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5 **Tackling the trickle: ensuring sustainable water management in**
6 **the Arab region**

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23 **Key points:**

24 • Arab region not on track to meet Sustainable Development Goal 6 on clean water supply and
25 sanitation for all

26 • Narrative of water scarcity and supply-side technological fixes masks systemic issues that
27 threaten sustainable water management

28 • Water security in Arab region cannot be understood in isolation from broader regional and
29 international political and socio-economic trends

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Abstract

Water scarcity in the Arab region is intensifying due to population growth, economic development and the impacts of climate change. It is manifest in groundwater depletion, freshwater ecosystem degradation, deteriorating water quality, low levels of water storage per capita and added pressures on transboundary water resources. High-income Arab countries have sought to circumvent the ever-present challenges of water scarcity through agricultural imports (virtual water trade), desalination and increasingly wastewater reuse. In this review article, we argue that the narrative of water scarcity and supply-side technological fixes masks more systemic issues that threaten sustainable water management, including under-performing water utilities, protracted armed conflict and displacement, agricultural policies aimed at self-sufficiency, evolving food consumption behaviors, the future of energy markets, and educational policy. Water management challenges, particularly on the demand side, and responses in the Arab region cannot be understood in isolation from these broader regional and international political and socio-economic trends. Recognizing the complex and interdependent challenges of water management, and how these vary across the Arab region, is the first step in reforming approaches and shifting to more sustainable development outcomes and stability in the Arab region and beyond.

Accepted Article

Introduction

For hundreds of years societies in the Arab region have adapted to arid landscapes through innovations and investments in water management and irrigated agriculture. Although the region has historically adapted to water scarcity, burgeoning populations, rapid urbanization and increased economic development mean that sustainable water management is becoming a defining issue for the Arab region in the 21st century (Gleick et al. 1994). The Sustainable Development Goals (SDGs) — agreed to by Arab countries in 2015 (Allen et al. 2017) — present a new set of ambitious targets and broaden the purview of water policy from the rather narrow perspective of the Millennium Development Goals (MDGs). At the same time, they challenge Arab countries to think about and manage water in new ways, including calling for new, multi-sectoral approaches and policies on sustainable water management.

This review assesses the status of sustainable water management in the Arab region by examining progress towards the ‘water SDG’ (i.e., SDG 6: “*Ensure availability and sustainable management of water and sanitation for all*”). It then describes how uncertain regional and global trends shape countries’ progress towards this goal. Although water challenges and responses are context-dependent and local, they are influenced by international and regional developments, including trends in population growth and movement, environmental shifts, and evolution in governance practices and ideas. Hence, this review seeks to account for the interactions between broad scale drivers of change and their manifestations for water management at more local scales.

Though Arab countries face some common water management challenges, the region is highly heterogeneous. To enable us to reflect economic differences across the region, whilst still writing a concise review, the following income-based typology (details in Supplementary Table 1) is used throughout this paper:

1. High-income with high oil rents: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates;
2. Middle-income with high oil rents: Algeria, Iraq, Libya;
3. Middle-income, low population: Djibouti, Lebanon, Jordan, Mauritania, Palestine, Tunisia;
4. Middle-income, populous agrarian economies: Egypt, Morocco and Sudan;
5. Low-income: Comoros, Somalia, Syria and Yemen.

Water issues facing the Arab region



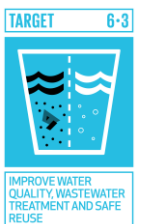




Access to water services

Access to drinking water supply and sanitation remains a challenge in low-income countries in the Arab region, especially those affected by conflict. In most other countries, access to basic water services

(Table 1) is on track or moderately good, with many Arab countries having reached the MDG targets in 2015 (Supplementary Table 2). Although access has improved, very large disparities exist in terms of the quality and reliability of water services within countries (Zawahri et al. 2011). Countries will have to significantly step-up their efforts in order to meet the safely managed water services targets expressed in SDG 6.1 and 6.2. Moreover, access statistics mask rural-urban disparities, which are particularly stark in Morocco, Yemen, Iraq and Palestine (Supplementary Table 2). Access statistics also mask the disproportionate impacts faced by children and women in accessing water services, including through higher incidence of water-related diseases (Walker et al. 2012), the hardship and opportunity costs of time spent fetching water for households (Sorenson et al. 2011) and greater barriers in conflict situations (e.g., absence of separate latrines, menstrual hygiene management) (Samari et al. 2017).

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Table 1. Sustainable Development Goal 6 scorecard for Arab countries.

Water Challenge	Drinking water		Sanitation		Water quality	Water stress	Water use efficiency	Integrated Water Resources Management	Water-related ecosystems	
Related SDG target										
Indicator	<i>Population using at least basic drinking water services (percent)</i>		<i>Population using at least basic sanitation services (percent)</i>		<i>Percentage of safely treated wastewater flows from households (percent)</i>	<i>Level of water stress: freshwater withdrawal as a percentage of available freshwater resources (percent)</i>	<i>Change in water-use efficiency over time (2013-2015), (percent)</i>	<i>Degree of integrated water resources management implementation (0-100)</i>	<i>Mean area that is protected in freshwater sites important to biodiversity (percent)</i>	
	Indicator value and rating	Trend	Indicator value and rating	Trend	Indicator value and rating	Indicator value and rating	Indicator value and rating	Indicator value and rating	Indicator value and rating	Trend
ALGERIA	93.5	↗	87.5	↗	40	88.0	-13	31-50	49.0	→
BAHRAIN	100.0	→	100.0	→	99	205.0	-9	31-50	• •	
COMOROS	83.7	↓	34.2	↗	36	1.2	-3	0-30	• •	
DJIBOUTI	76.9	→	51.4	→	13	7.9	-16	• •	0.0	→
EGYPT	98.4	→	93.2	↗	40	159.9	15	31-50	28.5	→
IRAQ	86.1	↗	85.7	→	20	93.0	36	0-30	5.1	→
JORDAN	98.6	↓	96.7	→	90	118.4	0	51-70	7.2	→
KUWAIT	100.0	→	100.0	→	94	2603.0	61	71-90	• •	
LEBANON	92.3	↗	95.4	↗	56	33.3	7	31-50	21.1	→

LIBYA	96.8	→	99.7	↓	17	1072.0	-3	31-50	• •	
MAURITANIA	69.6	↗	44.6	↗	40	15.9	-7	31-50	• •	
MOROCCO	83.0	↑	83.5	↑	46	49.0	2	51-70	80.8	↑
OMAN	90.9	↑	99.3	↑	47	106.2	-17	31-50	• •	
PALESTINE	87.7	↓	96.0	→	18	50.0	-8	• •	• •	
QATAR	100.0	→	100.0	→	98	472.5	-2	71-90	• •	
SAUDI ARABIA	100.0	→	100.0	→	36	1242.6	-21	51-70	12.4	→
SOMALIA	40.0	→	16.2	↓	6	30.3	-42	11-30	0.0	→
SUDAN	58.9	↗	34.6	→	24	93.7	-6	31-50	0.0	→
SYRIA°	27.0	↓	27.0	↓	32	109.4	• •	• •	4.3	→
TUNISIA	94.2	↑	93.1	↑	97	94.0	-28	51-70	43.4	↑
UNITED ARAB EMIRATES	100.0	→	100.0	→	83	2346.5	19	71-90	• •	
YEMEN, REP.*	58.3	↓	58.3	↓	32	227.7	• •	• •	7.7	→
Source	WHO (2017)		WHO (2017)		AbuZeid et al. (2019)	Sachs et al. (2018)	AbuZeid et al. (2019)	UN Environment (2018)		Sachs et al. (2018)

↓ → ↗ ↑ → • •

Decreasing Stagnating Moderately increasing On track Maintaining SDG achievement No data

Note: For indicator ratings, green denotes SDG achievement; red highlights major challenges, while yellow and orange indicate good and moderate progress respectively. * Drinking water and sanitation values for Yemen, Rep. are estimated based on the number of people requiring water supply and sanitation assistance (17.8 Million) in 2018 (United Nations 2019a). ° Drinking water and sanitation values for Syria are estimated based on the number of people requiring water supply and sanitation assistance (15.5 million) in 2018 (United Nations 2019b).

Water quality

Water in surface and groundwater bodies is polluted in most countries (Table 1), with harmful impacts for people and the aquatic environment. The region is not on track to meet SDG 6.3 on water quality and wastewater by 2030 and even in countries where SDG monitoring reports suggest good progress such as Jordan and Tunisia, local evidence suggests otherwise (e.g., Zarqa river in Jordan (Al-Omari et al. 2019), Medjerda river in Tunisia (Etteieb et al. 2017)). This highlights the need to consider SDG indicators with caution as national indicators might hide considerable sub-national variation. Three main sources of pollution threaten water quality in the region. First, domestic wastewater, of which more than 50 percent is discharged untreated in surface water bodies (WHO and UN Habitat, 2018). Second, industrial water pollution. Although countrywide estimates are lacking, Lebanon (Daou et al. 2018), Egypt (Abdel-Satar et al. 2017), and Morocco (Barakat et al. 2016) among others face widespread industrial pollution. Oil spills and seepage from pipelines are also causes of water pollution, as observed in Iraq (Mawlood et al. 2018; Human Rights Watch, 2019) and Libya (Koshlaf et al. 2016). Finally, uncontrolled runoff from agricultural land degrades water quality. Nitrogen losses from manured agricultural lands to freshwater courses are about 25 percent of the applied fertilizer, much greater than the global average of 11 percent; while phosphate releases to the environment are about 12 percent of the phosphorus applied as fertilizer, in line with a global average of 12 percent (Mateo-Sagasta et al. 2018). High concentrations of nitrogen, phosphate and other nutrients result in eutrophic lakes, reservoirs and coastal waters along the Mediterranean coast of Morocco (Bocci et al. 2016), the Red Sea (Jessen et al. 2013), and the Nile Delta (Oczkowski et al., 2008; El-Shazly et al. 2017).

Salinization of surface freshwater bodies owing to human activities is a critical water quality issue in the Arab region (Damania et al. 2019), with detrimental consequences for human health, ecosystems and agriculture. Hotspots of surface water salinization include the Mesopotamian Marshes (Al-Mudaffar Fawzi et al. 2016), Shatt al-Arab river (Mahdi and Al-Mudaffar Fawzi, 2014), Jordan valley (Farber et al. 2005) and increasingly the Nile basin, where careful management of drainage water salinity is needed given that one third of the irrigated areas in Egypt and Sudan are already salinized (Mutsch et al. 2017). In addition, groundwater salinization due to over-exploitation affects the coastal aquifer in Gaza (Dentoni et al. 2017), the Wadi Ham in the UAE (Sherif et al. 2012), the Nile Delta (Sefelnasr and Sherif, 2014; Molle et al. 2018) and the Sfax aquifer in Tunisia (Trabelsi et al. 2016), among others. The groundwater salinity situation is particularly dire in the Comoros Islands, where fewer than 30 percent of wells provide water of acceptable drinking water quality (Comte et al. 2016).

Coping with water stress and variability

Most Arab countries have high to very high-water stress meaning that water withdrawals exceed by more than 40 percent total renewable freshwater availability (Supplementary Figure 1). Highly variable and unpredictable rainfall compounds these high levels of water stress. On average across the Arab

region, annual freshwater availability can vary by more than 75 percent from the long-term average, compared to a global average of 25 percent (see coefficient of variation in Supplementary Figure 1). High year-to-year variability means that floods and droughts regularly affect Arab countries. The number of people affected by drought in the region from 1970 to 2019 is about 60 million, with at least 20 million just in the last decade according to the EM-DAT international disasters database (Supplementary Table 3). Region-wide economic estimates of the impact of droughts are lacking, though country-level evidence suggest that these are of the order of several points of GDP (Banerjee et al. 2014). At the other end of the hydrological spectrum, floods also create ongoing challenges across the region. A conservative estimate of the total number of floods, including riverine, pluvial and coastal floods, suggests that at least 283 major floods have occurred since 1970, affecting about 15 million people (i.e., people requiring immediate assistance following the flood), causing more than 10,000 fatalities and annual economic losses of USD 200 million (Supplementary Table 3). The impact of water-related disasters and variability is higher in countries affected by protracted conflict, as the populations' adaptive capacity is often overly strained in these contexts (Harris et al. 2013). The top three countries most affected by drought are also among the most fragile in the region (Sudan, Syria and Somalia). A similar pattern is observed for floods, where the largest number of people affected is concentrated in Sudan, Somalia and Yemen, which are all facing protracted armed conflict situations.

