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Key Points:
- Arab region is not on track to meet Sustainable Development Goal 6 on clean water supply and sanitation for all
- Narrative of water scarcity and supply-side technological fixes masks systemic issues that threaten sustainable water management
- Water security in Arab region cannot be understood in isolation from broader regional and international political and socioeconomic trends

Supporting Information:
- Supporting Information S1

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Tackling the Trickle: Ensuring Sustainable Water Management in the Arab Region

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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 manifested 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 underperforming 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 socioeconomic trends. Recognizing the complex and interdependent challenges of water management is the first step in reforming approaches and shifting to more sustainable development outcomes and stability in the Arab region and beyond.

1. Introduction

For thousands 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, 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. At the same time, they challenge Arab countries to think about and manage water in new ways, including calling for new, multisectoral approaches and policies on sustainable water management.

This review assesses the status of sustainable water management in the Arab region by examining progress toward 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 toward 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 ideas and practices. 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, while still writing a concise review, the following income-based typology (with income data from 2019, details in supporting information Table S1) is used throughout this paper:

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

2. Water Issues Facing the Arab Region

2.1. Access to Water Services

Access to drinking water supply and sanitation remains a challenge in low-income countries in the Arab region, and those affected by armed 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 Millennium Development Goal targets in 2015 (supporting information Table S2). 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 (supporting information Table S2). 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 armed conflict situations (e.g., absence of separate latrines and menstrual hygiene management (Samari, 2017); affordability and quality of water purchased from privately-operated tanker trucks (Abu-Lohom et al., 2018).

2.2. 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) and Medjerda River in Tunisia (Etteieb et al., 2017). This highlights the need to consider SDG indicators with caution as national indicators might hide considerable subnational variation. Three main sources of pollution threaten water quality in the region. First, domestic wastewater, of which more than 50% 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 (Human Rights Watch, 2019; Mawlood et al., 2018) 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% of the applied fertilizer, much greater than the global average of 11%, while phosphate releases to the environment are about 12% of the phosphorus applied as fertilizer, in line with a global average of 12% (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 & Nixon 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. Hot spots of surface water salinization include the Mesopotamian Marshes (Al-Mudaffar Fawzi et al., 2016), Shatt al-Arab River (Al-Mudaffar Fawzi & Mahdi, 2014), Jordan Valley (Farber et al., 2005), and increasingly the Nile basin (Multsch, Alquwaizany et al., 2017). In addition, groundwater salinization due to overexploitation affects the coastal aquifer in Gaza (Dentoni et al., 2015), the Wadi Ham in the UAE (Sherif et al., 2012), the Nile Delta (Molle et al., 2018; Sefelnasr & Sherif, 2014), and the Sfax aquifer in Tunisia (Trabelsi et al., 2016), among others. The groundwater salinity situation is particularly dire in

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	*Population using at least basic drinking water services (percent)*		*Population using at least basic sanitation services (percent)*		*Percentage of safely treated wastewater flows from households (percent)*	*Level of water stress: freshwater withdrawal as a percentage of available freshwater resources (percent)*	*Change in water-use efficiency over time (2013-2015), (percent)*	*Degree of integrated water resources management implementation (0-100)*	*Mean area that is protected in freshwater sites important to biodiversity (percent)*	
	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[a]	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.
[a]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). [b]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).

the Comoros Islands, where fewer than 30% of wells provide water of acceptable drinking water quality (Comte et al., 2016).

2.3. 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% total renewable freshwater availability (supporting information Figure S1). 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% from the long-term average, compared to a global average of 25% (see coefficient of variation in supporting information Figure S1). 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 (supporting information Table S3). 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 (supporting information Table S3). 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) (supporting information Figure S2). 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% of total electricity generation, apart from Egypt (7–10% from the High Aswan Dam and declining), Morocco (5%), and Iraq (4%) (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; Dillon et al., 2019; Lopez et al., 2014).

