ENHANCING WATER SECURITY IN THE MIDDLE EAST

Editor: Hussein A. Amery

الشرق للأبحاث الاستراتيجية

AL SHARQ Strategic Research

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This book is the product of the MENA Water Security task force organized by Al Sharq Strategic Research between March 2022 to February 2023.

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Preface

In the opening months of 2018, I had the honor of being among a select group of scholars invited by Galip Dalay, the previous research director of Al Sharq Strategic Research, to participate in planning the institution's second conference on the security architecture in the Middle East and North Africa (MENA) region. Al Sharq Strategic Research is a research and policy center that aims to foster democratic and inclusive political development in the Arab world. Al Sharq Forum, of which Al Sharq Strategic Research is a part, was established in 2012 by prominent intellectuals, activists, and academics from the MENA region. Our objective was to explore the various themes that shape the security landscape of the Middle East and North Africa.

We focused on four primary themes, the first three being traditional and widely studied topics. We examined the interactions between non-state actors and other regional actors and delved into the extent of their agency and the evolution of their roles and objectives over time. Our second theme was regionalism, and we had the privilege of studying the experiences of other regions and how they might apply to the MENA region, with a particular focus on the Association of Southeast Asian Nations, European Union, African Union, Shanghai Cooperation Organization, and the Arab League. Our third theme examined the interactions between great powers and the region, exploring the areas of convergence and competition and the impact these interactions have had and continue to have on the region.

The fourth theme was where we sought to be innovative. We decided to study the impact of non-conventional security threats, such as environmental degradation and climate change, and to consider the effects of the water-food-energy nexus on national security. We believed addressing these challenges could foster collaboration among the various regional actors. The environmental security literature refers to this as “low politics” because it carries the potential of creating diplomatic channels among rivals to solve cross-border problems and eventually build trust that can help to tackle a more comprehensive array of contentious issues. Later that year, Al Sharq Forum brought together over 140 experts, including academics and practitioners from across the region and beyond, to discuss and present ideas, research, and policies. We were especially eager to see how the debate on the fourth theme would unfold, but to our general disappointment, the bulk of the discussion did not go beyond the energy question, specifically the oil and gas trade. Nevertheless, it served as a valuable lesson.

First, non-conventional security threats are not necessarily perceived as “low politics.” In many cases, the threat perception is genuine, and the more significant it becomes, the harder it becomes to convince governments and states to collaborate with others. It is insufficient to raise awareness around the impact of non-conventional security threats. Rather, it is equally important to emphasize the rewards of collaboration and the improved long-term return on investment when collective solutions are forwarded. Additionally, where states fail or prove too rigid and inflexible to act, non-state actors can prevail. Whether by engaging local communities or encouraging NGOs to implement local initiatives with low environmental impact, non-conventional security threats are too significant to ignore and require a collective response.

Second, practitioners and independent research entities need more knowledge and expertise to advise relevant actors on responding to these challenges. To move forward, we decided to provide a platform for concerned researchers and experts to build a solid scientific foundation to lead the discussion. Such a group should comprise regional researchers with a stake in its welfare and future. Thankfully, the MENA region has given birth to a host of world-class experts, but the challenge is to provide them with the opportunity to work together.

Third, even though the general public discourse is dominated by debates on ideological wars, geopolitical contests, and the economy, non-conventional security threats still manage to garner some attention. Research has enumerated the region's abundant problems regarding water, food, climate, and energy security. What is missing from the debate are creative solutions and the optimism to find flexible and innovative solutions to the challenges and obstacles that may arise.

Four years after our initial involvement in planning the MENA security architecture conference, I was honored to receive an invitation from Dr. Mohammad Affan, the current research director of Al Sharq Strategic

Research, to partake in a new endeavour. This time, the objective was not to plan for another conference but to contribute to an edited volume with a recent research question. The opportunity to continue our exploration of non-conventional security threats was too valuable to pass up, and we were eager to delve deeper into the topic. This time we decided to focus on the specific issue of water security.

For several reasons, water security is one of the most critical non-conventional security threats in the MENA region. Firstly, the region is characterized by high water scarcity, with many countries being among the most water-stressed in the world. According to the World Resources Institute, 17 of the 20 countries with the lowest water availability per capita are in the MENA region.

Secondly, rapid population growth is straining the already limited water resources in the MENA region. The region's population is projected to increase by around 50% by 2050. This, along with improving quality of life and the concurrent rising consumption of water-intensive protein diets, will aggravate water scarcity.

Thirdly, the region is experiencing increasing droughts and extreme weather events, reducing freshwater availability and exacerbating water scarcity. Climate change is projected to decrease precipitation and increase evaporation in the region, reducing the availability of water resources and increasing the risk of droughts.

According to the United Nations, the region has the world's lowest water resources per capita, with less than 500 cubic meters per person per year. In some countries, such as Oman and Saudi Arabia, the figure is as low as 100 cubic meters per person per year. The World Bank estimates that the MENA region's economic cost of water scarcity could reach 14% of GDP by 2050.

These statistics show that water security is a vital issue in the MENA region and needs to be urgently addressed. The region needs to improve water management and address the underlying causes of water scarcity, such as over-extraction of groundwater, inefficient irrigation practices, and lack of investment in water infrastructure.

In light of our experience, it was of the utmost importance to us that a group of researchers from the MENA region undertake this current endeavor. Therefore, our primary challenge was to identify and secure the leadership of a senior expert to guide our efforts. My colleague, Miss Rawan Hamoud, a research fellow at Al Sharq Strategic Research, demonstrated her exceptional outreach abilities by shortlisting a group of distinguished academics. Through her efforts, we were fortunate to enlist Professor Hussein A. Amery as the volume editor. A professor at the Colorado School of Mines who specializes in water politics and policy and hails from the region by way of Lebanon, Dr. Amery, shared our enthusiasm for this venture.

As we moved forward, our interactions with Professor Amery were informative and enjoyable, as we quickly developed a strong rapport and friendship. Despite the time difference, with our meetings taking place late in the evening in Istanbul and early in the morning in Colorado, our virtual meetings were a source of valuable insights and knowledge. In a short period, we were able to finalize our proposed outline for the edited volume and select our experts for the book.

Determining the most appropriate approach to address the pressing issue of water security in the MENA region was challenging. We faced the critical question of whether to discuss the matter by theme, based on the type of problems the region faces, or to examine it from a geographical perspective by dividing the region into basins and discussing the challenges faced by each basin separately. After much deliberation and consideration, we decided to adopt the latter approach.

The primary rationale behind this decision was the nature of expertise traditionally garnered in the field. However, this approach also had its drawbacks: within the confines of a single volume, we could not exhaustively cover all of the region's basins. Nevertheless, this approach will provide a comprehensive understanding of the challenges faced by the MENA region's other basins and serve as a valuable resource for scholars, practitioners, and policymakers alike.

This edited volume presents an examination of the MENA region's water challenges, and it attempts to pay greater attention to opportunities related to enhancing water security. With this approach in mind, the Nile River basin is analyzed by Dr. Mohammed Mahmoud, the Euphrates and Tiger basins are examined by Dr. Neda Zawahri, Dr. Mohammad Al-Saidi addresses the issue of desalination in the Arab Gulf countries, and Dr. Hilmi S. Salem explores potential solutions for the water conflict between Palestinians and Israelis. Finally, a cross-regional chapter by Dr. Marwa Daoudy provides a broad human security framework for this volume. Water challenges in the Middle East and North Africa are too numerous to capture in one body of research. Dr. Amery provides an introductory chapter that provides an overview of the wide range of possible approaches for enhancing water security. Throughout our collaboration, we also discussed examining water insecurity in other parts of the region, such as Morocco, Iran, and Yemen.

In conclusion, we hope the insights and perspectives presented in this book will inspire further research and analysis on the themes discussed and contribute to a deeper understanding of the Middle East and North Africa security landscape. Through our research and discussions, we have highlighted the importance of addressing non-conventional security threats, such as the environment, climate change, and the water-food-energy nexus, and the potential for collaboration and innovative solutions to address these challenges. We encourage our colleagues in academia and think tanks to continue this important work and build on the foundation laid by this volume.

Sinan Hatahet, PhD.
22 January 2023
Istanbul, Türkiye

Chapter One

Enhancing Water Security in the Middle East

Hussein A. Amery

Abstract: The hydro-climatic conditions in the Middle East are such that most of the region's countries are arid or semi-arid. Water mismanagement, population pressure, climate change, hydro-politics, and rising incomes along with a transition towards protein-rich diets have all contributed to aggravating water scarcity. Despite its scarcity, today's dominant cultural norms do not appreciate the great value of freshwater which may be related to the fact that people have long enjoyed it at little to no cost. Pandemic-era supply-chain challenges, economic sanctions, trade wars and the fallout from the Ukraine war have created a backlash against dependence on imported food stuffs which has led some governments in the Middle East to take steps to expand domestic agriculture. The hydrological implications of this can be significant. Water security can be enhanced by increasing the efficiency of water use, such as getting "more crop per drop" and providing new water (supply management) or both. Specifically, 1) science and technology, hydro-diplomacy, 2) virtual water through international trade, and 3) nature-based solutions can help communities and countries move towards sustainable water security. Effective efforts towards this goal can happen at various scales: they range from small-scale such as installing water meters, to larger efforts such as building vast wastewater treatment and desalination plants, to complicated and delicate efforts like transboundary water diplomacy. Water meters to measure water consumption allow communities to more efficiently manage their resources, an intervention which can yield tangible results within a short time frame. On the other hand, cooperation over managing a transboundary river like the Nile takes a long time to develop and nurture. Finally, there is a need to create a new hydrologically-sensitive cultural outlook. By internalizing the scarcity of water, people would appreciate its critical value and use it more sparingly.

INTRODUCTION

"Anyone who can solve the problems
of water will be worthy of two Nobel prizes:
one for peace and one for science."
US President John F. Kennedy, 1962

Water scarcity is both a challenge and an opportunity. Human-based activities from climate change to the mismanagement of natural resources have all been multiplying the pressure on freshwater systems around the world. The opportunity lies in the immense potential for good governance domestically and for collaboration between governments in an international watershed in ways that help achieve water security for all. Next generation solutions for water scarcity require innovations in policy and technology that protect watersheds and people's wellbeing. This requires water management that is integrated, sustainable and inclusive.

Globally in the period between the 1900s and 2000s, water consumption increased fourfold while the population living under conditions of water scarcity increased from 14% to 58% (Kummu et al. 2016). Jay Famiglietti (2019) of the Global Institute for Water Security in Canada finds that "The world's high-latitude regions, including the northern half of the United States, as well as the global tropics, the low latitudes, are getting wetter. Simultaneously, the mid-latitudes—the arid to semiarid belt sandwiched in between—are getting drier" (See also Vörösmarty 2021). This pattern is consistent with predictions made in reports by the

Intergovernmental Panel on Climate Change (IPCC). He then wonders if these findings of "wet getting wetter, dry getting drier" would aggravate current conditions of aridity in Middle East or along the regions that are "already prone to conflict" (See also IPCC 2021).

In the Middle East, human activities have been aggravating the harshness of nature. The dominant hydrogeography in the region ranges from arid to hyper arid. A United Nations report summarizes the obstacles the region faces in achieving water security as the following: "dependency on shared water resources, pollution, climate change impacts and extreme events, non-revenue water losses from ageing systems, intermittency, inefficient use, and high population growth. It also states that "occupation and conflict" impact "people's ability to access water and sanitation services" (ESCWA 2019). The region is "home to 6% of the world's population and less than 2% of the world's renewable water supply" (Al-Otaibi 2015). In terms of the Middle East's overall dependency, some 66 per cent of its surface freshwater originates outside its borders (UNICEF 2017). Occupation and conflict limit people's choices, corrupts good water governance, and weakens sustainable water management.

In terms of politics and economics, enabling water security is further challenged by improvements in people's quality of life along with a shift towards protein-rich (water-intensive) diets, water mismanagement, distrust of political leaders, and a general lack of coordination between riparian states (Table 1). Despite water scarcity, the region "has the world's lowest water tariffs and the highest proportion of GDP (2 percent) spent on public water subsidies" (World Bank. 2017). The irony is while low tariffs do not cover the cost of water delivery, they enable farmers to grow water-intensive crops, such as bananas and oranges, and to continue using old, inefficient and wasteful irrigation methods (World Bank 2018). Given current trends in the region, "water availability per capita is expected to be cut in half by 2050" (UNICEF 2017).

Table 1 | Strains on Water Security

Climate Change	Warming temperatures, increasingly erratic weather patterns, decrease in precipitation, increase in evaporation, increase in the occurrence and duration of droughts, etc.
Freshwater Decline	Depletion of freshwater sources due to industrial and agricultural demand, amplified by population growth and a transition to water-intensive, protein-rich diets.
Impairment of Food-Producing Ecosystems	Increasing stress on world's arable lands and pastures. Once-productive land is damaged by soil erosion, desertification, compaction, salinization, and sometimes by water-logging. Depletion of fisheries. Synergistic effects of land degradation and climate change.
Organic and inorganic pollution	Leaching of water-soluble pesticides or fertilizers into surface and ground water. Toxic chemicals and heavy metals from industries and human settlements pollute water sources.

Remote settlements and poor communities	Inadequate or non-existent water infrastructure in rural and remotely located communities. Negligence of poorer areas with respect to water services.
Political instability and conflict	Poor water infrastructure due to neglect and conflict-induced damage.
Poor governance	Nepotism in hiring, top-down management, and lack of public participation result in unqualified staff drafting water policy that lacks buy-in from the public.

Almost all countries in the region "suffer from water scarcity" and some degree of water insecurity because their consumption far exceeds their total renewable water supplies (UNICEF 2017). In fact, they can be categorized as being in a state of absolute water scarcity where water availability is below 1000 cubic meters per person, per year. This is based on Falkenmark's Water Stress Indicator[1] (Kummu et al. 2016; AQUASTAT 2022). For example, over-pumping of aquifers has lowered water tables in the UAE by about one meter per year over three decades, and by one to two meters per year in Egypt (Al-Otaibi 2015; Salim 2012). In other words, while many of the water challenges in the region are driven by domestic factors, others are impacted by trans-national and global issues such as climate change. A recent paper notes that the Middle East's projected transition to warmer, drier and extreme weather events has the potential to upend societies due to "increasing severity and

1- Falkenmark's widely used indicator is based on a minimum need of 100 liters/person/day for household use, and from 5 to 20 times as much as for the agricultural and industrial sectors. She assumes 3000 kcal per capita per day, of which %20 comes from animal protein.

duration of heatwaves, droughts and dust storms, as well as torrential rain events that can trigger flash floods." This transition "can be expected to severely affect agriculture" including critical crops like olives, grape vines, legumes, wheat and barley (Zittis et al. 2022).

Water and food security are premised on a certain degree of environmental stewardship, and good water quality; they improve human health, ecosystem health and ultimately enhance human security. On the other hand, water shortages reduce agricultural output which creates a drag on the local or national economy, hence impacting people's health and livelihoods. They adversely impact many aspects of life, and sometimes affect political stability. A United Nations report concludes that in the Arab region, water scarcity is "a threat to national security, social well-being and political stability" (UNDP 2013). As water shortages mount so does the anger and frustration of the public. As people grow thirsty, they become more territorial and less tolerant. In 2021, water shortages led tens of thousands of Iranians to protest for about two weeks. Years of mismanagement resulted in water drying up in the celebrated Zayanderoud River. These protests were consequential as most of the people who were impacted, and hence protested, were ethnic Arabs from the Khuzestan Province (Fassihi 2021). That same year and as summer temperatures were peaking and drought conditions contributed to food and water insecurity, similar water protests happened in Iraq (Reuters 2021). In Jordan, summer heat and water deficits in 2014 helped spark

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Her graduated stress index begins when available water drops below 1,700 m3 /person /year (Falkenmark and Rockström 2004).

water riots in the northern parts of the kingdom where water pump stations were attacked (Mercy Corps 2014). Similarly, one of the sparks that helped trigger the Syrian civil war was a severe drought that hit northern Syria and Iraq from 2006 to 2011 (Daoudy 2020). In other words, enhancing water security needs to become one of the highest priorities for the region's governments.

The literature on water security and insecurity is rather extensive (for example, Gerlak et al. 2018; Lankford et al. 2013; Bakker and Morinville 2013; Zeitoun 2011; Daoudy 2020). However, only a small number of studies focuses on how policy, technology and management can enable countries to move towards water security, the focus of this volume. A notable exception is a study by The Economic and Social Commission for Western Asia, a regionally-focused branch of the United Nations. It is aptly titled "Moving towards Water Security in the Arab Region" (ESCWA 2019). Likewise, a detailed study by the World Bank (2018) aimed to look "Beyond Scarcity: Water Security in the Middle East and North Africa". Hence this volume seeks to expand the literature on this critical theme.

This book aims to recognize some of the water-related risks that face the people of the Middle East and suggest solutions that contribute to mitigating them and thereby enhancing water security. Conceptually, it is framed around improving populations' environmental and human security, and on advancing collaboration between riparian states for their mutual benefit. As such each contributor to this volume offers ideas that can help governments, nongovernmental organization, donors, intergovernmental organization, and communities move towards improving human security through water management that is more sustainable socially, economically and ecologically. This chapter provides a broad contextualization of some of the water challenges facing the people and governments in the hydrogeographic regions covered in this book, and provides a few examples of how water security can be fostered.

HYDRO-GEOGRAPHIC COVERAGE

The focus on water security in the Middle East led this book to be organized around the following hydrogeographic regions: the Arabian Peninsula, Tigris and Euphrates rivers, Jordan River, and the Nile River. The countries covered in these areas are home to most of the population of the Middle East. Nonetheless, some countries receive more in-depth treatment by authors than others. We, furthermore, did not have the bandwidth to take a deep dive into all the countries that have serious water security challenges like Lebanon, Iran and Yemen.

The Arabian Peninsula: Historically, the Arabian Peninsula was referred to as Al-Jazeera, Arabic for island. The latter is not a misunderstanding of geography, but a vivid reminder of Bedouin tribes' perceptions of the inhospitable An-Nafud desert in northwestern parts of the Saudi Arabia of today (Beaumont 1976). The massive, arid and harsh desert was challenging to traverse, and hence practically had the same isolating effect as a sea. Furthermore, as caravans of nomads and traders made their way through the sunbaked desert, their destination seemed like a mirage, hence the isolating effect that one associates with a (vanishing) "water" body which made the peninsula feel like an island.

Although the hydrogeography of the peninsula is generally similar, it is very different from other water basins under study in this volume. The Gulf Cooperation Council (GCC) countries suffer from low precipitation levels, very small areas of arable land and none of them has a permanently running river. The mountain ranges that straddle parts of the coastal areas of the United Arab Emirates, Oman, Yemen and Saudi Arabia receive higher precipitation levels than the more arid interior. However, a small percentage of the population lives here, with a clear majority concentrated in the arid urban core.[2] Historically, the Peninsula's meager natural resources and its harsh climate resulted in a sparse population. The discovery of hydrocarbons elevated the carrying capacity of the land which included the wide-spread adoption of desalination technologies to quench the thirst of the GCC countries' ballooning populations. However, because the process is energy intensive, the cost of the water it produces is relatively high. Therefore, its economic viability may be confined to supplying domestic water. While surface water is almost non-existent, countries in the Arabian Peninsula share a lot of aquifers. For example, Oman and the United Arab Emirates share the Paleogene aquifer, and Jordan and the Saudi Arabia share the Disi aquifer. In the wider Middle East region, a total of 41 aquifers are shared between 21 of the 22 Arab countries (ESCWA 2018). These, therefore, present opportunities for a lot of collaboration in the co-development and management of these

2- Saudi's capital city, Al-Riyadh, being an exception.

resources in ways that would enhance their water security.

Beyond the Arabian Peninsula, the Middle East has perennial rivers, some of which are shared between multiple countries. The riparian states along the Jordan, Tigris, Euphrates and Nile rivers are similar in that downstream Arab states are dependent on water from mostly non-Arab upstream countries with whom they do not have water allocations agreements. Also, these downstream Arab states have variable degrees of water-related tensions with upstream riparians, and have been rocked by political instability, poor or weak governance, or by warfare.

The Jordan River Basin: Relations between the countries that share the Jordan River range from open animus to cautious cooperation. Historically, riparian states have managed the river's water unilaterally by building dams to meet their needs. As countries capture water upstream, the quantity and quality of water flowing downstream are diminished. The meager volumes of water that reach the Dead Sea today have resulted in the cumulative and considerable contraction of its area. The pressure posed by limited water supplies is amplified by high population growth, a situation that became aggravated by the sudden influx of millions of Syrian refugees who fled into Lebanon and Jordan. Furthermore, as the Syrian government begins post-war reconstruction, it may choose to re-settle those who used to live in the upper reaches of the Jordan River into their native communities. In this scenario, when these people reestablish their farming activities, they will reduce water flow to downstream states, and hence escalate political tension and conflict between impacted riparians in the basin.

Lebanon, a riparian state on the Jordan River, and a country that is relatively well endowed with water, is crippled by political gridlock, poor governance and rampant corruption, all of which have degraded the country's water security. Its freshwater is so mismanaged that supplies are sometimes toxic to the point of harming human health (BBC 2021), as untreated residential, industrial and agricultural pollutants pour into river systems unabated. While Lebanon's challenges are mostly self-inflicted, conditions on the West Bank are very different.

Palestinians' lives are heavily constrained by Israel's military occupation which makes all critical decisions regarding water management. Because Israel controls the water supplies of the West Bank, it allocates significantly more water to Jewish settlers than to Palestinian Arabs who reside in the same area, and sometimes uses water as a political tool to pressure the occupied population into submission (Amnesty International, 2022). Palestinians' political disempowerment, as well as the considerable power differential between the occupied population and the occupier, poses significant challenges as to how Palestinians can enhance their water security.

The Nile River Basin: The Nile River basin covers 11 countries where over 500 million people live. With its long history of being the biggest user of, and the riparian that is most dependent on the Nile water, Egypt became very concerned when Ethiopia proposed and started building the Grand Ethiopian Renaissance Dam (GERD), despite the objections of downstream states. Some 85 percent of Egypt's water is supplied by the Nile River, mostly from the Blue Nile that rises in Ethiopia. Over a period of serval years, Egypt and Sudan, the riparian states most impacted by the GERD, held a series of talks with Ethiopia to arrive to an agreement on how to share and manage the river's water. Despite mediations from the White House, Arab League, African Union and other institutions, Egypt and Sudan appear to have all but accepted that Ethiopia will be the main if not sole manager of its dam.

The Tigris-Euphrates Rivers: Turkey, the upstream state on the Tigris-Euphrates rivers, has been building a series of hydroelectric dams. These dams have significantly reduced water flow to Syria and Iraq, and irrigation runoff from the extensive agricultural projects in eastern and southern Turkey degrade water quality downstream. Socio-economic conditions in the three main riparian countries that share the Tigris and Euphrates vary considerably. Compared to downstream states, Turkey has the advantages of having a significantly larger economy, a stable government and established institutions. On the other hand, both Syria and Iraq have gone through long periods of war and political instability, and as such their state institutions have frayed. As they rebuild from the extensive destruction caused by decades of war, and settle displaced populations, they will be in need for greater volumes of water which will reduce flow to downstream states. Ideas that can assist these countries to become more efficient in their water use will help mitigate the risk of political tension in the basin.

ENHANCING WATER SECURITY

Water security has long been acknowledged as central to political stability, and its success requires buy-in from different actors and stakeholders (Dean et al., 2016). Abell et al. (2018) argue that "strong incentives" are necessary to spur water conservation and innovation through "policies, pricing, allocation, or regulation." As water becomes increasingly scarce, studies sometimes quote the popular idiom that people will never miss the water till the well runs dry. While complacency in managing water challenges is not an option for the countries of the Middle East, extreme hydrological conditions can be viewed as involuntary "incentives" that push governments towards good water governance and creative solutions that are appropriate for their particular needs.

Enhancing national water security would improve people's quality of life, and increase trust in their government, hence leading to greater political stability. The varied environmental, economic, sociopolitical features of the Middle East mean that water challenges and solutions are context-dependent (Table 1). This is reflected in the authors' diverse menu of ideas. Solutions need to consider the prevailing hydro-climatic conditions, the impacts of climate change, varying water needs in urban and rural areas, hydropolitics across international borders, institutional capacity, and the current state of science and technology in a country. The collective hope of the contributors is that the ideas and strategies presented here would "have the potential to improve coordination and generate synergies between researchers, policy-makers, and practitioners" (Bakker 2012).

Table 2 | Attributes of water insecurity, and strategies to enable water security

Attributes of water insecurity	**Strategies to enhance water security**
Geography, location and scale factors related to water insecurity	Account for remote, rural, core/periphery, household scale
Sociocultural and political drivers of water insecurity	Improve public health, address power relationships, embrace public participation in policy making, educate and incentivize the public on water conservation
Inadequacy of coping strategies	Promote water reallocation between uses and sectors, embrace cooperation over shared waters, maintain and upgrade infrastructure, reduce water demand, consider importing virtual water (food), create new water through wastewater recycling and stormwater capture
Mismanagement, nepotism and bureaucracy	Promote integrated water resources management, develop a skilled workforce, uphold accountability, strengthen institutions, and support inter-ministerial coordination on water issues
Environmental degradation	Implement pollution-prevention measures, promote ecosystem protection and nature-based solutions

Sources: Bakker 2012; ESCWA 2018; Gerlak et al. 2018; Daoudy 2020; Lankford et al. 2013; Zeitoun 2011;

There are four general approaches to enhancing water security. First, political and diplomatic approaches, including environmental conflict resolution, water diplomacy and good-will, such as the sharing of hydrological data and joint management of international rivers. Second, technical approaches include water use efficiency such as installing drip irrigation systems, setting up desalination plants, using appropriate genetically modified organisms (GMOs) that produce more food with less water, and reusing treated wastewater. Third, water policy and good governance help reduce water consumption through water pricing mechanisms, water demand management, inclusive and transparent governance, agricultural policy that regulates cultivation of low-value and water thirsty crops (e.g. citrus, alfalfa; wheat) in arid countries. Finally, environmental approaches to water security are anchored on nature-based solutions (NBS) to water challenges, whereby natural systems, or green, infrastructure is used alongside traditional, or gray, infrastructure to treat wastewater, ensure water quality upstream or to develop climate-resilient agriculture. These approaches definitely overlap and complement one another (Table 3).

Table 3 | Conventional versus emerging water systems: A paradigm shift

The Old Paradigm	**The Emerging Paradigm**
Human waste is a nuisance. It is to be disposed of after the minimum required treatment to reduce its harmful properties.	Human waste is a resource. It should be captured, processed effectively, and used to nourish land and crops.
Stormwater is a nuisance. Convey stormwater away from urban areas as rapidly as possible.	Stormwater is a resource. Harvest stormwater as a water supply, and infiltrate or retain it to support urban aquifers, waterways, and vegetation.

Build to demand. It is necessary to build more capacity as demand increases.	Manage demand. Demand management opportunities are real and increasing. Take advantage of all cost-effective options before increasing infrastructure capacity.
Demand is a matter of quantity. The amount of water required or produced by water end-users is the only end-use parameter relevant to infrastructure choices. Treat all supply-side water to potable standards, and collect all wastewater for treatment in one system.	Demand is multi-faceted. Infrastructure choices should match the varying characteristics of water required or produced by different end-users: quantity, quality (biological, chemical, physical), level of reliability, etc.
One use (throughput). Water follows a one-way path from supply, to a single use, to treatment and disposal to the environment.	Reuse and reclamation. Water can be used multiple times, by cascading it from higher to lower-quality needs (e.g. using household graywater for irrigation), and by reclamation treatment for return to the supply side of the infrastructure.
Gray infrastructure. Infrastructure is only made of concrete, metal and plastic.	Green infrastructure. Besides pipes and treatment plants, infrastructure includes the natural capacities of soil and vegetation to absorb and treat water
Bigger/centralized is better. Larger systems, especially treatment plants, attain economies of scale.	Small/decentralized is possible, often desirable. Small scale systems are effective and can be economic, especially when diseconomies of scale in conventional distribution/collection networks are considered.

Limit complexity: employ standard solutions. A small number of technologies, well-known by urban water professionals, defines the range of responsible infrastructure choices.	Allow diverse solutions. A multiplicity of situation-tuned solutions is required in increasingly complex and resource-limited urban environments, and enabled by new management technologies and strategies.
Integration by accident. Water supply, stormwater, and wastewater systems may be managed by the same agency as a matter of local historic happenstance. Physically, however, the systems should be separated.	Physical and institutional integration by design. Important linkages can and should be made between physical infrastructures for water supply, stormwater, and wastewater management. Realizing the benefits of integration requires highly coordinated management.
Collaboration = public relations. Approach other agencies and the public when approval of pre-chosen solutions is required.	Collaboration = engagement. Enlist other agencies and the public in the search for effective, multi-benefit solutions.

Source: Pinkham. 2017.

The level of water security can be affected by politics, remote or rugged geography, and economic, ethnic or religious segregation of groups. In most Middle East countries, there is a significant gap between water security in urban areas and rural ones (UNDP, nd), with the gap widening in poorer and remote communities. Hence "improved water governance requires understanding the social, economic and institutional links between reducing poverty and ensuring access to safe water" (UNDP 2013). For example, although access to safe water in Egypt is almost universal and reliable in urban areas, some 12 percent of rural households and 23 percent of residents of urban slums are not connected to the water supply network (UNICEF nd).