Arab countries have adapted to water stress, variability and extremes in multiple ways, often with unintended consequences for long-term sustainability. They have long invested in water storage. As a result, the region as a whole has the largest volume of water stored in reservoirs as a share of its total freshwater resources endowment in the world (i.e., most of the scarce surface freshwater resources available have been stored in reservoirs) (World Bank 2018a). Even though most countries have a large proportion of their surface water resources stored in reservoirs, these stored volumes are relatively low on a per capita basis (especially in high-income countries) (Supplementary Figure 2). Relatively few dam sites are suitable for surface water storage—use of less suitable sites and high ambient temperatures means that evaporation losses from these reservoirs are high. The low levels of water storage are also reflected in the low hydropower generation, which accounts for less than 2 percent of total electricity generation, apart from Egypt (7-10 percent from the High Aswan Dam and declining), Morocco (5 percent), and Iraq (4 percent) (International Energy Agency 2016). Given the limits to expansion of surface water storage and increasing variability predicted under climate change, countries are increasingly resorting to aquifers to store water (Dawoud, 2008; Lopez et al. 2014; Dillon et al. 2019).

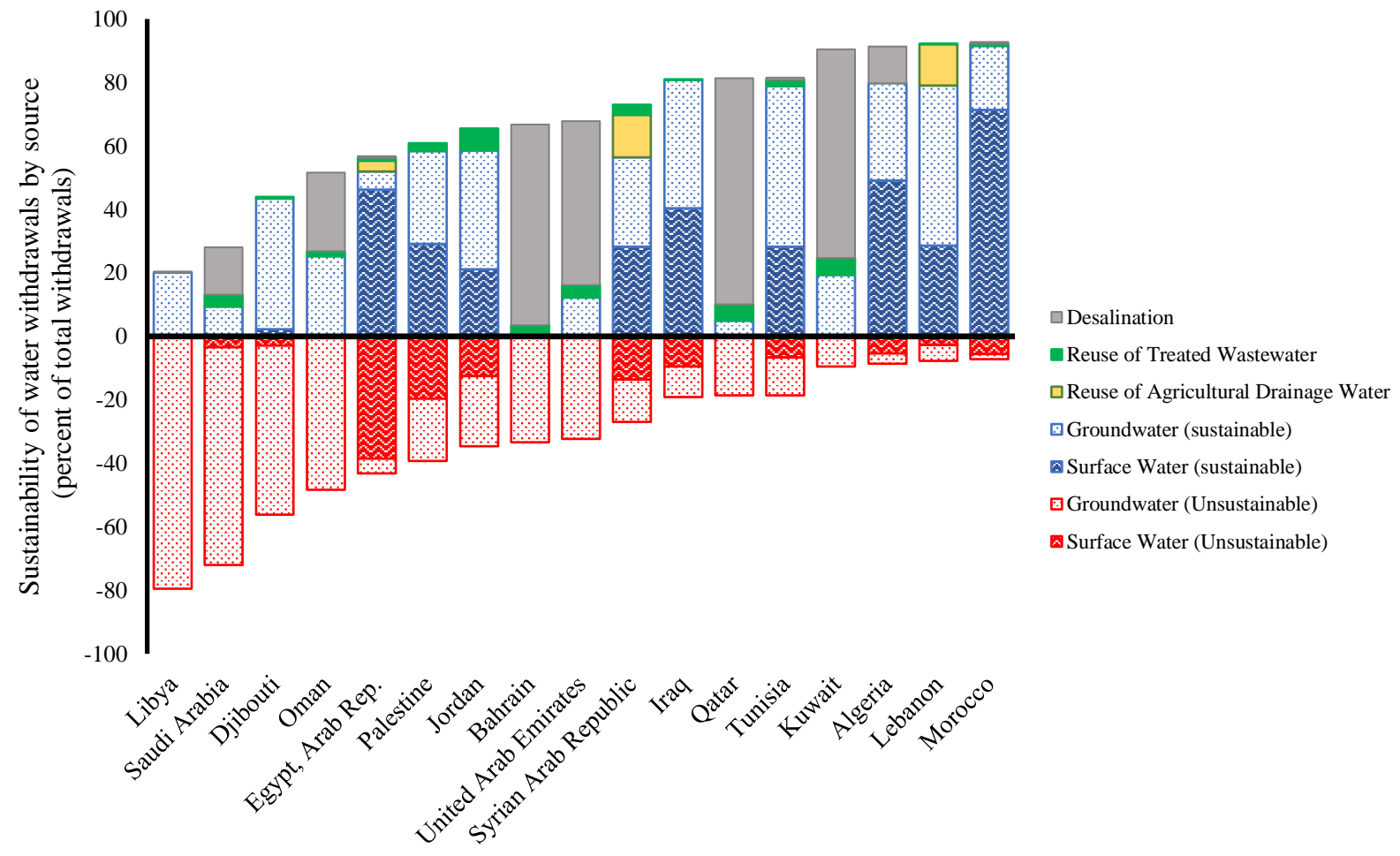
High-income countries have deployed desalination technologies at scale to augment supplies (Supplementary Table 4). They now account for about 50 percent of the world's desalination capacity, though they only host less than 1 percent of the global population (World Bank, 2018a). Reliance on nonrenewable energy for desalination is a key attribute of the region's water-energy nexus, especially in the high-income countries and Algeria, where desalinated water is the main supply source for

domestic users and its purification and distribution consume large amounts of energy (e.g., 10 percent of the total annual energy consumption in Saudi Arabia (Siddiqui and Anadon, 2011) and 20 in the UAE (Commander et al. 2015)). Beyond high energy costs, desalination also brings greenhouse gas emissions and impacts on marine ecosystems (Jones et al. 2018). Arab countries are also expanding their wastewater reuse capacity. Although most countries practice some reuse, the scale varies enormously with only a few countries having successfully implemented substantial reuse programs (Kfourri et al. 2009). In fact, in some middle- and low-income Arab countries, unplanned reuse is most prevalent, often because farmers have no alternative source of irrigation water, raising concerns for public health and protection of the environment (Qadir et al. 2010). In high-income countries, wastewater reuse is becoming an increasingly important component of these countries' water supply portfolios, thanks to policies to mandate water reuse and the existence of infrastructure systems for collecting and treating wastewater (Jeuland, 2015).

Water conservation, including water harvesting and management of green water (moisture from rain held in soils), is a key strategy for coping with water scarcity and variability in agriculture. Water harvesting has been practiced for centuries in the region, and a number of systems based on local knowledge are still in operation such as *jessour* and *meskat* in Tunisia, *tabia* in Libya, cisterns in north Egypt, *hafaer* in Jordan and Syria (Oweis et al. 2006). National water strategies and budgets do not currently include green water (Antonelli and Tamea, 2015), and water management policies often underestimate its potential to support rain-fed agriculture in regions where irrigation is not viable because of lack or over-allocation of blue water (surface and groundwater) resources (Rockström and Falkenmark, 2015). Across the region, reviving water conservation and green water management is a priority to cope with water scarcity and variability.

Notwithstanding these investments in infrastructure (storage, desalination, wastewater reuse) and water conservation, the Arab region is a global hotspot of unsustainable water use, with at least 30 percent of current water consumption exceeding sustainability limits (Figure 1) (Wada and Bierkens, 2014). Unsustainable water use arises when the ecosystems' needs for water are not satisfied due to human exploitation of surface water resources and when groundwater consumption exceeds the natural replenishment rate of groundwater bodies or taps into non-renewable water resources, such as fossil aquifers. Unsustainable water consumption has increased in all Arab countries since 1970, apart from high-income countries. In these countries, unsustainable water consumption remains high in absolute terms but has stabilized (Wada and Bierkens 2014), in part because of increasing reliance on desalination, phasing out of agricultural policies that promoted the use of fossil aquifers, especially in Saudi Arabia (Grindle et al. 2015), and reduction in cropland (Mutsch et al. 2017).

Figure 1. Sustainability of water consumption by supply source. Supply sources above zero are consumed sustainably, while supply sources below zero and colored in red are subject to unsustainable consumption. No data for the Comoros, Mauritania, Somalia, Sudan and Yemen, Rep. Adapted from World Bank (2018a).



The groundwater situation is extremely concerning; with global and local studies reporting systematic depletion across the region (Doell et al. 2014). Satellite-based estimates have identified significant declines in total water storage in the Northwest Sahara Aquifer System (Famiglietti, 2014) and in the Tigris and Euphrates basin, where at least 60 percent of water storage loss is attributable to groundwater depletion (Voss et al. 2013; Joodaki et al. 2014). Local studies suggest dramatic declines in aquifer levels in the Paleogene and Cretaceous aquifers in Syria (Stadler et al. 2012), in the Amman Zarqa and Lower Jordan basin in Jordan (Good et al. 2013; Al Naber and Molle, 2017) in the Souss-Massa aquifer in Morocco (Hssaisoune et al. 2017), and the transboundary Nubian Aquifer (Ahmed and Abdelmohsen, 2018) amongst others.

Water use-efficiency

In the face of water scarcity, degrading water quality and freshwater ecosystems, countries should seek to make the most of water by increasing the efficiency of use and avoiding wastage. Given the lack of comprehensive water accounts for the Arab region (i.e., systematic quantitative assessments of water supply, use, distribution), any analysis of changes in water-use efficiency is partial at best. Table 1 presents data collected by the Centre for Environment and Development for the Arab Region and Europe (CEDARE) (AbuZeid et al. 2019), which are in line with UN preliminary estimates (United Nations, 2018). Nonetheless, we recognize the uncertainties surrounding these estimates and focus the discussion on broad trends only.

When water-use efficiency is considered in economic terms (i.e., monetary output per volume of water inputs), there are striking differences across the region, with high-income countries showing increases in water-use efficiency and higher economic output being generated per unit volume of water (Table 1). These statistics partly reflect the structure of the economy. High-income countries typically have larger services and manufacturing sectors and smaller agricultural sectors than lower-income countries. Because the former sectors tend to achieve significantly higher economic returns per unit of water use, their overall economic water efficiency is higher. However, viewing a country's use of water just in terms of economic output per unit of water withdrawn and allocative efficiency is restrictive. Water use in the Arab region is embedded in social, cultural and geographical landscapes (e.g., agricultural terraces (Harrower, 2008)) and political visions (e.g., desert greening (McDonnell, 2014), food sovereignty (Harrigan, 2014)).

The water use-efficiency of urban water utilities (i.e., losses occurring in urban water distribution networks) varies, and is low in most countries with a few notable exceptions. In the middle-income countries of the Mashreq, urban water supply distribution systems lose in the range of 35-50 percent of water put into the supply system due to leakage and unregistered usage (UN Habitat, 2012). Similar levels of non-revenue water are reported for countries in North Africa, including Tunisia (26 percent) and Algeria (54 percent) (Danilenko et al. 2014). In the high-income countries, non-revenue water

ranges from 30 percent in Oman and Saudi Arabia, to 24 percent in Bahrain, 20 percent in Qatar, 13 percent in the UAE and 5 percent in Kuwait (World Bank 2017).

Integrated Water Resources Management

There is a mismatch between the scale of the Arab region's water challenges and governance responses. Assessment of water governance according to SDG 6.5 demonstrates that progress towards Integrated Water Resources Management (IWRM) — regarded as the framework for sustainable water governance — so far has been limited, with most countries needing to expand significantly IWRM (Table 1).

Governance of transboundary waters is a particular issue in the region because of the number of shared surface and groundwater resources and their potential to generate disputes between states in the region (World Bank 2018a; Nijsten et al. 2018). In fact, some of the seminal academic works on transboundary waters focused on the hydrogeopolitics of one of the major transboundary rivers of the region, the Nile basin (Waterbury 1979). To date, no inter-state wars have been fought over transboundary waters (Subramanian et al. 2014); however, potential tensions over transboundary waters might heighten as water use equals or exceeds available resources, as pollution increases and countries seek to develop water resources to foster economic growth (De Stefano et al. 2017), including in the Asi-Orontes (Bernauer and Böhmelt, 2014) Jordan (Jägerskog, 2003), Nile (Whittington et al. 2014), and Tigris-Euphrates (Kibaroglu, 2019) river basins (see Supplementary Note 1). The Arab region hosts two of the three transboundary aquifers in the world with an operational arrangement for water cooperation (North Western Sahara Aquifer system and the Nubian Sandstone aquifer system) (McCracken and Meyer, 2018) and examples of innovative management agreements (e.g., Disi aquifer pumping agreement between Jordan and Saudi Arabia (Müller et al. 2017)), demonstrating that cooperation over shared waters is feasible and has been applied in the region.