High-income countries have deployed desalination technologies at scale to augment supplies (supporting information Table S4). They now account for about 50% of the world's desalination capacity, though they only host less than 1% 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% of the total annual energy consumption in Saudi Arabia (Siddiqi & 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 (Kfouri 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

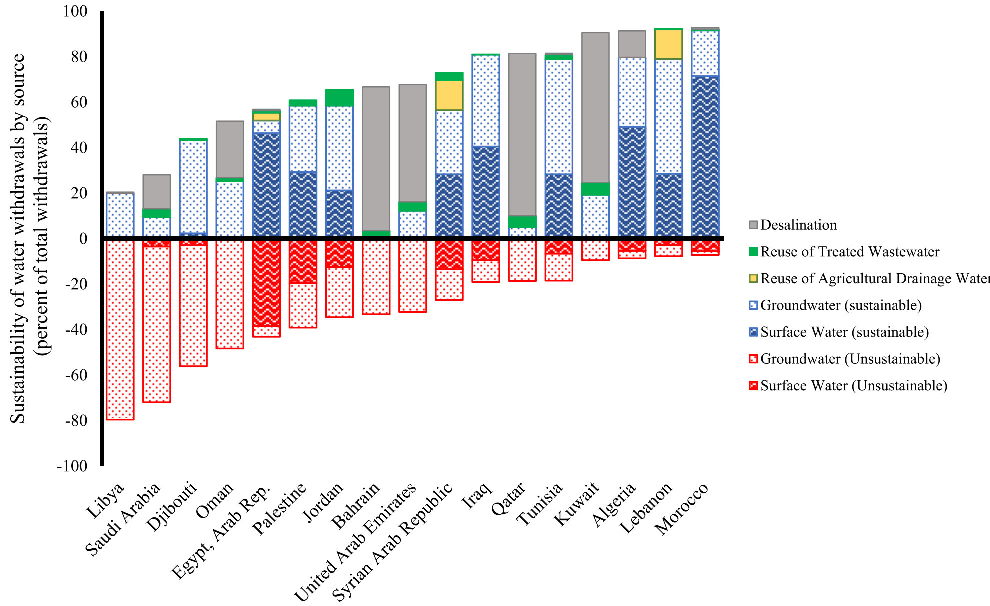

Figure 1. Sustainability of water consumption by supply source. Supply sources above zero are consumed sustainably, while supply sources below zero and colored in red are subject to unsustainable consumption. No data for the Comoros, Mauritania, Somalia, Sudan, and Yemen, Rep. Adapted from World Bank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

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, and *hafaer* in Jordan and Syria (Oweis & Hachum, 2006). National water strategies and budgets do not currently include green water (Antonelli & 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 overallocation of blue water (surface and groundwater) resources (Rockström & 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, and wastewater reuse) and water conservation, the Arab region is a global hot spot of unsustainable water use, with at least 30% of current water consumption exceeding sustainability limits (Figure 1) (Wada & 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 nonrenewable 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 & 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 (Multsch, Elshamy et al., 2017).

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. In this latter aquifer system, at least 60% of water storage loss is attributable to groundwater depletion (Joodaki et al., 2014; Voss et al., 2013). 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 (Al Naber & Molle, 2017; Goode et al., 2013) in the Souss-Massa aquifer in Morocco (Hssaisoune et al., 2017), and the transboundary Nubian Aquifer (Ahmed & Abdelmohsen, 2018), among others.

2.4. Water Use Efficiency

In the face of water scarcity and degrading water quality, 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, and 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 (AbuZeid et al., 2019), which are in line with preliminary estimates from the United Nations (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) and 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% of water put into the supply system due to leakage and unregistered usage (UN Habitat, 2012). Similar levels of nonrevenue water are reported for countries in North Africa, including Tunisia (26%) and Algeria (54%) (Danilenko et al., 2014). In the high-income countries, nonrevenue water ranges from 30% in Oman and Saudi Arabia to 24% in Bahrain, 20% in Qatar, 13% in the UAE, and 5% in Kuwait (World Bank, 2017).

2.5. 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 toward Integrated Water Resources Management—regarded as the framework for sustainable water governance—so far has been limited, with most countries needing to expand significantly Integrated Water Resources Management (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 (Nijsten et al., 2018; World Bank, 2018a). In fact, some of the seminal academic works on transboundary waters focused on the hydropolitics of one of the major transboundary rivers of the region, the Nile basin (Waterbury, 1979). To date, no interstate 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 & Böhmelt, 2014) Jordan (Jägerskog, 2003), Nile (Whittington et al., 2014), and Tigris-Euphrates (Kibaroglu, 2019) river basins (see supporting information Note S1). The Arab region hosts a number of transboundary aquifers with an operational arrangement for water cooperation (e.g., the Nubian Sandstone aquifer system (McCracken & 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.