Fostering water security in the Middle East faces challenges of geopolitics, hydropolitics, mismanagement, and poor governance such as marginalization of rural area, and disempowered groups like women and ethnic or religious minorities. In the 1980s, Turkey started to build a series of dams on the Tigris and Euphrates. Later that decade, Iraq entered an era of wars and political instability, with the same happening in Syria starting in 2011. Inside Iraq, there is a significant degree of political push-pull dynamics between the central government in Baghdad and the Kurdish Regional Government, upstream. The latter upstream power controls the decision-making process over economic development in its areas, while most of the population lives downstream. Similarly, Ethiopia initiated construction of The Grand Ethiopian Renaissance Dam (GERD) on the Blue Nile in 2011, which coincided with the Arab Spring, which followed by a military coup left Egypt in a state of political turmoil that took a few years to stabilize.

Impending risks to water security typically focus governments' thinking so to mitigate the threats. A low-hanging opportunity for fostering water security is to boost irrigation efficiency because current methods are wasteful, and the agricultural sector consumes up to 88% of available water resources. Even small improvements in irrigation efficiency would yield significant boost to water security. Furthermore, in times of protracted conflict or political tension, reconstruction plans and actions that enable water security need to be ranked and carried out without waiting for the conflict to end (Abell et al. 2018). A recent edited manuscript funded by the European Union spoke of the "urgency to ensure water security for local communities" across the Middle East and argued that water can be an important factor in relations between countries in the region as well as with the international community (Kronich and Maghen. 2020).

Water diplomacy: The U.S. Agency for International Development (USAID) has funded the construction of a treatment plant for brackish water desalination in the Jordan Valley. The plant taps water from currently unused saline streams to produce 100,000 cubic meters of freshwater that is delivered to Amman every day. Furthermore, the project allocated funds for installing smart meters to help reduce water loss by detecting tampering attempts, and for rehabilitating the water delivery infrastructure. This would reduce water loss from the current 43 per cent to 25 per cent by the year 2025. This will effectively generate additional amounts of water for the residents of Amman (Namrouqa, 2018; USAID, nd). The project would reduce over-pumping of aquifers, hence giving them time to replenish their storage capacity which would boost the water resilience of the capital city. USAID and other international development agencies can help Egypt and Iraq mitigate the risk of water insecurity that would occur if upstream users (including Kurds) were to initiate significant agricultural activities.

For water security to be resilient, the approach needs to be dynamic whereby decision makers understand change drivers, and are prepared to leverage current insights from and modern tools of science and technology to inform water policy. These tools can range from in-time data gathering to computational analytics and artificial intelligence.

The ideas for enhancing water security that are proposed by contributors to this volume, including this author, fall into one or more of the following approaches: virtual water through international trade, hydro-diplomacy, science and technology, and through nature-based solutions. Water security is commonly defined as "the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies" (Grey and Sadoff 2007). Sustaining health and livelihoods are closely related to socio-economic development and food security. Water security can be framed in a few different ways, depending on the disciplinary lens. It could be analyzed through the prism of access to potable water, through agricultural production, food security, protection against threats to water infrastructure from natural (floods or droughts) and human sources (contamination and terrorism), or through the lens of public health in terms of prevention and assessment of contamination of water in distribution systems (Cook and Bakker, 2012; Daoudy 2020; Lankford et al. 2013; Zeitoun 2011;).

Enabling water security requires good governance[3] while paying special attention to vulnerabilities, and the dynamic interrelationships between social, economic, political, and environmental factors. The definition of water security has evolved from a focus on the safe and reliable supply of freshwater to people to an ecosystem approach. Water security is analyzed through a wider prism, like watershed sustainability, to secure the health of humans and ecosystems alike. This approach is enabled by good governance and public participation (Allan et al. 2020; Dunn et al. 2012).

Virtual water: Egypt has gone from once being the breadbasket of the Roman Empire to now being the largest importer of wheat in the world, which cost it $2.8 billion in 2020. Reliance on the international trading system has been rocked by trade wars, the Corona virus pandemic and by the more recent Ukraine-Russia war, all of which have adversely impacted supply chains resulting in a backlash against globalization. Joseph E. Stiglitz, Nobel laureate in economics, recently argued that "globalization has peaked". Much of the world has moved from an era where everyone was "working for a world without borders" to a new era where "everyone" recognizes "that at least some national borders are key to economic development and security" (Stiglitz 2022). This created a contraction in global economic activities which included movements towards reshoring of once-offshored activities like agriculture[4] driven

3- For more on the principles of good governance, see UNDP (2013).

4- In 2022, China's leader, Xí Jìnpíng said that food security has become a matter of "national strategic import" and is moving his country towards ensuring that "the rice bowls of the Chinese people are filled with Chinese grain." A year earlier, an authoritative journal in by fear that international trade could be weaponized.[5] The full-blown war between Russia and Ukraine, the world's breadbasket, is seen by import-dependent countries as an existential threat. Much smaller geopolitical developments can cause severe disruptions to food supply chains like when Saudi Arabia, United Arab Emirates, Bahrain and Egypt imposed a total embargo (2017-2020) against Qatar. While Qatar managed to overcome the impacts of the embargo, it did so at a significant financial and political cost. Because of the 2022 Ukraine war in the European heartland, Egypt and some Arab Gulf states have taken steps to expand locally-produced food products to offset soaring food prices on the international market. This understandable aversion to the political risk of becoming food hostages has adverse impacts on limited water supplies and on environmental sustainability. Although wealthy and globally connected countries can afford to reduce their reliance on imported foodstuffs, poorer countries can ill afford such measures. Egypt, for example, faces multiple internal and external pressures and cannot afford to ensure water security at home by importing large quantities of virtual water (food). Governments in such developing countries will be forced into painful tradeoffs; invest in schools, healthcare and infrastructure or import food stuffs for the masses? They run the risk of being trapped in a downward spiral.

China argued that the country's economy needs to consider food security as "an important foundation for national security" (Che, 2022).

5- For more on this, see Farrell and Newman, 2015

In the final analysis, imports of virtual water can be a viable approach to easing the pressure on domestic supplies, therefore enhancing water security. However, it must be done after considering other domestic approaches that may be cheaper. For example, in the Middle East, some 20 to 50% of urban water is lost before it reaches the people. As for the utility of virtual water, Jordan provides a good example. The rising consumption of meat in the kingdom along with water scarcity and the rising cost of imported animal feed led the government to curtail domestic production and to "import livestock from countries such as Australia and Romania" despite the opposition from local farmers (Phillips 2019).

Ethiopia has been building the GERD on the Blue Nile, the largest tributary to the Nile, Egypt's sole river and most important water source. Egypt, Ethiopia and Sudan have spent years in negotiations to reach a binding water management agreement on the GERD. While the talks have all but failed, the dam construction seems to have had some positive unintended consequences in Egypt. As Ethiopia started to fill its mega dam, Egypt started to feel the hydrological pressure. This pressure and the fact that it has an annual water deficit of about 30 billion cubic meters, led the Egyptian government to decide in 2021 to invest $1.14 billion to rehabilitate about 7,000 kilometers (4,350 miles) of damaged irrigation canals (Omran 2021). They also passed a new water resources law that aims to protect the country's water supplies. Violators of the new law would be imprisoned and fined if they breach rules such as:

-- “Wasting water resources by exceeding the prescribed or authorized quantities”,

-- ”Using water in lands that are not planned for irrigation or that is not licensed for irrigation, or using it for unlicensed purposes”

-- ”Using an unlicensed irrigation method, obstructing the flow of water in the Nile River and its branches, or waterways, or a covered drainage network or a stream exit” (Egypt Today. 2022b).

In January 2022, Egypt’s Minister of Irrigation and Water Resources completed the lining of 3,913 kilometers of irrigation canals nationwide, and is working on lining additional canals, which would bring the total length covered by this project to 10,682 km. These are estimated to save 5 billion cubic meters in seepage losses (Egypt Today. 2022). Furthermore, the government is encouraging farmers to conserve water by switching from surface irrigation to more efficient methods. In other words, the country has become active in supporting water conservation.

Science and Technology: Technology makes it possible for people to enjoy all kinds of services including access to clean water. What may not be so obvious is that the successful deployment of new technology requires careful planning and assessment. However, techno-centric approaches to improving water security need to consider the cultural and economic settings to ensure the long-term sustainability of the newly introduced technologies. For instance, precision agriculture is a data-based approach to improving crop yields and water management decisions by using geographic information systems, remote sensing, and analysis of real-time data. This optimizes the use of water, agrochemicals, and labor (UNCCD 2022). Food production is the biggest consumer of freshwater, meaning that such technologies to conserve irrigation water and limit agricultural pollutants from reaching surface and ground water would greatly contribute towards enabling water security. However, for such computer-based approaches to work requires significant levels of training of farmers who may not have received much in terms of formal education. This is the case for many farmers in Yemen, Egypt, Sudan, Syria, Turkey and Iran. Similarly, while today nano filter technology holds a lot of promise for desalination and wastewater treatment, (UNCTD 2021) deployment of this technology requires a careful economic and social stage-setting which varies from one locale to another.

Good, inclusive governance would help countries move towards greater water security. As such, policies would include coverage for poor people who are sometimes harder to reach because they may live in geographically dispersed communities that are hard-to-access where infrastructure is inadequate, if it exists at all. Issues like this can be addressed by deploying "frontier technologies"[6] which "make it technically possible to disperse many important services or products to poor communities." They "make it possible to shift from large, centralized water and power plants ... to small-scale, distributed delivery systems such as village mini-grids, rooftop solar systems, and village or urban neighborhood water purification and distribution kiosks. These smaller

6- For more on this topic, see Palmer et al. 2015 scale distributed facilities are less expensive to install and operate" (UNCTD 202). These technologies have the potential to allow community control and hence broader social acceptance and empowerment of residents.

This does not diminish the weight of the logistical and administrative task of financing, planning, installing, and maintaining widely dispersed infrastructure. Early, bottom-up planning and careful consideration of socio-economic and political contexts would make it easier to develop sustainable and resilient water supply system. A study found that people who are engaged in their community and understand the importance of water issues are more likely to support water-related initiatives, and would in fact modify their behavior to address water challenges facing them (Dean et al., 2016). This has the potential to circumvent challenges related to people feeling marginalized due to their economic, religious or ethnic status. A related issue is distrust of "authority". Some people may perceive change as being "imposed" from the outside, especially if they live under non-inclusive governments.

A review of the global and regional experiences finds that "technology, policy, and institutional management must evolve together to achieve water security", and that it is short sighted for countries to think they can "desalinate their way out of water insecurity." They add that "progress towards water security is made when countries integrate conventional and nonconventional water supplies and water services, and mitigate threats to water supplies" (Abell et al. 2018). This integrated approach is expanded further through a wider prism, one that considers natural environment as infrastructure.

Nature-based solutions: There is a growing body of evidence that the integration of green (natural) and gray (manufactured) infrastructure can provide lower-cost and more resilient services, which can help "provide water, food, and energy to growing populations, lift communities out of poverty, and mitigate climate change" (Browder et al. 2019). Empirical evidence shows "policies that support blended green-gray approaches offer a pathway to future global water security but will require a strategic commitment to preserving natural capital" (Vörösmarty et al. 2021), such as biodiversity and top-soil. A recent literature review of nature-based solutions concludes that they should be prioritized over conventional water infrastructure (Oral 2020). Next generation solutions are needed to help "tackle the looming financial and environmental crisis facing global infrastructure systems." Performance of systems can be enhanced and communities better protected by "putting nature to work" through green infrastructure which enhances water security, reduces environmental risk, and develops greater community resilience to climate change at a cost that is lower than gray infrastructure (Browder et al. 2019). This approach is especially fitting for the Middle East where many governments face growing demands on limited budgets and dwindling water supplies.

A new United Nations report (UNCCD 2022) makes the case for a holistic, integrated approach to land and water management with special attention to "practices in agriculture, forestry, urbanization, mining, and infrastructure development", and for reducing the gap between "human demand and nature's supply." In this respect, nature-based solutions refer to sustainable management and restoration of ecosystems that simultaneously support human well-being and protect biodiversity. Relatedly, green infrastructure, sometimes called blue-green infrastructure, is a way of thinking of natural systems as infrastructure. This is about engineering with nature in a manner that "strategically preserves, enhances, or restores elements of a natural system" like agricultural land and coastal forests, such as mangroves, which also helps to provide clean water and richer biodiversity. On the other hand, gray infrastructure refers to human-built structures from various size reservoirs to water treatment plants and pumps. Green infrastructure along with requisite gray infrastructure can "cost-effectively enhance service delivery, while also empowering communities and increasing infrastructure systems' resilience and flexibility in a changing climate" (Browder 2019).

Abell et al. (2018) show many cities can reduce sediment and nutrient pollution by forest protection, reforestation of pasturelands, and by enhanced agricultural methods. Sixteen percent of cities "could recoup the costs of green infrastructure protection through savings in annual water treatment costs alone." A multi-agency expert report (UNEP 2014) details 12 green infrastructure solutions, explains their ecosystem services, and likely installation costs. It also describes a methodology for water management options assessment based on a step by step green-gray analysis, using multiple case studies to illustrate green infrastructure valuation. After this report was released, the UN and World Bank convened a high-level panel of experts which advocated for the "use of green infrastructure in harmony with gray infrastructure" to make water infrastructure resilient and sustainable (HLPW 2018).

Traditional infrastructure systems are human-made solutions that support the safe living in and functioning of societies. Additionally, multiple water-related threats posed by climate change, along with the extreme weather systems it generates, threaten infrastructure as well as coastal aquifers and farmlands (Vörösmarty 2021). On the other hand, green infrastructure is a nature-friendly method of integrating natural processes with human-made technologies so as to better manage water resources. This network of natural or seminatural features has the "same objectives" as the conventional gray infrastructure (Palmer et al. 2015). Although green infrastructure is not a cure-all, it nonetheless has fewer social and environmental impacts than gray infrastructure. For example, green approaches to crop and soil management can reduce evaporative losses from fields, hence reducing irrigation needs. Another example is rainwater harvesting. It tends to be small, farm-scale which allows for a more socially and economically inclusive approach to increasing water supply at the local level. A rainwater harvesting study in arid Saudi Arabia shows that this approach can provide farmers with 6% of their irrigation needs. Despite its small contribution, this water can be used as a secondary source (Bogis 2021), and, under less arid environments, the technology yields a lot more water. A study of rooftop rainwater harvesting in Ajloun governorate, Jordan, shows that it can increase domestic water supply by the equivalent of 7.6% in a dry year and 16.8% in a wet year (Al-Houri and Al-Omari 2021). These examples are illustrative of the low-cost, complimentary role that green technology promises to play in the Middle East: it helps decision makers manage their often-limited water supplies in ways that are more efficient and sustainable.

Despite its name, green infrastructure is often complemented by manufactured infrastructure to move and store water. In addition to its application at the farm (e.g., rain harvesting) and city levels, a green perspective on transboundary water issues can be a way of enlarging the proverbial "pie" which could make it possible for each riparian country to walk away from water negotiations having gained something meaningful to it. That "something" may be water-related services like food or hydroelectricity or to show flexibility on political or economic matters like creating a free trade agreement zone for all the riparian states. Egypt could, for example, agree to grant land-locked Ethiopia special access to its seaports. This is important for Ethiopia because when GERD is fully operational, it will offer a significant boost to the country's economy.

The process of implementing natural infrastructure solutions requires examining causal relationships between freshwater ecosystem services upstream and their uses downstream which would help in determining the type and scale of natural infrastructure that is needed to ensure ecosystem services cum water security during extreme environmental events (Chung 2021). It should be used to expand consideration of potential conflicts that may arise between stakeholders, both upstream and downstream.

CONCLUSION

The water crisis in the Middle East is partly a management crisis. As such, good water governance is central to enhancing water security. As planners, government decision makers and funding agencies step up to help enhance water security, it is recommended that they carry broad and transparent consultations, and consider the contexts outlined in this chapter. Additionally, science and technology, water diplomacy, virtual water through international trade, and integrated, nature-based solutions provide helpful pathways to mitigate the risk and impacts of water stress. Perhaps most importantly, leaders in the Middle East need to help their populations develop a new consciousness about just how scarce water is and to nurture a deep appreciation for its existential value. There is a need to update and adapt cultural norms to the "new normal" that water mismanagement, population pressure, nutritional transition, and climate change have created. The new norms should nudge societies to transition toward nature-compatible consumption.

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Chapter Two

Water and Climate Challenges in the Middle East: A Human Security Perspective

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Abstract: This chapter examines water scarcity and other issues in the Middle East such as food insecurity and migration that directly or indirectly result from climate change. I argue that a human security perspective offers the most appropriate perspective to assess the effects of climate change and outline sustainable policy responses by regional states and international bodies. This chapter assesses the vulnerability of different populations to these varying threats in the Jordan, Tigris, Euphrates and Nile basins, and outlines solutions for enhanced water security. Resource scarcity and human insecurity can be overcome through a variety of institutional and political tools, including treaties over shared waters. 2. To be effective in the long run the structural underpinnings of water scarcity must be targeted and ideas of water justice must begin to enter policy discourse. 3. While it is important to consider how water scarcity might contribute to new migrants, it is also critical to consider how it affects the plight of those already displaced and increases the likelihood of secondary displacement. 4. In Palestine, life under occupation determines access to a critical resource like water, with enhanced effects along gender and disability lines. 5. Transition to climate-smart crops should be implemented, thus, increasing agriculture's resilience to climate change and productivity, while also reducing emissions. 6. Governments should also simultaneously initiate widespread reform and improvements to existing water infrastructure, including irrigation systems. 7. Examples of past transboundary water cooperation efforts should be explored to consider how preexisting efforts can be revived and reformulated rather than beginning anew. 8. Examples from other regions should also be explored. 9. Lastly,

collaboration between environmental scientists and social scientists is critical to developing a better understanding of the socioeconomic dimensions of drought.

Introduction

The Middle East is home to the largest hyper-arid, semi-arid, and arid zones in the world, placing almost all countries in the region in semi-arid and arid regions that face a high degree of vulnerability to climate change and subsequent extreme drought conditions (Adamo et al., 2020, 53). The Intergovernmental Panel on Climate Change (IPCC) predicts that a strong negative regional trend in precipitation beginning in the 1960s will be further exacerbated by climate change, putting the region's water and broader human security at risk (IPCC 2018, chapter 3). The origins of the region's climate vulnerability, however, can not only be attributed to trends in regional warming, but also lies in poor resource management and ongoing conflict which jeopardize the region's environmental well-being and foster a high degree of climate risk. The Middle East's climate vulnerability was clear in 2021, when the region experienced both extreme high temperatures in the summer above the 95th percentile, and low precipitation below the 5th percentile in the winter and spring. The concurrence of both extreme heat and low rainfall makes conditions in 2021 worth paying attention to (Dezfuli et al. 2021, 2). Climate change worsens the social and economic vulnerability of populations faced with water scarcity, food insecurity and displacement, sometimes in conflict-affected areas within the Middle East.

This multilayered approach to water and climate vulnerability brings to the fore the concept of human security. This chapter will examine the impacts of climate change on resources and livelihoods from the perspective of human insecurity. We start by explaining why this perspective is important. We then delve into the empirics of the impacts of climate change in the Euphrates and Tigris, Jordan and Nile basins and outline possible solutions for policymakers.

Why Human Security?

In 2012, the United Nations General Assembly (UNGA) adopted Resolution 66/290, thereby recognizing how human security synergizes the three pillars of the UN (i.e. development, human rights, and peace and security) in "an interlinked and mutually reinforcing manner" (United Nations General Assembly, 2012). Human security as a concept was first developed by two prominent non-Western economists—Nobel Prize winner Amartya Sen and special adviser to the UNDP Habib Ul-Haq—in a 1994 report for the UNDP Human Development program. Combining security and development concerns, human security was framed in terms of the principles of social justice, mutual cooperation, and equity. In recent years, the discussion around human security expanded to include environmental concerns. By adopting a human security lens, the focus in security studies has transitioned from military-based national security concerns to consider vulnerable groups within societies. This development has brought new meaning to policy and academic debates on climate change and its human impacts, which are highly relevant to analysis of the Middle East.

There are four essential characteristics of human security: 1) human security is a universal concern relevant to people everywhere, 2) the components of human security are interdependent, 3) human security is easier to ensure through early prevention, and 4) the referent object of human security is shifted away from states to people (Dalby 2013: 122). In this framework, human security focuses on issues relating to individual human life and well-being, rather than the state-level, militarized concepts that have traditionally dominated the national security discourse. At the same time, policy-driven approaches have tended to focus on human security as “freedom from” harm, danger, and suffering, rather than the more traditional “freedom to” conception of civil and political liberties. The Fifth Assessment Report issued by the IPCC in 2014 provides a wide definition of human security as “a condition that exists when the vital core of human lives is protected, and when people have the freedom and capacity to live with dignity” (IPCC, 2014: 759). Human security, therefore, is not innate, but rather must be actively pursued and protected. Still other concepts of human security focus on the need to protect lives from potential risk and dangers—in this approach, human security “is about prevention—anticipating dangers and acting to head them off before the downward spirals happen” (Dalby, 2013: 135). All these approaches to human security can help us to identify the risks climate change poses, especially as it interacts with various sociological, economic, and geological factors.

Human Security: An emerging framework for the environment

Human security has often been defined as the framework by which practitioners can seek to protect humans from economic, political, or environmental suffering. The state has traditionally been the referent object of security. In response, Ul-Haq and Sen place human beings as the reference objects of security and development by arguing that improving human lives should be an explicit development objective (Ul-Haq, 1995: 103–104). They focus on vulnerability as an underlying premise of human security, and also tie the enhancement of human development and security to environmental and ecological concerns. Other definitions of human security make explicit reference to addressing the unequal relationship between the Global South and North, which has been the source of much human insecurity. This framework seeks not only to protect, but also to undo unequal power structures that have caused or encouraged human suffering. This definition also has significant implications for climate insecurity—as the latter is also linked to unequal power relations between the Global North and South as well —and for how societies can improve the safety, well-being, and livelihood of their citizens, all of which are made more difficult in an insecure climate.

The intersection of human security and the environment provides an interesting framework for exploring questions of resource use, human development, and political and economic freedom. For human rights practitioners, human development seeks to widen people's economic, social and political choices and freedoms (Tadjbakhsh and Chenoy, 2007: 107). Therefore, climate instability presents a critical risk to human well-being, inasmuch as it limits societies' ability to pursue development goals. Human security and development can be considered in tandem, since individual human security also enhances human capabilities and quality of life (Sen, 2000: 28). Furthermore, if development goals leave some groups vulnerable to risk, either from natural disasters or conflict over scarce resources, the human security framework addresses this by pointing to the need for protection for the most vulnerable (Tadjbakhsh and Chenoy, 2007: 105). Sen goes further in arguing that human development can be defined as "growth with equity," and human security as "downturn with security" (Sen, 1999: 28). Human security enables people to make choices safely and freely. Therefore, it is a useful framework to understand resource use and environmental risk (Tadjbakhsh and Chenoy, 2007: 107).

Finally, the human security framework can be useful in forming an understanding of how to build policy that is centered on the most pressing human priority: sustainability of resources to facilitate the continuation of human and ecological life. Policymaking must therefore put sustainability at the core of all politics—not necessarily just by preserving natural resources, but also by preserving human and natural capital (Ul-Haq, 1995: 18). Overuse of natural resources can therefore be seen as incurring an "ecological debt," which, along with economic and social debt, has the effect of severely threatening the sustainability of life (Ul-Haq, 1995: 76). In response, policies are needed to correctly price natural resources based on their contribution to the safety of future human life, rather than treating them as free and unlimited (Ul-Haq, 1995: 85). The human security framework for the environment allows for an understanding of security that considers the deterioration of natural resources as a clear and present threat to human security, and which encourages countries to find regional and national policy solutions to environmental threats (Ul-Haq, 1995: 8–9). Such approaches will be better equipped to untangle the complex knot of human and environmental factors that drive resource and water crises in the Middle East.

Background to the Water Crisis in the Middle East: Climate Vulnerability, Upstream Projects and Domestic Mismanagement

Three of the main river basins in the Middle East, the Tigris and Euphrates, the Nile, and the Jordan River Basins and the downstream populations they support, face a high degree of climate vulnerability. Water scarcity in the three river basins is often attributed to climate change and population growth. It is important to scrutinize the role of politics in fostering climate vulnerability and consider how water scarcity has a variable effect on individual and community level security, creating an uneven landscape of vulnerability. A critical perspective also indicates how the origins of vulnerability are rooted in political and structural, and not only climatic variables, thereby transcending environmental determinism (Daoudy, 2020, 2021). In each of these basins, vulnerability is rooted in a complex web of political and climatic factors that are complicated by transboundary water politics and upstream extractions. Ongoing conflict and poor domestic water resource management further exacerbates the crisis in downstream countries. Examining water scarcity through a human security perspective can help correct these blind spots. This approach highlights how water scarcity affects multiple layers of vulnerability for different populations, disproportionately affecting the marginalized. For example, water scarcity can contribute to health risks and food shortages, jeopardizing the health and food security of surrounding populations (Dezfuli 2021, 4). For this reason, the United Nations (UN) enshrines access to water as a basic human right (UN Water 2022).

The below sections will consider the current water scarcity in the three basins, the impacts of upstream projects and domestic resource mismanagement and the layers of human insecurity from a health and food perspective.

Jordan River Basin

1. Climate Change and Human Insecurity

The Jordan River Basin is already witnessing the effects of climate change. The effects of climate change in the basin elongate and intensify all three drought types, hydrological, meteorological, and agricultural droughts, with the likelihood of each drought type projected to increase individually as well as the likelihood of multiple drought types occurring contemporaneously (Rajsekhar and Gorelick 2017, 5). Higher temperatures will furthermore increase the rate of evaporation in the basin, limiting the already dwindling available water resources (Rajsekhar and Gorelick 2017, 3). The Jordan river's historic flow of 1200-1350 mm^3/ year has been reduced to less than 100mm^3/ year. Much of the remaining water is furthermore of reduced quality, largely preventing it from being used, rendering the Jordan river a largely non-functional river for riparians like Jordan and Palestine (Katz 2022, 5). The effects of climate change on the Jordan River basin led the Dead Sea to decline by up to 40m over the last half century (Katz 2022, 5). Landsat false color images provided by the National Aeronautics and Space Administration (NASA) demonstrate the extent to which the dead sea's surface levels reduced between 1972 and 2011, which is directly related to the deterioration of the Jordan river basin (NASA Earth Observatory, 2022). The health of the Jordan river is also threatened by climatic and political factors. Already one of the most water-scarce countries in the world, Jordan's water crisis continues to deepen, jeopardizing the health, food, and livelihoods of rural and urban households, with researchers estimating that prolonged water shortages will become prevalent by the year 2100 (Yoon et al. 2021, 1). The outlook is not much better in Palestine, where restrictions on water access by the occupying power (Israel) intensify as water levels decrease (Amnesty International 2017).

2. Israeli Occupation and Asymmetrical Uses

The human security implications of asymmetrical Israeli development in the basin are staggering. Development along the river, disproportionately pioneered by Israel, is devoid of considerations for the long-term environmental health of the river and the human security of other riparian populations in Lebanon, Jordan, Palestine and Syria. Following the 1967 occupation and illegal annexation of the Syrian Golan Heights in 1981, Israel reversed its riparian position on the Jordan River from downstream to upstream, excluding Syria from accessing the river. It also occupied the West Bank and monopolized access and use of its groundwater resources. Today Israel is the largest user of water from the Jordan river, despite the reality that Jordan and Palestine are in desperate need of water resources, with some estimates classifying Jordan as the second most water-scarce country in the world (UN International Children's Emergency Fund 2022).

The contested nature of the Jordan river is rooted in the reality that the river was transformed into a political border, making the river beholden to territorial influence and not environmentalism (Alatout 2014, 306). Since the mid-1960s, Israel has been diverting the upper Jordan river from Lake Tiberias in the north to the Negev Desert in the south (Alatout 2014, 307). The occupation of the West Bank is also responsible for the perpetuation of water scarcity in Palestine and overall increasing vulnerability to climate change. Although Israel publicly endorses new sustainable technologies and environmental reform, its domestic policy involves restricting Palestinians from accessing needed water resources and climate adaptation measures (Amnesty International 2017). Since the issuance of a military order in 1967, Palestinians are unable to extract water from any new source or develop new water infrastructure without first obtaining a permit from Israel, a difficult and often unsuccessful feat. Palestinians are, thus, unable to drill new water wells, deepen wells, or install new pumps, and are even prevented from accessing the Jordan river as well as fresh water springs. Israel furthermore oversees and dictates the collection of rainwater throughout the West Bank and prevents Palestinians from using rainwater harvesting cisterns (Amnesty International 2017). Due to Israeli military occupation, the Palestinian Authority (PA) thus ultimately lacks the capacity to manage its own water resources in the West Bank, preventing effective water management (Aviram et al. 2020). Meanwhile, in Gaza, Israel restricts the transfer of water from the East Bank to Gaza, leaving residents with insufficient and largely contaminated water. Gaza's only freshwater source is the Coastal Aquifer which is largely depleted and contaminated, rendering it unsafe for human use (Amnesty International, 2017). Without access to adequate water resources and climate adaptive measures, Palestinians in the West Bank and Gaza will experience increased water shortages due to low rainfall and increased evaporation, reduced surface and groundwater quality, and groundwater decline (United Nations Development Programme 2013,14). Such effects will yield substantial human security risks including shorter growing seasons, decline in grazing ranges and stocks, higher food prices, higher rates of public health ailments related to water-borne diseases like diarrhea and cholera as well as vector-borne diseases like malaria, leishmaniasis, and tick-borne diseases, in addition to a greater risk of dehydration (United Nations Development Programme 2013, 14).