Water-related ecosystems

The impacts of unsustainable water use, alterations of river flow regimes, water pollution and drought on freshwater ecosystems - and on the livelihoods of people who depend on ecosystem services - have not been quantified at the regional level. Nonetheless, SDG monitoring data and regional studies suggest that freshwater biodiversity and ecosystems, including wetlands, are deteriorating and that freshwater species are highly threatened with extinction (Darwall et al. 2014; Garcia et al. 2015; Al-Obaid et al. 2017; United Nations 2018). These trends are also causing major losses in cultural knowledge and livelihoods (Al-Mudaffar Fawzi et al. 2016).

The discharge of brine-effluents from desalination plants into coastal environments poses a rising threat to marine ecosystems. The Arab region is responsible for about 70 percent of the brine produced in the world, with Saudi Arabia alone accounting for 22 percent of the global share (Jones et al. 2018). This proportion is much larger than the share of desalinated water produced, indicating that desalination plants in the region operate at very low recovery ratios (ratio of the desalinated water volume to the

seawater volume). Brine production negatively affects marine ecosystems in the Arabian/Persian Gulf (Al-Sharrah et al. 2017) and in the Red Sea (Petersen et al. 2018). Brine-discharge can also increase the overall costs of desalination, because of the increased salinity at plant intakes and lower recovery ratios, challenging its cost-effectiveness (Bashitialshaaer et al. 2011).

Critical trends and uncertainties shaping sustainable water management

The previous section briefly reviewed major water issues in the Arab region. This section expands this description by exploring the critical trends and uncertainties shaping these issues and available responses. Considering these broader trends outside of the ‘water box’ is essential, because social, economic, political and environmental factors outside of the water sector, including political interests, largely define water challenges and responses (Zhu et al. 2019). Eight major critical trends with the potential to shape the region’s water outlook are examined: urbanization and demographic growth, the presence and extent of conflict (including its impact on displacement), agricultural and food security policies, developments in energy markets, climate change, land management and erosion, state-citizen relationships and educational policy. Issues of trade create multiple uncertainties, which we discuss under the respective areas of energy and food. Combined together, these critical trends make water management a new and more critical challenge than ever before in the Arab region, and one that extends far beyond just coping with water scarcity.

Urbanization and population growth

The Arab region experienced rapid population growth over the past decades (UN DESA 2018). Though population growth is expected to slow down in the coming decade, the region’s population will still increase by 110 million people by 2030 and 210 million people by 2050, mostly in cities (OECD/ FAO 2018). By 2050, urban population is projected to double from 2017 levels, with 75 percent of the region’s population living in cities (World Bank 2018b). These high levels of urbanization are turning parts of the Arab region into a highly congested landscape: 3 percent of the region’s surface area is home to 92 percent of the total population, 50 percent in urban areas and along the coast (UN Habitat 2012).

As the urbanization and population growth trends continue, water resources are likely to come under increasing pressure. Population growth will lead to increasing water demands and water shortage, with the impacts of population growth on the latter expected to be larger than the impacts of climate change in all countries (Droogers et al. 2012). Urbanization and related income growth in urban areas may also bring about a shift towards more water-intensive diets rich in animal proteins. In addition, as countries urbanize and cities expand, water competition between cities and agriculture might intensify, requiring adaptation in rural areas to avoid impacts on rural water availability becoming a hindrance to

agricultural development and potentially reinforcing rural-urban migration. In southern Iraq, lack of water of adequate quantity and quality is already forcing people to move (IOM 2019).

Urban sprawl is poised to have negative impacts on water supplies by encroaching on sources and contributing to pollution, highlighting the need for legislation to regulate land use and protect supply sources. Uncontrolled urban expansion has resulted in water quality deterioration in Egypt (Zaghloul et al. 2011) and increased the impervious surface areas, thereby contributing to higher flood peaks and related urban flood hazards, as observed in Saudi Arabia (El Alfy, 2016) and Morocco (El Garouani et al. 2017). In addition, rapid urban expansion and poor land use and development planning mean that unsafe areas exposed to flash floods are emerging in many cities, and risks are particularly acute for low-income households and informal communities (often internally displaced persons or refugees) in some areas that encroach on natural drainage systems (wadis) (Verner 2012).

High rates of urbanization also outpace urban water infrastructure and related service provision. Urbanization often exacerbates the decline in service provision caused by ageing infrastructure, inadequate operation and maintenance, and overall neglect. As a result, many secondary cities in the region and informal settlements around larger cities lack access to water infrastructure and services, in particular sanitation (Schäfer 2012). In the high-income oil-exporting countries, abundance of resources spurred ambitious investments in megaprojects to extend urban infrastructure, including water (Al-Saidi and Elagib 2018). However, analysts suggest that poor planning regulation and implementation still mean that this infrastructure is underperforming in terms of its ability to keep up with urbanization (Rizzo 2014).

Youth employment is a critical issue at the intersection of urbanization, population growth, rural-urban migration, and sustainable water management. On current population trends, large numbers of youths will be entering the labor market across the Arab region in coming decades. However, neither public nor private job creation is currently matching the demand for jobs (Devarajan and Ianchovichina, 2018). This gives middle- and low-income countries in the region youth unemployment rates of about 25 percent, among the highest in the developing world, paired with the lowest female labour force participation in the world (ILO 2017). In this context, employment opportunities that depend on sustainable water management – notably in agriculture but also ecotourism – can partly absorb the labor force resulting from population growth (Nin-Pratt et al. 2017) and contribute to promoting environmental awareness among youths.

A shift towards water policies more explicitly linked to youth employment and female education in rural areas, especially in low-income and middle-income agrarian countries, could contribute to more sustainable development strategies in the face of population growth and urbanization. These include water policies aimed at improving educational achievement of girls, for instance through water supply and sanitation and menstrual hygiene programmes in schools (Sommer et al. 2012) and female

employment by promoting gender equality in irrigation through technological development, trainings and institutional support (Najjar et al. 2019).

Conflict and migration

Protracted armed conflict, displacement and protracted refugee situations compound water challenges in the region. Given the powerful geopolitical forces at work from hegemonic aspirations of regional powers and from international political orders, these intra-state and national conflicts are likely to remain a critical factor shaping Arab development prospects, including how water is made available, used and reused. Many of the armed conflicts currently playing out in the Arab countries are protracted; fought in urban areas and non-international (e.g., between a State and Non-State Armed Groups). This means that the scale and complexity of action needed is unprecedented, requiring close collaboration of all stakeholders involved in water resources management and service delivery, including humanitarian and development agencies operating in these contexts.

The unparalleled displacement of people, with over ten million internally displaced persons (IDPs), more than 6 million registered refugees (UNHCR 2017) (about 4 times the number in 2010 (UNHCR 2011)) and many more unregistered refugees, has compounded existing challenges faced by host communities, while leaving vulnerable refugees with limited or no access to resources and services. In Jordan and Lebanon, where 75 percent of the refugees hosted in the Arab region are registered, the influx of Syrian refugees has increased water demand and wastewater generation (MOE/EU/UNDP 2014). In Lebanon, the Ministry of Environment estimates that domestic water demands have increased between 8 to 12 percent and wastewater generation between 8 and 14 percent following the influx of refugees (MOE/EU/UNDP 2014). In Jordan, the influx of refugees has caused a significant increase in the country's population—by as much as 50 percent in the northern part of the country—increasing pressures on scarce resources and compounding existing challenges including gaps in water infrastructure, service delivery and high levels of unaccounted for water (Mercy Corps 2014). In some areas, the presence of refugees has caused the cost of tanker water to quadruple because of the high willingness to pay among humanitarian aid providers (Ruckstuhl 2014). In turn, this has made it increasingly difficult for poor communities to purchase tanker water, exacerbating existing resource scarcity and infrastructure deficiencies and reinforcing perceptions of exclusion and neglect among some Jordanian communities (Baylouny and Klingseis 2018). Surveys of Syrian refugees and IDPs show that up to a quarter of them do not plan to return to their homes, suggesting that water policies will increasingly have to tackle their long-term needs and rights (UNHCR 2018). Migration also affects shared international waters, with part of the increased flow in the Yarmouk River to Jordan observed since 2013 attributable to the sudden reduction in Syrian water use (Müller et al. 2016).

Besides the indirect impact from armed conflict, the direct impact that results in the destruction and damage of water and wastewater infrastructure is also another way in which conflicts compound

existing water challenges (Gleick, 2019). Evidence from recent conflicts (Gaza, Iraq, Libya, Syria, and Yemen) shows that extensive destruction of infrastructure (including water, wastewater, and energy infrastructure) is an increasingly prevalent form of warfare in the region (ICRC 2015a; Sowers et al. 2017). Given the inter-related nature of public infrastructure, attacks on power plants also have significant impacts on water supplies as they force the shutdown of pumping stations and treatment plants.

Over time, direct and indirect impacts of protracted armed conflict on water resources management and services combine. This leads to cumulative impacts that make rapid system rehabilitation impossible, leading to increased risks to public health and inequalities in access to services (ICRC 2015b). A case in point is Iraq, where the cumulative impacts inflicted by decades of conflict decimated infrastructure and state capacity to provide services (World Bank 2018c), leading to intermittent and low-quality access, which in turn sparks social tensions among the population (Human Rights Watch 2019).

The compounding effect of conflicts and refugee crises on water availability and use varies by social group and gender. Socially excluded and more vulnerable groups, including women and children, face the greatest water risks in these circumstances. Vulnerable women face risks of physical harm when fetching water, often reside in areas not prioritized for service delivery and/or suffer reduced cash flows for purchasing water from tankers (Ruckstuhl 2014). In addition, conflicts and migration amplify sanitation challenges faced by women and girls, who often have to confront lower or no access to sanitation facilities and sanitary material, with serious dignity and health implications as well as restricted freedom of movement (Van der Helm et al., 2017). Water in the Arab region is therefore both a multiplier of conflict impacts and a tactic of conflict. The net result is a growing erosion of human security and compounded water challenges in an already vulnerable region.

Agricultural and food policy

Agriculture contributes to a relatively small share of the region's gross domestic product (about 13 percent in the period 2010-2014) (Nin-Pratt et al. 2017). However, it has a disproportionate role in water issues because of agriculture's connection to social and national identities, its key role in employment (26 percent on average, 50 percent in low-income countries) and livelihood security, and its share of water consumption (about 85 percent of regional water consumption) (Nin-Pratt et al. 2017). Any agricultural policy that contributes to realizing real water savings in irrigated agriculture will have effects on the overall sustainability of water use and might potentially contribute to reducing depletion rates and pressures on freshwater ecosystems. Agriculture is also a major source of pollution, so improved management of fertilizer, pesticide and livestock excreta runoff can significantly enhance sustainable water outcomes.

Trade in agricultural products and other goods has been key to prevent additional exploitation of limited and dwindling land and water resources in the region (Allan, 1993; Allan 2002). Trade in agricultural

products is regarded as 'virtual water trade' as it avoids agricultural water use in the importing country whilst increasing it in the exporting country. Research has confirmed the importance of virtual water trade for the region's food security and water management (Wichelns, 2011; Gilmont, 2015) and has demonstrated how the region hosts some of the world's top virtual water importers (Antonelli and Tamea, 2015; Oki et al. 2017). Almost all Arab countries confront the dual challenge of high and rising food import dependency and a limited and dwindling land and water resource base. In the high-income countries, imports provide up to 90 percent of domestic food needs, though these countries are among the most food secure in the world because their purchasing power allows them to access affordable and safe food through global markets (Intini et al. 2012). Hence high food import dependence is not necessarily an indicator of fragile food security, and in fact it is (and will continue to be) a significant policy instrument for the region to cope with demands for water and goods. For low-income and middle-income countries in North Africa and in the Mashreq, however, high food import dependence without appropriate measures to protect poorer members of society from international food price fluctuations (e.g., supporting pro-poor growth, expanding social safety nets and targeted nutrition programs) can compromise food security and generate broader instability (Maystadt et al. 2014).

In spite of limited land and water resources and extensive dependence on agricultural imports and virtual water trade, agricultural policies focused on food-self-sufficiency have always been politically appealing in the region (Richards and Waterbury, 1990), partly because of the political isolation and sanctions implemented against certain Arab countries. Food self-sufficiency is considered a key national security objective; however, agricultural policies prioritizing self-sufficiency and protection of staple crops have contributed to undermining land and water resources, creating broader challenges to sustainable development (Borgomeo and Santos, 2019). In the face of dwindling water and land resources, some countries in the region (e.g., Morocco) are moving away from policies targeting self-sufficiency of low-value staple crops for which the region has no competitive advantage towards more balanced policies targeting demand factors related to food security, such as income and social protection (Borgomeo and Santos, 2019).

