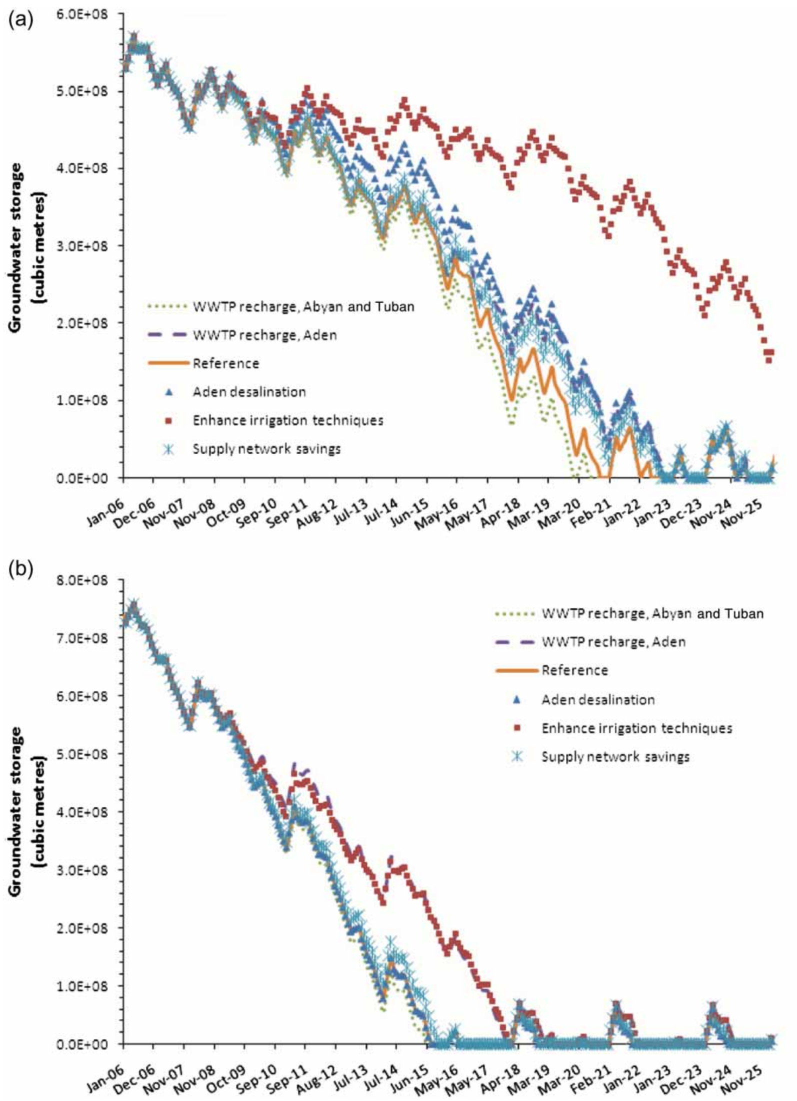

Figure 8. Groundwater storage in the Aden basin under various adaptation scenarios simulated independently for (a) Abyan aquifer and (b) Tuban aquifer.

course for groundwater use in Sana'a and Aden. The outlook for Sadah is more grim, as all identified strategies, when implemented simultaneously, do not appear to forestall full groundwater depletion there more than a few years beyond the reference condition. This suggests that this region in particular is on the cusp of a severe water scarcity crisis, which it may be too late for incremental improvements to avoid.