The effect of asymmetrical upstream development also greatly hinders the water access of downstream Jordan, such that by the time the river flows downstream it is merely a trickle and largely too contaminated for safe use. Israeli development has further affected groundwater resources in Palestine. Whereas Palestinians are not able to develop their own water infrastructure and networks in the Occupied West Bank without receiving a permit, Israeli state-owned water company Mekorot has done so freely for the use of its citizens by creating wells and tapping into springs in the West Bank (Amnesty International 2017). In Palestine, the World Health Organization (WHO) maintained that the average water consumption in the West Bank is below the WHO minimum amount (World Bank Group 2018, 2). In Jordan, increased pressure on water resources due to the refugee crisis, climate change, and resource mismanagement are worsened by Israeli upstream development. It is forecasted that by 2100 destabilizing water shortages will become a regular occurrence (Yoon et al. 2020, 2). Israel also faces the threat of water scarcity. However, its attempts to address its own water needs should not directly detract from the ability of Jordan and Palestine to do so and jeopardize the health and longevity of the river itself, which will impede any state along the basin from benefiting from its resources in the future.

3. Domestic Mismanagement

Domestic water mismanagement is also a problem in the Jordan River Basin, with compounding water-woes related to geo-climatic factors for downstream riparian states. Jordan faces significant domestic water management challenges that feed the country's worsening water crisis. Jordan's water-distribution system is inefficient, with approximately 50% of piped water supply lost as Non-Revenue Water (NRW) due to factors like leaky pipes, water theft, incorrect meter readings, and underbilling (Yoon et al. 2020, 2). These deficiencies adversely affect the human security of households, which on average in Amman have piped water for only 36 hours per week (Yoon et al. 2020, 2). As is often the case, poor households and marginalized communities bear the largest burden (Yoon et al. 2020, 2). Researchers predict that without meaningful intervention, over 90% of the low-income household population will experience critical water scarcity by the end of the century, demonstrating the extent of this human security concern and the uneven landscape of vulnerability (Yoon et al. 2020, 1).

In Palestine, food insecurity is also closely linked to water scarcity. Israel's tight control over water resources and limitations on irrigation-fed agriculture poses challenges for Palestine's agriculture sector, preventing Palestinians from maximizing agriculture potential and forcing them to rely on mostly rain-fed agriculture, which is vulnerable to drought and fosters import dependency (Amnesty International 2017). With Russia's invasion of Ukraine undermining the global wheat supply, there is reason for concern over the future of food security in the region, especially if water scarcity and issues of supply and quality remain unchecked.

Nile River Basin

1. Climate Change

The Nile River Basin is extremely vulnerable to the effects of climate change. Projections for the Nile's future flow maintain that the interannual variability of the total Nile flow could increase by 50% in the twenty-first century compared to the twentieth, increasing the risk of both extreme drought and flooding events (Siam and Eltahir 2017, 1). Researchers indicate that the dramatic projected change in interannual variability can be attributed to the forecasted increase in El Niña and El Niño events (Siam and Eltahir 2017, 1). By 2030, it is predicted that almost half of the Nile basin countries will live below the water scarcity level of 1,000 m^3/person/year (Siam and Eltahir 2017, 1). In addition to water quantity, water quality is also a growing concern. Much of the river's water is deemed unfit for aquatic life, especially near the Nile Delta in Egypt due to the expansion of industrial, agricultural, and recreational activities coupled with poor drainage and sewage systems, leading to high levels of agricultural, industrial, and municipal wastewater (Abdel-Satar et al. 2017, 22). The Delta region in Egypt is becoming especially polluted due to a reduction in annual flooding that is necessary to flush and clean the water from human and agricultural waste. The Delta coastline is further receding by an estimated 1.6 mm per year which contributes to saltwater intrusion and the salinization of farmland (NASA Earth Observatory 2022). In fact, according to the Food and Agriculture Organization (FAO), 15% of the most fertile arable land in the Nile Delta has already been adversely affected by sea level rise and saltwater intrusion (Food and Agriculture Organization 2022, 1). A set of Landsat images from July 1984 and August 2021 provided by NASA demonstrate how rising sea levels have led to a reduction in farmland near the Delta (NASA Earth Observatory 2022). The human security implications of this reduction will be examined in a subsequent section.

2. Upstream/Downstream Dynamics

Downstream of the Nile River, Egypt grapples with its own transboundary water dilemma with Ethiopia over the construction of the Grand Ethiopian Renaissance Dam (GERD) at a time when climate change and a legacy of poor water management threatens the river's flow. As Egypt's water demand continues to grow, some researchers speculate that within the decade Egypt could begin importing more virtual water than the amount of water supplied by the Nile (Nikiel et al. 2021, 1).

Since Ethiopia announced the construction of the Grand Ethiopian Renaissance Dam (GERD) in 2011, Egypt has been apprehensive over the prospect of the dam reducing the 55.5 billion cubic meters of water allocated to Egypt during colonial-era agreements (Amery 2020, 31). Because Egypt relies on the Nile for 95 percent of its freshwater supplies, it declared the dam to be an "existential threat" (Amery 2020, 30). Estimates have it that the volume of water reaching Egypt could be cut by 25% and electricity generated by the Aswan dam could be reduced by one third, the effects of which would be disastrous for Egypt's economy and agriculture sector, yielding significant human security consequences, especially with regards to economic security and food security (Amery 2020, 31). With agriculture providing employment for an approximated 21% of the population in 2019, the effects of GERD on reducing Egypt's share of Nile waters needed for agriculture would risk the productivity and prosperity of the agriculture sector (The World Bank 2019). The dam will furthermore hold a significant amount of silt behind it, harming aquatic life and potentially eradicating certain species of fish (American University of Cairo 2022). In turn, a reduction in water needed to irrigate crops and adverse effects on the fishing sector are likely to contribute to increasing rates of poverty, which correlate with higher rates of food insecurity (Sen 1981, 22). It should also be noted that due to Russia's invasion of Ukraine, Egypt is already struggling to meet domestic demand for rice and wheat, two water-intensive crops. This raises concerns as to how Egypt will keep up with increasing demand in a post-GERD reality in which available water supplies will be reduced (Aman 2022).

As much as the Nile River plays a leading role in Egypt's political economy, development trajectory, and even national identity, it should not be overlooked how the river plays a similarly important role for other basin states like Ethiopia (Amery 2020, 29; Cascão et al. 2016, 504). While Egypt has reason to raise alarm over the potential implications of GERD, Ethiopia has framed GERD as critical to its own human security and development through the prospect of generating 6,000 megawatts of electricity, advancing Ethiopia's ambition to achieve universal electricity by 2025 (Amery 2020, 30). The dam would also help boost food production in Ethiopia through the provision of reliable irrigation and temper floods in Sudan. With that being said, since the river experiences fluctuations of wet and dry spells according to the El Nino and El Nina cycles, these cycles must be factored into Ethiopia's planning process in order for the dam to be effective, necessitating a greater deal of cooperation between scientists, engineers, and diplomats (NASA Earth Observatory 2022).

As of date, the third filling stage of the dam is scheduled to begin with the start of the planting season in the summer in July 2022. The first filling phase in 2020 captured approximately 4.9 billion cubic meters of water and the second phase 6 billion cubic meters. The third phase is expected capture even more water. Although Ethiopia announced its ambitions to reach a solution with Egypt and Sudan, tensions over the dam remain high (NASA Earth Observatory 2022; Saied 2022).

3. Domestic Mismanagement

In Egypt, GERD is not the only water woe. Rampant domestic water mismanagement alongside climate change and upstream development drives water-related human security concerns. Despite the need to conserve water and implement sustainable water management practices, Egyptian leaders have spearheaded costly, ambitious, and water-intensive agriculture projects, many of which could have adverse environmental impacts. For example, in the 1960s, the Egyptian government discussed implementing an agriculture project in the south, later to be discredited, that would siphon water from Lake Nasser in order to irrigate 500,000 acres of reclaimed desert farmland (Amery 2020, 32). Later, in 1988, President Hosni Mubarak launched the New

Valley Development Project seeking to double the area of arable land in the region. Environmental assessments, however, were not conducted for the projects, leaving it uncertain whether underground aquifers would be affected (Amery 2020, 32).

Perhaps more needed than such costly and potentially environmentally harmful endeavors is movement towards more sustainable farming and irrigation practices throughout the country. Numerous challenges exist on the domestic demand side including seepage losses from canals and drains, evaporation loss from water surfaces, nonexistent withdraw control in deep groundwater, damages to drip irrigation systems, distribution losses in the drinking water network, and poor public awareness around conservation in domestic water use (Omar and Moussa 2016, 404). Collectively, these deficiencies contribute to a high rate of NRW, estimated at 3.5 billion m^3 of treated water lost per year (Khalifa 2021, 3500). Reducing the amount of NRW would ensure there is sufficient water available for agricultural purposes as well as important domestic functions like hygiene and sanitation. Reducing NRW is thus critical to securing broader human security. In addition to water quantity, domestic water mismanagement contributes to degradation of water quality. The Nile's waters are threatened by pollution from industrial, agricultural, and recreational activities, poor sewage and drainage systems, and insufficient protection mechanisms against dumping (Abdel-Satar et al. 2017, 22).

In Egypt, a country in which the agricultural sector serves as one of the main employers, the dwindling water supply presents a grave threat to livelihoods and food security. The agriculture sector's vulnerability to drought coupled with high levels of poverty, create conditions conducive for food insecurity (WFP 2022). Already dependent on wheat imports, the agriculture sector in Egypt will be further weakened due to the threat of both a decrease in Nile waters and rain-fed farming, leading to an overall reduction in crop harvests, including essential crops like wheat. A weakened agricultural sector also contributes to the loss of livelihoods which correlates with food insecurity. Similarly, in Jordan water scarcity contributes to food insecurity due to the reality that much of the country's agricultural production is reliant on rain, generating high vulnerability to drought.

This deterioration of water quality is also associated with public health concerns. The growth of urban space coupled with poor water management raises the risk of pollution of surface and groundwater. Polluted Nile waters harm aquatic life and human health, responsible for increased incidents of water borne diseases as well as gastrointestinal illnesses, undermining the populations' health security (El- Kowrany et al. 2015, 782). In Egypt it has been found that the level of bacteria in the Nile was higher than what is typically permitted for municipal and irrigation purposes (Gad, 2017, 44). The effect of water scarcity on hygiene practices must also be considered, given that water scarcity limits populations' ability to uphold good hygienic practices necessary to stymie the spread of infectious illness and COVID-19 in recent years.

Tigris and Euphrates Basins

1. Climate Change

In 2021, extreme drought conditions were experienced in the Tigris and Euphrates Basin in eastern Syria to central Iran, which had the highest temperatures on record over the past decade (Dezfuli et al. 2022, 2). It is estimated that in total over 12 million people in Syria and Iraq and 300 towns and cities in Iran were affected by drought in 2021 (Dezfuli et al. 2022, 3).

The Tigris and Euphrates River Basin has lost a significant portion of its freshwater reserves over the last decade. Between 2003 and 2009, it is estimated that 117-million-acre feet (144 cubic kilometers) of freshwater was lost. Natural-color imagery from the Landsat 5 satellite depict the substantial shrinkage of the Qadisiyah Reservoir in Iraq between 2006 and 2009 (NASA Earth Observatory 2022).Climate projections for the Tigris and Euphrates River basin indicate that it is likely to continue to witness a substantial decline in its water resources up to 30 to 70% compared to its water resources over the last three decades due to changes caused by the North Atlantic Oscillation, a weather phenomenon in the North Atlantic Ocean resulting from climate change (Adamo et al. 2018, 59 and 65). Rising temperatures and increasing rainfall have already been witnessed in the Tigris and Euphrates Basin. Recently, beginning in the fall of 2020, low precipitation in the eastern Mediterranean Basin fostered a reduction in water flow in the Tigris and Euphrates River and created drought conditions in Iraq and Syria (UN Office for the Coordination of Humanitarian Affairs 2021).

2. *Upstream Extractions*

The "hot spot" for climate change in the Tigris and Euphrates basin coincides with Turkey's Southeastern Anatolia Project (GAP), the region's largest hydro-development project which risks undermining downstream communities' human security and could itself be negatively affected by climate change (Dezfuli et al. 2022, 1 and 2). Upstream development in tandem with the effects of climate change pose an array of human security implications for downstream riparian states in the Tigris and Euphrates River Basin. Upstream development in the Tigris and Euphrates basins increased significantly after Turkey announced the construction of the Grand Anatolia Project (GAP) in 1975. Upon completion, the GAP is projected to reduce water flows into Iraq by 80% and into Syria by 40% (Daoudy 2009, 367). In both Syria and Iraq, reduced water flows contribute to worsening droughts and the further exploitation of limited groundwater resources. Drought conditions have a negative impact on rural employment, in turn increasing rates of poverty, which positively correlate with a host of other human security concerns like food insecurity (Amery 2020, 27). It is also possible that a reduction in agricultural employment could lead to internal migration outside of rural areas as people seek new employment opportunities. Syria and Iraq have also experienced an uptick in severe sandstorms caused by upstream development. Dried bodies of water are more susceptible to wind erosion, thereby serving as a source of dust (Boloorani et al. 2021, 2). Increased dust emissions yield health concerns like respiratory distress and adversely impact agricultural production, potentially undermining the livelihood of those living in rural areas. An uptick in malaria cases have even been reported and associated with upstream development projects like GAP. According to researchers, the increase in humidity from irrigated areas in the GAP region covering what used to be drylands creates conditions conducive for malaria parasites (Dezfuli et al. 2022, 6). It must be noted that even within Turkey, GAP undermines human security through developmental-induced displacement, highlighting that GAP is not only a transboundary concern but also a domestic concern for Turkey. This perhaps paves the way for a degree of transboundary solidarity between communities in Turkey, Syria, and Iraq who are all negatively affected by the dam (Dezfuli et al. 2022, 2).

3. Domestic Mismanagement

Domestic water resource mismanagement also contributes to the deterioration of the Tigris and Euphrates River, both in terms of water quantity and quality. In Syria, failed government policy is largely responsible for allowing dry conditions to turn into a drought and humanitarian crisis in 2006-11 (Amery 2020, 27; Daoudy 2020a, 118). Between 1971 and 2000, the Assad regime's ambitions to attain food security facilitated unsustainable agricultural policies aimed at boosting production and amassing rural support, such as subsidies for diesel. In application the policies led to the overexploitation of limited land and water resources (Amery 2020, 27). The policies culminated in a severe drought between 2006-11, which had disastrous human security consequences including loss of rural livelihood, displacement, and food insecurity, to the point that 17% of the population by 2010 was food insecure (Amery 2020, 28). This number peaked to almost 50% of the population (9.3 million) in 2020 (Daoudy 2020c). Thus, subsequent regime attempts to frame the drought as exclusively the result of geopolitical and climatic factors obscures the significant role of government-led resource mismanagement in fostering climatic insecurity and broader human insecurity (Daoudy 2020a).

Throughout the war in Syria, the water in the river basin has both been adversely affected by conflict and weaponized by different state and non-state actors in a manner that jeopardizes the population's human security. Water systems have been greatly affected by the ongoing conflict (Al-Ansari 2019, 40). There are numerous documented incidents in which a party of the conflict, like the regime, has deliberately weaponized water as an act of warfare, reducing available water supply and harming waterways. For example, in 2014 and 2013, battles between regime forces, ISIS, and opposition groups like the Syrian Defense Forces (SDF) destroyed water plants and sewage pipelines in Aleppo, Deir Ez-Zor, Homs, Hama, Idlib, and Raqqa to the point that in July 2014 approximately 35 percent of Syria's water treatment plants had ceased functioning (Daoudy 2020b, 1358). The Syrian regime itself has been one of the main actors to weaponize water as a military strategy. In 2017, for example, the UN High Commissioner for Refugees (UNHCR) said that Syrian air forces deliberately destroyed the Fijeh spring in Wadi Barada outside Damascus in December of 2016, depriving over five million citizens from accessing potable water for one month (Daoudy 2020b, 1353). The UNHCR considered this strategy to constitute a war crime. The availability of water per person is estimated to have declined by up to one-third from 75 to 24 liters per person per day from pre-crisis levels (Al-Ansari 2019, 40). The quality of water must also be considered. Throughout the conflict, little has been done to preserve the health of the river basin and prevent the drainage of irrigation water into the river and dumping of hazardous materials which undermine health security (Ibid, 59). As a result, much of the available water is not suitable for drinking or use for agricultural purposes and has led to sanitation-related illnesses, as well as animal deaths and agricultural losses (Ibid).

Moreover, the armed conflict's effect on water has contributed to infectious disease outbreaks. Polio resurged in the country in 2017, despite prior success in eradicating it. Outbreaks of Polio, like other communicable diseases, are driven by poor access to WASH services, the contamination of waterways, as well as an inability to treat and monitor water quality due to damaged infrastructure and lack of staffing during wartime. Although the Polio outbreak was successfully stopped in 2018, it serves as a testament to the dangers of contaminated waterways and inadequate access to sanitation and hygiene during armed conflict (World Health Organization 2018).

Similar issues of resource mismanagement and human insecurity have plagued Iraq. Decades of poor water resource management and outdated irrigation systems have led to a reduction of vegetation cover in Iraq, desertification, and droughts (Sissakian et al. 2013, 1087). Conflict has also worked in tandem with domestic water mismanagement to drive the water crisis, most notably through the drying up of the Mesopotamian marshes (Sissakian et al. 2013, 1087). In the southern city of Basra, 118,000 people were hospitalized in 2018 for water-related illnesses (Human Rights Watch 2019). The Shatt al Arab river flows from the confluence of the Tigris and Euphrates and is thus influenced by the deteriorating condition of the Basin. Inadequate water infrastructure, ineffective regulations on pollution control, poor water quality monitoring and communication about the risk of contaminated water, and failure to provide citizens safe alternatives led to a human security crisis, jeopardizing the right enshrined in international law for people to have access to water, sanitation, and health information (Human Rights Watch 2019).

In terms of health and food insecurity, varied risks are associated with a decrease in water supply in the Tigris and Euphrates Basins, especially in relation to GAP. Drying conditions over wetlands in Southeastern Iraq and a growing dust source south of the Tigris and Euphrates headwaters are also associated with the risk of respiratory diseases due to increased dust (Dezfuli et. al. 2022, 5). There was a recent uptick in malaria cases due to an increase in temperature and humidity, with increased humidity largely associated with irrigated areas in the GAP region covering what used to be drylands (Dezfuli et. al. 2022, 6). Meanwhile, accounts from humanitarian actors draw attention to how poor resource management compounded by Turkish water cuts and low rainfall, led the al Khabour

River, the largest perennial tributary to the Euphrates, to dry up and transform into an open sewage site conducive for the proliferation of sandfills carrying a parasitic skin disease endemic to the Middle East called Leishmaniasis. The disease, also referred to as the "Aleppo boil," plagues neighboring villages, particularly affecting children (UNICEF 2019).

Finally, water scarcity in the Euphrates and Tigris basins also poses a serious threat to food security. Drought in 2021 in the Tigris and Euphrates basin caused a 50-70 percent decline in wheat production in the Kurdistan region in Iraq (Dezfuli et al. 2022, 3). Survey results from the World Food Programme (WFP) in May 2021 indicate that 8 percent of people in Ninewa and Kirkuk governorates experienced insufficient food consumption (WFP 2021).

An Uneven Landscape of Climate and Water Vulnerability: Further Considerations and Solutions for Enhanced Water Security

A human security perspective lends itself to broader conversations about reform and water justice, by drawing attention to the underlying structural factors. Water justice "[transcends] questions of distribution to include those of cultural recognition and political participation, and is intimately linked to the integrity of ecosystems" (Zwarteveen et al. 2014, 141).

1. Resource scarcity and human insecurity can be overcome through a variety of institutional and political tools, including treaties over shared

waters. Other potential tools for addressing greater water security include the establishment of international water law and river authorities, along with increased emphasis on a climate of cooperation and trust among actors, which could be accomplished through "peace-promoting institutions" like international legal and cooperation bodies. This section outlines sustainable solutions for policymakers and NGOs within these basins that would help break the climate-scarcity-vulnerability cycle and provide an enhanced mitigation of climate impacts.

2. As is clear in the case of each water basin examined, not only climate change lies behind the water crisis, but inefficient water management and agricultural policies and discriminatory policies that hinder the ability of the most marginalized groups to access a vital resource. Thus, secondly, to be effective in the long run the structural underpinnings of water scarcity must be targeted and ideas of water justice must begin to enter policy discourse.

3. Thirdly, populations will be affected differently by water scarcity, with traditionally marginalized communities facing the highest risk. This is apparent when examining the 2021 drought in Iraq. Humanitarian organizations like the Norwegian Refugee Council (NRC) highlight the unique vulnerability of internally displaced people (IDPs) and new returnees to the water scarcity crisis in Iraq (NRC 2021). IDPs and returnees tend to be concentrated in regions of medium to high severity to drought, resulting in a high degree of environmental insecurity, which

predisposes them to the negative effects of water scarcity and prevents them from implementing effective coping mechanisms (NRC 2021, 12). IDPs and new returnees often have fewer resources to cope with drought and increase their resilience to climate vulnerability, and are also further at the risk of secondary internal displacement in response to drought conditions, which jeopardize their access to food, livelihood, and hygiene (NRC 2021). Thus, while it is important to consider how water scarcity might contribute to new migrants, it is also critical to consider how it affects the plight of those already displaced and increases the likelihood of secondary displacement (Black and Collier 287). Meanwhile in Jordan there has been a trend to place the blame for the country's intensifying water crisis on Syrian refugees, although they are some of the hardest hit communities by the water crisis (Hussein et. al. 2020, 1). This is not to mention broader inequality over water access in Jordan, with access to water often dependent on socioeconomic status and connections, necessitating an examination of the intersection between water access and issues of class, race, and mobility among other factors (Yoon et. al. 2021, 12).

4. In Palestine, life under occupation determines access to a critical resource like water. Gender and able-bodiedness also affect vulnerability to water scarcity. Existing literature demonstrates how water scarcity affects men and women differently. Because women and girls are often burdened with the primary responsibility for managing household water they are at the forefront of the water crisis and face elevated risk

due to limits on implementing climate adaptive practices (UN Water 2022; Sultana 2014, 375). Meanwhile, the plight of those who are disabled, which often falls between the policy and scholarly cracks, is also made more difficult by water scarcity, with those with disabilities often facing mounting difficulty to get the care they need in the face of climate change (Chan et al. 2014, 74).

5. On the domestic front, regional governments and local and international non-government organizations (NGOs) can advocate in favor of measures that will increase climate resilience and human security. First of all, water-stressed countries in the region must transition to climate-smart crops that are less water-intensive, an action that would address both water and food security concerns. Not only is agriculture vulnerable to climate change, but it is also a large contributor of greenhouse emissions, contributing about 19-29% of total greenhouse emissions annually (Research Program on Climate Change, Agriculture and Food Security 2012). A fifth solution is to transition to climate-smart crops, thus, increasing agriculture's resilience to climate change and productivity, while also reducing emissions. Additional NGO programming should support such endeavors and domestically governments should consider the prospect of creating an incentive structure to motivate farmers to switch to climate-smart crops.

Examples of such initiatives include an effort pioneered by the Jordanian non-governmental organization (NGO) Tulua which advances the use of aquaponic systems to generate higher yields and reduced waste (Bernadaux 2021). Given the region-wide need to transition to sustainable agriculture, it would be useful for countries in the region to create a mechanism to share lessons learned, creating a channel for knowledge exchange and regional conversation when it comes to this critical endeavor. In this regard, platforms that already exist should be capitalized on. One such example is AgraME, a trade fair in the UAE that seeks to address regional food insecurity through showcasing new technologies for sustainable agriculture (Bernadaux 2021).

6. Governments should also simultaneously initiate widespread reform and improvements to existing water infrastructure, including irrigation systems, to reduce levels of Non Revenue Water (NRW). This will involve fixing leaking pipes, creating stronger water metering systems, monitoring water theft, and launching public awareness campaigns to emphasize the need to practice water conservation, especially in water-intensive industries like agriculture. NGOs working in the region must also prioritize fixing existing infrastructure as a prerequisite to broader water sector reform.

7. Moreover, cooperation on water issues must be framed as critical to the collective climate and human security of all riparian states. It must be understood that a failure to cooperate will detract from the ability of all basin states to use shared water resources. Cooperation on water management must also include broader cooperation and

information sharing about climate change and its effect in the basins. Examples of past transboundary water cooperation efforts should be explored to learn from past examples and case studies and consider how preexisting efforts can be revived and reformulated rather than beginning anew. Cooperation on water issues has been approached in the Tigris and Euphrates basin for example through the Euphrates-Tigris Initiative for Cooperation-ETIC established in 2005. This track-two initiative served as a non-governmental entity that was constituted by water professionals, diplomats, technocrats, and academics (including the author), and sought to open dialogue about bilateral water disputes and the basin and broader regional socioeconomic concerns related to water (Kibaroglu 2020). Still, however, no basin-wide agreements for the management of water resources in the basin exist and collaboration over water management has remained contested and uncoordinated. For instance, in the 1980s, riparians in the basin developed the joint Technical Committee (JTC) involving all three riparians. The committee however failed to reach jointly agreed upon mandates and an effective plan for joint water management and land development. Such initiatives also fell short of developing treaties and mechanisms to monitor and protect against water quality issues related to pollution and develop a free-flowing channel of communication about the effects of climate change and climate research in the basin. To be effective, such measures must have an enforcement mechanism as well as conflict resolution mechanisms should conflict arise. Riparians in the basin may benefit from leaning from the efforts of a multinational third part like UN Water, to play a role in facilitating effective dialogue on transboundary water-sharing and preserving water quality and basins' overall environmental health, as well as research coming out of centers like the Geneva Water Hub which promotes hydro-diplomacy.

8. Examples of transboundary water-cooperation from other regions should also be studied and considered. Downstream riparians in the Middle East should look to the experience of downstream states in other water-stressed basins, for instance, by looking to how downstream states like Myanmar, Laos, Thailand, Cambodia, and Vietnam, responded to Chinese dam-building in the Mekong basin. Downstream neighbors developed the Mekong River Commission in 1995 to promote regional cooperation on Mekong water development. The commission has seen a degree of success, for example, by conducting technical studies on water management and achieving greater information sharing with China on water development and climate change, but it is limited by its weak enforcement powers and the reality that China is not a part of the Commission as a full member. Downstream states in the Middle East should take note of lessons learned from the Mekong River Commission, and the experience of other downstream states in different regions and consider facilitating regional solidarity among downstream riparian states across different basins in the Middle East. This would allow for greater knowledge exchange and troubleshooting for developing effective solutions for water management and climate adaptation. Because many downstream riparians face similar concerns from upstream development, this could also be a powerful lobbying mechanism (Aviram et al. 2020; Climate Diplomacy 2022).

9. Lastly, collaboration between environmental scientists and social scientists is critical. STEM training can play a significant role in enhancing these synergies. Through such collaboration, understanding of drought not just as an environmental occurrence, but also a socioeconomic one can be achieved. Developing a better understanding of socioeconomic drought in the region is key because it highlights that even in instances when there might not be a drought by meteorological standards, water demand still might be exceeding supply, water quality might be unsafe for human use, and reduced water might be limiting hydroelectric power production, all of which would indicate the existence of a socioeconomic drought that undermines human security. Reaching a better understanding of the risk of socioeconomic drought could help downstream states more strongly argue and quantify the risks of upstream dams, even in situations where there might not be a drought by meteorological metrics. Platforms like the Famine Early Warning System Network (FEWS NET) could serve as a model for future efforts to monitor and forecast socioeconomic drought based on human security indicators to allow local and international relief agencies plan accordingly and help guide policymakers' conversations about the effects of upstream development.

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Chapter Three

The Nile River: Modern Solutions for Evolving Challenges

Mohammed Mahmoud

Abstract: The Nile River is a critical water resource that has historically provided water supply, food production, energy generation, and local economic benefits to its riparian nations. However, evolving challenges and non-cooperation in the Nile River Basin have fostered unilateral water development that has resulted in a climate of conflict between the riparian nations. Chief of these challenges is the stress that climate change has placed on the river, in terms of more hydrologic variability – droughts have become more prolonged and sustained while precipitation events have become more intense and capable of generating dangerous flooding events. In addition, the construction of the Grand Ethiopian Renaissance dam has raised tensions between Ethiopia, Egypt, and Sudan, a situation that threatens to produce more harmful unilateral actions with respect to Nile water resources amongst these countries as opposed to multilateral efforts on beneficially sharing the Nile River. Much of the cause of these modern-day challenges can be traced back to the 1959 Nile Waters Treaty and how it allocated Nile river water amongst the Nile River riparians. To address these challenges, this chapter proposes several solution strategies: 1) Incorporating improved technical tools and resources for water management in the Nile River Basin by leveraging international investments as incentives to enhance the existing technical capacity of Nile riparian countries, 2) Coordinating dam operations with respect to storage and releases for major dams across riparian nations by building a technical coalition for water operations between the Nile River riparian nations, and 3) updating the 1959 Nile Waters Treaty from a renegotiation perspective to begin a collaborative process to adapt it and future Nile water treaties with

consideration of the basin's currently drier hydrologic conditions as a consequence of climate change. Through cooperative action on these particular strategies, the Nile River riparians will be able to take the first steps towards a more water-secure and resilient Nile River Basin.