Concerns over food self-sufficiency and direct control of food production have led some Arab countries, notably high-income oil exporting countries, to invest in the large-scale acquisition of agricultural land within the region and outside (Rulli et al. 2013). This phenomenon, referred as 'land grabbing', has prompted concerns with respect to freshwater resources and risks in countries where these investments are being made (including Sudan (Sulieman, 2015)), in addition to social consequences of large-scale land acquisition (Allan, 2012).

The prominence of irrigated agriculture and food self-sufficiency in national water policy discourses lies at the core of some of the region's water challenges (Allan, 2007). By supporting water intensive forms of agriculture through subsidies and unregulated agricultural water use, some governments

promoted unsustainable use of freshwater resources, in particular groundwater, as exemplified by the Syrian (Aw-Hassan et al. 2014) and Yemeni (Moore, 2011) cases. Attempts at water reform have performed poorly in terms of water sustainability because they have often been implemented with the objective of maintaining socio-political compromises rather than ensuring environmental sustainability (Kuper et al. 2017). In Syria, decades of mismanagement of water resources, paired with the removal of agricultural subsidies and government failures to respond to resource overexploitation, increased the vulnerability of rural areas to drought, exacerbated rural socio-economic grievances and formed one of the contributory factors to the 2011 uprising (De Châtel, 2014; Selby et al. 2017).

High consumption of high-calorie foods such as sugar, vegetable oils and wheat, characterizes diets in the region, especially in high-income and middle-income countries. These dietary practices, which explain the alarming levels of diabetes and obesity in some Arab countries (Abuyassin and Laher, 2016), partly arose because of protectionist and food self-sufficiency policies, especially for wheat (Borgomeo and Santos, 2019). As a large share of the region's population moves into cities and incomes rise, demand for animal-derived foods is expected to increase (OECD/FAO 2018). Meeting increasing demand for animal produce with local production might compromise even further the region's water resources through increased demand for feedstuffs; conversely, limiting animal product consumption in diets and reducing food loss could help alleviate water scarcity, especially in the middle-income countries of North Africa and the Mashreq. Reducing loss percentages by a half in food supply chains could reduce water consumption by 15 percent, and—if these food waste reductions were to be paired with changes in diets and a cap on animal-based proteins— then water use could be reduced by as much as 33 percent (Jalava et al. 2016).

Given the multiple channels through which food policy and agriculture shape sustainable water management, strategies to improve the performance of the agricultural sector and achieve food security will prove key to managing water sustainably, and vice versa. Rural development policies aimed at reducing water use in agriculture, promoting higher value crops and modernizing agricultural systems could help the region cope with its limited water and land resources and growing dependence on agricultural food markets and virtual water trade. To face this dual challenge of modernizing internal agricultural systems and reducing exposure to volatile food markets, countries will have to (1) build resilience to shocks in international agricultural markets through more efficient supply chains, (2) use financial instruments to hedge risk, and (3) seize innovations in agricultural water management to increase domestic productivity (e.g., water accounting, controlled-environment agriculture) and (4) strengthen safety nets. An alternative approach to food policy should emphasize rural development, support for production of higher-value horticulture products, accompanied by a more robust technical extension system and risk management mechanisms (Lampietti et al. 2011).

Developments in energy markets

Oil prices and energy policies are a critical uncertainty for water policy and, more broadly, economic stability and energy security for the Arab region (Griffiths 2017). The operating costs of desalination plants depend on energy prices, increases in which would further incentivize the ongoing transition away from energy-intensive thermal desalination technologies towards membrane-based technologies such as reverse osmosis. In addition, high oil prices could make renewable energy desalination an economically viable alternative in the near future (Ghaffour et al. 2015) and could contribute to the rolling out of wastewater reuse technologies, which consume less energy than desalination. Any reduction in government revenues following energy price fluctuations or blockades could significantly reduce governments' capacity to produce and distribute water or provide additional water-related investments needed to secure supplies.

International energy price fluctuations also have significant impacts on other aspects of the water-energy nexus, notably subsidized groundwater pumping in agriculture. The underpricing of electricity and, more importantly, fuel products, is one of the factors behind groundwater depletion in the Arab region (Commander et al. 2015). Removal of energy subsidies in response to developments in international energy markets could have an impact on groundwater withdrawals, reducing the incentives for irrigating. In turn, this could force farmers to adopt more efficient irrigation techniques, switch out of water intensive crops or abandon farming altogether, with the latter scenario leading to significant negative effects on rural employment, livelihoods and rural-urban migration. Moving towards renewable energy technologies for irrigation and water production might provide an opportunity to reduce the region's water sector dependence on hydrocarbons, while contributing to meeting international climate agreements (Closas and Rap, 2017; Borgomeo et al. 2018). In addition, it could contribute to reducing water consumption for oil production, which is high relative to global averages across the region, with Saudi Arabia, the UAE and Iraq among the top twenty-five countries with the highest freshwater consumption in energy generation in the world (Spang et al. 2014).

Climate change

Climate change compounds and exacerbates existing water challenges in the Arab region (Sowers et al. 2011). The observational record suggests that temperatures across the region have already been increasing since the 1970s, while no significant changes in rainfall patterns have been observed (in part because of data limitations and the inherent variability in rainfall in the region) (Lelieveld et al. 2016). This warming trend is projected to continue, with strongest warming in Northern Africa close to the Mediterranean coast and in areas surrounding the Arabian/Persian Gulf (Waha et al. 2017). This will be accompanied by an increase in the frequency of extreme temperatures and duration of dry spells, which will accelerate surface water loss through evaporation and threaten agricultural production (Garcia-Ruiz et al. 2011; IPCC 2014).

Climate models project changes in precipitation patterns throughout the region. Although projections of drought and precipitation deficits vary between climate models, an increase in extreme drought conditions in countries in North Africa and the Mashreq is consistently projected across climate models used by the IPCC (IPCC 2012). North Africa and the Mashreq are possible hotspots where the frequency of drought might increase by more than 20 percent by the end of the century under a high-emission scenario (Prudhomme et al. 2014). With 4°C global warming, runoff across North Africa and the Middle East could decrease by as much as 75 percent by the end of the century, while the southern part of the Arabian Peninsula (Oman and Yemen) could experience an absolute increase in water availability, which will likely be delivered through a substantial intensification of extreme precipitation events (Waha et al. 2017).

Climate change contributes to sea-level rise, increasing the risk of flooding in rapidly urbanizing coastal areas and deltas of the region. Low lying deltas such as the Nile and the Shatt-al Arab (Tessler et al. 2015), as well as low lying areas in the Mediterranean coast (Snoussi et al. 2008) have been identified as at risk from the impacts of climate change on coastal zones, including permanent inundation from slow-onset sea level rise, increased damages from coastal storms and saltwater intrusion in coastal aquifers.

Land management and erosion

Soil erosion and land degradation have multiple impacts on water resources, ranging from deteriorating water quality to reducing reservoir capacity. Reservoir sedimentation and pollution of surface water have been linked to soil erosion in Algeria (Lahlou, 1996), Jordan (Kraushaar, 2016), Iraq (Ezz-Aldeen et al. 2018), Morocco (Alahiane et al. 2016), and Tunisia (Hentati et al. 2010) among others. Soil erosion also reduces soil water holding capacity, reducing the amount of soil moisture available for productive transpiration by crops (green water) and thus increasing blue water requirements over irrigated areas and compromising agriculture in rainfed areas. Global assessments suggest that most countries in the Mashreq (Syria, Lebanon, Jordan and Iraq) and Egypt show an increasing trend (between 0.5 to 5 percent) in soil erosion over the period 2001-2013 (Borrelli et al. 2017), as confirmed by local evidence (Abdo and Salloum, 2017). A similarly increasing trend is reported for North Africa, while soil erosion is decreasing in high-income Gulf countries (Borrelli et al. 2017). In Somalia and Yemen, estimates suggest extensive land degradation, affecting about 30 and 50 percent of the countries' land area respectively (Omuto et al. 2014; Almeshreki et al. 2012). Widespread land degradation and desertification are manifestations of soil erosion in the region's dryland systems (Zdruli, 2014; Heshmati and Squires, 2013). From 1975 until 2010, North Africa lost two million hectares of agricultural land to desertification (UNECA 2010). These conditions are likely to escalate as dryland systems expand under climate change, worsening aridity conditions across the region, enhancing regional warming and exacerbating risks of desertification (Huang et al. 2016). Increasing aridity

conditions might also increase the incidence of dust storms and related drinking-water contamination (Middleton and Sternberg 2013).

Fragmented land tenure is another important aspect of the land-water nexus, as it is generally considered to be an impediment to improvements in agricultural water use efficiency (Masih and Giordano 2014). Land fragmentation is common in the Arab region, mostly because of sub-divisions of land for inheritance as well as poorly formalized land rights and persistent land tenure insecurity (Shetty, 2006; UNECA 2010). Land fragmentation affects the extent to which various agronomic practices and technologies are adopted and their system-scale effectiveness in reducing overall water use as well as women participation in irrigation. Land fragmentation can also act as a significant productivity constraint—more than water scarcity in some areas— though its effects on farm productivity also depend on wider agrarian political economy questions (Dyer 2014).

Political economy and state-citizen relationships

Water issues in the Arab region cannot be understood in isolation from the nature and priorities of the state (Barnes, 2009; Mustafa et al. 2016), state-citizen-relationships (Barnes, 2017a), and state development and geopolitics (Zeitoun 2008). The Arab region was the focus of early theorization of the role of water management in state-building (Wittfogel 1959), a view which has been disputed in the context of the modern Arab world (Selby, 2005)). At the local level, there is evidence that politics influences water management and vice versa, in particular through subsidized water services and electricity for irrigation – with the region having the highest level of water subsidies in the world (Kochhar et al. 2015). This utilization of water to fulfil political objectives reflects broader state-citizen relationships at play in the region, especially before the Arab Spring, characterized by subsidized food and fuel and the State providing jobs, and little involvement of social groups in political decisions (Yousef, 2004). While this approach built largely on oil rents and international aid has worked well in the past, its effectiveness and sustainability for delivering services (including subsidized water and electricity for irrigation) to ordinary citizens in times of volatile energy prices and stretched welfare systems is coming under question (Malik and Awadallah, 2013).

A move towards more accountability and citizen participation in service delivery and resource management has been suggested as a way forward (Brixi et al. 2015). Increased participation and autonomy in irrigation water management have already been promoted, with mixed success (Ghazouani et al. 2012). This shift towards participatory water management is likely to remain a focus of water policy in the region, assuming a public willingness and readiness to participate and given the interest of international agencies (Ker Rault et al. 2013; FAO/World Bank, 2018). The extent to which sustainable water management will be a result of external pressures, including environmental shocks and financial pressures, the decisions of ruling elites or the result of concerted action in response to concerns from domestic constituencies is a question still to be answered in the region.

Educational policy

At the most basic level, encouraging sustainable development is about encouraging changes in human behavior, norms and belief systems (Sachs et al. 2019). In this sense, educational policy is a key factor to empower citizens to contribute to sustainable water management and win public acceptance for water policies, including wastewater reuse (Amery and Haddad, 2016). Although surveys of the region's population indicate high levels of awareness of the region's water issues and excessive consumption (Saab, 2015), unsustainable behavior and consumption patterns persist, as indicated by high levels of food waste (Abiad and Meho, 2018), water losses and high per capita water consumption in the high-income countries (Al-Zubari et al. 2017). In this context, educational policy is a key instrument to move towards sustainable water management and regional experience demonstrates that it successfully leads to positive water-related outcomes, notably water conservation. In Jordan, for instance, students exposed to water education at school are more likely to implement water conservation practices in their households (Middlestadt et al., 2001) and to be more empowered to contribute to solving water issues through their behavior (Hussein, 2018).