2.6. 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 (Al-Obaid et al., 2017; Darwall et al., 2014; García et al., 2015; 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% of the brine produced in the world, with Saudi Arabia alone accounting for 22% 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).

3. 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 armed 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 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.

3.1. 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/Food and Agriculture Organization of the United Nations, 2018). By 2050, urban population is projected to double from 2017 levels, with 75% 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% of the region's surface area is home to 92% of the total population, 50% 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 toward 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 and causing tensions between adjacent governorates (International Organization for Migration (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 & Elwan,

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 Gxarouani 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) and river banks (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 aging 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 & 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 & Ianchovichina, 2018). This gives middle- and low-income countries in the region youth unemployment rates of about 25%, among the highest in the developing world, paired with the lowest female labor force participation in the world (ILO (International Labour Organization, 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 toward water policies more explicitly linked to youth employment and female labor participation increase 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 programs 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).

3.2. 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, International Armed Conflicts and Non-International Armed 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 response 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 10 million internally displaced persons (IDPs), more than 6 million registered refugees (UNHCR, 2017) (about 4 times the number in 2010 (United Nations High Commissioner for Refugees (UNHCR), 2011)), and many more unregistered refugees, has compounded existing challenges faced by host communities, while leaving vulnerable IDPs and refugees with limited or no access to resources and services. In Jordan and Lebanon, where 75% 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 (Ministry of Environment of Lebanon, European Union, and United Nations Development Program), 2014). In Lebanon, the Ministry of Environment estimates that domestic water demands have increased between 8% and 12% and wastewater generation between 8% and 14% following the influx of refugees (MOE/EU/UNDP (Ministry of Environment of Lebanon, European Union, and

United Nations Development Program), 2014). In Jordan, the influx of refugees has caused a significant increase in the country's population—by as much as 50% 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 & Klingseis, 2018). Surveys of Syrian refugees 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 result of warfare being waged in urban areas in the region (ICRC (International Committee of the Red Cross), 2015a; Sowers et al., 2017). Given the interrelated nature of public services and 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 (International Committee of the Red Cross), 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 Group, 2018), leading to intermittent and low-quality access, which in turn sparks social tensions among the population (Human Rights Watch, 2019).

The compounding effect of armed 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, armed conflicts, displacement 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.

3.3. Agricultural and Food Policy

Agriculture contributes to a relatively small share of the region's gross domestic product (about 13% 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% on average, 50% in low-income countries) and livelihood security, and its share of water consumption (about 85% 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, 2002). Trade in agricultural products is regarded as "virtual water trade" as it avoids agricultural water use in the importing country while increasing it in the exporting country. Research has confirmed the importance of virtual water trade for the region's food security and water management (Gilmont, 2015; Wichelns, 2001) and has demonstrated how the region hosts some of the world's top virtual water importers (Antonelli & 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% 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 and 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 & 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 & 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 toward more balanced policies targeting demand factors related to food security, such as income and social protection (Borgomeo & 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). Support of water intensive forms of agriculture through subsidies and unregulated agricultural water useled, in some countries, to 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 sociopolitical 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 socioeconomic 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 & Laher, 2016), partly arose because of protectionist and food self-sufficiency policies, especially for wheat (Borgomeo & 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%, 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% (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, (3) seize innovations in agricultural water management to increase domestic productivity (e.g., water accounting and 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).

3.4. 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 toward 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 toward 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 (Borgomeo et al., 2018; Closas & Rap, 2017). 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 25 countries with the highest freshwater consumption in energy generation in the world (Spang et al., 2014).

3.5. 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 (García-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 (Field, et al., 2012). North Africa and the Mashreq are possible hot spots where the frequency of drought might increase by more than 20% 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% 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.