Introduction

The Nile River has long been an essential water supply for all of its riparian nations, none more so than its two most downstream nations of Egypt and Sudan, who are more arid in comparison to their upstream neighbors. The Nile River Basin includes nine other upstream riparian countries: South Sudan, Ethiopia, Eritrea, Tanzania, Kenya, Uganda, the Democratic Republic of Congo, Rwanda, and Burundi. The Nile owes its volume to two major tributaries, the White Nile and the Blue Nile. The Blue Nile is the river's principal contributor, providing approximately 83% of the Nile's volume, originating from Lake Tana, in the highlands of Ethiopia. The White Nile on the other hand contributes 16% of the Nile's total volume from its headwaters of Lake Victoria (Nile Basin Water Resources Atlas 2022).

The Nile's historical importance to Egypt as a crucial source of water cannot be overstated: Egypt is almost completely dependent on the Nile's water supply, as it provides 98% of the country's freshwater resources. When coupled with the country's sizeable population – 104.3 million and the 14th largest in the world as of 2021 (World Bank, 2022), and its current pace of population growth – 2.1% per year since 1989 to 2018 (Nikiel and Eltahir 2021), it becomes very clear why 99% of Egypt's population lives along the banks and within the floodplain of the river. The significance of the Nile River as the main water supply source for Egypt is equally matched by the importance of the Nile Delta to Egypt as a source of agricultural production – more than 80% of Egypt's water portfolio is used to support agricultural production. The Nile Delta is considered the most fertile region in Egypt, owing to the accumulation of silt deposits over thousands of years. This makes it an area ideally suited for agricultural irrigation, so much so that it is home to 63% of Egypt's arable land and more than half of the country's population (Fishar 2018).

Sources of Current Challenges

Though the challenges that the Nile River Basin currently faces are not novel, they are challenges that have been amplified by modern developments and events. These sources of modern-day challenges include antiquated Nile river agreements that are limited in their capability to address contemporary challenges, the construction of Ethiopia's Grand Ethiopian Renaissance Dam and how it influences the existing framework of river operations, and the amplifying impacts of climate change on the basin.

<u>Historical Nile River Agreements</u>

The current state of affairs with respect to the transboundary management of the Nile is strongly connected to the role that British colonialism and the foundational Nile River legal compacts had on the basis of how the waters of the river were allocated. Britain's interest in the Nile was associated with its need to meet the economic demand for cotton during a global shortage of the crop in the earlier part of the 20th century. This placed pressure on Britain and her colonies, especially Egypt and Sudan, to meet this demand for cotton, making flood control and water development on the Nile a primary concern for the British.

Following the end of World War I and the signing of the Versailles Treaty, it became evident to Britain that any regional development in the Nile Basin would require formal agreements regarding the allocation of its water. A 1925 study on water allotment by a Nile water commission became the framework for a feasible water agreement between Egypt and Sudan, leading to the Nile Water Agreement of 1929. The agreement heavily favored Egypt's rights to water in the Nile, as it was a key agricultural asset for Britain and an important trade route due to the Suez Canal. The benefits that Egypt gained from this deal included unrestricted access to river flow during the peak runoff season to support cotton production, and other stipulations that limited Egypt from upstream development on the river. Egypt was also allocated 48 billion cubic meters annually while Sudan was allotted only 4 billion cubic meters, and 32 billion cubic meters were left unclaimed (Lumumba 2007).

Following the Egyptian revolution of 1952, the new Egyptian government declared its intentions to build a new dam and water storage facility in Aswan. The first round of preliminary negotiations between Egypt and Sudan on this matter took place in 1954, prior to Sudan's complete independence from the British regime in 1956. However, after much deliberation it became clear that both sides held very opposing views on the matter. Egypt claimed that the annual average flow of the Nile was 80 billion cubic meters (as measured at Aswan) and that it had priority rights to 51 billion cubic meters of that volume based on their water needs, leaving Sudan with its 1929 allocation of 4 billion cubic meters. Sudan vehemently disagreed to this proposal and insisted on using the standard average annual Nile discharge rate of 84 billion cubic meters while also bringing attention the fact that under the initial Nile Waters Agreement of 1929 Egypt was only to be allocated 48 billion cubic meters (Abdalla 1971).

Egypt remained focused on the idea of building one large storage facility, namely the High Dam at Aswan. According to Sudan, if Egypt pushed to have this high dam completed, then any evaporation losses that would occur from it (which would be relatively high because of the size of this facility) would be deducted from Egypt's share of the Nile and not from Sudan's. Negotiations broke off with no resolution, though they resumed again briefly in 1955 only to end inconclusively again. Upon Sudan's gaining of independence in 1956, the contentious disputes between the two major Nile riparians over the issues of water allocations escalated, leading Sudan to unilaterally quit the 1929 agreement.

In 1958, a bloodless military coup in Sudan introduced a new regime that was more open to negotiations with the Egyptian government. In 1959, Nile water negotiations resumed with a more conciliatory tone and within a year the two countries renegotiated the 1929 agreement and in 1959 signed the Agreement for the Full Utilization of the Nile Waters, or the Nile Waters Treaty as it is referred to.

Under this agreement, Egypt procured a total of 55.5 billion cubic meters per year of Nile water while Sudan secured an annual water right of 18.5 billion cubic meters. Both nations also agreed that the combined needs of all other upstream Nile river riparians would not exceed 2 billion cubic meters per year (Abdalla 1971). No other provisions were made for any other Nile basin country to develop water projects on the Nile, and even though annual allocation determinations of Nile River Water volume were exclusively made by Sudan and Egypt, all other Nile riparian states that were not represented in these negotiations were still expected to abide by the treaty.

This historical summary of Nile river agreements and negotiations illustrates the difficult nature of multi-nation water management resolutions, even for two riparian countries on the Nile that from a broad view seemed to be in political and cultural alignment. If this level of hardship to achieve Nile river consensus was the case for Egypt and Sudan, one must consider how difficult further negotiations would be with other riparian nations upstream. In the post-colonial era, the historical agreements that govern how the Nile waters are managed are problematic in the sense that they exclude a whole set of riparian nations that are situated at the headwaters of the river. They are also limited in that since their adoption no further addendums to the treaties have been effectively applied to address the changing political conditions (sovereign and independent riparians) and hydrological conditions, such as the flow of the river over the span of decades due to external factors like drought and climate change. The agreements intended to manage the Nile have essentially remained static while the hydrologic conditions of the river have been anything but. This effectively enabled a status quo where any slight deviation to the river's management framework would yield an untenable outcome to the downstream nations of Egypt and Sudan.

The Grand Ethiopian Renaissance Dam (GERD)

For many decades after the construction of the Awan High Dam, any new water development projects on the Nile was curbed due to Egypt's strong opposition (and threat of military action). Upstream nations in both the Blue and White Nile tributaries have indicated interest, and in some cases developed plans, to harness the Nile for their own water projects. But any proposed water projects of significance were abandoned because of lack of sufficient funding to support those projects or due to Egypt's fervent opposition against pursuing those projects. This moratorium on upstream water development projects on the Nile effectively ended when Ethiopia began to pursue the development of the GERD.

The process that would eventually culminate with the construction of the GERD started in 2010 when Ethiopia declared its intention to build a large-scale reservoir on the Blue Nile, then referred to as the Grand Millennium Dam. In conjunction with other upstream nations, Ethiopia signed the Nile Basin Cooperative Framework Agreement in 2010, more commonly known as the Entebbe Agreement. The Entebbe Agreement was put forth as a replacement to the previous Nile water agreements. In opposition, Egypt and Sudan signed their own agreement the same year to preserve and protect their historical water rights as dictated in the 1959 Nile Waters Treaty.

In 2011, after the designs for the Grand Millennium Dam were completed, Ethiopia made public its project plan by awarding the construction contract to an Italian company for 4.8 billion dollars. The project then officially changed its name to the Grand Ethiopian Renaissance Dam. What followed for the next several years as the construction of the dam progressed was a series of failed negotiations and proposals between Egypt, Sudan, and Ethiopia on how best to resolve their differences regarding the dam's potential hydrological, environmental, and socio-economic implications.

In 2013, Ethiopia ratified the Entebbe Agreement in its parliament and started diverting the flow of the Blue Nile to the GERD, despite Egypt's protestations that proceeding as such, unilaterally, would place Egypt's water and food (production) security at extreme risk. As the negotiations between the three nations continued to stall, Ethiopia ultimately moved ahead with its plans to eventually complete the first filling in 2020 which was followed by second and third fillings in 2021 and 2022. The three nations remain at odds over finding mutually acceptable terms regarding how the GERD should be operated within the existing water management framework of the Nile (i.e. the 1959 Nile Waters Treaty).

Climate Change

Climate change has caused the Nile to experience more variability with respect to hydroclimatic extremes, meaning that even though the state of drought in the basin has worsened, periodic events of above normal precipitation have also become more extreme. This shift has increased the likelihood for both significantly hotter weather and extreme flooding events, as evidenced in the last few years by the frequency of flood-inducing heavy rainfall that has inundated Sudan. Simply put, the conditions in the river basin have gotten hotter, drier, and in terms of river flow, more variable than normal (Mahmoud et al. 2022).

The potential future implications of unabated climate change on the basin do not paint a better picture. The 2021 IPCC sixth assessment report associated with the physical science basis of climate change provided insight on the future projected impacts of climate change on different global sub-regions. How two of those sub-regions identified in the report – the Mediterranean and the Sahara, are expected to experience climate change will have direct consequences to the Nile River Basin.

Implications of future climate change on the Mediterranean are most pertinent to the Nile River Delta, an area of agricultural importance to Egypt. The coastal band of the Mediterranean Sea has already been experiencing the effects of sustained drought conditions. However, projections for the Mediterranean sub-region under continued global warming include further aridification due to diminished precipitation and enhanced fire weather conditions that elevate the risk of wildfires. In addition, these projections also consider significant sea level rise to occur by mid-century if increases in global warming exceed 2 degrees Celsius (IPCC 2021). These projected changes put at great risk the land in the Nile Delta that is available to support agricultural production, which is progressively shrinking due to rapid population growth and urban sprawl – further threatening Egypt's food security (Radwan et al. 2019).

The arid Sahara region, with the exclusion of the coastal areas along the Mediterranean, is expected to see pronounced increases in surface temperatures. However, heavy precipitation events are projected to also occur in greater frequency (IPCC 2021). This intensity in precipitation activity will likely also generate more flooding events for this region. The combination of hot and dry conditions in the Sahara with more frequent and intense precipitation events may seem to be a beneficial byproduct when one considers that periods of above normal rainfall could alleviate extended episodes of drought. But intense precipitation events in this arid zone increase the likelihood of floods. For the Nile River Basin, this is especially dangerous as the river system is already prone to serious flooding events, particularly in the areas surrounding Khartoum, Sudan, at the confluence of the Blue and White Nile.

These current and potential effects of severe climate change in the basin pose an added hurdle in the transboundary management of the Nile River Basin. These potentially severe future outcomes underscore the urgent need for intra-basin coordination between Nile River nations, especially when it comes to matters of water supply, water demand, and water operations, as doing so can mitigate the effects of prolonged droughts and pluvial floods while still meeting regional water demands from the river.

Opportunities for New Solution Strategies

In light of these modern-day challenges that are rooted in historical issues, several strategies are recommended to begin mitigating the current and future vulnerability of the Nile River Basin. These suggested solutions look to resolve the river basin's challenges by compensating for missed past opportunities while also finding new opportunities borne out of the present water crisis on the Nile. Fundamentally, these recommendations address issues of water supply, water demand, and water management in the Nile River Basin.

Improved Technical Tools for Water Management

One aspect of technology that can assist in the collaborative management of the Nile River is looking for tools to improve the capacity for riparian nations to resolve the hydrological and physical difficulties associated with managing the river. Especially when we look at the recommendation of coordinated water operations between river nations, making that goal a reality requires more than just better relationships between the nations and wider communication between their technical water operation staff. It requires enhanced and more advanced technological tools that must be mainstreamed in the river operations of the basin countries.

An important improvement that can be pursued is for these nation's water operators to utilize improved forecasting tools that can yield better hydrological and metrological forecast information. This type of enhanced information is beneficial from a real-time operations perspective because it allows water operators access to the most up-date data with respect to river flow, snow melt runoff, precipitation storms, etc. This can improve their ability to coordinate dam releases in consideration of extreme drought and/or extreme flooding risk downstream. Yue et al. (2022) evaluated the use of 1-15 day medium-range precipitation forecasts from the Global Forecast System (a global numerical weather prediction system containing a global computer model) in the Nile's nine sub-basins. Though results indicate low performance accuracy with respect to the forecasts, the analysis-identified methods (e.g. post-processing and bias correction techniques) that could improve the performance of forecasts from the Global Forecast System. Reliable weather forecasts add significant operational value, and evaluation studies like this help enhance the accuracy and usability of forecasts for operational use.

Another suggested tool that can enhance the long-term understanding of the river system's behavior by water operation technical staff in the basin is the rigorous use of simulation models. Computer modeling of current and future basin conditions (in conjunction with short to mid-term forecasts) allows operators to prepare for potential hydrological shifts in the basin, enabling them to make sound water operation decisions that are layered months (and in some cases years) beyond the most immediate forecast window. For example, Basheer et al. (2018) developed a daily model of the Blue Nile that utilized satellite-based rainfall data to simulate system components such as river hydrology, irrigation water use, and hydropower generation. The model was used to illustrate how the water-energy-food nexus in the Blue Nile River Basin would be affected by improved transboundary cooperation between Ethiopia and Sudan. Results from model simulations of 120 scenarios illustrated how long-term economic gain increases when collaboration between Ethiopia and Sudan increases. Therefore, in this case, computer modeling was able to provide quantitative justification for better cooperation between the Nile riparian countries.

Obviously, these types of technological improvements will require significant investments to upgrade the existing tools available to water operators in terms of both hardware/software, and training to allow their adequate mainstreaming in the basin. However, the positive outlook, as demonstrated by Yue et al. (2022) and Basheer et al. (2018), is that these tools and resources are available for use and integration and continue to be enhanced and improved through active research and development.

Exchange of Resource Services and Benefits

Another prospect for mitigating water scarcity in the Nile is exploring mutually beneficial cooperation deals on the exchange of resource services and benefits between the riparian nations to supplement the most pressing use and need for each country's allocation of Nile River water (Al-Saidi et al. 2017). For instance, in a regional sense, the hydropower generated from the GERD (with a generation capacity of up to 6,000 MW) has the potential to benefit more than Ethiopia (Tesfa 2013), with Sudan being one such potential beneficiary. Sudan has for decades been struggling from energy deficits that have translated to regular power blackouts (Ghandour, 2016), and according to "Tracking SDG 7: The Energy Progress Report" (IRENA, 2021), Sudan is one of the top 20 countries with the largest populations lacking access to electricity (with 20 million people in Sudan without access to electricity). The energy capacity that the GERD can bring to bear can provide a partial solution to Sudan's energy deficit woes. This will require investments to upgrade Sudan's energy grid and its connectivity to Ethiopia to handle the transmission of this new energy source into Sudan. This energy transfer between the two nations can be facilitated through a direct energy purchase by Sudan or with a water for energy exchange deal, whereby Sudan can reduce its Nile River use to offset the water release necessary for the added power generation.

A proposal with a similar concept (energy for water exchange) was recently agreed to between Jordan and Israel. Per the agreement, A sizable solar energy farm would be built in Jordan and the generated solar power (up to 600 MW) would be sent to Israel in exchange for water produced from a new coastal desalination facility (up to 200 million cubic meters per year). Masdar, the UAE's renewable energy company, is a partner to this agreement as it would be responsible for building and financing the solar energy farm in Jordan. The electricity generated in Jordan would be sold to Israel at a cost of $180 million per year, with both Jordan and Masdar sharing in that revenue. At this stage, little technical information on this deal has been unveiled. But upcoming feasibility studies should resolve details regarding the energy and water infrastructure connections between the two countries, distribution of construction costs, and inter-country operations to manage the exchange of water and energy resources (Mahmoud 2021). If this particular resource exchange deal becomes operational and successful, it could set a good example for Ethiopia and Sudan to follow.

Similarly, Egypt and Sudan can explore a mutually beneficial resource exchange that meets their respective water use needs. Both countries have significant agricultural sectors that they are heavily reliant on to meet their food security goals (Egypt and Sudan have the largest irrigated areas in Africa – just over 6 million hectares combined) (Nile Basin Water Resources Atlas 2022). With less population in contrast to Egypt, Sudan might have some flexibility to supplement Egypt's food production with its own agricultural production in exchange for more water allocation from the Nile via a reduction of Egypt's water use. Since most of Egypt's water consumption goes towards agriculture, providing that food production through Sudan is an alternative way of supporting Egypt's food security goals. When considered in conjunction with an energy for water deal with Ethiopia, Sudan can in essence exchange part of its food production for energy by serving as an intermediary to transfer natural resources between Egypt and Ethiopia.

Increasing Agricultural Water Use Efficiency

When it comes to agricultural water use, there are huge possibilities for increased agricultural water efficiency in both Egypt and Sudan, especially considering that agricultural water use has the largest water footprint out of all sectors in those countries (Nile Basin Water Resources Atlas 2022). Employing more water efficient farming practices can maximize the water available for agriculture from the Nile. Shifting to improved applications of drip irrigation (as opposed to flood irrigation), lining irrigation canals to minimize water conveyance losses, and introducing policies that limit sowing of water intensive crops are some examples of how this level of agricultural water use efficiency can be achieved. Water conservation efforts in irrigated agriculture that focus on improving the infrastructure (e.g. reduced irrigation canal water loss) and/or the management of the irrigation system (e.g. drip irrigation) have demonstrated significant water savings – increasing average farm irrigation efficiency by up to 20% depending on the existing level of farm irrigation efficiency and room for efficiency improvement (Clemmens and Allen 2005).

The agriculturally productive Gezira Scheme situated in the state of Al Jazirah is the oldest and largest gravity-driven (flood) irrigation and one of the largest irrigation schemes globally with an irrigation area of approximately 850 thousand hectares (Nile Basin Water Resources Atlas 2022). Flood irrigation, in contrast to other irrigation methods (such as drip or sprinkler), has the lowest irrigation water use efficiency because much of the water used to inundate the agricultural field in this manner becomes surface water runoff (as the excess water exceeds the infiltration capacity of the field's soil).

With an irrigation scheme of such size and age, the opportunity for improved agricultural water use efficiency is ever-present, and improving water use efficiency can increase the agricultural yield of the scheme for the same water footprint. In fact, studies have identified that when compared to other irrigation schemes, the Gezira scheme's water use efficiency is low. This is primarily attributed to poor water distribution across the scheme and irrigation mismanagement, with better water use efficiency possible through harvesting rainwater and drained irrigation water (Al Zayed et al. 2015). Improving this scheme's water use efficiency and thus boosting its agricultural productivity can also make a potential food for water exchange program with Egypt much more viable.

Coordinated Dam Operations

Egypt, Sudan, and Ethiopia each have a vested interest in the viability of the Nile River as a water resource to meet their respective needs. However, there are actually nuanced priorities for each country, which include primary water security objectives targeting each nation's unique vulnerability with respect to the river.

In the case of Egypt, rapid population and economic growth (2.1% population and 4.4% GDP increases annually from 1989 to 2018) have caused water demand to outgrow available water supply from the Nile (Nikiel and Eltahir 2021). It becomes obvious then why Egypt cannot accept any water utilization scenario in the basin that diminishes its available water supply from the river, as it would be quite detrimental for both the agricultural and urban sectors' ability to meet the growing needs of the country's population. Unlike its upstream Nile riparians, Egypt is not home to any of the headwaters of the Nile tributaries (such as Ethiopia and the East African nations bordering Lake Victoria) and does not include any major confluences of the river within its borders (like Sudan). Recognizing its downstream vulnerability in the river, Egypt has made efforts to diversify its water portfolio through the construction of coastal water desalination plants. But the Nile remains its primary water source in terms of volume of supply, cost of development, and the renewable nature of the resource.

Sudan's need for the Nile's water supply is also important – as it sustains its own agricultural food production industry. But in terms of water security, Sudan is much more prone to experience flooding, as the confluence of both the White and Blue Nile along with smaller tributaries occur within its borders. Historically, Sudan (and South

Sudan) has experienced severe flooding events due to overflow of the Nile and its tributaries, brought about by heavy rainfall and subsequent large runoff volumes in the river. Severe floods not only cause the loss of lives, infrastructure, livelihoods, and arable land, but further propagate environmental, health, and sanitary issues (El Tohami 2019). In this matter, the GERD can provide some level of mitigation for Sudan against extreme flooding, as it adds a large reservoir buffer against large upstream runoff by controlling river discharge into Sudan (similar to what the Aswan High Dam does for Egypt).

The primary water security objective for Ethiopia was made evident with its desire to pursue construction of the GERD – the need for a reliable energy source through hydropower generation. And though the GERD will have the capacity to store 74 billion cubic meters of water, from Ethiopia's perspective it is a hydroelectric power-generating dam first. Indeed, the GERD's proximity to the Sudanese border renders any water released from the dam of little use as a water supply for Ethiopia, as it cannot truly capitalize on the water released in the span of the approximately 45 km of remaining riverway between the dam and the border.

Though concerns regarding how the construction and filling of the GERD will affect the continuity of water supply downstream are valid (Modros et al. 2020), the presence of the GERD (once fully operational) can still provide an opportunity to mitigate the principal water security risks of these three most downstream riparian nations. Doing so requires a high level of technical cooperation between the three nations with respect to how they conjunctively operate their reservoirs along the Blue Nile between the GERD and the Aswan High Dam (Wheeler et al. 2020). The two dams in the system would need to be closely synched in terms of their operations. It is not difficult to imagine, though may be difficult to execute at this stage of disagreement between the riparians, that Ethiopia's GERD and Egypt's Aswan High Dam, along with Sudan's smaller dams can be operated in a manner that simultaneously maximizes Ethiopia's ability to generate hydropower, protects Sudan from dangerous flooding events, and secures Egypt's access to ample Nile River water supply. This level of coordination would require a multi-objective approach with respect to dam operations, including considerations for seasonal minimum and maximum water releases from each dam (in context to drought and flood seasons), timing of water releases for hydropower and water demand, and maintenance schedules for these hydraulic structures. For example, Ethiopia may adjust its releases from the GERD if the risk of flooding downstream in Sudan is elevated (due to larger flow from the White Nile and/or localized intense precipitation). Similarly, Ethiopia may coordinate its releases from the GERD with the storage elevation at the Aswan High Dam – releasing more water when the Aswan High Dam's storage reaches lower thresholds (e.g. in the summer), in consideration of Egypt's water supply needs.

There is precedent to this type of multi-reservoir coordinated approach that has been deemed successful in managing water resources in other river basins. For example, the Colorado River Basin, which spans two countries (United States and Mexico) as well as seven states within the United States, follows this approach. Much like the hydrological framework of the Nile, the Colorado River watershed encompasses a series of smaller reservoirs and two large reservoirs in Lake Mead and Lake Powell. Both Lake Mead and Lake Powell are operated in a conjunctive manner to optimize their respective capacity to generate hydropower, maximize their water storage, and provide flood control while meeting the water demands of the states that share the river (Colorado River Interim Guidelines 2007). The delicate balance of attempting to meet several potentially competing objectives, such as maximizing hydropower generation from Ethiopia's GERD while satisfying the growing water demands of downstream users in Egypt and Sudan, and improving flood control measures for Sudan will be very difficult to achieve if cooperative reservoir management between these nations is not strongly aligned.

Updating the 1959 Nile Waters Treaty

One of the more controversial topics when it comes to finding future collaborative pathways between the Nile river basin riparians is considering amendments to 1959 Nile Waters Treaty. This concept has been a source of fundamental disagreements between the two principals of the agreement – Egypt and Sudan, and the other upstream riparians.

Egypt and Sudan stand by the legality of the document even though Ethiopia and the other East African nations sharing the Nile argue that the treaty is invalid based on the principle of "rebus sic stantibus" – a term in international treaty law that allows for the termination of a treaty due to a fundamental change in circumstance. One such circumstance for termination that can be argued by upstream riparians on the White Nile is that they all gained independence from the yoke of European colonialism after 1959 (South Sudan being the most recent exception when it separated from Sudan in 2011). Therefore, a treaty like the 1959 Nile Waters Treaty that was derived from a prior agreement (i.e. the 1929 Nile Waters Agreement) based on the influence of a colonial power (Britain) could be considered no longer valid. Another glaring reason for a revision of the treaty is the simple fact that it does not explicitly include the representation of other Nile River riparians.

Another reason to update the 1959 treaty is the chance to recalibrate the agreement to reflect the significant basin changes that have occurred since its signing and to incorporate modern Nile River issues. Besides explicitly including all Nile River riparians under one pact, an amended or new Nile agreement can allow for stipulations on how riparian countries may develop new water infrastructure projects on the river in a manner that does not pose harm to other river users. Furthermore, the impact of climate change on the river, at least with regards to how it has altered annual river flow (flow decreases of up to 114.1 cubic meters per second every decade after 1964, Mahmoud et al. 2022), can be reflected by appropriate revisions to water allocations, thus making the appropriations between river nations reflective of the basin's current physical conditions.

Finally, additional nuance can be added in a revised or updated agreement with respect to coordination activities between the nations. Inclusion of coordinated water operations between tributary reservoirs, how to manage river flows and allocations under conditions of water surplus or deficit, and the identification of appropriate technical committees for intra-basin resolutions could be achieved under an amended Nile River treaty. All of these examples of recommended revisions or amendments to the treaty serve the important purpose of getting ahead of further conflict in the basin. The process to redraw the terms of the treaty will be difficult without a doubt, but targeting those changes now can prevent further delay on action and mitigate potential conflicts from deteriorating hydrologic conditions in the basin, as indicated by future projections.

Steps to Facilitate Action on Solutions

For these potential solutions to be implementable, several initial steps need to be established to facilitate action. These are steps that should be taken by the Nile River riparian countries in order to fully on-board the larger-scale strategy recommendations previously discussed, with the overarching objective of managing the various water management challenges within the basin.

1. Leverage investments for incentives that can enhance Nile River Basin management

Targeted investments for beneficial multilateral projects within the basin can also provide incentives for cooperative water management between the Nile River nations. Examples of these types of targeted investments include funding to upgrade the energy grid transmission and capacity between Ethiopia and Sudan to facilitate a hydropower-based energy for water exchange between the nations. In addition, these investments can be utilized to improve the technical capacity of the respective Nile riparians to better coordinate water operations and incorporate better technical tools (e.g. forecasting and modeling) for the benefit of the water planners and operators managing each nation's water use.

As to where this level of funding and investment can come from, several traditional forms of loans and funding from international agencies, NGOs, foreign governments, and donor foundations are an option. However, one source of funding that can be appropriate due to its relevance to how climate change is affecting the basin is the United Nations Framework Convention on Climate Change's Green Climate Fund (GCF). The GCF was established to assist developing nations in implementing climate adaptation and mitigation strategies (Green Climate Fund 2022a).

In fact, in 2016 Egypt submitted a funding proposal (FP053) under the GCF for a project on "Enhancing Climate Change Adaptation in the North Coast and Nile Delta Regions in Egypt." The objective of the proposal was to reduce coastal flooding risks in Egypt's North Coast due to future projected sea level rise and more frequent and intense extreme storm events – by installing 69 km of sand dune dikes along five previously identified vulnerable locations within the Nile Delta, and developing an integrated coastal zone management plan for the entire Egyptian North Coast. The proposal was approved in 2017, receiving $31.4M to date from the GCF (along with co-financing from other sources). The project is currently under implementation with a target completion date of December 2024 (Green Climate Fund 2022b). Water management strategies, such as those recommended in this chapter (e.g. flood control in Sudan, efficient agricultural water use, and climate-conditioned water operations), could also be categorized as climate adaptation solutions that address the adverse impacts of climate change on the basin's water resources and suitable projects for potential funding from the GCF.

2. Build a technical coalition of water operations between the Nile River riparian nations

While cooperation on Nile water issues will require the governments of each riparian nation to engage with each other, when it comes to implementing collaborative solutions that address water management issues – that engagement has to occur at a different level. To explore feasible and best practices on the Nile with respect to optimal intra-basin water operations, there has to be an established basis of communication at the technical level between the riparian nations. This means instituting a technical working group composed of water operators, engineers, and meteorologists that can work towards coordinating their respective nations' water operations on the Nile. Such a technical committee can be an extension of existing Nile river cooperation institutions like the Nile Basin Initiative (an intergovernmental partnership of the Nile Basin countries formed in 1999). The focus of this technical committee would be to resolve the technical water resource issues associated with Nile River water management.

3. <u>Begin a collaborative process to adapt existing Nile River agreements to current conditions</u>

One of the most challenging steps with respect to prompting action is assembling the Nile River riparian nations to commence a new and fresh process to review and amend existing Nile River agreements. Though difficult, this step will become more inevitable the longer it is delayed. Observations and projections from climate model simulations suggest that climate change will push the basin into extreme hydrological conditions with interannual variability of Nile river flow increasing by 50% (Siam and Eltahir 2017), making management of water resources in the basin even more challenging in the future. Therefore, initiating a collaborative process for both upstream and downstream riparians to incorporate the impacts of climate change, cooperative river water operations, and water development projects in a revised or new agreement, can position the basin to better navigate the foreseeable challenges that lie ahead. Motivating collaboration at the governance level between the river basin countries can come from leveraged investments that incentivize cooperation (such as from the GCF). This in turn can help foster efficient working relationships at the technical level to coordinate water operations in the basin.

Conclusion

When it comes to the Nile River Basin, improving intra-basin water management begins by building better collaborative relationships between the upstream and downstream riparian nations. The means of addressing this goal involves taking difficult steps to rectify the water management missteps of the past, such as the limitations of historical Nile River agreements (borne from the manipulation of colonial powers on the African continent), and taking proactive measures to prepare for a difficult hydrological future in the basin due to climate change.