Conclusions

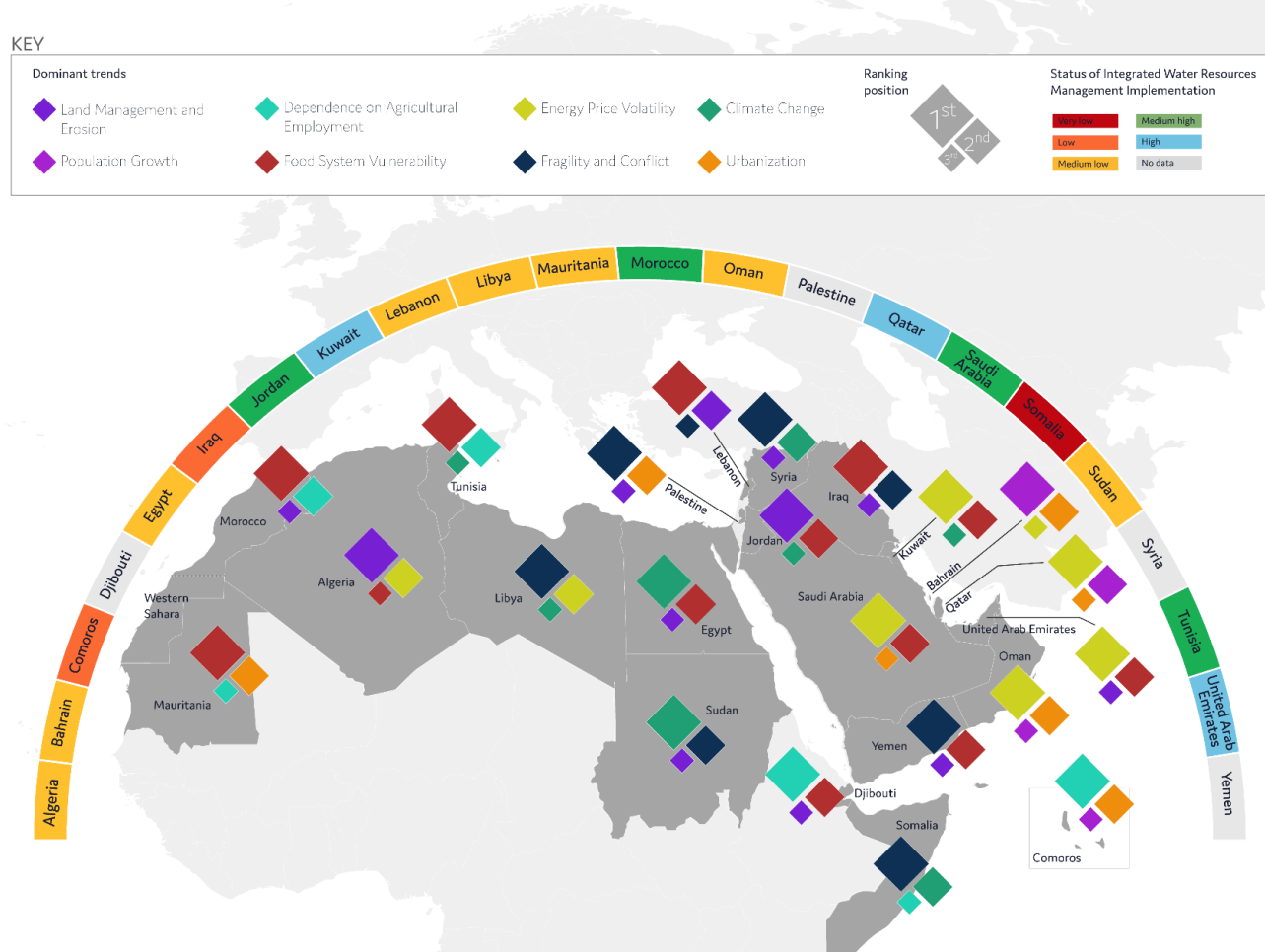
This paper reviewed the status and prospects for sustainable water management in the Arab region in the context of major global and regional trends. The review has shown that the region is not on track to meet SDG 6 and that sustainable water management challenges, particularly on the demand side, and responses in the Arab region cannot be understood in isolation from broader regional and international political and socio-economic trends. In order to frame potential solutions, a broader view that goes beyond simple considerations around increasing water stress under climate change is needed. The way in which water is managed, developed and shared in the context of uncertain regional and global trends has important implications for the region's ability to achieve sustainable development, attain resilience and maintain political stability. Clearly not all countries will be exposed to the same issues and trends in the same way, so we have attempted to compare the dominant trends in each country in Figure 2 (see Supplementary Note S2). We have not attempted to identify policy responses, as these will be context-specific and will involve analysis of interdependencies between SDGs (Weitz et al. 2018).

Future research needs to fill persistent data gaps, as at present official statistics and global data do not adequately cover the monitoring needs of SDG 6. The water accounting framework (i.e., systematic assessment of the status of, and trends in, water supply, demand, accessibility and use in specified spatial domains), paired with Earth Observation and low-cost sensors, will become central to monitor SDG 6 implementation in the Arab region (c.f., Hogeboom et al. 2020). Beyond monitoring, the role played by advances in high-resolution remote sensing, nanostructured membranes, smart information and communication technologies in solving the region's water issues also needs investigation. In addition, research should examine the distribution of water-related impacts through society, the

potential role of citizens in driving sustainable water management through participation as well as changing consumption, the role of ecosystem services in mitigating water risks, and the potential for water policy to contribute to state building and peacebuilding efforts. This latter point is of particular policy relevance given the increasing need to bridge humanitarian and development efforts in the water sector in situations of protracted conflict. Finally, researchers need to examine the potential and limitations of gender equality in helping to achieve sustainable water management. Arab women are far more engaged in agricultural water management than previously thought (ILO, 2017), calling for research and policy to understand this involvement and develop ways to strengthen it. So far, research and discourse on gender and water has mostly focused on increasing women's voices as 'stakeholders' in specific projects (Sowers et al. 2011), while we identify a need to map progress on gender equality, and

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Figure 2. Uncertain trends shaping sustainable water management in the Arab countries. Diamonds show the top three trends shaping sustainable water resources management in each country. The semicircle shows the status of Integrated Water Resources Management Implementation (Sustainable Development Indicator 6.5.1) and is taken as a general indicator of a country's ability to achieve sustainable water management in the face of these uncertain trends.



in particular on female education, employment and access to family planning services, to sustainable water management.

At the broadest level, sustainable water management will likely require diversification of water supplies, including through wastewater reuse, water conservation and aquifer storage, reductions in water use, and a better integration of water policy with agricultural, energy and trade policies. In countries affected by protracted armed conflict, the scale, complexity, and duration of water challenges create unprecedented needs that require a more holistic response beyond humanitarian relief. Policy-makers and practitioners alike need to explore ways in which humanitarian and development actors can work together to strengthen water resources management and service delivery in situation of protracted conflict and examine the contribution of sustainable water management to peacebuilding processes.

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References

- Abdel-Satar, A.M., Ali, M.H. and Goher, M.E., 2017. Indices of water quality and metal pollution of Nile River, Egypt. *The Egyptian Journal of Aquatic Research*, 43(1), pp.21-29.
- Abdo, H. and Salloum, J., 2017. Mapping the soil loss in Marqya basin: Syria using RUSLE model in GIS and RS techniques. *Environmental Earth Sciences*, 76(3), p.114.
- Abiad, M.G. and Meho, L.I., 2018. Food loss and food waste research in the Arab world: A systematic review. *Food security*, 10(2), pp.311-322.
- Abuyassin, B. and Laher, I., 2016. Diabetes epidemic sweeping the Arab world. *World journal of diabetes*, 7(8), p.165.
- AbuZeid, K., Wagdy, A., Ibrahim, M., CEDARE, Arab Water Council. 2019. 3rd State of the Water Report for the Arab Region - 2015. Water Resources Management Program. Cairo: CEDARE & Arab Water Council.
- Ahmed, M. and Abdelmohsen, K., 2018. Quantifying modern recharge and depletion rates of the Nubian Aquifer in Egypt. *Surveys in Geophysics*, pp.1-23.

Al Naber, M. and Molle, F., 2017. Controlling groundwater over abstraction: state policies vs local practices in the Jordan highlands. *Water Policy*, 19(4), pp.692-708.

Alahiane, N., Elmouden, A., Aitlhaj, A. and Boutaleb, S., 2016. Small dam reservoir siltation in the Atlas Mountains of Central Morocco: analysis of factors impacting sediment yield. *Environmental Earth Sciences*, 75(12), p.1035.

Allan, J. A. 2007. Rural economic transitions: Groundwater uses in the Middle East and its environmental consequences. In M. Giordano & K. G. Villholth (Eds.), *The agricultural groundwater revolution: Opportunities and threats to development* (Vol. 3). Wallingford, UK: CABI.

Allan, J.A. and Allan, T., 2002. *The Middle East water question: Hydropolitics and the global economy* (Vol. 2). London: IB Tauris.

Allan, J.A. ed., 2012. *Handbook of land and water grabs in Africa: Foreign direct investment and food and water security*. London: Routledge.

Allan, J.A., 1993. Fortunately there are substitutes for water otherwise our hydro-political futures would be impossible. *Priorities for water resources allocation and management*, 13(4), p.26.

Allen, C., Nejdawi, R., El-Baba, J., Hamati, K., Metternicht, G. and Wiedmann, T., 2017. Indicator-based assessments of progress towards the sustainable development goals (SDGs): a case study from the Arab region. *Sustainability Science*, 12 (6), pp.975-989.

Almeshreki, D., Mohamed, H., Alsharjabi, D., Khalil, M., Bafadhl, M., Omer, A., Almedheji, M., Ahmed, M.S., Al-Khulaidi, D.A., Alabiadh, M. and Khairi, M., 2012. *Combating Land Degradation in Yemen-A National Report* (No. 565-2016-38930). Beirut: International Center for Agricultural Research in the Dry Areas.

Al-Mudaffar Fawzi, N., Goodwin, K.P., Mahdi, B.A. and Stevens, M.L., 2016. Effects of Mesopotamian Marsh (Iraq) desiccation on the cultural knowledge and livelihood of Marsh Arab women. *Ecosystem Health and Sustainability*, 2(3), p.e01207.

Al-Obaid, S., Samraoui, B., Thomas, J., El-Serehy, H.A., Alfarhan, A.H., Schneider, W. and O'connell, M., 2017. An overview of wetlands of Saudi Arabia: Values, threats, and perspectives. *Ambio*, 46(1), pp.98-108.

Al-Omari, A., Farhan, I. and Kandakji, T., 2019. Zarqa River pollution: impact on its quality. *Environmental monitoring and assessment*, 191(3), p.166.

Al-Saidi, M. and Elagib, N.A., 2018. Ecological modernization and responses for a low-carbon future in the Gulf Cooperation Council countries. *Wiley Interdisciplinary Reviews: Climate Change*, 9(4), p.e528.

Al-Sharrah, G., Lababidi, H.M. and Al-Anzi, B., 2017. Environmental ranking of desalination plants: the case of the Arabian Gulf. *Toxicological & Environmental Chemistry*, 99(7-8), pp.1054-1070.

Al-Zubari, W., Al-Turbak, A., Zahid, W., Al-Ruwis, K., Al-Tkhais, A., Al-Muataz, I., Abdelwahab, A., Murad, A., Al-Harbi, M. and Al-Sulaymani, Z., 2017. An Overview of the GCC Unified Water Strategy (2016-2035). *Desalination and water treatment*, 81, pp.1-18.

Amery, H.A. and Haddad, M., 2016. Ethical and Cultural Dimensions of Water Reuse: Islamic Perspectives. In *Urban Water Reuse Handbook* (pp. 311-320). CRC Press.

Antonelli, M. and Tamea, S., 2015. Food-water security and virtual water trade in the Middle East and North Africa. *International Journal of Water Resources Development*, 31(3), pp.326-342.

Aw-Hassan, A., Rida, F., Telleria, R. and Bruggeman, A., 2014. The impact of food and agricultural policies on groundwater use in Syria. *Journal of hydrology*, 513, pp.204-215.

Banerjee, A.; Bhavnani, R.; Burtonboy, CH.; Hamad, O.; Linares-Rivas Barandiaran, A.; Safaie, S.; Tewari, D.; Zanon, A. 2014. Natural disasters in the Middle East and North Africa : a regional overview (English). Global Facility for Disaster Reduction and Recovery (GFDRR). Washington DC; World Bank Group.

Barakat, A., El Baghdadi, M., Rais, J., Aghezzaf, B. and Slassi, M., 2016. Assessment of spatial and seasonal water quality variation of Oum Er Rbia River (Morocco) using multivariate statistical techniques. *International soil and water conservation research*, 4(4), pp.284-292.

Barnes, J., 2009. Managing the waters of ba'th country: the politics of water scarcity in Syria. *Geopolitics*, 14(3), pp.510-530.

Barnes, J., 2017a. States of maintenance: Power, politics, and Egypt's irrigation infrastructure. *Environment and Planning D: Society and Space*, 35(1), pp.146-164.

Barnes, J., 2017b. The future of the Nile: climate change, land use, infrastructure management, and treaty negotiations in a transboundary river basin. *Wiley Interdisciplinary Reviews: Climate Change*, 8(2), p.e449.

Bashitialshaaer, R., Flyborg, L. and Persson, K.M., 2011. Environmental assessment of brine discharge and wastewater in the Arabian Gulf. *Desalination and Water Treatment*, 25(1-3), pp.276-285.