These results underscore the extreme vulnerability that Yemen faces with regard to water availability over the coming decade and the monumental coordination effort that will be required just to forestall full water resource depletion, let alone achieving sustainable balance between water demand and supply. The implications of this finding are overwhelming from a policy perspective. As noted by World Bank (2010), Yemen's National

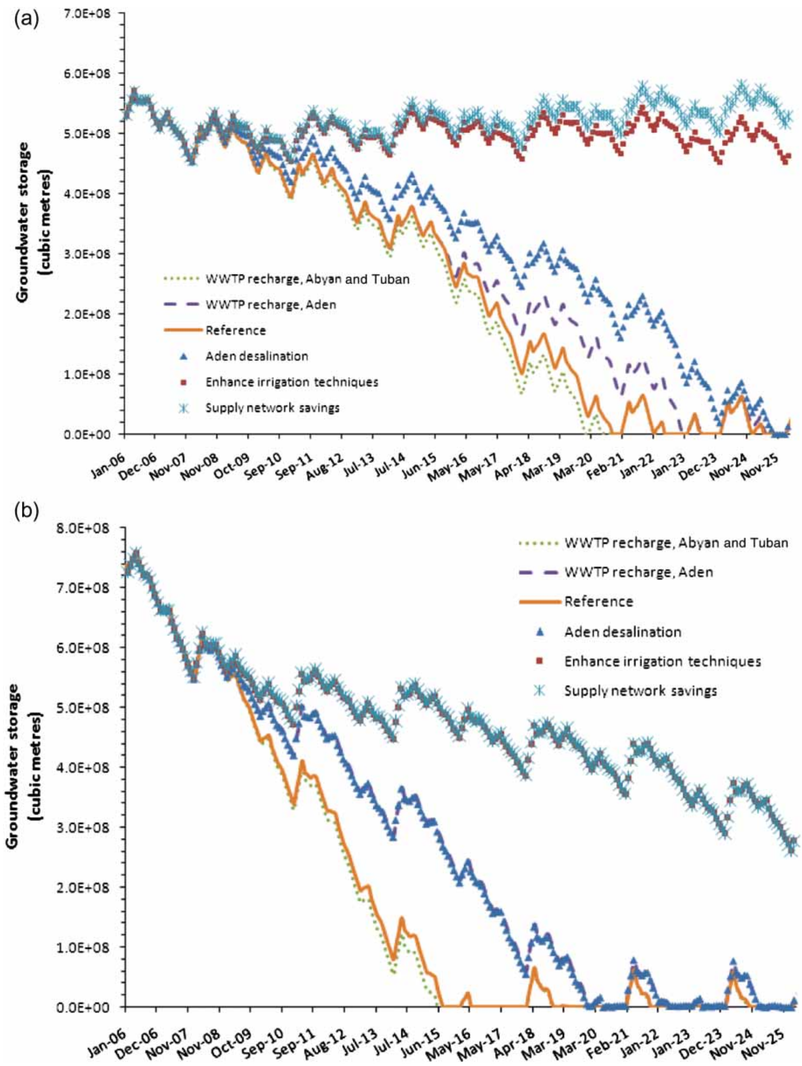

Figure 9. Groundwater storage in the Aden basin under various adaptation scenarios simulated additively for (a) Abyan aquifer and (b) Tuban aquifer.

Water Sector Strategy and Investment Program, updated in 2009, and its National Plan of Action provide existing frameworks for facilitating and supporting such adaptation measures. Indeed, that study discussed how currently ongoing government agency initiatives can already accommodate initiatives focused in particular on efficient irrigation, rejuvenating indigenous water harvesting methods, and rethinking cropping pattern choices (World Bank 2010).

Obviously, other, more intensive (e.g. strict water rationing), expensive (e.g. long-distance water hauling and importation) and politically unpalatable (e.g. relocation of existing communities) strategies will likely need to explored, soon, to minimise this crisis. The implications of continued inaction to resolve the supply/demand imbalance in Yemen are already being felt; the water shortage in Yemen is starting to cause civil unrest. A recent report from Sana'a University suggests that 70–80% of rural conflicts are related to water in Yemen and Abdulrahman Al Eryani, Yemen's minister of Water and Environment, argues that much of the country's rising militancy can be tied to a conflict over resources—either land, oil, or water (Kasinof 2009).

Note

1. Qat, in the form of bitter, chewable leaves, is a narcotic drug chewed by many in Yemen. Typically, Qat is chewed after lunch and continually through the day. As referenced above, the use of water to grow qat is a major contributor to Yemen's water crisis.

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