Assessing the deficiencies of the Nile Waters Treaty through a science-based approach is a pathway to better cooperative water management that can open the door to future Nile River agreements that consider all riparian countries; acknowledge the influence of climate change on water supply; allow for mutually beneficial water development projects; and encourage technical coordination on the river's water operations. Absent these difficult steps, the basin will likely remain in a state of competitive deadlock, where basin countries unilaterally pursue their socio-economic interests in harnessing the Nile's water. Down that path lie further obstacles, not just from the inherent conflicts that will arise from such an approach, but because of the further complexities and hardships that the worsening impacts of climate change will pose to the water resources management of the basin.

One positive outlook is that this is not the path that countries in the basin have to follow. There are multiple opportunities to improve conditions in the basin with respect to water resources management and intra-basin relationships. Furthermore, these solutions do not have to completely rely on governmental action from each of the basin nations. While the governance level of each riparian nation can set the objectives for collaboration and cooperation, ultimately it is the technical personnel that will resolve the hydrological water sharing issues of the basin; this being the engineers, water operators, modelers, and meteorologists of these nations. The opportunity for corrective action in the Nile River is still present, if the nations in the basin choose to act on it.

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Chapter Four

Potential Solutions for the Water Conflict Between Palestinians and Israelis

Hilmi S. Salem

Abstract: The Palestinian people's thirst is not only for their freedom, but also water, as they are deprived of their own water resources. Denying Palestinians their basic rights to water is part of Israel's 75-year-old (since 1948) repression against them in their homeland of Historic Palestine, which includes the Occupied Palestinian Territories (OPT), comprised of the West Bank (including East Jerusalem) and the Gaza Strip. The OPT has a total area of about 6,000 km^2 (forming approximately 22% of Historic Palestine (27,000 km^2) and a total population of around 5.4 million (3.2 million in the West Bank, and 2.2 million in the Gaza Strip). The Palestinians in the OPT currently have very little water to use for domestic, agricultural, and industrial purposes, especially in light of the impacts of population growth and climate change. This study presents potential hydro-solutions to mitigate and solve water problems between the two conflicting parties – the Palestinians and the Israelis. These proposed hydro-solutions can be briefly summarised as: 1) The Palestinian people in the OPT should obtain their full rights in their transboundary renewable surface water and groundwater resources in the Jordan River System; Lake Tiberias (Sea of Galilee); Dead Sea Basin (DSB); Mountain Aquifer System and its subsystems (Western, North-eastern, and Eastern); water springs; and dams to be built in the OPT to harvest rainwater without restrictions from the Israeli occupation authorities; 2) All these water resources must be subject to the "principles of international law," based on "fair and reasonable use" and "limited sovereignty," taking into account equality, equity, justice, population growth, climate change impacts, and sustainability; 3) Based

on the Palestinian and Israeli populations, the Palestinians should receive about 810 MCM/yr, instead of the 265 MCM allotted to them annually, and the Israelis should receive about 1,455 MCM/yr, instead of the 2,000 MCM/yr that they currently consume. The annual per capita consumption of Palestinians and Israelis should be around 150 m^3/yr, instead of the 88 m^3/yr and the 214 m^3/yr, which are currently consumed by the Palestinians and Israelis, respectively; and 4) An international-Palestinian-Israeli joint management structure must be agreed upon to address monitoring and compliance with water quotas, and to ensure the protection of all water resources, the environment, biodiversity, and ecosystems in Historic Palestine.

1. Introduction

Water is of particularly great importance to human beings, as without it there can be no agriculture, food, industry, or development, and absolutely no life. Thus, water is a fundamental human right for sustainability and continued survival. The countries of the Middle East and North Africa (MENA) region are currently experiencing severe water stress, scarcity, and shortages. With regard to Historic Palestine, as part of the MENA region, the issue of water is very sensitive and crucial, because the indigenous Palestinian population is under unbearable pressures in connection with the occupation of their homeland (Historic Palestine), and the expropriation of their natural resources including water resources, which Israeli controls almost entirely.

Strategists, policy makers, and scientists have predicted a number of different scenarios they expect to occur in the next few decades due to the negative impacts of climate change. The MENA region, including Historic Palestine (Israel and the Occupied Palestinian Territories – OPT), is affected not only by climate change impacts, such as droughts, desertification, and deforestation (Salem 2011a; Yihdego et al. 2019), but also by population growth, as well as geopolitical instability, military conflict, and wide-ranging wars, including the ongoing Israeli-Palestinian conflict since the establishment of the Israeli state in 1948 (Salem 2020a). In May 1948, Israel was established on 78% of the lands of Historic Palestine. In June 1967, the new-born state of Israel further occupied the rest (22%) of the land of Historic Palestine, as well as some other territories of neighbouring Arab countries, namely Egypt, Syria, Lebanon, and Jordan.

As a result of the Israeli military occupation of the Palestinian Territories (the West Bank, including East Jerusalem, and the Gaza Strip) in violation of international law (Salem 2020a; Amnesty International 2022), Israel has come in full control of not only the land of Historic Palestine, but also its natural resources, including its water resources (surface water and groundwater). Accordingly, 5.4 million Palestinians in the OPT have been severely suffering from water stress and shortages, especially in the summer (World Bank 2009; B'Tselem 2017; World Bank 2018; PCBS 2019a; B'Tselem 2021; OCHA 2021a; Salem et al. 2021; Salem et al. 2022).

Since June 1967, Israel has imposed tight control over the water sector and water resources in the Occupied Palestinian Territories. The water shortages, which the Palestinian people have been suffering from for decades, are a direct result of the policies and activities of the Israeli occupation and full control of water resources. As a matter of fact, the water shortages represent a flagrant violation of the basic human rights of the Palestinians living under Israeli occupation. These water shortages have greatly affected the health and economy of the Palestinian people. This is despite the abundance of water in Historic Palestine, which the Palestinians are deprived from using. In view of the above, water has been a major strategic asset for both sides of the conflict: the Palestinians under occupation and the Israeli occupiers who control almost all water and other natural resources in Historic Palestine.

This study examines some issues related to water resources in Historic Palestine, with focus on the OPT. The Palestinian-Israeli conflict over water has been investigated for the sake of introducing hydro-solutions based on justice, population, climate change impacts, international law, and sustainable development.

2. Results and Discussion

2.1. History of Water Conflict, in Brief

To find a solution to the conflict over water between the Palestinians and Israelis, it is important to look at the conflict's historical roots, which return to the end of the 19^{th} century when the Zionist movement began its plans to create a homeland for the global Jewish population in

Historic Palestine at the expense of Palestine's indigenous population – the Palestinian people (Rouyer 1996; Rouyer 2000; Sayegh 2012; CD 2015; Salem 2020a; UL 2021; Hildebrandt-Wypych 2022; Youssef 2022).

As a matter of fact, the Zionist movement, led by the founder of "Modern Political Zionism" – Theodor Herzl – and other Zionist leaders (such as Chaim Weizmann, David Ben-Gurion, Yitzhak Tabenkin, and others) focused on the importance of water resources in Historic Palestine before and after the establishment of the state of Israel (Nijim 1990; Amery 1998; Lipchin 2007; Anton 2008; Salem 2009; Francisco 2010; Da'Na 2013; Inbari 2022). Zionist leaders considered bringing more water to their future Israeli state in Historic Palestine from neighbouring countries, such as Jordan, Lebanon, and Egypt. In 1875 (about 75 years before the establishment of the state of Israel in 1948), it was proposed that the Jewish homeland should include Historic Palestine and parts of Jordan with its water resources, so that it could accommodate 15 million Jews to be brought from all over the world to replace the indigenous population of Palestine (Isaac and Hosh 1992; Reichman et al. 1997; TJAI 2022) – a goal that continues to this day.

In September 1953 (i.e., shortly after the establishment of the state of Israel in May 1948), Israel began the construction of the Israeli National Water Carrier (NWC) (CIE 1964; Davis et al. 1980). The NWC is a 130-km (about 81 mi) conveyance water system of pipes, canals, tunnels, reservoirs, and pumping stations. Integrated with most of Israel's water systems, the NWC traverses all types of terrain through a variety of elevation changes. The NWC can carry up to 1.7 million cubic meters of water per day (MCM/d) (or 19 million gallons per hour), which is equivalent to approximately 620–630 million cubic meters per year (MCM/yr). The water diversion through NWC originates at the Banat-Yacoub Bridge in the demilitarized zone between Israel and Syria (CIE 1953). After Arab objections to the drilling process, a temporary freeze was announced and the USA presented another plan as an attempt to resolve the water conflict in the region.

Moreover, regarding the Palestinian water resources in the OPT, the Israeli water company Mekorot has an important role in controlling the water resources in the West Bank, especially after 1982. Founded in 1937 (11 years before the establishment of the state of Israel in May 1948), Mekorot has been supplying Israel with 90% of its drinking water, and also operating the National Water Carrier (NWC), making it the most important water supply network across the country (Wikipedia 2022a).

Mekorot and its subsidiaries have partnered with many countries around the world in various areas related to water, including seawater desalination, wastewater treatment and reuse, and water resources management. Mekorot, for instance, is planning to undertake mega water projects in Bahrain and the United Arab Emirates (UAE). "Mekorot is conducting discussions regarding collaborating on various projects with our colleagues in Bahrain and the United Arab Emirates," said Eli Cohen, CEO of Mekorot, Israel's water company, in an interview with Yaakov Katz, Editor-in-Chief of the Jerusalem Post at the virtual UAE-Israel Business Summit, sponsored by the Jerusalem Post and the Khaleej Times, that took place earlier this week" (KT 2021; MEP Staff 2021).

Israel, since its occupation of the Palestinian Territories in June 1967, has been selling Palestinian water to its rightful owners – the Palestinian people – at very high prices (WPTIOI 2013; Salem et al. 2021). In this regard, Israel also collects and treats some of the wastewater discharged into the occupied West Bank (some of which is discharged by Jewish settlers), and charges the Palestinian Authority for its treatment, even though the Palestinians do not benefit from the treated wastewater (Hammad 2020; PUI 2021; Salem et al. 2021). The treated wastewater, in turn, is completely reused by Israel for agricultural irrigation, whereas large amounts of the agricultural crops are produced and sold to the Palestinians in the Occupied Palestinian Territories (Salem et al. 2021), in which high levels of hazardous materials were recorded (Ben Mordechay et al. 2021).

2.2. Palestinian Water Resources and Israeli Military Orders

Shortly after it occupied the Palestinian Territories in June 1967, Israel secured its control over the waters of the Jordan River. Additionally, Israel imposed a number of military orders to control Palestinian water resources in the occupied West Bank (Rabah and Fairweather 1995). On

15 August 1967, the Israeli Military Commander issued Order No. 92, in which water was considered a "strategic asset for Israel." This was followed by a large number of many other military orders, aimed at making fundamental changes to the water laws and regulations in force in the Occupied Palestinian Territories. For example, under Military Order No. 158 of 1967, it is not permissible for any person to set up, assemble, possess, or operate a water installation unless a license has been obtained from the area's Israeli Military Commander (Shuval and Dweik 2007). This order applies to all Palestinian wells and irrigation facilities in the OPT. Accordingly, the Military Commander of the area can refuse to grant authorization without the need for justification.

A large number of military orders followed, including No. 291, No. 457, No. 484, and No. 494 (all of 1972); No. 715 of 1977; and No. 1376 of 1991 (Rabah and Fairweather 1995; Isaac 2006; Isaac and Salem 2007). All of these military orders were issued by the Israeli occupation authorities, in order to achieve full control over Palestinian water resources. "[T]hese orders are still in effect, but they only apply to Palestinians and not to Israeli settlers who are subject to Israeli law" (Zohud and Alam 2022).

It is important to note that prior to the 1967 war, Palestinians owned 217 wells for agricultural and domestic purposes, many of which since 1967 have come under the full control of the Israeli occupation authorities (Isaac and Salem 2007). Immediately after the 1967 war ended, Israel destroyed 140 Palestinian water pumps in the Jordan Valley, and made it difficult to obtain permits to drill and/or operate new/old water wells. Despite the rapid increase in population and, thus, more demand for water, Israel, since its occupation of the West Bank (including East Jerusalem) and the Gaza Strip in June 1967, has granted Palestinians in the West Bank few permits to drill new water wells, all of which were to be used exclusively for domestic purposes. Additionally, the Israeli policy of steady monitoring of all Palestinian wells has been another means of restricting quotas on Palestinian water use. "Israeli authorities also maintain primary control over water resources in the West Bank and allocate water in a discriminatory fashion to Palestinians" (Al-Haq 2020; HRW 2021).

2.3. Oslo II Agreement Regarding Water Resources in the OPT

Apart from the Israeli military orders and actions on the ground, in 1995 the Israelis and Palestinians signed the Oslo II Agreement that also dealt with water allocation between the two parties. Palestinian and international water specialists (academicians, research scientists, engineers, hydrologists, hydrogeologists, environmentalists, policy- and strategy-makers, etc.) have widely criticized the Oslo II Agreement, as it did not deal at all with the Palestinian share in the waters of the Jordan River's System (JRS) as well as the Dead Sea Basin (DSB), and did not emphasize more shares of water from the Western, North-eastern (or Northern), and Eastern Aquifer Subsystems (WAS, NEAS, and EAS) of the Mountain Aquifer System (MAS) (Figure 1). These groundwater basins are located entirely underneath the occupied West Bank (Selby 2003; Isaac and Salem 2007; Salem and Isaac 2007; Al-Haq 2013a; Salem et al. 2021).

Figure 1: A map showing the Mountain Aquifer System (MAS) and its three subsystems: Western Aquifer Subsystem (WAS), North-eastern (or Northern) Aquifer Subsystem (NEAS), and Eastern Aquifer Subsystem (EAS), as well as the Coastal Aquifer System (CAS), and the directions of water flow through them (after PASSIA 1996; JVL 2022a).

2.4. International Law on Water and the Case of the Occupied Palestinian Territories (OPT)

As an occupying power, Israel has obligations, in accordance with international law, to provide the Palestinians living under the rules of its military occupation with water resources, both in quantity and quality. Taking into account the fact that the Palestinian water resources are being forcibly seized by Israel, ignoring by that the full rights of the Palestinians to their water resources, this requires an understanding of international law that should be applied, based on the principles of equity, equality, and justice, as investigated and discussed below.

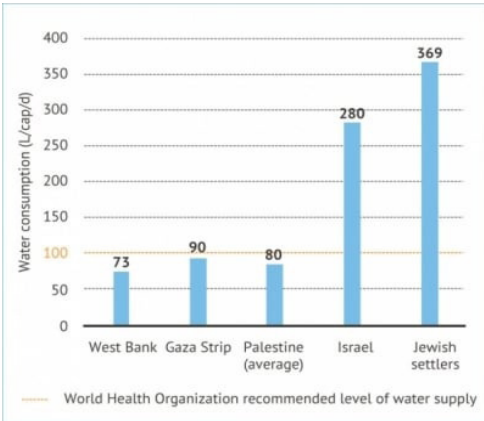
2.4.1. Administration of water sector in the OPT

<u>A) Prohibition of changing legislation:</u> Article 43 of the Hague Regulations of 1907 prohibits the occupying power (in this case, Israel) from changing the legislation in force prior to occupation (Sassòli 2004; B'Tselem 2014). Military orders issued by Israel, regarding water resources and water supply in the Occupied Palestinian Territories (as discussed above), have significantly changed the legal and institutional structure of the water sector in the OPT. The water resources of the Occupied Palestinian Territories have been integrated into the legal and bureaucratic systems of the Israeli occupation authorities, in a way that severely limits the ability of the Palestinian people to use and develop their own water resources.

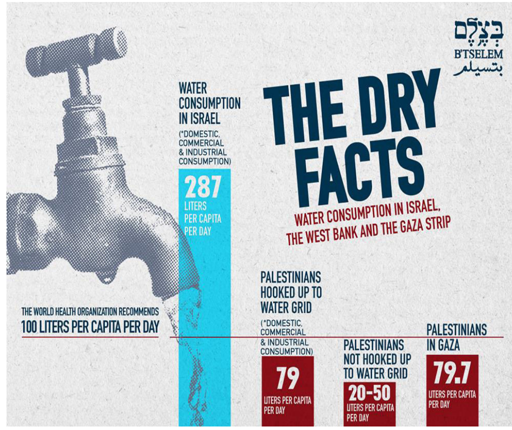
<u>B) Israeli illegal use of Palestinian water resources:</u> Article 55 of the Hague Regulations of 1907 limits the right of the occupying power (Israel, in the present case) to use water resources in the occupied territories (the Occupied Palestinian Territories, in the present case) (ECCAP 2014). The use by Jewish settlers in the Occupied Palestinian Territories and the Israeli occupying forces of the water resources owned by the Palestinian people, who live under the military rule of the Israeli occupation authorities, is illegal and, thus, violates Article 55.

<u>C) Distinguishing (discriminating) between the indigenous Palestinian population and the Israeli (Jewish) settlers in the OPT:</u> The rules, policies, and actions on the ground by the Israeli occupation authorities have prevented any development that would enable the water sector

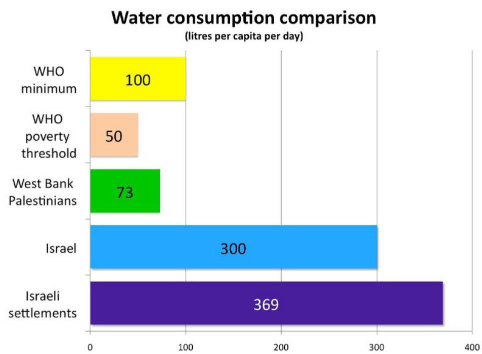
in the Occupied Palestinian Territories to meet the basic needs of the Palestinians and their growing demands for water. Since its occupation of the Palestinian Territories in June 1967, Israel has imposed restrictions and prohibitions, in terms of military orders and other tools and mechanisms (as discussed above), to prevent the Palestinian people in the Occupied Palestinian Territories from using their own water resources. These restrictions and prohibitions, which have been created and implemented by Israel, did not exist under the Jordanian and Egyptian rule over the West Bank and Gaza Strip, respectively, which lasted until June 1967. The Jordanian and Egyptian rule continued in effect until the June 1967 war when Israel occupied the Palestinian Territories (West Bank, including East Jerusalem, and Gaza Strip), along with other Arab territories. Article 27 of the Fourth Geneva Convention of 1949 prohibits the occupying power (Israel, in this case) from discriminating against citizens of the occupied territories (in this case, the Occupied Palestinian Territories) (ICRC 2022). The amounts of water supplied to the Jewish settlers in the Occupied Palestinian Territories far exceed those provided to the original population of the land (i.e. the Palestinian people living in the Occupied Palestinian Territories) (Figure 2). "As temperatures soar in the Palestinian territories, thousands of Palestinian families suffer from severe water shortages, while Israelis living in nearby Jewish settlements enjoy abundant amounts of water" (Oguz 2017). Likewise, the regularity of supply is much greater in the Jewish settlements, which were built illegally in the Occupied Palestinian Territories, than in the Palestinian communities.



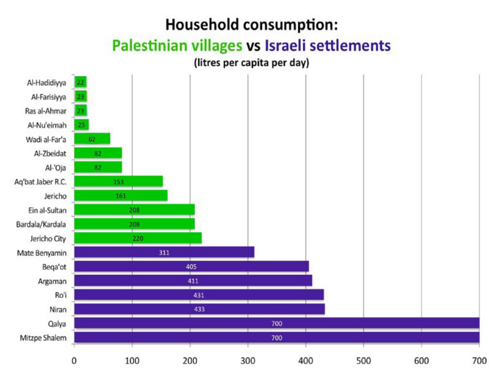
Water consumption (L/cap/d)
400
350
300
250
200
150
100
50
0
73
90
80
280
369
West Bank
Gaza Strip
Palestine (average)
Israel
Jewish settlers
World Health Organization recommended level of water supply



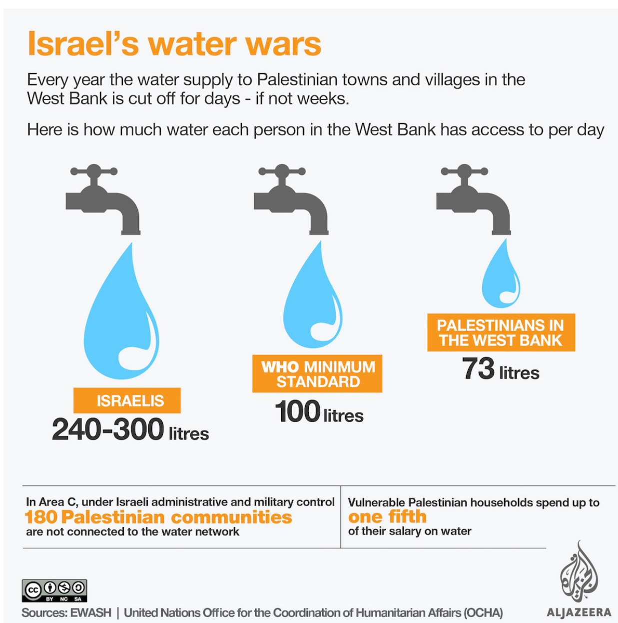
בצלם
BTSELEM
بتسيلم
THE DRY FACTS
WATER CONSUMPTION IN ISRAEL, THE WEST BANK AND THE GAZA STRIP
WATER CONSUMPTION IN ISRAEL
(*DOMESTIC, COMMERCIAL & INDUSTRIAL CONSUMPTION)
287
LITERS PER CAPITA PER DAY
THE WORLD HEALTH ORGANIZATION RECOMMENDS
100 LITERS PER CAPITA PER DAY
PALESTINIANS HOOKED UP TO WATER GRID
(*DOMESTIC, COMMERCIAL & INDUSTRIAL CONSUMPTION)
79
LITERS PER CAPITA PER DAY
PALESTINIANS NOT HOOKED UP TO WATER GRID
20-50
LITERS PER CAPITA PER DAY
PALESTINIANS IN GAZA
79.7
LITERS PER CAPITA PER DAY



Water consumption comparison
(litres per capita per day)
WHO minimum
100
WHO poverty threshold
50
West Bank Palestinians
73
Israel
300
Israeli settlements
369
0
100
200
300
400



Household consumption:
Palestinian villages vs Israeli settlements
(litres per capita per day)
Al-Hadidiyya 22
Al-Farisiyya 23
Ras al-Ahmar 23
Al-Nu'eimah 25
Wadi al-Far'a 62
Al-Zbeidat 82
Al-'Oja 82
Aq'bat Jaber R.C. 153
Jericho 161
Ein al-Sultan 208
Bardala/Kardala 208
Jericho City 220
Mate Benyamin 311
Beqa'ot 405
Argaman 411
Ro'i 431
Niran 433
Qalya 700
Mitzpe Shalem 700
0
100
200
300
400
500
600
700



Israel's water wars
Every year the water supply to Palestinian towns and villages in the West Bank is cut off for days - if not weeks.
Here is how much water each person in the West Bank has access to per day
ISRAELIS
240-300 litres
WHO MINIMUM STANDARD
100 litres
PALESTINIANS IN THE WEST BANK
73 litres
In Area C, under Israeli administrative and military control
180 Palestinian communities
are not connected to the water network
Vulnerable Palestinian households spend up to
one fifth
of their salary on water
Sources: EWASH | United Nations Office for the Coordination of Humanitarian Affairs (OCHA)
ALJAZEERA

Figure 2: Access to water by Palestinians and Israelis, in litter per capita per day (L/c/d), in the occupied West Bank and Gaza Strip, Palestinian average, Israel's average, and Jewish settlers living in the occupied West Bank, compared with the World Health Organization's (WHO) minimum standard (after: **Upper Left:** Amnesty International 2009, Fanack 2015a; **Upper Right:** B'Tselem 2016, WAFA 2022; **Middle Left and Right:** Al-Haq 2013b, 2020; and **Lower:** Corradin 2016, Khaled 2016, Salem et al. 2021). Note the mismatch in the figures for the quantities of water supplied to Palestinians and Israelis, based on different institutions: Israeli, Palestinian, and international.

D) Israel clearly violates Palestinians' "Right to Water": This is based on the fact that the "right to water" (in terms of sufficient quantity and quality) is directly and strongly linked to the rights to freedom, health, adequate housing, education, equality, and the benefiting from natural resources, including water resources, in particular. Articles 11 and 12 of the International Covenant on Economic, Social and Cultural Rights state that, "The human right to water entitles to sufficient, safe, acceptable, physically acceptable and affordable water for personal and domestic uses" (UN 2002). Therefore, the damages resulting from water shortages, which are accompanied by the severe effects of the policies and practices of the Israeli occupation, are based on the unfair division and unequal use of water resources between the Israelis and Palestinians in Historic Palestine and, particularly, in the Occupied Palestinian Territories. Accordingly, the unjust distribution of water resources between the occupying power (Israel, in this case) and the people under occupation (the Palestinian people) is a paramount violation of international law and treaties (UNHROHC 2019).

2.4.2. Use of transboundary (shared) international water resources

Under international law, the main principle of the division of transboundary (shared) water resources between riparian parties is the principle of "fair and reasonable utilization" (WWF 2013; Salman 2021). This principle is based on the "doctrine of limited sovereignty" (UN WCC 2022), which states, "Because all parts of a watershed drainage basin are hydrologically interconnected, riparian states are not allowed to use the waters in their territories [or the territories they occupy, as in the case of Israel] as they wish, but must take into account other riparian states that share the respective resources." This principle does not provide a precise formula specifying the rights of each riparian state to share an international watercourse. Instead, it lists the factors that must be considered when negotiations take place between the riparian states (parties) to determine the division of water. Article 6 of the United Nations' Convention on the Law of the Non-Navigational Uses of International Watercourses demonstrates the following factors (UN 2014):

- The natural features (geographical, geological, climatic, hydrological, hydrogeological, and the like) of the watercourses shared by the riparian parties.
- The social and economic needs of the shared watercourses between the riparian parties.
- The dependence of the population on the watercourses for each party involved.
- Effects of the use of the watercourses by a riparian party on the other riparian party (parties) using the same watercourses.

■ Current and potential uses of the watercourses for all riparian parties.
■ Preserving, protecting, and developing the water resources of watercourses and the costs of actions taken in this regard.
■ Availability of alternatives for a particular planned or existing use of the watercourses or water resources.

Taking into account the elements of the principle of "equitable and reasonable utilization of the United Nations", an examination of the current division of water supply between Israel and the Palestinian people in the OPT leads to the conclusion that the current illegal division of water severely and profoundly violates the basic human rights of the Palestinian people regarding the fair shares in their legitimate water resources, as it contradicts international law with regard to water resources.

2.5. Potential Solutions to the Israeli-Palestinian Water Conflict

Al-Shalalfeh et al. (2018) discussed what role the international community can play in support of Palestinian water sovereignty, with respect to the 6th United Nations Sustainable Development Goal (UN SDG-6: Clean Water and Sanitation for All). They concluded that water policy in Israel and the Occupied Palestinian Territories is best understood as part of "settler colonial dynamics," in which ethnic cleansing is achieved through the dispossession of essential resources, namely and mainly "water resources." This aspect or paradigm (settler colonial dynamics aimed at the ethnic cleansing of Palestine) has been also indicated, used, and confirmed by many scholars and researchers, including, for instance, Pappe (2007); Da'Na (2013); Salem (2019a); Abu Akleh (2020); Salem (2020a); Braverman (2021); Mulligan (2021); Ben White (2022); and Yacobi and Milner (2022).

2.5.1. Factors to be considered for water allocation between conflicting parties – the Palestinians and Israelis: The decision to allocate water between the Palestinians and Israelis and the right of the Palestinians to their water resources must be subject to the "principles of international law," based on equality, equity, and justice. Equality means that each of the conflicting parties is given the same resources and opportunities regarding water resources. Equity recognizes that every party has different circumstances, but allocates the exact resources and opportunities needed to reach equal outcomes. Justice means the quality of being just, righteousness, equitableness, and moral rightness. In view of these definitions of the three aspects or humanistic values (equality, equity, and justice), principles of international law outline the factors to be taken into account when resolving riparian's water conflict.

These factors, in relation to each of the relevant surface and underground water bodies (seas, rivers, lakes, springs, systems, sub-systems, man-made water constructions such as dams and canals, etc.), using the term "water basin" for each of them, can be summarized as given below. The water basins in the entire conflict region investigated include the Jordan River System (JRS – including Lake Tiberias), the Dead Sea Basin, the Coastal Aquifer System, and the Mountain Aquifer System (MAS) and its sub-systems mentioned above (WAS, NEAS, EAS) (Figure 1; above), as well as the many water springs existing in various regions of the occupied West Bank.

- Geography of the water basin, including, in particular, its extent of water drainage and flow areas (Giordano et al. 2002; Al-Haq 2013a; USGS 2019; Salem et al. 2022). The use of the term of geographical basin is not intended to make any judgments regarding the legal or other status of any water basin in the region. The process of water allocation can involve the allocation of water at a variety of administrative and geographic levels, including the national or regional level.
- Hydrology and hydrogeology of the water basin, including, in particular, the basin's contribution of water and its catchment area (Speed et al. 2013; Salem et al. 2022). The water allocation process should be supported by detailed hydrological and economic assessment procedures of the water basin. This includes a modular exercise that looks at efficiency levels across different sectors (domestic, agricultural, industrial) and considers the potential effects of any downsizing of the basin's water. This should also be enhanced by a comprehensive hydrological modeling process aimed at determining the total water available for the allocation assignment. It also requires new planning techniques and new sets of hydrology and engineering skills for hydrological and hydrogeological assessments of the basin. Additionally, hydrological variability both in seasons and between years, which pose different challenges, should also be considered and assessed.