Baylouny, A.M. and Klingseis, S.J., 2018. Water Thieves or Political Catalysts? Syrian Refugees in Jordan and Lebanon. *Middle East Policy*, 25(1), pp.104-123.

Bernauer, T. and Böhmelt, T., 2014. Basins at risk: Predicting international river basin conflict and cooperation. *Global Environmental Politics*, 14(4), pp.116-138.

Bocci, M., Brigolin, D., Pranovi, F., Najih, M., Nachite, D. and Pastres, R., 2016. An Ecosystem Approach for understanding status and changes of Nador lagoon (Morocco): application of food web models and ecosystem indices. *Estuarine, Coastal and Shelf Science*, 171, pp.133-143.

Borgomeo, E., Jagerskog, A., Talbi, A., Wijnen, M., Hejazi, M. and Miralles-Wilhelm, F., 2018. *The Water-Energy-Food Nexus in the Middle East and North Africa: Scenarios for a Sustainable Future*. Washington, DC: World Bank.

Borgomeo, E.; Santos, N. 2019. *Towards a new generation of policies and investments in agricultural water in the Arab region: fertile ground for innovation*. Rome, Italy: FAO; Colombo, Sri Lanka: International Water Management Institute (IWMI). 124p. doi: 10.5337/2019.207

Borrelli, P., Robinson, D.A., Fleischer, L.R., Lugato, E., Ballabio, C., Alewell, C., Meusburger, K., Modugno, S., Schütt, B., Ferro, V. and Bagarello, V., 2017. An assessment of the global impact of 21st century land use change on soil erosion. *Nature communications*, 8(1), p.2013.

Brixi, H., Lust, E. and Woolcock, M., 2015. *Trust, voice, and incentives: Learning from local success stories in service delivery in the Middle East and North Africa*. Washington, DC: The World Bank.

Cascão, A.E. and Nicol, A., 2016. GERD: new norms of cooperation in the Nile Basin?. *Water International*, 41(4), pp.550-573.

CEDARE. 2014. *North Western Sahara Aquifer System (NWSAS) M&E Rapid Assessment Report, Monitoring & Evaluation for Water In North Africa (MEWINA) Project*, Water Resources Management Program, CEDARE.

Chaudhary, A., Gustafson, D. and Mathys, A., 2018. Multi-indicator sustainability assessment of global food systems. *Nature communications*, 9(1), p.848.

Chen, C., Noble, I., Hellmann, J., Coffee, J., Murillo, M. and Chawla, N., 2015. *University of Notre Dame global adaptation index country index technical report*. ND-GAIN: South Bend, IN, USA.

Closas, A. and Rap, E., 2017. Solar-based groundwater pumping for irrigation: Sustainability, policies, and limitations. *Energy Policy*, 104, pp.33-37.

Commander, S., Nikoloski, Z. and Vagliasindi, M., 2015. *Estimating the size of external effects of energy subsidies in transport and agriculture*. The World Bank.

Comte, J.C., Cassidy, R., Obando, J., Robins, N., Ibrahim, K., Melchioly, S., Mjemah, I., Shauri, H., Bourhane, A., Mohamed, I. and Noe, C., 2016. *Challenges in groundwater resource management in*

coastal aquifers of East Africa: Investigations and lessons learnt in the Comoros Islands, Kenya and Tanzania. *Journal of Hydrology: Regional Studies*, 5, pp.179-199.

Damania, R., Desbureaux, S., Rodella, A.S., Russ, J. and Zaveri, E., 2019. Quality Unknown. Washington, DC: World Bank.

Danilenko, A., Van den Berg, C., Macheve, B. and Moffitt, L.J., 2014. The IBNET water supply and sanitation blue book 2014: The international benchmarking network for water and sanitation utilities databook. Washington DC: The World Bank.

Daou, C., Salloum, M., Legube, B., Kassouf, A. and Ouaini, N., 2018. Characterization of spatial and temporal patterns in surface water quality: a case study of four major Lebanese rivers. *Environmental monitoring and assessment*, 190(8), p.485.

Darwall, W., Carrizo, S., Numa, C., Barrios, V., Freyhof, J. and Smith, K., 2014. Freshwater Key Biodiversity Areas in the Mediterranean Basin Hotspot: Informing species conservation and development planning in freshwater ecosystems. Cambridge: IUCN.

Dawoud, M.A., 2008. Strategic water reserve: new approach for old concept in GCC countries. Environment Agency: Abu Dhabi.

De Châtel, F., 2014. The role of drought and climate change in the Syrian uprising: Untangling the triggers of the revolution. *Middle Eastern Studies*, 50(4), pp.521-535.

De Stefano, L., Petersen-Perlman, J.D., Sproles, E.A., Eynard, J. and Wolf, A.T., 2017. Assessment of transboundary river basins for potential hydro-political tensions. *Global Environmental Change*, 45, pp.35-46.

Dentoni, M., Deidda, R., Paniconi, C., Qahman, K. and Lecca, G., 2015. A simulation/optimization study to assess seawater intrusion management strategies for the Gaza Strip coastal aquifer (Palestine). *Hydrogeology Journal*, 23(2), pp.249-264.

Devarajan, S. and Ianchovichina, E., 2018. A broken social contract, not high inequality, led to the Arab spring. *Review of Income and Wealth*, 64, pp.S5-S25.

Devarajan, S.; Mottaghi, L. 2017. Refugee crisis in MENA: meeting the development challenge (English). *Middle East and North Africa (MENA) Economic Monitor*. Washington, D.C. : World Bank Group.

Dillon, P., Stuyfzand, P., Grischek, T., Lluria, M., Pyne, R.D.G., Jain, R.C., Bear, J., Schwarz, J., Wang, W., Fernandez, E. and Stefan, C., 2019. Sixty years of global progress in managed aquifer recharge. *Hydrogeology journal*, 27(1), pp.1-30.

Doell, P., Mueller Schmied, H., Schuh, C., Portmann, F.T. and Eicker, A., 2014. Global-scale assessment of groundwater depletion and related groundwater abstractions: Combining hydrological modeling with information from well observations and GRACE satellites. *Water Resources Research*, 50(7), pp.5698-5720.

Droogers, P., Immerzeel, W.W., Terink, W., Hoogeveen, J., Bierkens, M.F.P., Van Beek, L.P.H. and Debele, B., 2012. Water resources trends in Middle East and North Africa towards 2050. *Hydrology and Earth System Sciences*, 16(9), pp.3101-3114.

Dyer, G., 2014. *Class, state and agricultural productivity in Egypt: study of the inverse relationship between farm size and land productivity*. London: Routledge.

El Alfy, M., 2016. Assessing the impact of arid area urbanization on flash floods using GIS, remote sensing, and HEC-HMS rainfall-runoff modeling. *Hydrology Research*, 47(6), pp.1142-1160.

El Garouani, A., Mulla, D.J., El Garouani, S. and Knight, J., 2017. Analysis of urban growth and sprawl from remote sensing data: Case of Fez, Morocco. *International Journal of Sustainable Built Environment*, 6(1), pp.160-169.

El-Shazly, M.M., Omar, W.A., Edmardash, Y.A., Ibrahim, M.S., Elzayat, E.I., El-Sebeay, I.I., Abdel Rahman, K.M. and Soliman, M.M., 2017. Area reduction and trace element pollution in Nile Delta wetland ecosystems. *African journal of ecology*, 55(4), pp.391-401.

Etteieb, S., Cherif, S. and Tarhouni, J., 2017. Hydrochemical assessment of water quality for irrigation: a case study of the Medjerda River in Tunisia. *Applied Water Science*, 7(1), pp.469-480.

Ezz-Aldeen, M., Hassan, R., Ali, A., Al-Ansari, N. and Knutsson, S., 2018. Watershed Sediment and Its Effect on Storage Capacity: Case Study of Dokan Dam Reservoir. *Water*, 10(7), p.858.

Famiglietti, J.S., 2014. The global groundwater crisis. *Nature Climate Change*, 4(11), p.945.

FAO. 2018. AQUASTAT Main Database - Food and Agriculture Organization of the United Nations (FAO).

FAO/World Bank (Food and Agriculture Organization of the United Nations; World Bank Group). 2018. *Water Management in Fragile Systems: Building Resilience to Shocks and Protracted Crises in the Middle East and North Africa*. Cairo: FAO and World Bank.

Farber, E., Vengosh, A., Gavrieli, I., Marie, A., Bullen, T.D., Mayer, B., Holtzman, R., Segal, M. and Shavit, U., 2005. Management scenarios for the Jordan River salinity crisis. *Applied geochemistry*, 20(11), pp.2138-2153.

García, N., Harrison, I., Cox, N. and Tognelli, M.F. (compilers). 2015. The Status and Distribution of Freshwater Biodiversity in the Arabian Peninsula. Gland, Switzerland, Cambridge, UK and Arlington, USA: IUCN

García-Ruiz, J.M., López-Moreno, J.I., Vicente-Serrano, S.M., Lasanta-Martínez, T. and Beguería, S., 2011. Mediterranean water resources in a global change scenario. *Earth-Science Reviews*, 105(3-4), pp.121-139.

Gassert, F., Landis, M., Luck, M., Reig, P. and Shiao, T., 2013. Aqueduct global maps 2.0. Water Resources Institute (WRI): Washington, DC, pp.202011-2012.

Ghaffour, N., Bundschuh, J., Mahmoudi, H. and Goosen, M.F., 2015. Renewable energy-driven desalination technologies: A comprehensive review on challenges and potential applications of integrated systems. *Desalination*, 356, pp.94-114.

Ghazouani, W., Molle, F. and Rap, E., 2012. Water Users Associations in the NEN region: IFAD interventions and overall dynamics. Rome: International Fund for Agricultural Development and International Water Management Institute.

Gilmont, M., 2015. Water resource decoupling in the MENA through food trade as a mechanism for circumventing national water scarcity. *Food Security*, 7(6), pp.1113-1131.

Gleick, P.H., 1994. Water, war and peace in the Middle East. *Environment: science and policy for sustainable development*, 36(3), pp.6-42.

Gleick, P.H., 2019. Water as a weapon and casualty of armed conflict: A review of recent water-related violence in Iraq, Syria, and Yemen. *Wiley Interdisciplinary Reviews: Water*, 6(4), p.e1351.

Global Water Intelligence. 2016. Global Water Market 2017: Meeting the World's Water and Wastewater Needs until 2020. Global Water Intelligence, Oxford.

Goode, D.J., Senior, L.A., Subah, A. and Jaber, A., 2013. Groundwater-level trends and forecasts, and salinity trends, in the Azraq, Dead Sea, Hammad, Jordan Side Valleys, Yarmouk, and Zarqa groundwater basins, Jordan (No. 2013-1061). US Geological Survey.

Griffiths, S., 2017. A review and assessment of energy policy in the Middle East and North Africa region. *Energy Policy*, 102, pp.249-269.

Grindle, A.K., Siddiqi, A. and Anadon, L.D., 2015. Food security amidst water scarcity: Insights on sustainable food production from Saudi Arabia. *Sustainable Production and Consumption*, 2, pp.67-78.

Harrigan, J. 2014. The Political Economy of Arab Food Sovereignty. London: Palgrave Macmillan.

Harris, K.; D., Keen; T., Mitchell. 2013. When disasters and conflicts collide. Improving links between disaster resilience and conflict prevention. London: Overseas Development Institute.

Harrower, M.J., 2008. Hydrology, ideology, and the origins of irrigation in ancient Southwest Arabia. *Current Anthropology*, 49(3), pp.497-510.

Hentati, A., Kawamura, A., Amaguchi, H. and Iseri, Y., 2010. Evaluation of sedimentation vulnerability at small hillside reservoirs in the semi-arid region of Tunisia using the Self-Organizing Map. *Geomorphology*, 122(1-2), pp.56-64.

Heshmati, G.A. and Squires, V.R., 2013. Combating desertification in asia, africa and the Middle East. New York, NY: Springer.

Hogeboom, R.J., de Bruin, D., Schyns, J.F., Krol, M.S. and Hoekstra, A.Y., Capping human water footprints in the world's river basins. *Earth's Future*.

Hssaisoune, M., Bouchaou, L., N'da, B., Malki, M., Abahous, H. and Fryar, A.E., 2017. Isotopes to assess sustainability of overexploited groundwater in the Souss–Massa system (Morocco). *Isotopes in environmental and health studies*, 53(3), pp.298-312.

Huang, J., Yu, H., Guan, X., Wang, G. and Guo, R., 2016. Accelerated dryland expansion under climate change. *Nature Climate Change*, 6(2), p.166.

Human Rights Watch. 2019. Basra is thirsty. Iraq's failure to manage the water crisis. New York: Human Rights Watch. ISBN: 978-1-6231-37502.