3.6. 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). 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% and 5%) in soil erosion over the period 2001–2013 (Borrelli et al., 2017), as confirmed by local evidence (Abdo & 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% of the countries' land area, respectively (Almeshreki et al., 2012; Omuto et al., 2014). Widespread land degradation and desertification are manifestations of soil erosion in the region's dryland systems (Heshmati & Squires, 2013; Zdruli, 2014). From 1975 until 2010, North Africa lost 2×10^6square kilometres of agricultural land to desertification (United Nations. Economic Commission for Africa, 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 & 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 & Giordano, 2014). Land fragmentation is common in the Arab region, mostly because of subdivisions of land for inheritance as well as poorly formalized land rights and persistent land tenure insecurity (Shetty, 2006; United Nations. Economic Commission for Africa, 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).

3.7. 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, 2017), 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 fulfill 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

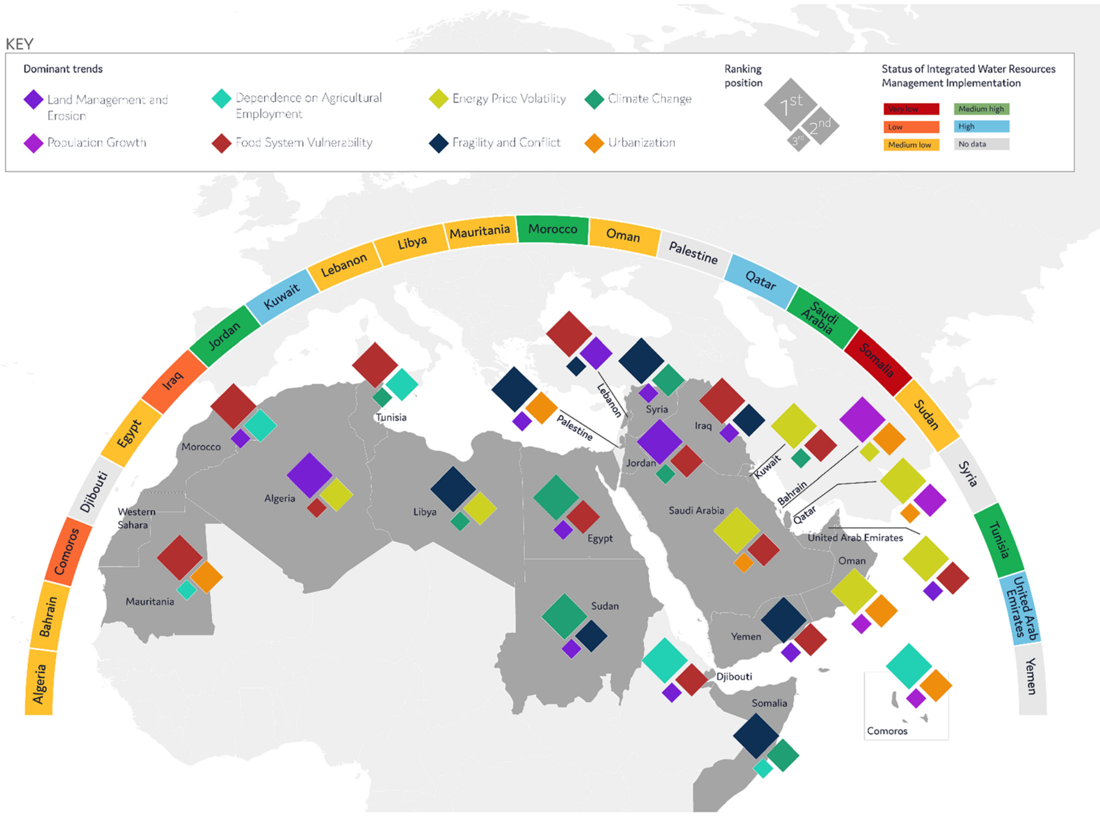

Figure 2. Uncertain trends shaping sustainable water management in the Arab countries. Diamonds show the top three trends shaping sustainable water resources management in each country. The semicircle shows the status of Integrated Water Resources Management Implementation (Sustainable Development Indicator 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.

subsidized water and electricity for irrigation) to ordinary citizens in times of volatile energy prices and stretched welfare systems is coming under question (Malik & Awadallah, 2013).

A move toward 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 toward 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 (Food and Agriculture Organization of the United Nations; World Bank Group), 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.

3.8. 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 & 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 & 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 toward 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).

4. 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 socioeconomic 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 supporting information 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 (cf. 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 peace-building 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 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 armed conflict and examine the contribution of sustainable water management to peace-building processes.

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