- Climate change impacts on the basin's water, such as higher temperatures, less precipitation, more water scarcity, etc. (UNECE and INBO 2015; Sarsour and Nagabhatla 2022). The water allocation process should take into account the impacts of climate change on the short, intermediate, and long runs. This requires modeling of several climatic factors that result in climate change and its impacts, such as variations in temperatures, rates of precipitation and evaporation, etc. These are good indicators to understand the nature and frequency of extreme events and natural disasters resulting from climate change, such as droughts and floods. This also requires setting different scenarios related to changes/ fluctuations in water prices, food productivity, hunger rates, migration, illnesses resulting from the climate change impacts on water resources, etc. Such conditions should contribute to raising concerns about the need to develop more flexible allocation practices and the ability to better respond to scarcity of a basin's water supply during extreme events resulting from climate change. Also, reduced water amounts, due to the effects of climate change, can deteriorate the well-being of children, in particular, and families in general (Naylor 2021; UNICEF 2021).
- Overexploitation and environmental degradation of a water basin (Salem 2009; Salem 2011a; Speed et al. 2013; Schwind 2019; Salem et al. 2022). One of the objectives of formulating a water allocation scheme is to reverse the environmental degradation of water basins. Concrete actions are needed to achieve this goal, including reducing the overexploitation of surface water and groundwater and gradually restoring their levels in the basins concerned.

- Water exploitation in the past and the present from a water basin (Angelakis et al. 2021; Zhang et al. 2022). Such disputes over the exploitation of water from a particular basin or basins must take into account the past and present use of water. Accordingly, when allocating water from a specific basin to the conflicting parties, the history of the basin's utilization should be understood and, thus, substantially taken into consideration.
- Basin's water economic and social needs by the people who benefit from the waters of that basin (Minoia and Camuffo 2006; Speed et al. 2013; USAID 2014; Mehrparvar et al. 2015; Rezaee et al. 2021; Dong et al. 2022; Salem et al. 2022). When allocating basin's water between the conflicting parties, more detail should be given to the socioeconomic component or factor. Thus, socioeconomic assessments are used to guide allocation decisions. Therefore, greater concern for use efficiency in determining water requirements for different sectors and users, as well as environmental flow assessments related to the socioeconomic component, should be a central issue of the water allocation process. This should also be with the consideration of sustainable development, regarding the socioeconomic sectors.
- Physical characteristics of the basin and population dependency on its water (Kasymov 2011; Speed et al. 2013; Gorgoglione et al. 2019; Salem et al. 2022). In so far as the basin's water must be allocated proportionally amongst competing users taking into account the above-mentioned factors, the allocation of water must also take into account other important facts. These include the physical characteristics of the basin (size, runoff, water quality and quantity, etc.), along with the populations

living in or dependent on the basin's water. Residents must be assured that the process of water allocation ensures that they have a permanent supply of water on a regular basis for their domestic, agricultural, and industrial uses, as well as for the development of land tenure.

- Comparison of costs for alternative means to meet the economic and social needs of the basin's water (Berbel et al. 2018). As water basins have come under increasing pressures, with limited potential for future resources' development and increased economic costs from poor allocation practices, greater emphasis has been given to economic and water-use-efficiency assessments regarding water basins. In the context of limited water resources and rapid economic growth and development, as well as population growth and climate change impacts, scientists and policy-makers place greater emphasis on mechanisms for assessing and integrating current and future development scenarios into the planning of water allocation and cost reduction, while preserving the welfare of the peoples and in-dispute water basins.
- Availability of water resources other than the water of a specific basin (UNECE 2021; Salem et al. 2021; Salem et al. 2022). Conflicting parties over water basins should potentially take into account other sources of water other than the disputed water basin or basins. Climate change and unexpected natural disasters, as well as political instabilities, locally, regionally, and globally, provide a further reason for maintaining a contingency to provide a buffer against the reduction of water's availability. For example, the Russian-Ukrainian war, which has continued since February 2022, has affected the water resources of

the conflict zone. This means that if the war is to be prolonged, which may result in shortage and/or contamination of water resources, the population should accordingly think about the availability of water from other resources (see, for instance, Gleick 2022; Pereira et al. 2022).

- Health and education risks resulting from allocation of basin water (Levy and Sidel 2011; OECD 2016). As a matter of fact, the limited existing amounts of water, due to unbalanced and unfair processes of water allocation between conflicting parties, may result in the deterioration of the health and education sectors of the affected populations.
- Avoidance of unnecessary waste in the use of the basin's water (Ashton 2002; Cosens 2003; Cosgrove 2003; ESCWA 2003; Cosgrove and Loucks 2015). Overuse of a contested basin's water is like putting salt on a wound, and is no less harmful than polluting the water of that basin.
- Practical compensability for one or more of the uses of the basin's water, as a means of settling disputes or more complicated conflicts amongst all users of the basin's water (UN News 2016; ECDPM 2019; GWP 2021). In the event that the water of a disputed basin cannot be balanced between the conflicting parties, the people, territory, or sector (which has not been given adequate amounts of water) must be compensated by having a greater share of any surplus water available at a later time.

According to Sarsour and Nagabhatla (2022), "Shared water agreements are affected by geopolitics, segregation, water availability, and access rights." However, the above-mentioned-factors demonstrate the degree to which it can meet the needs of all the conflicting users of the waters of the basins in dispute (such as seas, rivers, lakes, aquifer systems, aquifer subsystems, springs, artificial dams and canals, etc.), without causing significant harm to any of the users.

Given this list of relevant factors, it is not surprising that each riparian party is able to invoke principles that support its perceptions of “legitimate national rights” (Niehuss 2004; EWASH and Al-Haq 2011; HRC 2021). However, rights over certain water resources or basins cannot be legitimately based on relevant individual factors. The relevant factors must be viewed as a whole, and the rights of the disputing parties must be interpreted not in absolute but relative terms with respect to the applicability of the relevant factors to the different parties involved, based on their approval.

2.5.2. Water rights of the Palestinian people: In light of the above, the water rights of the Palestinian people in the Occupied Palestinian Territories can be summarized as follows:

1. The Mountain Aquifer System (MAS): As indicated by the United Nation’s Human Rights Council (HRC 2021), Palestinians should obtain their full rights to all of the West Bank’s Mountain Aquifer System (MAS) and its three subsystems (Western Aquifer Subsystem (WAS), North-eastern (Northern) Aquifer Subsystem (NEAS), and Eastern Aquifer Subsystem (EAS)). This is simply due to the fact that the three subsystems of the mother aquifer system are recharged, almost entirely,

from the territories of the occupied West Bank, and are largely located underneath the occupied West Bank (Figure 1; above).

2. The Jordan River System (JRS): Full rights to the waters of the Jordan River System must be clearly and immediately addressed in any negotiations over the river's water. As a downstream riparian nation to JRS, the Palestinian people are legally entitled to enjoy their indisputable and unquestionable legal rights to the JRS' water (Corradin 2016; Rudolph and Kurian 2022).

3. The West Ghor Canal (WGC): This is according to the 1955-Johnston Plan (ECF 2014; JVL 2022b), calling, amongst other things, for the construction of the WGC, to supply the West Bank with 120 MCM annually to meet the needs of the Palestinian people. While the WGC's plan has never been implemented unilaterally, as a result of the geopolitical conflict in the region, Palestinian water rights in JRS must remain as strong as ever.

4. Lake Tiberias (Sea of Galilee): Full water and fishing rights in this lake must be clearly addressed (HBS 2014). Based on the fact that Lake Tiberias is a natural reservoir in the conflict zone, and because the lake is an integral part of the JRS, the Palestinian people are legally a riparian party of the JRS, with the privilege of proper use of all the JRS' available resources, including Lake Tiberias' water and fishing rights.

5. Palestinians should have their full rights in the shores and waters of the Dead Sea Basin (DSB) for the purposes of tourism and industry, as well as scientific research. As a matter of fact, the Palestinian people have been excluded from benefiting from the DSB, given the fact that the north-western part of the shores of the DSB is geographically and

politically located in the south-eastern side of the occupied West Bank (Figure 1; above) (Salem 2009; Salem 2019b; Salem 2020b). This is with the consideration that Israel has been exercising, since June 1967, total control over the western side of the DSB (Abu-Baker and Farah 2020), while Jordan controls the eastern side.

6. Use of the waters produced by all the West Bank's springs, should be based on health, distribution, and climatic regulations and considerations, as well as equality, equity, and justice (Wikipedia 2022b).

7. Allowing Palestinians to build reservoirs (dams) in the occupied West Bank to harvest runoffs from winter floods and rainfall, without any restrictions from the Israeli occupation authorities. This is based on the fact that the Israeli occupation authorities have demolished Palestinian dams and pools built in the occupied West Bank to collect water used for agriculture (WAFA 2021; Billy 2022).

8. Allowing Palestinians to build wastewater treatment plants in the OPT (West Bank and Gaza Strip) and freely reuse, without Israeli restrictions, the treated wastewater for agricultural and industrial purposes, etc. (Salem et al. 2021; Giacomelli et al. 2022).

9. Compensation: Paying full compensation on the damages caused by Israel to the Palestinian water resources, which have resulted from the Israeli occupation's policies and activities in the Occupied Palestinian Territories over the past 55 years (i.e., since June 1967) and which continue to this day (Dajani 2014; Salem et al. 2021).

10. Reimbursement: Full reimbursement of all stolen Palestinian waters in the occupied West Bank and the besieged Gaza Strip, which

(the waters) have been illegally used by Israel and its approximately 0.7 million Jewish settlers who are illegally living in the occupied West Bank (including East Jerusalem) and, thus, violating international law (Qumsieh 1998; Nieuwhof 2013; B'Tselem 2019; EU 2022).

11. Full compensation for the massive damages caused to the water springs, surface water bodies, and underground water systems in the Occupied Palestinian Territories (Trottier 2019; NGOM 2021) and the massive "theft" of Palestinian water resources, as expressed by Rabi (2014) and Al-Qudwa (2021). Those massive damages have resulted from the brutal construction of the Israeli Apartheid Segregation Wall (Trottier 2007; Abdallah and Swaileh 2011; Salem 2011a; Ajarma et al. 2019; Trottier 2019) and the hundreds of illegal Jewish settlements established on Palestinian lands. It is important to note that all Israeli settlements, along with the Israeli Apartheid Wall, must be dismantled, as they represent blatant violations of international law, the norms and principles of human rights, and the Fourth Geneva Convention (UN 2002; HRW 2021; OCHA 2021b; UNHROHC 2022). A report issued very recently by the United Nations Human Rights Commission states, "Actions by Israel constituting de facto annexation include expropriating land and natural resources, establishing settlements and outposts, maintaining a restrictive and discriminatory planning and building regime for Palestinians and extending Israeli law extraterritorially to Israeli settlers in the West Bank" (Berman 2022). The UN report also "accuses Israel of discriminatory policies against Arab citizens, of stealing natural resources, and of gender-based violence against Palestinian women" (Berman 2022). From this standpoint, Palestinian women have

suffered greatly, especially in rural areas, in relation to water resources and agricultural activities (Salem 2019c).

12. For the Palestinian citizens in the Gaza Strip (about 2.2 million), who are facing acute water crises (Salem 2011b; Fanack 2015b; Abu-alnaeem et al. 2018; Kubovich 2018; EL-Sheikh and Bateh 2020; Seyam et al. 2020; EMM 2021; Elburai et al. 2022), immediate solutions must be implemented, in addition to the following: i) Allowing Gazans to obtain more water from Israel; and ii) Regulating and minimizing their extraction from the Coastal Aquifer System (CAS) underneath the Gaza Strip (Figure 1; above), which is the only source of water for the Gazans (Salem and Isaac 2007; Hilles et al. 2010; Ghabayen et al. 2013; Zaineldeen et al. 2014), for the sake of CAS' long-term sustainability. However, immediate solutions may include the establishment of several wastewater treatment plants throughout the Gaza Strip, as well as the establishment of seawater desalination plants on the coasts of the Mediterranean Sea (Weibel and Elmughanni 2014; EL-Sheikh and Bateh 2020; Salem et al. 2021).

3. Outlook of the Israeli–Palestinian Water Conflict

Negotiations over the allocation of water, based on the rights of the Palestinian people to their water resources, must be conducted with due-regard for justice, equity, equality, population growth, and climate change impacts, as already mentioned above. Negotiations on water should not rely on force or dictation by the powerful party, but with due-regard for legitimate and equal participation and distribution rather than deprivation, denial, control, hegemony, domination, discrimination, apartheid, colonization, and militarization (UN 1980; Abdalla 2013; Zeitoun et al. 2013; B'Tselem (2014; Rabi 2014; WCC 2016; Al-Shalalfeh et al. 2018; EJA 2019; Al-Haq 2020; Selby 2020; Billy 2022; Giacomelli et al. 2022; Gupta 2022; Rudolph and Kurian 2022; Salem et al. 2021; Sarsour and Nagabhatla 2022). Thus, independent arbitration, with respect to water resources in Historic Palestine, should be a necessity.

Many of the world's transboundary water resources (surface and underground) are shared fairly, equitably, and without problems. Thus, the water resources in Historic Palestine should not be an exception. The management of water resources amongst the riparian parties (Israelis and Palestinians) in Historic Palestine must be integrated and must include the respective parties without distinction. This is with the consideration, based on historic facts, that the Palestinian people are the legitimate owners of the land, its water resources, and other natural resources. Management should not only include the allocation of water quantities, but more importantly, it should also include the protection and efficient uses of water resources, qualitatively, quantitatively, environmentally, and sustainably.

The world is gradually moving from water sovereignty to water solidarity (Salem et al. 2022). According to Gupta (2022): "Sharing and Solidarity Mode: Another option is hegemonic power, where states say: 'we are not going to share water with our neighboring states'. We then move back to absolute territorial sovereignty or full permanent sovereignty.

States also ‘securitize’ water, where water becomes a very political issue because of its existential risks to the state. Then they don’t want to share water or even water data with each other.”

As long as Israel denies the Palestinian people their rights in their own water resources in the Jordan River System (JRS) and the West Bank’s Mountain Aquifer System (MAS) and its subsystems (WAS, NEAS, and EAS), the Dead Sea Basin, and the water springs in the occupied West Bank, the Palestinian people need to remain firm regarding their water sovereignty and solidarity (Reliefweb 2003; Al-Haq 2011; EWASH and Al-Haq 2011; Van R 2012; Abdalla 2013; Amnesty International 2017; Nebehay 2019; Al-Haq 2021; B’Tselem 2021; Salem et al. 2021; WAFA 2022).

As the conflicting parties in Historic Palestine had finally negotiated, during the 1990s and 2000s, regarding a permanent and sustainable political solution, the issue of water is more pressing than ever, especially in the presence of the impacts of climate change and population growth, which increase demand on water and food. The resolution of the Israeli–Palestinian water conflict, as part of the conflict on the land of Palestine and appropriations (including water sovereignty as a priority), should be based on justice, equity, equitability, and principles of international law, as frequently indicated in this study, with the support of a wide range of published works by Palestinian, Israeli, and international organizations, policy-makers, and academicians. However, there is no way to institutionalize this issue under the current circumstances, as Israel believes that "might makes it right" (Ahmed 2020; Motala 2021). Thus, Israel, with might, can continue its control over the water resources in Historic Palestine, as much as it is currently controlling, illegally and forcefully, the land and its indigenous population – the Palestinian people, by using military power.

As recently published by the Euro-Med Human Rights Monitor, "Israel killed five times as many Palestinians in 2022 than it killed in the same period in 2021" (EMHRM 2022). It is noteworthy to mention that this Euro-Med report was issued in April 2022. However, seven months later (as in November 2022), the number of the Palestinians killed by the Israeli occupation army is much greater than that reported in April 2022 by the Euro-Med Human Rights Monitor. More recently, Berger (2022) reported that, "2022 was deadliest year for West Bank Palestinians in nearly two decades." In view of this, Israel must change its attitude towards the Palestinian people regarding their humanity and dignity, as well as their land and water resources, which should be based on justice, equity, equality, and international law.

While the question of control of the region's waters is fundamentally related to different points of view, including the "legitimate rights" (hydro-legitimacy) of the conflicting parties, the Palestinian people, as a primary party to the water conflict, have been deprived through many decades of their rights to their legal water resources. However, although each party invokes a variety of legal principles to substantiate its claims, these principles for the Palestinian people must include, amongst other things, first-in-time first-in-right (Fery 2013). This is the "priority of water right," which determines who gets water first in times of shortage, based on sovereignty, justice, equity, and equality, regarding the distribution and allocation of water resources in Historic Palestine.

In making claims, each party involved is merely selective and able to choose the legal principles that reinforce its claims. However, since the ultimate goal is to achieve a just and sustainable peace in the region, a political settlement must include agreement on the equitable distribution and equitable utilization of the region's waters, in terms of hydro-allotment (hydro-allocation) and the institutions and structures that ensure sustainable use of the scarce water resources in the region.

It is argued, however, that the equitable use and balanced joint management of water resources between the Palestinians and Israelis can provide a just and sustainable basis for resolving the Palestinian–Israeli water conflict. The method of allocating, distributing, and managing the water resources in the region (hydro-allocation), which has been applied in practice over the past decades (i.e., since the Israeli occupation of the Palestinian Territories in June 1967 to the present), has created a feeling of injustice and anger amongst the Palestinians in the Occupied Palestinian Territories. Certainly, this injustice cannot and should not continue forever. A comprehensive and sustainable peace should be based on justice, equity, and equality (hydro-equality), as well as with reference to international law. The two parties (Palestinians and Israelis) agreed on the principle of "equitable use" of water resources (Parks 2013). However, the definition of this expression "equity and equality" must be agreed upon. The expression "equity and equality" is proposed here as a simple and straightforward interpretation of the expression "fair utilization and allocation of water resources" between the Israelis and the Palestinians.

The current population of the two peoples (Palestinians and Israelis) in Historic Palestine is around 15.1 million. This includes about 5.4 Palestinian citizens in the West Bank (including East Jerusalem) and the Gaza Strip (Worldometer 2023), and about 9.7 million Israeli citizens (JVL 2022c). The population of 9.7 million within Israel includes about 7.1 million Jews (constituting 73.6% of the Israeli total population) and about 2.6 million Palestinian Arabs. In 2050, the population of both peoples in Historic Palestine is estimated to reach between 22 million and 29 million (JVL 2001; Chenoweth and Wehrmeyer 2006), where the Palestinian population will outnumber the Jewish population, which has already happened (Salem 2020a). This is if conditions and circumstances persist without extreme events, such as regional and/or global instabilities, wars, and natural disasters that may result in massive migration movements.

For domestic purposes, Israel consumes approximately 2,000 MCM/yr and the Palestinians consume 376 MCM/yr of renewable water resources (Hass 2008; Al-Haq 2013b; Worldometer 2017; PCBS 2019b; PCBS 2022). Despite the fact that these references have been made over a period of about 14 years, they agree, more or less, about the same amounts of renewable water consumed by both peoples (Palestinians and Israelis). It is possible that the Israeli consumption of renewable water for domestic uses has not changed dramatically, because Israel relies heavily on non-conventional waters obtained from seawater desalination and wastewater treatment processes for its agricultural and industrial uses (Kaplan-Zantopp 2022). This can also be explained by the fact that Israel does not publish real figures on water, because water is considered by the Israeli government as a strategic asset, as mentioned earlier (Stork 1983; UCLA 2017; HRW 2021). By 2050, Israel is speculated to consume around 3,000 MCM/yr for all sectors (domestic, agricultural, and industrial) (Rajwan 2011).

The distribution of water between the two peoples (Palestinians and Israelis) must be shared equally (hydro-equality) and, therefore, the water rights between them should be based on the population of each of the two peoples (hydro-demography). This means that the annual renewable amount of water, which is around 2,265 MCM that is currently available in Historic Palestine (2,000 MCM/yr shared by Israel and 265 MCM/yr shared by the Palestinians in the OPT) (Worldometer 2017; PCBS 2019b) should be equitably shared. This would result in the Palestinian people (about 5.4 million in the OPT, as of January 2023, according to Worldometer 2023) obtaining around 810 MCM, instead of the 265 MCM currently allocated to them annually, which is the renewable water pumped from Palestinian wells (PCBS 2019b). On the other hand, the Israeli population (about 9.7 million, as of December 2022, according to JVL 2022c, as indicated above) should receive about 1,455 MCM/yr, instead of the 2,000 MCM/yr that they currently obtain. The annual per capita consumption of the Palestinians and Israelis (with a joint population of 15.1 million, as indicated above) should be around 150 m^3/yr (i.e., 2,265 MCM of water divided by 15.1 million population), instead of 88 m^3/yr (PCBS 2019b) and 214 m^3/yr (Worldometer 2017), which are currently consumed by the Palestinians and Israelis, respectively.

Furthermore, a joint International-Palestinian-Israeli management structure should be agreed upon to address monitoring and quota compliance, and to ensure the protection of all water resources in this volatile region of the world. This management structure should also address periodic reallocations, based on climatic and demographic changes, political instabilities, natural and anthropogenic disasters, and other changes and challenges that may occur. This management approach has the following advantages:

- It is based on the values of equality, equity, and justice, with reference to international law, which are essential elements for sustaining peace and stability in the region.
- It provides a quick and simple way to resolve the water rights' issue that, otherwise, would prolong or obstruct final status negotiations.
- It presents an integrated water management scheme that will certainly be of great value to resolving the water conflict between the

Palestinians and Israelis in Historic Palestine, towards reaching lasting peace between both peoples, based on justice, equity, equality, and international law, as frequently mentioned and emphasized above.

- It demonstrates whether Israel is sincere in its peaceful aspirations or not.
- It clarifies that negotiations based on justice are the ultimate means of resolving conflicts. This indicates that the approximately thirty years (i.e., since the signing of the Oslo Accords in 1993 and 1995) without reaching peace were waste of time for the Palestinians. This is due to the fact that Palestinian negotiations with the Israelis were based on Israel's might rather than justice, rightness, respect of human rights, and international law.
- It allows effective use of existing water systems and water inter-regional transportation systems amongst districts within Historic Palestine.
- It deals with important issues, such as demographic growth, sustainable development, and climate change.
- It provides an essential tool for environmental protection of water resources, biodiversity, ecosystems, etc., while taking the climate change impacts that affect the region into consideration.
- It stimulates cooperation between the Palestinians under occupation and the Israeli occupiers – at least with regard to water issues – as well as regional and international cooperation regarding the water sector, and last but not least,
- It is likely that water circulation will be allowed amongst provinces, regions, and countries.

It is important to emphasize that this approach can possibly be reached if the goodwill of both peoples – Israeli and Palestinian – is present.

The Oslo II–1995 Accord called for the creation of the Israeli–Palestinian Joint Water Committee (JWC), but since then joint-efforts have had limited success (Schwind 2019). The JWC is a joint Israeli–Palestinian authority, created with the purpose of managing water and sewage infrastructure in the West Bank, particularly in taking decisions on maintenance of existing infrastructure and approval of new projects (TUE 1995). However, effective cooperation between Israelis and Palestinians on water issues is unlikely in the foreseeable future if the two parties insist on a business-as-usual approach (Dai 2021). What hinders the parties from reaching a consensual agreement are political tensions, current technological limitations, differing perceptions of the value of shared waters, mistrust between the two peoples and their leaderships, lack of external enforcement mechanisms, and domestic effects on the political environment.

In her Master Thesis carried out at the Massachusetts Institute of Technology (MIT), Schwind (2019) presented five guiding points on how best to restructure the Israeli-Palestinian JWC. These points are: 1) JWC needs to adopt a long-term perspective and allow itself to evolve over time, rather than expecting to create a committee with a fixed structure and framework. In doing so, JWC should establish agreed-dispute resolutions' mechanisms and joint fact-finding mechanisms, to ensure equal power dynamics between the two parties; 2) A greater role in technical decision-making should be given to JWC; 3) JWC must shift from a confidentiality-based model to a transparency-based model, to become more transparent as the Palestinians and Israelis as well as outsiders (the public, concerned governments, the international community, etc.) begin to build greater confidence in the ability of JWC to bring about positive and tangible changes; 4) JWC should seek international support to financially assist in the implementation of joint projects identified by the JWC's technical subcommittees; and 5) JWC should reframe water in terms of "water security" rather than "national security". In this case, the restructured JWC between Israelis and Palestinians can help facilitate cooperation for the discussion and implementation of joint water projects and research, and rebuild trust amongst water negotiators and experts on both sides.

While it cannot be said with certainty that water will be an immediate step towards comprehensive peace in the region, it is a worthwhile first step. As such, Israelis and Palestinians must work together to achieve water security mutually, build trust along the way, and prove or demonstrate that both sides can work together to provide their peoples with the water they need, without compromising each side's most important interests.

4. Conclusion

After more than 30 years of meetings and negotiations (since the Madrid Conference in 1991, Madrid, Spain), the gap in positions on water, as well as other issues (like Jerusalem, Palestinian refugees, borders, and so forth) between Palestinians and Israelis remains as wide as ever. This is because Israel has the upper hand as the occupying power, with the continuing support of the US administration. Accordingly, the region's politicians, strategists, planners, decision-makers, research scientists, and academicians are still speaking and will continue to speak in different tones and at different wavelengths, bearing in mind that the loudest and most effective voice is the Israeli voice.

A common understanding of the Israeli–Palestinian conflict over water, if resolved, will go a long way in enhancing the prospects for development, economic growth, stability, prosperity, and sustainability. Conversely, failure to reach this common ground will certainly hamper any efforts to achieve this goal and, thus, will lead to the deterioration of any deals towards peace-making in the region. Therefore, there is no substitute for frank and honest discussion about water issues to reach concrete outcomes within a certain and specific period of time. This kind of discussion should reveal the current unsustainable reality of inequality, mismanagement, and total denial of the inalienable rights of the Palestinian people to all of their water resources, including surface water and groundwater resources.

This indicates that the occupying power (Israel) has been considerably draining the Palestinian water resources in the Occupied Palestinian Territories, in particular, and in the region, in general. This has led to a decrease in the Palestinian people's share of water for domestic, agricultural, and industrial usages. Current water allocations are the result of compliant arrangements that reflect the balance of power rather than international law and internationally drafted conventions and formulated agreements.

This study aims to provide practical and viable solutions to the water conflict between the Israelis and Palestinians in Historic Palestine, on the basis of justice, equity, equality, demographics of both sides, and international law, while taking into account core issues, such as territorial conflict, demographic growth, history, geography, topography, climate change impacts related to water resources, and other factors as well, regarding hydro-history and hydro-politics (history and politics of the water conflict), hydro-allocation (water appropriations), and hydro-legitimacy (water legality), in order to reach balanced and just hydro-solutions (water solutions).

As a final note, it is worth-mentioning that the author has found some inconsistencies in the available data regarding the water resources in Historic Palestine. This is probably due to the fact that, though scarce, most of the information and data available regarding water issues, such as field and laboratory measurements, raw data, computer analyses, and simulation modeling, as well as other related matters are mostly produced by Israelis. As for the Palestinian side, in most cases Palestinians are recipients rather than producers or generators of water data and information, because they have no control on water resources in Historic Palestine, including the Occupied Palestinian Territories (OPT). More importantly, for Israel the water resources are strategic assets. Therefore, any data and information relevant to water issues in Historic Palestine (Israel and the OPT) are strictly considered by Israel as "highly confidential," especially if the data are raw. Accordingly, such data and information are not permissible to be made available for public or to be published. However, some data and information, regarding water issues, are probably available in Hebrew for Israelis.

In conclusion, resolving the water conflict between the Palestinians and Israelis, as shown in this research work, is of paramount importance, because this work introduces an integrated water management scheme which, if adopted by the conflicting parties with the assistance of international organizations, would help resolve the water conflict between the two parties involved. Finally, it should be known that quantitative and qualitative amounts of water are necessary for survival and are not just a luxury, as water is a basic human right for human dignity and continued survival, as well as for societies' sustainability and prosperity. According to UN Committee on Economic, Social and Cultural Rights, General Comment No. 15, Paragraph 1, "The human right to water is indispensable for a dignified life" (OHCHR 2003).

5. Recommendations

The following brief suggested solutions are recommended:

- The decision to allocate water between the riparian parties – the Palestinians and Israelis – and the right of the Palestinians to their water resources must be subject to the "principles of international law." Under international law, the main principles of the division of transboundary (shared) water resources are the "principle of fair and reasonable use" and the "principle of limited sovereignty", whereas equality, equity, justice, population, and climate change impacts should be considered. The right of the Palestinian people to their water resources should include their rights to renewable surface water and groundwater resources, which should include the following: The Jordan River System; Lake Tiberias (Sea of Galilee); Dead Sea Basin; the Mountain Aquifer System and its subsystems (Western, North-eastern, and Eastern); water springs, and dams to be built in the Occupied Palestinian Territories (OPT) without restrictions from the Israeli occupiers.
- The Palestinian people in the OPT, with a population of about 5.4 million (as of January 2023), should receive about 810 million cubic meters/year (MCM/yr), instead of the 265 MCM/yr allotted to them annually. On the other hand, the Israelis, with a population of about 9.7 million, should receive about 1,455 MCM/yr, instead of the 2,000 MCM/yr they are currently consuming. The annual per capita consumption of Palestinians and Israelis (with a total population of approximately 15.1 million) should be around 150 m^3/yr, instead of the 88 m^3/yr and 214 m^3/yr, which are presently consumed by Palestinians and Israelis, respectively.