Hussein, H., 2018. A critique of water scarcity discourses in educational policy and textbooks in Jordan. *The journal of environmental education*, 49(3), pp.260-271.

ICRC (International Committee of the Red Cross). 2015a. Bled dry: how war in the Middle East is bringing the region's water supplies to breaking point. Geneva: ICRC.

ILO (INTERNATIONAL LABOUR OFFICE), 2017. Global Employment Trends for Youth 2017: Paths to a better working future. International Labour Office.

International Committee of the Red Cross. 2015b, Urban services during protracted armed conflict: a call for a better approach to assisting affected people, International Committee of the Red Cross, Geneva.

International Energy Agency. 2016. Share of electricity generation by fuel. Available from: <https://www.iea.org/statistics/>

International Organization for Migration (IOM) 2019. Assessing water shortage-induced displacement in Missan, Muthanna, Thi-Qar and Basra. IOM Iraq, Baghdad.

Intini, Vito, Clemens, Breisinger, Ivana, Brnovic, Fidele, Byringiro, Olivier, Ecker, Kenneth, Iversen, 2012. Food Security Strategies in the GCC Countries. Economic and Social Commission for Western Asia ESCWA. Strengthening Development Coordination among Regional Actors in ESCWA Region. E/ESCWA/ECRI/2012/Technical Paper. 2. Available from: <https://www.unescwa.org/ar/file/31400/download?token=yitznd1w>

IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 688.

IPCC. 2012. Managing the risks of extreme events and disasters to advance climate change adaptation (SREX). In: Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Ebi KL, Mastrandrea MD, Mach KJ, Plattner G-K, Allen SK, Tignor M, Midgley PM (eds) A special report of working groups I and II of the intergovernmental panel on climate change. Cambridge: Cambridge University Press

Jägerskog, A., 2003. Why states cooperate over shared water: The water negotiations in the Jordan River Basin. Linköping: Doctoral dissertation, Linköping University Electronic Press.

Jalava, M., Guillaume, J.H., Kummu, M., Porkka, M., Siebert, S. and Varis, O., 2016. Diet change and food loss reduction: What is their combined impact on global water use and scarcity?. *Earth's Future*, 4(3), pp.62-78.

Jessen, C., Lizcano, J.F.V., Bayer, T., Roder, C., Aranda, M., Wild, C. and Voolstra, C.R., 2013. In-situ effects of eutrophication and overfishing on physiology and bacterial diversity of the Red Sea coral *Acropora hemprichii*. *PLoS One*, 8(4), p.e62091.

Jeuland, M., 2015. Challenges to wastewater reuse in the Middle East and North Africa. *Middle East Development Journal*, 7(1), pp.1-25.

Jones, E., Qadir, M., van Vliet, M.T., Smakhtin, V. and Kang, S.M., 2018. The state of desalination and brine production: A global outlook. *Science of the Total Environment*.

Joodaki, G., Wahr, J. and Swenson, S., 2014. Estimating the human contribution to groundwater depletion in the Middle East, from GRACE data, land surface models, and well observations. *Water Resources Research*, 50(3), pp.2679-2692.

Ker Rault, P.A., Vreugdenhil, H., Jeffrey, P. and Slinger, J.H., 2013. Readiness and willingness of the public to participate in integrated water management: some insights from the Levant. *Water Policy*, 15(S2), pp.101-120.

Kfourri, C., Mantovani, P. and Jeuland, M., 2009. Water reuse in the MNA region: constraints, experiences, and policy recommendations. In: Jagannathan, N.V., Mohamed, A.S. and Kremer, A., (eds.) *Water in the Arab World: Management Perspectives and Innovations*. Washington, DC: World Bank., pp.447-77.

Kibaroglu, A., 2019. State-of-the-art review of transboundary water governance in the Euphrates–Tigris river basin. *International Journal of Water Resources Development*, 35(1), pp.4-29.

Kochhar, M.K., Pattillo, M.C.A., Sun, M.Y., Suphaphiphat, M.N., Swiston, A., Tchaidze, M.R., Clements, M.B.J., Fabrizio, M.S., Flamini, V., Redifer, M.L. and Finger, M.H., 2015. Is the glass half empty or half full? Issues in managing water challenges and policy instruments. *International Monetary Fund*.

Koshlaf, E., Shahsavari, E., Aburto-Medina, A., Taha, M., Haleyur, N., Makadia, T.H., Morrison, P.D. and Ball, A.S., 2016. Bioremediation potential of diesel-contaminated Libyan soil. *Ecotoxicology and environmental safety*, 133, pp.297-305.

Kraushaar, S., 2016. *Soil Erosion and Sediment Flux in Northern Jordan: Analysis, Quantification and the Respective Qualitative Impacts on a Reservoir Using a Multiple Response Approach*. Springer.

Kuper, M., Hichem Amichi & Pierre-Louis Mayaux. 2017. Groundwater use in North Africa as a cautionary tale for climate change adaptation, *Water International*, 42:6, 725-740, DOI: 10.1080/02508060.2017.1351058

Lahlou, A., 1996. Environmental and socio-economic impacts of erosion and sedimentation in North Africa. *IAHS Publications-Series of Proceedings and Reports-Intern Assoc Hydrological Sciences*, 236, pp.491-500.

Lampietti, J.A., Michaels, S., Magnan, N., McCalla, A.F., Saade, M. and Khouri, N., 2011. A strategic framework for improving food security in Arab countries. *Food Security*, 3(1), pp.7-22.

Lelieveld, J., Proestos, Y., Hadjinicolaou, P., Tanarhte, M., Tyrlis, E. and Zittis, G., 2016. Strongly increasing heat extremes in the Middle East and North Africa (MENA) in the 21st century. *Climatic Change*, 137(1-2), pp.245-260.

Lopez, O., Stenchikov, G. and Missimer, T.M., 2014. Water management during climate change using aquifer storage and recovery of stormwater in a dunefield in western Saudi Arabia. *Environmental Research Letters*, 9(7), p.075008.

Mahdi, B.A. and Al-Mudaffar Fawzi, N., 2014. Iraq's inland Water quality and their impact on the North-Western Arabian Gulf. *Marsh Bulletin*, 9(1), pp.1-22.

Malik, A. and Awadallah, B., 2013. The economics of the Arab Spring. *World Development*, 45, pp.296-313.

Masih, I. and Giordano, M., 2014. Constraints and opportunities for water savings and increasing productivity through Resource Conservation Technologies in Pakistan. *Agriculture, ecosystems & environment*, 187, pp.106-115.

Mateo-Sagasta, J., Zadeh, S.M. and Turrall, H. eds., 2018. More people, more food, worse water? A global review of water pollution from agriculture. Rome, Italy: FAO Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE).

Mawlood, I., Ziboon, A.R. and Al-Obaidy, A.H., 2018. Assessment of pollution in water quality of oil and grease for Tigris River-Iraq by GIS mapping (2010-2016). In *MATEC Web of Conferences* (Vol. 162, p. 05016). EDP Sciences.

Maystadt, J.F., Tan, J.F.T. and Breisinger, C., 2014. Does food security matter for transition in Arab countries?. *Food Policy*, 46, pp.106-115.

McCracken, M. and Meyer, C., 2018. Monitoring of transboundary water cooperation: Review of Sustainable Development Goal Indicator 6.5. 2 methodology. *Journal of hydrology*, 563, pp.1-12.

McDonnell, R.A., 2014. Circulations and transformations of energy and water in Abu Dhabi's hydrosocial cycle. *Geoforum*, 57, pp.225-233.

Mercy Corps. 2014. *Tapped Out: Water Scarcity and Refugee Pressures in Jordan*. Portland, Oregon: Mercy Corps.

Middlestadt, S., Grieser, M., Hernandez, O., Tubaishat, K., Sanchack, J., Southwell, B. and Schwartz, R., 2001. Turning minds on and faucets off: Water conservation education in Jordanian schools. *The Journal of Environmental Education*, 32(2), pp.37-45.

Middleton, N.J. and Sternberg, T., 2013. Climate hazards in drylands: A review. *Earth-Science Reviews*, 126, pp.48-57.

MOE/EU/UNDP (Ministry of Environment of Lebanon, European Union, and United Nations Development Program). 2014. "Lebanon Environmental Assessment of the Syrian Conflict and

Priority Interventions.”

<http://www.undp.org/content/dam/lebanon/docs/Energypercent20andpercent20Environment/Publications/EASC-WEB.pdf>.

Molle, F., Gaafar, I., El-Agha, D.E. and Rap, E., 2018. The Nile delta's water and salt balances and implications for management. *Agricultural water management*, 197, pp.110-121.

Moore, S., 2011. Parchedness, politics, and power: the state hydraulic in Yemen. *Journal of Political Ecology*, 18(1), pp.38-50.

Movilla Pateiro, L., 2016. Ad hoc legal mechanisms governing transboundary aquifers: current status and future prospects. *Water international*, 41(6), pp.851-865.

Müller, M.F., Müller-Itten, M.C. and Gorelick, S.M., 2017. How Jordan and Saudi Arabia are avoiding a tragedy of the commons over shared groundwater. *Water Resources Research*, 53(7), pp.5451-5468.

Müller, M.F., Yoon, J., Gorelick, S.M., Avisse, N. and Tilmant, A., 2016. Impact of the Syrian refugee crisis on land use and transboundary freshwater resources. *Proceedings of the national academy of sciences*, 113(52), pp.14932-14937.

Multsch, S., Alquwaizany, A.S., Alharbi, O.A., Pahlow, M., Frede, H.G. and Breuer, L., 2017. Water-saving strategies for irrigation agriculture in Saudi Arabia. *International journal of water resources development*, 33(2), pp.292-309.

Multsch, S., Elshamy, M.E., Batarseh, S., Seid, A.H., Frede, H.G. and Breuer, L., 2017. Improving irrigation efficiency will be insufficient to meet future water demand in the Nile Basin. *Journal of Hydrology: Regional Studies*, 12, pp.315-330.

Mustafa, D., Altz-Stamm, A. and Scott, L.M., 2016. Water user associations and the politics of water in Jordan. *World Development*, 79, pp.164-176.

Najjar, D., Baruah, B. and El Garhi, A., 2019. Women, irrigation and social norms in Egypt: ‘The more things change, the more they stay the same?’. *Water Policy*, 21(2), pp.291-309.

Nijsten, G.J., Christelis, G., Villholth, K.G., Braune, E. and Gaye, C.B., 2018. Transboundary aquifers of Africa: Review of the current state of knowledge and progress towards sustainable development and management. *Journal of Hydrology: Regional Studies*, 20, pp.21-34.

Nin-Pratt, A., El-Enbaby, H., Figueroa, J.L., ElDidi, H. and Breisinger, C., 2017. Agriculture and economic transformation in the Middle East and North Africa: A review of the past with lessons for the future. Washington DC: Intl Food Policy Res Inst.

Oczkowski, A. and Nixon, S., 2008. Increasing nutrient concentrations and the rise and fall of a coastal fishery; a review of data from the Nile Delta, Egypt. *Estuarine, Coastal and Shelf Science*, 77(3), pp.309-319.

OECD/Food and Agriculture Organization of the United Nations. 2018. *The Middle East and North Africa: Prospects and challenges*. In *OECD-FAO Agricultural Outlook 2018-2027*, OECD Publishing, Paris/Food and Agriculture Organization of the United Nations, Rome.

Oki, T., Yano, S. and Hanasaki, N., 2017. Economic aspects of virtual water trade. *Environmental research letters*, 12(4), p.044002.

Omuto, C.T., Balint, Z. and Alim, M.S., 2014. A framework for national assessment of land degradation in the drylands: a case study of Somalia. *Land degradation & development*, 25(2), pp.105-119.

Oweis, T. and Hachum, A., 2006. Water harvesting and supplemental irrigation for improved water productivity of dry farming systems in West Asia and North Africa. *Agricultural Water Management*, 80(1-3), pp.57-73.

Petersen, K.L., Paytan, A., Rahav, E., Levy, O., Silverman, J., Barzel, O., Potts, D. and Bar-Zeev, E., 2018. Impact of brine and antiscalants on reef-building corals in the Gulf of Aqaba–Potential effects from desalination plants. *Water research*, 144, pp.183-191.

Prudhomme, C., Giuntoli, I., Robinson, E.L., Clark, D.B., Arnell, N.W., Dankers, R., Fekete, B.M., Franssen, W., Gerten, D., Gosling, S.N. and Hagemann, S., 2014. Hydrological droughts in the 21st century, hotspots and uncertainties from a global multimodel ensemble experiment. *Proceedings of the National Academy of Sciences*, 111(9), pp.3262-3267.