- An international-Palestinian-Israeli joint management structure must be agreed upon to be used as an instrument to address monitoring and compliance with quotas, and to ensure the protection and sustainable development of all water resources in Historic Palestine. This management structure must also address periodic reallocations, based on climatic and demographic changes, political instabilities, and other changes and challenges that may occur anytime all the time. This management approach has many advantages, which mainly include: 1) It is based on the values of equality, equity, and justice, with reference to international law, as they are essential elements for sustainable peace and stability in the region; 2) It deals with issues of demographic growth, sustainable development, and the impacts of climate change; and 3) It provides an essential tool for the environmental protection of water resources, biodiversity, and ecosystems.

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Chapter Five

Averting A Humanitarian Crisis Along the Euphrates and Tigris Rivers

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Abstract: Drought and increased upstream developments by Turkey are impacting the quality and quantity of water available in the Euphrates and Tigris rivers, challenging Iraq and Syria's ability to meet water, food, and energy security. Overexploitation, mismanagement, inefficient use, conflict, and variance in state capacity are also combining to further challenge state capacity to meet individual and national water, food, and energy security needs. These factors are contributing to the loss of livelihoods, poverty, malnutrition, hunger, and the spread of waterborne diseases, which are impacting millions of people across Syria and Iraq. As a consequence, people in these downstream states are resorting to unhealthy coping skills that include skipping meals, drinking contaminated water, and limiting nutritional intake. The region is confronting a humanitarian crisis, which is increasing risk for domestic and regional tension. The international donor community, environmental non-governmental organizations, and international organizations have an important function to perform in the short and long run in order to help address these challenges. In the short term they can: 1) assist in repairing and rebuilding hydrological infrastructure essential for the delivery of water supply and irrigation water along with the collection and treatment of wastewater; 2) fund the distribution of good quality seeds and the transfer of technology to improve the efficiency of water use in the agricultural sector; 3) install water quality and quantity monitoring along with measuring facilities along the Euphrates and Tigris Rivers; 4) construct joint projects between Turkey, Syria, and Iraq along these rivers that help to address water quality and quantity issues; 5) collect and distribute water quantity data to help states prepare for

upcoming droughts; 6) undertake training of technical expertise capable of carrying out environmental impact assessments, assess and share best farming practices, and awareness of current scientific standards in water resource management; 7) help to design and build effective water, agriculture, and environmental institutions with the capacity to adapt to climate change; and 8) mediate the establishment of a formal commission combining the three riparian states and the international donor community to help address immediate and short-term water issues in the basin and provide a mechanism for communicating early warnings in times of droughts or floods. In the long run, international actors can begin to lay the groundwork towards: 1) the negotiation of a multilateral agreement over the Euphrates and Tigris Rivers between the riparian states. Preliminary work can include collecting possible ideas on the content of effective treaties governing transboundary rivers, identifying negotiation points and proposing solutions, identifying issue linkages, and summarizing best practices in treaty design; 2) undertake preliminary studies about the effective design of river basin organizations that can help states implement treaties and facilitate the management of riparian disputes; 3) identify issue linkages that can be used in the long-run to help the riparian states to negotiate a treaty; and 4) once Syria and Iraq have stable governments the international donor community can help to mediate a multilateral treaty.

Introduction

The Euphrates and Tigris Rivers represent a vital source of water, food, and hydropower that helps to meet individual and national food security needs and contributes to the energy security of millions of people living in Turkey, Syria, and Iraq. Climate change, population growth, overexploitation, mismanagement, inefficiencies, conflict, war, and variance in state capacity among the riparian states are all challenging states' abilities to meet domestic needs for water in the agricultural, industrial, and municipal sectors. These factors are also combining to challenge the ability of the riparian states to cooperate over these rivers and share their water sustainably. A history of fragmented cooperation between Turkey, Syria, and Iraq has also contributed to unilateral and uncoordinated development of the rivers, which has resulted in negative impacts on the quality and quantity of waters flowing through the Euphrates and Tigris. Despite these challenges, many of which predate the current conflicts plaguing the riparian states and are likely to continue through the post-conflict reconstruction period, this chapter suggests that there are short-term and long-term opportunities to improve the domestic and basin-wide governance of the rivers. These opportunities are possible with the help of the international donor community, such as the European Union, United States, United Arab Emirates (UAE), and the World Bank. Environmental Non-governmental Organizations (NGOs) or intergovernmental organizations (IGOs) can also play an important role in facilitating analysis and providing guidance through the implementation of opportunities that can contribute to the sustainable and coordinated development of the rivers.

Prior to discussing the opportunities for improving governance of the rivers and helping riparian states meet human and national water security needs, the following sections present an overview of the history of sharing the Euphrates and Tigris along with current challenges confronting the basin.

Attempts to Govern the Rivers

The Euphrates and Tigris Rivers originate in Turkey's Southeastern Anatolia region and flow to Syria, and then combine to form Shat al-Arab in Iraq before emptying into the Persian Gulf. Snowmelt and precipitation in upstream Turkey provide the predominant contribution of water to the Euphrates River, while the Tigris is fed relatively equally by waters from Turkey and Iraq along with some tributaries originating in Iran. Throughout the rivers' course, they bring to life an otherwise arid and semi-arid region, and provide water to the agricultural, municipal, and industrial sectors.

Downstream Iraq was the first riparian state to develop the rivers by building hydrological infrastructure in 1914. Iraq is also the most dependent state on the rivers' waters, which meet some 61 percent of its domestic needs. The Euphrates River represents 72 percent of Syria's domestic water supplies (Mueller et al., 2021). In the 1970s, Syria undertook the construction of its first dam along the Euphrates River. As the Tigris crosses Syria on its way to Iraq, the typography is steep and rugged, which has thus far prevented the former state from fully developing the river's water.

Although it controls the headwaters of the rivers, Turkey waited until the mid-1960s to begin exploiting their hydropower and irrigation potential. During the 1980s, Turkey began to undertake implementation of its Southeastern Anatolia Project (Turkish acronym GAP), which is designed to build 22 dams, 19 hydroelectric power plants, and irrigate 1.8 million hectares of agricultural land along the Euphrates and Tigris Rivers. As of writing, Turkey has completed 92 percent of its planned dams along the Euphrates and Tigris Rivers and 54 percent of its planned irrigation projects (GAP Web Page, 2022). Due to the amount of hydrological infrastructure constructed along the Euphrates River, Turkey acquired the ability to significantly control the flow of water in the basin to not only prevent floods, but also withhold water from flowing downstream (Hockenos, 2019).

Fragmented Governance

As the riparian states' planning, development, and consumption of the Euphrates and Tigris Rivers increased, they began to undertake international negotiations. Historically, there has been a tendency to reach bilateral protocols, instead of multilateral or basin-wide agreements. In 1987, Turkey and Syria signed a Protocol on Economic Cooperation that covered security, water, and economic issues. The Protocol committed Turkey to release a yearly average of more than 500 m3/sec at the Turkish-Syrian border (Protocol on Economic Cooperation, 1987). During ministerial level meetings between Turkish and Syrian officials in 1992 and 1993, the 500 m3/sec commitment was reconfirmed. In 1990, Iraq and Syria signed an agreement fixing the allocation of the Euphrates River between them. According to this protocol, Syria keeps 42 percent of the water entering the country from Turkey, while Iraq receives the remaining 58 percent (Zawahri, 2006). Both protocols were relatively short and underdeveloped because they focused only on water quantity issues and disregarded water quality. The protocols also disregarded the impacts of climate change on water supplies and neglected to include mechanisms to monitor and resolve disputes or even compel compliance with the commitments. In 1998, Syria's expulsion of Abdullah Ocalan, leader of the Kurdistan Workers Party (PKK), led to an immediate improvement in relations with Turkey and the signing of the Adana Accords that covered bilateral water issues. In 2002, Syria and Iraq signed an agreement to install a pumping station along the Tigris within Syria, which specified the quantity of water withdrawn.

In 1946, Turkey and Iraq reached the Treaty of Friendship and Good Neighbourly Relations, which covered economic, security, water, and educational issues. In terms of the water portion of the treaty, the signatory states agreed to build hydrological infrastructure in Turkey along both rivers to prevent downstream flooding, build metering stations upstream to collect data to be shared with Iraq, and Turkey committed to share information about its upstream development plans (Treaty of Friendship and Good Neighbourly Relations, 1946).

Although the riparian states lack a multilateral agreement, they succeeded in establishing a water commission. The Joint Technical Committee (JTC) has its origins in the 1960s, when Turkey and Syria began construction of dams along the Euphrates River and the riparians needed to coordinate the filling of their reservoirs and exchange information to minimize downstream damage. Initially, meetings were bilateral, between Turkey and each of the downstream states, and sporadic. The first trilateral meeting occurred in 1965, followed by another trilateral meeting seven years later to reach an agreement on an impounding schedule for Turkey's Keban dam and the Tabqa dam in Syria. In 1980, the JTC was reconstituted initially bilaterally, but in 1983 Syria joined. Trilateral meetings continued until 1993 in attempts to meet several short-term objectives, such as exchanging hydrological and meteorological data, information on planned or completed hydrological infrastructure, information about impounding schedules for reservoirs, and joint tours of hydrological infrastructure. The JTC's long-term assignment was to negotiate an agreement on allocating the shared waters. After meeting 16 times, the committee ceased to exist. During its tenure, it succeeded to provide a forum for information exchange, but failed in meeting its long-term goal of reaching a treaty to allocate the shared water resources (Zawahri, 2006). The JTC's failure to meet its long-term goal can be attributed to its weak design and lack of authority to negotiate. Commissioners were highly dependent on higher ranking government officials for instructions, and they lacked the capacity to monitor the basin's development or resolve disputes that arose.

Between 2001 and 2021, Turkey reached memorandum of understandings (MOUs) with each of the downstream states. In 2001, Turkey and

Syria signed a Joint Communique stressing the importance of using basin water sustainably. In 2005, the Euphrates-Tigris Initiative for Cooperation (ETIC) was established as an informal channel to promote dialogue and collaboration between the riparians. Turkey then largely used High-Level Strategic Cooperation Council meetings, with each of its downstream riparian states, that combined several issues, which include economic, security, and water issues. In 2009, Turkey and Syria signed four MOUs covering their joint water resources (including joint dam construction, Syria building a water pumping station on the Tigris River, joint management of water quality, development of water policies, and agreement that water is a source of cooperation) (MOU, 2009). Turkey and Iraq also signed an MOU in 2009 that covered the sharing of hydrological data, harmonization of measurement facilities, and modernizing irrigation systems among other things (Kibaroglu and Scheumann, 2011). This MOU was updated in 2014 to include discussions to decide each riparian's share of water from the rivers (Shafaq News, 2021). This was followed by another MOU on water signed in 2021 that recognized Iraq's "fair and equitable quota" from the Euphrates and Tigris Rivers and discussed joint construction of projects (Iraqi News Agency, 2021). In 2019, Turkey and Iraq agreed to establish a water resources center in Baghdad for studying and evaluating regional water resources (Hurriyet Daily News, 2019). While the riparian states have signed several MOUs, the majority of the commitments remain unimplemented.

Challenges Confronting the Basin

The Euphrates and Tigris Rivers' riparian states confront several challenges in their attempt to coordinate and share the waters. While many of these problems are structural in nature, some arose more recently.

Climate change

Climate change is expected to aggravate the water crisis in the Euphrates and Tigris by increasing the temperature between 2 to 5 degrees Celsius (°C), decreasing precipitation between 8 to 10 mm, and increasing evaporation. All of this is expected to combine to decrease the flow of water in the rivers and increase the aridity in the region. Modeling of climate change in the Euphrates and Tigris indicate a 23.5 percent decrease in the Euphrates flow and a 28.5 percent decrease for the Tigris by the end of this century (Bozkurt and Sen, 2013). Models also indicate an increase in the frequency and duration of droughts, heatwaves, and dust storms, which are already heavily impacting the region. Due to its impact on rainfed and irrigated agriculture along with the forward and backward linkages associated with this sector, the World Bank estimates that climate change will decrease the GDP of Syria and Iraq by 9.8 and 3.9 percent respectively (Taheripour et al., 2020).

From 1970 through 2022, Syria and Iraq confronted a series of severe, prolonged droughts along with many mild to moderate droughts (Rateb et al., 2021). An analysis of precipitation data in Syria revealed that severe droughts have plagued the region every decade (Kelley et al., 2015). Droughts contribute to crop failure that can threaten food and water security of small-scale farmers. They also threaten the livelihood of pastoralists as they contribute to livestock loss. Droughts also increase desertification of grasslands and pastures along with depletion of water supplies available for animals in both Syria and Iraq. They also have significant negative impact on the livelihoods of rural communities through crop failures and livestock loss, resulting in waves of rural to urban migration. Nationally, droughts can substantially reduce states' available water supplies and compromise their ability to meet national food, water, and energy security needs. For Iraq, between 2008 and 2009, a prolonged drought destroyed about 40 percent of its farmland and threatened its ability to meet its food security needs (Giovanis and Ozdamar, 2021). The 2020-2022 drought in Syria contributed to consecutive years of crop failure, resulting in food insecurity, malnutrition, water insecurity, and an increase in poverty (Zawahri, 2022).

Climate change can be a threat multiplier in increasing the risks of domestic social turmoil as deprivation and poverty brought about by crop failure drive farmers to migrate from urban to rural areas in search of livelihoods. Especially when this migration wave is combined with pre-existing social tensions and inequalities along with ineffective governance of water resources and tense state-society relations, the likelihood of social turmoil increases significantly (Werrell and Femia, 2015). This likelihood is especially prevalent in conflict-torn or weak states, such as Syria and Iraq. In these states, people's capacity to buffer another wave of food, water, and energy insecurity is compromised by years of warfare that drained remaining social safety nets. The 2020-2022 drought impacted millions of people who were already confronting a financial crisis brought about by a 224 percent depreciation of the Syrian pound, soaring inflation that reached 114 percent, and the COVID pandemic (World Bank, 2022). It also occurred as the world was confronting increasing grain and energy prices brought about by the war in Ukraine. Poverty in Syria increased to 90 percent and 55 percent of the population faced food insecurity (UNICEF, 2022; World Food Program, 2022). People resorted to unhealthy coping mechanisms, such as skipping meals, eating less nutritious food, and reducing meal size. The lack of adaptative capacity to climate change will challenge the capacity and legitimacy of already fragile or weak Syrian and Iraqi political institutions.

Without a stable agreement to effectively share the rivers, climate change can also increase the potential for tension between the riparian states over the decrease in available water supplies. As Turkey increases its consumption of the rivers to meet its demand for water, the quantity of water available to the downstream riparian states is likely to continue to decrease (Hockenos, 2019). IGOs involved in Syria have revealed the substantial decrease in the Euphrates River's flow as it enters Syria and attribute this reduction to increased upstream consumption (OCHA, 2021). Such uncoordinated and unilateral development of the rivers can lead to tensions with downstream riparian states and inflict substantial economic along with political losses that can increase the potential for regional conflict. Thus, climate change can contribute to regional and domestic instability. To mitigate this potential and minimize the social, economic, and political losses that climate change can inflict on states, it is essential that they build up their resilience capacity to climate change.

State Capacity

Upstream Turkey is not only the most militarily powerful state along the Euphrates and Tigris Rivers, but is also the only politically stable state. Turkey is also well represented in the international community, and is the most capable riparian state at presenting its national interests in developing, managing, or sharing the rivers to the international donor community. Midstream Syria has been historically sandwiched between two more powerful riparian states and since 2011, has been a conflict-torn failed state. After 1992, downstream Iraq's government turned from a fragile to a failed state, and is currently a weak state. Both Syria and Iraq are too weak militarily and politically to balance Turkey's power within the basin or contest its interests in developing or using the water. Syria is also too weak to advocate for its national interest within the international community or compel Turkey to join basin-wide negotiations. Iraq's government is somewhat stronger in presenting its case to the international community, but it is certainly not strong enough to balance Turkey's interest. The deficit in governance capacity has complicated, and in the case of Syria prevented, policy coordination in developing the rivers. Consequently, there is tremendous variance in state capacity between the riparian states in the basin.

Institutional Deficit

Given the current governance deficit in Iraq and Syria, they confront substantial challenges in domestically managing their water resources. Prolonged internal conflict, fragmented control of the land, and years of sanction in Syria resulted in a brain drain of technicians and engineers capable of managing, maintaining, or repairing hydrological infrastructure. In fact, there is between 30 to 40 percent shortage in technicians and engineers needed to operate water facilities in Syria (OCHA Services, 2021). Decades of sanctions along with war in Iraq also resulted in a brain-drain of technicians and engineers with water resource management skills. Due to the brain-drain and the flight of technicians, for instance, there has been a deficit in the collection of hydrological data because some measurement stations have been unmanned, not maintained, or unrepaired. The lack of hydrological data complicates the ability to manage domestic water resources or to formulate policy in both Syria and Iraq.

Weak water governing institutions along with lack of technical capacity has also complicated the ability to not only effectively manage domestic water resources but also maintain, repair, modernize, or rebuild dilapidated hydrological infrastructure destroyed by years of conflict and neglect (OCHA, 2021). War and conflict in Syria and

Iraq have damaged and threatened the integrity of water supply systems, dams, barrages, canals, and wastewater treatment plants (Sowers et al., 2017). Some hydrological infrastructure incurred substantial direct damage by state and non-state actors (UNICEF, 2021; UNESCO, 2021). In 2012, wastewater treatment facilities in Damascus and Aleppo were directly targeted. As of 2022, they remain inoperative (OCHA, 2021). Of the seven drinking water systems in Syria, six were directly targeted during the war (OCHA, 2022). Warring parties have purposefully targeted hydrological infrastructure and used water resources as a weapon against adversaries and citizens during wars in both Syria and Iraq (Sowers et al., 2017; UNICEF, 2021).

Since the 2011 uprising and then civil war in Syria, control of the land surrounding the Euphrates and portions of the Tigris along with the hydrological infrastructure has been contested by both states and non-state actors. Due to its incursion into Syria, since 2019, Turkey has controlled Ras Al Ain along with the Alouk Water station. This water station provides water, directly or indirectly, to one million people in northeast Syria, a region under the control of the U.S. backed Syrian Defense Forces. Fragmented governance and disruption in electricity to the Alouk water stations has resulted in regular and prolonged disruption in its operation. Repairs to the water station require international mediation and diplomacy, which means severe water insecurity in this arid region of Syria which historically functioned as its breadbasket.

The Tabqa Dam, which is essential for generating hydropower to 5.5 million people and providing water supply to major cities in Syria, sustained some damage during the fighting to extract ISIS from the Euphrates basin. Due to sanctions on Syria, the parts to repair the Tabqa dam's turbines cannot be imported. The remaining operational turbines are highly vulnerable to a stable and sustained supply of water in the Euphrates River from Turkey. In the summer of 2021, drought conditions and upstream consumption led Lake Assad, Tabqa Dam's reservoir, to reach one meter above its dead storage capacity. Should the reservoir reach its dead storage, it would inflict damage on the dam that would be well beyond the financial and technical capacity of Syrians to repair.

Given the history of prolonged conflict, ineffective management of water resources, and destruction of hydrological infrastructure within the basin, a humanitarian crisis is plaguing innocent civilians. Armed conflict in Syria and Iraq contributed to a 70 percent decline in access to safe water and safe sanitation system, and a proliferation of water-borne diseases (OCHA, 2021). In Syria, people are resorting to unsafe coping mechanisms, such as restricting cleaning and bathing, and using any water available regardless of its quality (OCHA, 2022a). As a result, there is significant water insecurity and reliance on unsafe water, and in August and September of 2022, acute diarrhea was one of the two leading cause of morbidity in Syria and the region experienced a significant cholera outbreak (Save the Children, 2022; OCHA, 2022a).

Failure to protect, repair, or maintain aging hydrological infrastructure has contributed to waste and inefficiency in using domestic water resources (UNICEF, 2021). However, inefficiency in using the water resources is a problem that plagues all the riparian states sharing the Euphrates and Tigris Rivers. That is, not only Syria and Iraq, but also Turkey, have failed to improve the efficiency by which they use their water resources in the agricultural, municipal, and industrial sectors. Dated irrigation technology within the riparian states, such as surface irrigation, has decreased the agricultural sector's efficient use of water. Iraq, for instance, uses some 90 percent of its domestic water resources in the agricultural sector, which some studies suggest has contributed to salinization of the rivers' waters due to poor and inefficient irrigation techniques (Whitaker and Varghese, 2010). It is important to note that this large consumption of water in the agricultural sector is much more than the global average of 70 percent (World Bank Blogs, 2017).

Due to the history of uncoordinated development and conflict that destroyed hydrological infrastructure, the Euphrates and Tigris Rivers confront two challenges, which include insufficient water quantity to meet all riparian states' needs and poor water quality. Uncoordinated development by Turkey, Syria, and Iraq resulted in about 45 percent reduction in water flowing downstream (Shamout and Lahn, 2015). Due to upstream developments of the Euphrates River in Turkey, the quantity of water entering Syria has declined significantly, which has impacted the ability to meet domestic water and electricity needs (UNICIF, 2021; OCHA, 2021). The quantity of water entering Iraq from the Euphrates

River has declined from 700 m^3/s in the 1970s to 260 M3/s (Shamout and Lahn, 2015). During the 2020-2022 period, Syria received an average of 200 M3/s of Euphrates water from Turkey, which is much less than the 1987 protocol commitment (Sottimano and Samman, 2022). Iraq complained in the summer of 2022 that the water level in the Euphrates and Tigris Rivers was one third of its historic flow (Al Arabia News, 2022).

Current and future irrigation projects in upstream Turkey lowered the water quality in the Euphrates River, which is expected to continue to deteriorate in the future due to the impacts of climate change (Giovanis and Ozdamar, 2021). The heavy use of pesticides and fertilizers by the agricultural sector and the dumping of industrial affluents by all riparian states, is combining to destroy the water quality in the rivers. Upstream developments in Turkey have dried up two tributaries—Balikh and Khabur—of the Euphrates River that originate in Turkey and connect to the Euphrates inside of Syria. Today, the Khabur is dry inside of northeast Syria, while the Balikh is made up of irrigation runoff and wastewater from Turkey's Urfa-Harran region and northeastern Syria (UNESCWA and BGR, 2013). The quality of the Euphrates River is further deteriorating due to sewage, irrigation, and industrial runoff inside of Iraq.

The destruction and disrepair of wastewater treatment plants is also contributing to deteriorating water quality as large quantities of effluents are discharged directly into the rivers. In Syria, 70 percent of the sewage remains untreated (UNICEF, 2021). Due to upstream contaminations, the water is highly salinized and polluted as the rivers join to flow through southern Iraq, which contributed to loss of farm land and a high spread of waterborne diseases (Giovanis and Ozdamar, 2021). The less developed Tigris River has better water quality as it enters Iraq than the Euphrates because Turkey has not developed the agricultural potential of the region, but its quality deteriorates substantially in downstream Iraq due to sewage and pollution inflows (Ibid).

Responses to these challenges:

In order to address the challenges confronting the riparian states, it is necessary to consider both short-term solutions that do not require stable national governments in Syria and Iraq as well as long-term solutions that can be implemented once political stability returns to these states. Given the governance deficit in the basin, there is a critical need for the active involvement of the international donor community and NGOs in meeting both long-term and short-term solutions. The international donor community is essential for addressing the significant imbalance of power between the basin riparian states. Powerful Turkey is upstream and has the capacity to unilaterally secure its interest in consuming and developing the waters of the Euphrates and Tigris Rivers. Given the governance deficit in Syria along with its weak military capacity, it lacks the ability to challenge Turkey's consumption of the rivers, compel Turkey to enter negotiations, force compliance with existing protocols, or promote its national interest in international forums or to the international donor community. While politically more stable, Iraq's ability to promote its interest is also challenged by its weak state capacity and weak military capability to balance a more powerful Turkey. IGOs and NGOs will be critical to carrying out the necessary studies that will serve as the bedrock for implementing long-term solutions.

Short-Term Solutions

1) Small Steps Towards Cooperation:

Issue linkages can be used in the short-term through MOUs to facilitate small efforts at cooperation. Combining water with economic, energy, and security issues remains a viable option to encourage Turkey to negotiate with Syria and Iraq. Today, Turkey has an interest in building a stable Syria and Iraq because its long border with the downstream riparian states complicates its ability to control Kurdish militants that continue to operate across the border. Turkey also seeks to prevent a large number of refugees from crossing its borders from Syria because of the social and economic problems occurring between Turkish nationals and Syrian refugees. Currently, Turkey hosts more than 3.6 million Syrian refugees, and it has undertaken the construction of homes inside of Syria to encourage the refugees to return (Hubbard and Ince, 2022). A mediator can immediately work with Syria's regime and Turkey to facilitate an MOU by linking these two security issues and bringing Turkey to the negotiation table.

Through issue linkages, Turkey can be persuaded to purse the construction of joint projects with Syria and Iraq to address water quality and quantity issues that are expected to increasingly impact the region. For instance, given Iraq's desperate need for water in the south, the donor community can facilitate an energy for water exchange, where Iraq sells fossil fuels for a subsidized price to Turkey, and donors along with assistance from Turkey can construct a desalinization plant in Iraq to help meet its water shortages. The desalinization plant can draw on aquifer water or salinized water located in the southern portion of Iraq. In preparation for constructing a desalinization plant, donors or NGOs can undertake studies to propose joint water and energy projects by which the riparians can build interdependences that facilitate issue linkages and cooperation between the states. While Syria is not as rich as Iraq in fossil fuels, it does have great potential for solar energy, which it can generate and then use to carry out an energy for water exchange with Turkey. This exchange would result in interdependencies that are generally believed to contribute to building cooperation between states with a history of mistrust. An example of such a case is the 2021 energy for water exchange signed between Israel, Jordan, and the UAE. The agreement committed Jordan to build, generate, and export solar energy to Israel. In exchange, Israel would sell Jordan water by building a desalinization plant along its Mediterranean coast. The UAE's Masdar Corporation would undertake the construction of the solar plants in Jordan (Zawahri and Weinthal, forthcoming). While the creation of an energy for water exchange can be a long-term possibility for Syria and Turkey, it can be a short-term option for Iraq and Turkey in that it can be negotiated and implemented within the next 5 years through MOUs and with the support of donors.

2) Establish a Multilateral Institution:

Donors can mediate the establishment of a formal commission consisting of government officials from the three riparian states, NGOs, IGOs, and donors to collect, organize, and share timely data on the rivers' flow, water quality, precipitation, and water quantity. The commission can also collect data about the status of hydrological infrastructure in the three riparian states. International donors can support this commission by providing the funding needed to collect the data, in some cases repairing or updating inoperative measurement technologies or through the use of satellites to collect the data.

3) Collection and Dissemination of Data:

Collection of this data is crucial since historically the three states sharing the Euphrates and Tigris have perceived hydrological data as a national secret and refused to share hydrological data in public or with neighboring riparian states (Zawahri, 2006). As mentioned previously, in both Syria and Iraq some important hydrological data is missing due to the destruction and lack of maintenance of this necessary infrastructure. Through the collection of this data, the commission is able to fact check government-allocated data and secure high-quality data, which can bestow it with high social capital and trust in its data by outside actors, donors, and riparian states.

Once collected and processed this data can be shared immediately with not only the riparian states, but also humanitarian organizations. The commission can work with both the Syrian and Iraqi governments by sharing this data to help improve their ability to manage their water resources. The collected data will also be of tremendous value for humanitarian agencies by helping them to provide immediate and effective assistance in times of crisis in Syrian or Iraqi conflict-zones, such as repairing damaged pipes or barrages, and shipping water to a region to address water shortages or poor water quality, all of which are critical to human security.

Currently, there is an absolute lack of water quality monitoring facilities at the borders and within the two downstream conflict-torn states. Through the use of this commission, donors can facilitate the transfer of technology to improve the ability to collect and share water quality data. Given the disputes within the Euphrates River between the riparian states over water quality concerns, donors can undertake the installation of water quality monitoring systems that have the capacity to identify contaminants and pollution at international borders and within the downstream states. These water quality monitoring facilities can also serve as early warning systems for the states and help to identify sources of contamination in order to undertake the necessary steps to clean the pollution.

Access to accurate and trusted water quantity and quality data can provide an important foundation towards the peaceful governance of these rivers by allowing the donor community and riparian states to use it during future multilateral negotiations. The data can also be useful during the post-conflict reconstruction period in Syria, as it seeks to build effective governing institutions with resilience to climate variability in the water and agricultural sectors.

4) Reconstruction of Hydrological Infrastructure:
Donors, IGOs, and NGOs need to come together and finance the reconstruction of essential hydrological infrastructure—such as Syria's dilapidated water stations, water treatment facilities, wastewater treatment plants, and canals—to begin addressing the critical water quality and quantity issues in Syria and Iraq. The reconstruction of destroyed infrastructure in Syria and Iraq will be essential for addressing the outbreak of waterborne diseases, the impending humanitarian crisis, and help during the post-conflict state building. Expanding wastewater treatment facilities will enable these states to address water quality issues, provide irrigation water to farmers, and control waterborne diseases. Stable access to sufficient water quality and quantity will be essential for the economic and political stability of Syria and Iraq. A state's failure to provide its people access to sufficient water quality and quantity has resulted in protests and civil unrest against governments, thereby contribute to political instability. In fact, the U.S. intelligence community argues that water grievances among the populace is a threat multiplier contributing to regime instability (Annual Threat Assessment of the U.S. Intelligence Community, 2021). Iraq's fragile government has also experienced protests against its poor governance of domestic water resources. Social protests in Iraq against insufficient water supplies resulted in the death of 14 people in 2018 (Mueller et al., 2021).