Qadir, M., Bahri, A., Sato, T. and Al-Karadsheh, E., 2010. Wastewater production, treatment, and irrigation in Middle East and North Africa. *Irrigation and Drainage Systems*, 24(1-2), pp.37-51.

Richards, A. and Waterbury, J., 1990. *A political economy of the Middle East: State, class, and economic development*. Boulder: Westview Press.

Rizzo, A., 2014. Rapid urban development and national master planning in Arab Gulf countries. Qatar as a case study. *Cities*, 39, pp.50-57.

Rockström, J. and Falkenmark, M., 2015. Agriculture: increase water harvesting in Africa. *Nature News*, 519(7543), p.283.

Ruckstuhl, Sandra. 2014. *Conflict-Sensitive Development Programming in Transitional Situations: Lessons from Water Related Projects*. Research Paper, United States Agency for International Development, Washington, DC.

Rulli, M.C., Saviori, A. and D'Odorico, P., 2013. Global land and water grabbing. Proceedings of the National Academy of Sciences, 110(3), pp.892-897.

Saab, N. 2015. Consumption Patterns in Arab Countries. AFED Public Opinion Survey. Beirut: Arab Forum for Environment and Development.

Sachs, J., Schmidt-Traub, G., Kroll, C., Lafortune, G., Fuller, G. 2018. SDG Index and Dashboards Report 2018. New York: Bertelsmann Stiftung and Sustainable Development Solutions Network (SDSN).

Sachs, J.D., Schmidt-Traub, G., Mazzucato, M., Messner, D., Nakicenovic, N. and Rockström, J., 2019. Six Transformations to achieve the Sustainable Development Goals. Nature Sustainability, pp.1-10.

Samari, G., 2017. Syrian refugee women's health in Lebanon, Turkey, and Jordan and recommendations for improved practice. World medical & health policy, 9(2), pp.255-274.

Schäfer, K. 2012. Urbanization and urban risks in the Arab region. 1st Arab Region Conference for Disaster Risk Reduction, 19 – 21 March 2013 at Aqaba – Jordan. Available from: <https://bit.ly/2KL8GcL>

Sefelnasr, A. and Sherif, M., 2014. Impacts of seawater rise on seawater intrusion in the Nile Delta aquifer, Egypt. Groundwater, 52(2), pp.264-276.

Selby, J., 2005. The geopolitics of water in the Middle East: fantasies and realities. Third World Quarterly, 26(2), pp.329-349.

Selby, J., 2013. Cooperation, domination and colonisation: The Israeli-Palestinian joint water committee. Water Alternatives, 6(1), p.1.

Selby, J., Dahi, O.S., Fröhlich, C. and Hulme, M., 2017. Climate change and the Syrian civil war revisited. Political Geography, 60, pp.232-244.

Sherif, M., Kacimov, A., Javadi, A. and Ebraheem, A.A., 2012. Modeling groundwater flow and seawater intrusion in the coastal aquifer of Wadi Ham, UAE. Water resources management, 26(3), pp.751-774.

Shetty, S., 2006. Water, food security and agricultural policy in the Middle East and North Africa region. World Bank. Middle East and North Africa Working Paper Series, No. 47.

Siddiqi, A. and Anadon, L.D., 2011. The water–energy nexus in Middle East and North Africa. Energy policy, 39(8), pp.4529-4540.

Snoussi, M., Ouchani, T. and Niazi, S., 2008. Vulnerability assessment of the impact of sea-level rise and flooding on the Moroccan coast: the case of the Mediterranean eastern zone. *Estuarine, Coastal and Shelf Science*, 77(2), pp.206-213.

Sommer, M., Vasquez, E., Worthington, N. and Sahin, M., 2012. WASH in schools empowers girls' education. In *Proceedings of the Menstrual Hygiene Management in Schools Virtual Conference* (Vol. 2013).

Sorenson, S.B., Morssink, C. and Campos, P.A., 2011. Safe access to safe water in low-income countries: water fetching in current times. *Social science & medicine*, 72(9), pp.1522-1526.

Sowers, J., Vengosh, A. and Weinthal, E., 2011. Climate change, water resources, and the politics of adaptation in the Middle East and North Africa. *Climatic Change*, 104(3-4), pp.599-627.

Sowers, J.L., Weinthal, E. and Zawahri, N., 2017. Targeting environmental infrastructures, international law, and civilians in the new Middle Eastern wars. *Security Dialogue*, 48(5), pp.410-430.

Spang, E.S., Moomaw, W.R., Gallagher, K.S., Kirshen, P.H. and Marks, D.H., 2014. The water consumption of energy production: an international comparison. *Environmental Research Letters*, 9(10), p.105002.

Stadler, S., Geyh, M.A., Ploethner, D. and Koeniger, P., 2012. The deep Cretaceous aquifer in the Aleppo and Steppe basins of Syria: assessment of the meteoric origin and geographic source of the groundwater. *Hydrogeology Journal*, 20(6), pp.1007-1026.

Subramanian, A., Brown, B. and Wolf, A.T., 2014. Understanding and overcoming risks to cooperation along transboundary rivers. *Water Policy*, 16(5), pp.824-843.

Sulieman, H.M., 2015. Grabbing of communal rangelands in Sudan: The case of large-scale mechanized rain-fed agriculture. *Land Use Policy*, 47, pp.439-447.

Tessler, Z.D., Vörösmarty, C.J., Grossberg, M., Gladkova, I., Aizenman, H., Syvitski, J.P.M. and Fofoula-Georgiou, E., 2015. Profiling risk and sustainability in coastal deltas of the world. *Science*, 349(6248), pp.638-643.

Trabelsi, N., Triki, I., Hentati, I. and Zairi, M., 2016. Aquifer vulnerability and seawater intrusion risk using GALDIT, GQI SWI and GIS: case of a coastal aquifer in Tunisia. *Environmental Earth Sciences*, 75(8), p.669.

U.N. Habitat, 2012. *The State of Arab Cities 2012: Challenges of Urban Transition*. Nairobi: UN Habitat.

UN DESA. 2018. *World Population Prospects: The 2017 Revision*. New York: Population Division, Department of Economic and Social Affairs, United Nations Secretariat.

UN Environment. 2018. Progress on integrated water resources management. Global baseline for SDG 6 Indicator 6.5.1: degree of IWRM implementation. New York: United Nations.

UNHCR. 2017. UNHCR Global Appeal 2018-2019 - Middle East and North Africa (MENA) regional summary. Geneva: UNHCR.

UNHCR. 2018. Fourth regional survey on Syrian refugees' perceptions and intentions on return to Syria (RPIS). Egypt, Iraq, Lebanon and Jordan. Director's Office in Amman (DOiA) of the MENA Bureau, UNHCR.

United Nations High Commissioner for Refugees (UNHCR), 2011. Global trends 2010. Geneva: UNHCR.

United Nations. 2018. Sustainable Development Goal 6 Synthesis Report 2018 on Water and Sanitation. United Nations: New York.

United Nations. 2019a. Humanitarian Needs Overview (HNO), Yemen. Available from: <https://urlzs.com/t1JVH>.

United Nations. 2019b. Humanitarian Needs Overview (HNO), Syrian Arab Republic. Available from: <https://bit.ly/2WjfCzU>

United Nations. Economic Commission for Africa, 2010. Land policy in Africa: North Africa regional assessment. Addis Ababa: United Nations. Economic Commission for Africa.

Van der Helm, A.W.C., Bhai, A., Coloni, F., Koning, W.J.G. and De Bakker, P.T., 2017. Developing water and sanitation services in refugee settings from emergency to sustainability—the case of Zaatari Camp in Jordan. *Journal of Water Sanitation and Hygiene for Development*, 7(3), pp.521-527.

Verner, D. ed., 2012. Adaptation to a changing climate in the Arab countries: a case for adaptation governance and leadership in building climate resilience. Washington DC: The World Bank.

Voss, K.A., Famiglietti, J.S., Lo, M., De Linage, C., Rodell, M. and Swenson, S.C., 2013. Groundwater depletion in the Middle East from GRACE with implications for transboundary water management in the Tigris-Euphrates-Western Iran region. *Water resources research*, 49(2), pp.904-914.

Wada, Y. and Bierkens, M.F., 2014. Sustainability of global water use: past reconstruction and future projections. *Environmental Research Letters*, 9(10), p.104003.

Waha, K., Krummenauer, L., Adams, S., Aich, V., Baarsch, F., Coumou, D., Fader, M., Hoff, H., Jobbins, G., Marcus, R. and Mengel, M., 2017. Climate change impacts in the Middle East and Northern Africa (MENA) region and their implications for vulnerable population groups. *Regional Environmental Change*, 17(6), pp.1623-1638.

Walker, C.L.F., Perin, J., Aryee, M.J., Boschi-Pinto, C. and Black, R.E., 2012. Diarrhea incidence in low-and middle-income countries in 1990 and 2010: a systematic review. *BMC public health*, 12(1), p.220.

Waterbury, J. 1979. *Hydropolitics of the Nile valley*. New York: Syracuse University Press.

Waxman, J.B., Mehyar, M., Bromberg, G., Khateb, N. and Milner, M., 2015. A Water and Energy Nexus as a Catalyst for Middle East Peace. *International Journal of Water Governance*, pp.71-92.

Weitz, N., Carlsen, H., Nilsson, M. and Skånberg, K., 2018. Towards systemic and contextual priority setting for implementing the 2030 Agenda. *Sustainability science*, 13(2), pp.531-548.

Wheeler, K.G., Basheer, M., Mekonnen, Z.T., Eltoun, S.O., Mersha, A., Abdo, G.M., Zagona, E.A., Hall, J.W. and Dadson, S.J., 2016. Cooperative filling approaches for the grand Ethiopian renaissance dam. *Water International*, 41(4), pp.611-634.

Whittington, D., Waterbury, J. and Jeuland, M., 2014. The Grand Renaissance Dam and prospects for cooperation on the Eastern Nile. *Water Policy*, 16(4), pp.595-608.

Whittington, D., Wu, X. and Sadoff, C., 2005. Water resources management in the Nile basin: the economic value of cooperation. *Water policy*, 7(3), pp.227-252.

WHO (2017). *Progress on Drinking Water, Sanitation and Hygiene: 2017 Update and SDG Baselines*. Geneva: World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), 2017. Licence: CC BY-NC-SA 3.0 IGO.

WHO and UN Habitat. 2018. *Progress on wastewater treatment. Piloting the monitoring methodology and initial findings for SDG indicator 6.3.1. Guidelines on Sanitation and Health*. Geneva: World Health Organization. Licence: CC BY-NC-SA 3.0 IGO.

Wichelns, D., 2001. The role of 'virtual water' in efforts to achieve food security and other national goals, with an example from Egypt. *Agricultural water management*, 49(2), pp.131-151.

Wijesekera, S. 2017. *When Water Becomes A Weapon Of War*. The Huffington Post.

Wittfogel, K.A., 1959. *Oriental despotism: A comparative study of total power*. Yale University Press, New Haven.

World Bank. 2018a. *Beyond Scarcity: Water Security in the Middle East and North Africa*. MENA Development Report. Washington, DC: World Bank.

World Bank 2018b. *Population estimates and projections*. Retrieved from: <https://datacatalog.worldbank.org/dataset/population-estimates-and-projections>

World Bank Group. 2018c. Iraq Reconstruction and Investment: Damage and Needs Assessment of Affected Governorates. Washington, DC.: World Bank.

World Bank. 2017. Water for Prosperity and Development : Risks and Opportunities for the Gulf Cooperation Council Countries. Washington, DC.: The World Bank.

Yousef, T.M., 2004. Development, growth and policy reform in the Middle East and North Africa since 1950. *Journal of Economic Perspectives*, 18(3), pp.91-115.

Zaghloul, S.S. and Elwan, H., 2011. Water quality deterioration of middle Nile Delta due to urbanizations expansion, Egypt. In *Proceedings of the XV International Water Technology Conference*, Alexandria, Egypt.

Zawahri, N., Sowers, J. and Weinthal, E., 2011. The politics of assessment: water and sanitation MDGs in the Middle East. *Development and change*, 42(5), pp.1153-1178.

Zdruli, P., 2014. Land resources of the Mediterranean: status, pressures, trends and impacts on future regional development. *Land Degradation & Development*, 25(4), pp.373-384.

Zeitoun, M., 2008. *Power and water in the Middle East: The hidden politics of the Palestinian-Israeli water conflict*. London: IB Tauris.

Zhu, T., Ringler, C. and Rosegrant, M.W., 2019. Viewing agricultural water management through a systems analysis lens. *Water Resources Research*, 55(3), pp.1778-1791.