5) Technology Transfer to Increase Efficiency in the Agricultural Sector:
Turkey, Syria, and Iraq all have a history of using their domestic water resources inefficiently, which has contributed to a shortage of water in the basin. To improve the efficiency by which water is used, donors can fund technology transfers to Iraq and Syria, such as drip irrigation that can help in conserving water by reducing the consumption of water by 60 percent (World Bank, 2018). In Iraq, donors can upgrade the urban water conveyance system to help reduce water loss in pipes. Turkey can also be encouraged to improve its use of irrigation water in Southeastern Anatolia as it confronts its own environmental problems brought about by the overuse of water (Cullu et al., 2022). Turkey and the downstream riparian states can undertake studies on how their agricultural sector can not only improve its use of water, but also become more resilient to climatic variability and the other impacts of climate change. The donor community's promotion of improved water efficient technology throughout the rivers in Turkey, Syria, and Iraq is in the interest of the entire community because it can help to address existing water shortages. Helping the riparians to improve the efficiency by which water resources are used can help to minimize domestic and regional conflict in the future as it will help to address water quantity in the basin and to minimize tension between the riparians.

6) Training Cadre of Technical Experts
Given the brain drain and shortage of technical expertise, donors and NGOs should undertake training of technical expertise in both Syria and Iraq that can carry out environmental impact assessments, efficiently

manage domestic water supplies, assess farming practices, and gain knowledge about the most current accepted scientific standards regarding water resource measurement and data gathering. To facilitate greater cooperation and trust between the riparian states, these engineers can be trained by Turkey. The newly trained engineers and scientists can undertake scientific studies of the impact of climate change in the basin and use this knowledge to design policies that can help Iraq and Syria to build adaptive capacity. For Syria and Iraq, it is important to train engineers that can be used to staff bureaucracies and ministries, and be responsible for governing the water and agricultural sectors. This cadre of engineers can serve to improve the management and governance capacity immediately in Iraq. Building technical scientific capacity will be critical to assist Syria in preparation for its post-conflict reconstruction process. Through capacity building and training of scientific and technical expertise, the asymmetry in technical capacity between Turkey, Syria, and Iraq can be improved.

7) Domestic Institution Building:

The donor community can help Iraq in designing and building effective water, agriculture, and environment governance ministries. Once Syria enters the post-conflict reconstruction phase, donors can also assist it in building these effective water, agriculture, and environment institutions. In preparation, studies can be carried out to identify the most effective governing institution design, best policy practices, and effective regulation methods that can be used in both Syria and Iraq.

Building effective governance institutions is especially important as the states confront the negative impacts of climate change and the need to build adaptive capacity. The challenges of building adaptive capacity to climate change or managing water resources in times of significant variability can weaken the institutional capacity of existing bureaucracies and negatively impact regime stability.

Long-Term Solutions

1) Mediating a Multilateral Agreement:

When political conditions influencing the basin states begin to improve, such as the establishment of stable states in Iraq and Syria, the donor community and riparian states can immediately begin to undertake multilateral negotiations for a treaty to govern their shared water. To achieve a multilateral agreement over the Euphrates and Tigris, donors will be essential in mediating and facilitating the negotiation process by suggesting issue linkages and overcoming obstacles to cooperation. Moreover, the only means to somewhat balance the unequal power dynamic during the negotiations is to involve a third party, such as the World Bank. An example of the effective use of a mediator to negotiate a transboundary river agreement between two states with a history of conflict and power asymmetry is the Indus Waters Treaty signed between India and Pakistan in 1960. The World Bank was critical to the negotiations leading to the signing of the treaty and its implementation during its first 10 years (Zawahri, 2009). Important preliminary work can be undertaken immediately in preparation for these multilateral negotiations. The international donor community and NGOs can begin laying the ground for the multilateral negotiations by preparing ideas on the content of effective treaties governing transboundary rivers, identifying negotiation points and possible solutions, identifying possible issue linkages that can be used, and summarizing best examples of treaty design.

2) Establishing a River Basin Organization:

Along with negotiating a multilateral treaty, Turkey, Syria, and Iraq will need to redesign and negotiate over the establishment of a new river basin organization (RBO) to replace the JTC. The literature on the management of transboundary rivers argues that riparian states establish RBOs to implement new treaties and facilitate long-term management of water disputes (Schmeier, 2013; Mitchell and Zawahri, 2015). Donors and NGOs can begin to carry out studies to analyze the design of effective RBOs that can facilitate the implementation of a treaty and contribute to long-term cooperation. Once the states begin negotiating over a treaty, they should be encouraged by the mediator to include in their treaty an effectively designed RBO.

3) Mechanisms for Encouraging Cooperation

In the long-term, several factors can combine to encourage Turkey to become interested in negotiating a trilateral or bilateral agreement over the Euphrates and Tigris Rivers. Historically, cooperation over water resources between the riparian states arose through the use of issue linkages and when national leaders had a national interest in cooperation. The 1946 treaty between Turkey and Iraq relied heavily on issue linkages, combining economic, security, water, culture, and educational interests. It was also negotiated and signed by the nations' leaders. The Economic Protocol between Turkey and Syria is another case in point. Negotiated between the states' leaders, the 1987 protocol was reached through the use of issue linkages that combined natural gas, electricity, water, trade, and banking interests (Economic Protocol, 1987). It is generally believed that Turkey's concerns with the Kurdish PKK are often linked with Syria's interest in securing its water supply from the Euphrates as Turkey constructs dams along the river (Warner, 2012).

As the international community prepares studies about future negotiations between the riparian states, it can analyze and assess current or future issue linkages. For instance, they can consider combining Turkey's economic, political, energy, and security interests. Turkey seeks to expand its economic and energy interests in Iraq and stabilize the Kurdish conflict in southeastern Anatolia. Historically, there has been substantial trade between Turkey and Iraq, which has allowed for the use of issue linkages that include trade in goods and fossil fuel in exchange for a guaranteed quantity of water in the Euphrates and Tigris Rivers. Energy-poor Turkey would most likely look favorably at an energy for water exchange with energy-rich Iraq. It also seeks to minimize the power of Kurdish rebels operating in Syria and minimize the flow of Syrian refugees entering its territory. Another issue linkage that can be included in negotiations between Syria and Turkey is the Orontes River (or, Asi River) that flows from Syria into Turkey.

Turkey's desire to join the European Union (EU) can push it to address its transboundary water issues through either a trilateral treaty or bilateral MOUs. Turkey is in the process of adapting EU policies towards the management of its rivers. According to Kibaroglu (2014), Turkey has been altering its water legislation in order to comply with the EU Water Framework Directive, as it seeks to join the European Union. As a result, Turkey's interest in joining the EU can be an important factor in altering its interest to settle its transboundary water disputes with its downstream neighbors.

4) Historically in this basin, tension over water supplies has at times contributed to the signing of a protocol (Kibaroglu, forthcoming). For example, as Turkey sought to fill the Ataturk Dam, tension increased with its downstream riparians, which was managed by the signing of a protocol between Turkey and Syria. According to the 1987 protocol, the 500 M3/s commitment is to remain in effect until it is superseded by another agreement. Tension between Syria and Iraq over the Euphrates River was resolved through the signing of the 1990 protocol. However, tension over water can also contribute to conflict if it is not effectively mediated by a third party. When Syria began filling Lake Assad, Iraqi soldiers threatened to invade because of the substantial decrease in the

Euphrates flow downstream. Intervention by Saudi Arabia succeeded in mediating the conflict and preventing war. Donors can think of using the negative impact of climate change on the region's water supply to encourage the riparians to cooperate and avert further conflict or tension.

Alternatively, as the rivers' water quantity and quality continue to deteriorate, and downstream farmers and citizens continue to confront water and food insecurity, tensions and hostilities can increase. That is, without Turkey cooperating with the downstream riparian states to assure them sufficient quality and quantity of water, it might confront increasing turmoil and hostilities along with a deterioration in relations. Turkey might also confront a flood of climate refugees, as consecutive and prolonged droughts continue to drain the livelihoods and social safety nets of farmers.

The international donor community should be aware of previous examples of cooperation under duress along with the possible rise in hostilities should water insecurities continue. They should prepare for the possibility that the increasing shortages of water within the rivers can increase Turkey's interest in cooperation to avert conflict over the impending impacts of climate change. Alternatively, climate change can increase the possibility for tension.

Conclusion

Due to years of mismanagement, inefficiencies, climate change, conflict, poor economic development, and instability in the governance of Iraq and

Syria, the riparian states sharing the Euphrates and Tigris Rivers are confronting water quality and quantity problems that are challenging their ability to meet national and individual water and food security needs. Through the help of the international donor community, IGOs, and NGOs, this chapter has proposed both long-term and short-term solutions that can help address some of these significant challenges and lay the groundwork for the post-conflict reconstruction process in Syria and Iraq. The literature on post-conflict reconstruction emphasizes the importance of the agricultural sector in building economic and political stability. Without securing sufficient quality and quantity of water in both Syria and Iraq, the agricultural sector will continue to be unstable in providing food security.

In the short-term, the international donor community will be essential as it can assist both Iraq and Syria with several critical steps needed to effectively and sustainable manage and secure their domestic water resources. These include undertaking studies and assisting to build effective water management institutions, training water management engineers, rebuilding hydrological infrastructure damaged by years of conflict, upgrading irrigation technology, and building resilience to climate change. These activities are beyond the financial and technical capacity of Syria and Iraq to implement due to brain drain and a collapsed economy. The international donor community can assist them in implementing these policy options. This assistance can begin by initially carrying out program studies, followed by implementation.

Without the active involvement of the international donor community, many of these recommendations cannot be implemented given that Syria and Iraq lack the financial and institutional capacity to undertake these activities.

Over the long-term, the riparians sharing these rivers will need to negotiate an effective multilateral treaty to govern their shared waters. This can happen with the help of a mediator that can facilitate the use of issue linkages that create interdependencies between water, the economy, and security for signatory states. Historically, protocols and MOUs between the riparian states tended to rely on issue linkages that combined water, economic, and energy interests.

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Chapter Six

Assessing Desalination Governance and the Promise of Technology in the Arabian Peninsula

Mohammad Al-Saidi

Abstract: Desalination is expected to grow across the Middle East and North Africa due to increased water scarcity. The cost of desalinated water has decreased significantly over the last decades, but it has not reflected the mounting environmental impacts of desalination. Desalination can result in significant negative impacts on the environment, such as harmful emissions and the destruction of terrestrial and marine ecosystems. Sustainable desalination should address environmental problems across the entire lifecycle of desalination plants, and embed desalination activities within a larger good governance view. This chapter maps out solutions and best practices relevant for the desalination industry using the case study of the Arabian Peninsula. It provides three main solution categories for making desalination sustainable, affordable, and safe. First, technological remedies to address the environmental impacts of desalination should go hand in hand with environmental regulation. Solutions related to lowering pollution, waste and marine impacts of desalination require clear and enforceable regulation frameworks that include thresholds, standards, reporting mechanisms and monitoring plans. Second, providing affordable desalination requires collaboration between the state, the private sector, and civil society. The private sector can share some of the desalination costs through joint ventures with state companies. Civil society and donor organizations can provide technical knowledge and aid programs in order to expand small-scale desalination for remote communities. Third, safe desalination requires the protection of desalination infrastructure as critical assets. This includes paying attention to the operational security of desalination plants and developing contingency plans. Related to this, regional

cooperation through knowledge sharing and joint action to mitigate the cross-country impacts of desalination activities is important for regions such as the Arabian Gulf. Overall, sustainable desalination is a multi-actor task that should integrate the perspective of water policymakers with that of desalination plants' managers and operators. While desalination managers prioritize issues related to their technical performance, policymakers should encourage more collaboration and co-development of environmentally friendly desalination. Public leadership is important for lowering the desalination cost, investing in green desalination technologies, providing clear institutional frameworks, and improving awareness about water conservation in collaboration with civil society.

1. Introduction: The age of (sustainable) desalination?

Desalination activities have grown tremendously in the last decades, with now ca. 16.000 plants in 177 countries existing, mainly for satisfying municipal water demands (Jones et al., 2019). The drivers behind the increase in desalination activities are related to the availability of desalination technology and increased water scarcity, as billions of people are already living under water scarce conditions (Bennett, 2013; Pistocchi et al., 2020). Desalination technologies have also become economically feasible for many countries due to the decline in costs and increase in water recovery over the older technologies used in past decades. This cost decrease is mainly related to improved energy recovery technologies, operational innovations, and the dissemination of membrane desalination technologies – especially reverse osmosis (or RO) and nanofiltration (NF), (Bennett, 2013). While the rise of RO technologies has significantly decreased costs, these costs still vary from one plant to another depending on the deployed technologies, energy use and water type (Karagiannis and Soldatos, 2008; Pinto and Marques, 2017). Desalination is cost-effective in many places because many of the environmental impacts of desalination are not adequately internalized through environmental regulation (Pinto and Marques, 2017). Sustainable desalination has become even more important because some new technologies can also lead to additional negative environmental impacts. For example, RO achieves higher water recovery ratios and lower energy use, but discharges more dense brines than the Multi-Stage Flash (MSF) or Multi-Effect Distillation (MED) technologies frequently used in the Arab Gulf countries (Jones et al., 2019; Morillo et al., 2014).

In the Middle East and North Africa region (MENA), despite requiring significant financial investments, valuable coastal land, and energy, desalinated water has become a vital water source due to aridity and increased water usage (Barau and Al Hosani, 2015; Heck et al., 2017). By far, the Middle East holds the largest share of desalination capacity worldwide, with the region of the Gulf Cooperation Council (GCC) leading desalination activities. Some 29% of global desalination capacity stem from the three GCC countries of Saudi Arabia (15.5%), UAE (10.1%) and Kuwait (3.7%) (Jones et al., 2019). Despite the cost and environmental impacts of desalination, the dissemination of desalination in the Middle East is increasingly seen as a popular managerial-technical fix for water supply problems. There is little focus on sustainable pathways to achieve good governance of desalination activities in the region. Using the Gulf region as a case study, the aim of this contribution is to highlight emergent sustainable solutions to common problems facing the growth of the desalination industry in the MENA region while critically reflecting on desalination as a panacea for the region. This contribution first presents the case of the desalination expansion (both vertically across countries, regions and sub-regions, and horizontally across use sectors). Later, it introduces common challenges in the areas of a) environmental impacts of desalination (mainly the two issues of brine management, and desalination emissions); b) affordability and finance; and c) supply security (e.g., risks to coastal infrastructure). While presenting these challenges in the Arabian Peninsula, the paper explains solutions and relevant case experiences, e.g., the regulation of brine disposal/discharge, solar desalination, and public-private finance schemes through Independent Water and Power providers or resilience-based supply management in desalination. Such solutions can move the increasing desalination activities in the region towards more financial and environmental sustainability.

2. Background: Desalination as a techno-managerial fix for the MENA region

The Middle East and North African region currently accounts for ~48% of the total global desalinated water produced daily which is estimated at around 95 million cubic meter per day (25 billion US Gallons per day) (Jones et al., 2019). For the GCC countries, desalination as a water supply option represents an old solution for water scarcity and rising demands. The first desalination plants were built on the Gulf coast in the 1950s, with the number of plants increasing steadily since then (Le Quesne et al., 2021). Nowadays, the desalination sector is providing a reliable supply of good-quality water for domestic use in all GCC states. Table 1 provides some indicators on current GCC desalination capacity. It is noticeable that thermal desalination technologies (MSF and MED) are still strongly represented in the Gulf, particularly MSF technology. At the same time, RO is the main technology for newly constructed desalination plants in the Gulf and worldwide. There has been a great expansion in the use of RO technology over the last decades. While ~84% of desalinated water worldwide was produced using thermal technologies in 1984, this number declined to ~50% in 2000 and only ~30% currently (Jones et al., 2019). Despite the higher energy efficiency of RO – and the less expensive operations, the Gulf countries still rely on thermal technologies due to their abundance of fossil fuels and the high salinity of feed water, which limits the operations and water recovery in RO desalination. GCC countries furthermore preferred MSF plants due to factors such as ease of operation, reliability, and use as cogeneration plants (producing both water and electricity) (Parmigiani, 2015). However, with the rise of environmental concerns and the advancement of RO in terms of energy efficiency and membranes' reliability, and thus the decrease of desalination costs, GCC countries have started to rely more on membrane-based technologies, mainly RO for now.

Table 1. Desalination indicators for GCC countries

Indicator	Bahrain	Kuwait	Oman	Qatar	Saudi Arabia	United Arab Emirates
Total Renewable Water Resources Per Capita (Cubic Meter Per Capita Per Year) (2013–2017) [1]	84	5	312	26	76	16
Desalinated water per capita (Cubic Meter Per Capita Per Day) (2016) [2]	0.47	0.48	0.17	0.59	0.17	0.66
Annual freshwater withdrawals (Billion Cubic Meters per year) (2017) [1]	0.2	0.8	1.6	0.3	21.2	2.6
Produced desalinated water (Billion Cubic Meter per year) (2016) [2]	0.24	0.71	0.28	0.56	1.95	2.0
% of desalination capacity produced from thermal desalination (only MSF and MED) (2017) [3]	82%	100%	94%	99%	50%	91%
% of desalination capacity produced from membrane-based desalination (only RO) (2017) [3]	18%	0%	6%	<1%	50%	9%

Sources: [1] FAO Aquastat, https://www.fao.org/aquastat/en/; [2] GCC Stat, Water Statistics Report 2016, https://www.gccstat.org/images/gccstat/docman/publications/water_statistics_1.pdf; [3] GCC Stat retrieved from Dawoud et al. (2020)

The rise of desalination technology as a viable and significant water supply option throughout the MENA region can be witnessed in two main trends. As earlier-mentioned, GCC countries have for decades relied on desalination almost entirely with regard to domestic water supply. First, besides these countries, major desalination plants are expanding to other countries in the Mashreq and Maghreb regions. For example, Algeria is one of the first North African countries to invest in desalination. In 2001, it launched a program to invest 14 billion USD in 43 desalination plants, some of which were indeed built, giving Algeria one of the biggest desalination capacities in the MENA region, with an overall capacity of over 2.2. million cubic meter a day (Djoher, 2020). Since 2005, Israel has developed a well-functioning desalination sector, supplying almost 50% of total freshwater consumption and almost all domestic consumption (Bar-Nahum et al. 2022; Teschner et al. 2013). Desalination plants are also being built in countries with relative high water abundance, such as Egypt and Morocco. Morocco's ambitious desalination program dates back to the mid-1990s, but it has expanded significantly over the last decade (El-Ghzizela et al., 2021). Egypt has also committed itself to build more desalination plants – up to 17 by the mid-2020s with a combined capacity of 2.8 million cubic meters per day. Its current desalination capacity in 2011 stands at ~0.8 million cubic meters per day, and it should increase to ~6.4 million by 2050 (Werr, 2021). Even in water-scarce countries, desalination is being considered as a solution to solve water shortages, e.g., for supplying water in Jordan through the planned 1.8 billion USD Al-Aqqba Desalination Plant or the many plans by international organizations for large-scale plants to supply major cities in Yemen, such as Sana'a and Taiz.

Second, desalination has expanded into new sectors beyond the domestic water supply. In agriculture, it is increasingly being used to remediate the current water use (desalination of the increasingly salty groundwater) and to providing new supply – seawater desalination. Desalinating salty groundwater used for agriculture through water treatment applications has become relatively common in the GCC region (Batarseh et al., 2021). Farmers have been using this groundwater for irrigation free of charge, and they now need to pay for any onsite desalination activities. It is possible to desalinate brackish water and make it available for use in agriculture through the widely applied method of nanofilteration (Tian et al. 2021). Seawater is also being considered for irrigation, such as in Morocco where a large-scale desalination plant in the coastal city of Agadir (producing up to 0.45 million cubic meter per day) will supply both drinking water and water for an irrigation system in the Ctouka plain (El-Ghzizela et al., 2021). One reason for the expansion of the desalination to other sectors (beyond domestic supply) is the decrease of cost in recent years, reaching 0.5 USD per cubic meters and 1-2 USD including transport and distribution (Parmigiani, 2015). Often for farmers in the MENA region, paying the full price of desalinated water can make their production uneconomic. Therefore, using desalinated water for irrigation will depend on the farming economics of certain crops, and subsidies (for either the water price or directly to certain farmers) might be necessary in some cases.

While desalination is on the rise worldwide, awareness about the negative impacts of desalination activities is slowly increasing. However, desalination remains largely perceived as a panacea for solving water supply problems at reasonable costs. These costs are often discussed in terms of the one-off expenditure in installing the desalination plants and the operational costs, mainly related to the use of energy and chemicals. Desalination is therefore seen as a depoliticized, techno-managerial issue (Swyngedouw and Williams, 2016). It can also reinforce neoliberal ideas about water governance solutions, i.e. the primacy of supply-side solutions through commercial technologies over demand-side solutions (Fragkou and Budds, 2020). While the pitfalls of desalination are often seen as being related to affordability and some environmental impacts (mainly the brine issue or carbon emissions), recent academic literature demonstrates more wide-ranging consequences. Desalination is changing water control and water governance notions, and maybe promoting in the long-run the primacy of technologies and the private sector (Teschner et al., 2013; Williams, 2018). As this contribution will argue in the next section, desalination should also be embedded in wider frameworks related to sustainable development and good water governance.

3. Towards sustainable desalination: obstacles and emergent remedies

3.1 Common challenge synopsis

This chapter highlights some sustainable and policy-relevant directions for desalination in the MENA region, while focusing on experiences of

Gulf countries. It has already mentioned how drivers have increased interest in desalination as a techno-managerial solution. These drivers include socio-economic and environmental changes (e.g., economic growth, scarcity, and the need for resilient supplies), and techno-economic feasibility (e.g., cost reductions mainly due to membranes' advancement). In the case of the Gulf, other drivers will be discussed in this chapter, namely requirements for political control (i.e., preference for large-scale, centralized, and supply-side remedies). While desalination is on the rise, this chapter argues for a wider perspective on desalination challenges and for embedding them within a larger understanding of good governance of water supply. This is in line with the emerging body of knowledge promoting neglected issues such as desalination governance (Barau and Al Hosani, 2015; Mumme et al., 2017; van der Merwe et al., 2013), regulation (Navarro Barrio et al., 2021), and public control (Campero and Harris, 2019; Haddad, 2013).

Figure 1 shows desalination as embedded in a wider good governance task. The aim of desalination good governance is to foster the implementation of certain normative principles underlying the modern concept of sustainable development. Al-Saidi (2017a) explains how many of these good governance principles are guiding contemporary water management instruments used for solving local water problems. While these principles are often applied to (integrated) water management in general, they can steer desalination because it is a multi-actor and cross-sectoral task (Compagnucci and Spigarelli, 2018). Some of the selected principles explained in Figure 1 are specific to the desalination challenge, while the mentioned issues will be highlighted in the next sections. The overall argument is that desalination is a broader water governance challenge with environmental regulation at the heart of making desalination more sustainable. As this chapter will show, there is a wide range of often context-specific solutions to tackle desalination issues ranging from brine management solutions, renewable energy use, participation of private actors, the level of centralization, tariffs, and resilience-based strategies.

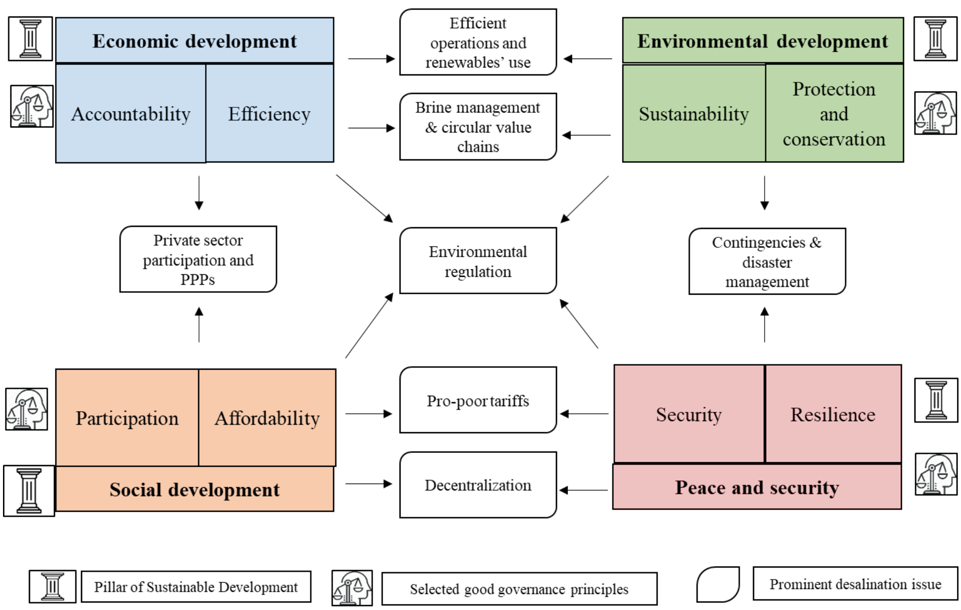

Figure 1. Desalination management as a (good) governance task (NOTE: figure to be redesigned professionally)

3.2 Low-impact desalination: mitigating environmental problems

Environmental impacts are plenty and can be caused before, during, or after the operation of a plant, summarized together with remedies, in Table 2. Therefore, low-impact desalination needs to consider and solve environmental problems of desalination across the life cycle of a desalination plant (Mannan et al., 2019), within which one-off impacts associated with plant construction such as pollution and environmental damage related to the use of land and materials should be considered (Zhou et al., 2014). While these impacts are common to other industries, they can be addressed through compensation or minimization strategies. Similarly, the decommissioning of a desalination plant leaves waste materials and often degraded lands and coasts. In case no new desalination plants are built on the same site – which is the regular practice (Ziolkowska, 2015a), sound waste disposal strategies and additional measures such as the rehabilitation of costal reefs (e.g., through artificial ones) and soil should be undertaken (Seyfried et al., 2019).

There are also other environmental impacts typical to other industries, such as noise or air pollution and harmful gases during the operation of a desalination plant. These impacts can be mitigated through the use of site-specific measures to reduce noise, improve energy recovery, or use renewable energy to lower emissions (Ogunbiyi et al., 2021; Panagopoulos, 2021). The remaining category of environmental impact is specific to the desalination industry and centers around the water intake and brine disposal during the desalination operations. The impacts include various forms of disruptions or destruction of aquatic systems during water intake and several threats arising from the temperature, turbidity, or salinity of the disposed brine (Hosseini et al., 2021; Panagopoulos and Haralambous, 2020).

For a sustainable and low-impact desalination, it is important to tackle the rising environmental problems associated with the desalination industry. Considering the urgency of providing additional water supplies, many countries have decided to ignore or delay action on environmental damage, or to only focus on more serious impacts such as those related to greenhouse gas emissions or brine disposal (Elsaid et al., 2020; Panagopoulos and Haralambous, 2020). For brine disposal, there are a wide range of treatment and disposal methods reviewed in recent academic literature (Bello et al., 2021; Khan and Al-Ghouti, 2021). For example, some types of brine can be used for other purposes such as hydrotherapy, wetland regeneration, or saline agriculture, although the use of the more concentrated (e.g. more salty) brine from RO remains difficult (Rodríguez-DeLaNuez et al. 2012). The brine can also be "safely" discharged into deep wells or specified surface areas (discharge zones). For RO brine, it is possible also possible to minimize the impacts through several treatment and disposal technologies, although these technologies can increase the energy requirements of desalination (Amy et al. 2017). All of these applications for reuse and safe disposal come with their own potential impacts on the receiving sectors and environments, and often do not eliminate the brine problem. Research and technology development is therefore seeking ways to minimize or eliminate the brine through Zero-Liquid-Discharge (ZLD), although this idea should be rather understood as an ultimate – but still quite costly and difficult – goal for future desalination technologies (Ihsanullah et al., 2021; Khan and Al-Ghouti, 2021). Materials recovery (i.e., minerals, salt, and precious materials) can help transform desalination towards the ZLD aim (Al-Absi et al., 2021), although the current processes are largely not economic or commercial (Ihsanullah et al., 2021). Currently, the more common approach is to treat the brine before discharge through different methods such as dilution (relatively cost-effective and commonly used), evaporation ponds (a common but more expensive method), disinfection (rather as a pre-treatment step), or as adsorption (rather novel and not widely used).

While the desalination debate has so far focused on technology or environmental regulation through water quality thresholds, punishments or incentives is the missing link for making desalination sustainable. Environmental impacts such as the brine problem are receiving increasing attention, particularly in regions such as the Gulf, where brine production in Saudi Arabia, UAE, Kuwait, and Qatar accounts for 55% of the global brine production (Jones et al., 2019). Nonetheless, the brine is often disposed of without any remediation in the Gulf and elsewhere. New desalination plants might apply some forms of disinfection and dilution before discharge. As the important missing link in the debates on sustainable desalination, environmental regulation should be more explicit and enforceable. The current best practice of environmental regulation is to mandate the use of

Environmental Impact Assessments (EIAs) with specified requirements for desalination activities. These EIAs should also include Environmental Monitoring Plans (EMPs), and additional emergency protocols, which together specify thresholds, (emergency) practices and reporting procedures. This approach (EIA with EMPs) is followed in some countries such as the USA, Spain, Australia, Chile, Israel, and Saudi Arabia, but with different standards and levels of enforcement (Sola et al., 2021). Even without mandating EMPs, it is also possible to enforce certain quality standard or thresholds, and to assign monitoring tasks to regulatory agencies. In Kuwait, for example, the Kuwait Environment Public Authority assumes the tasks of monitoring water quality and compliance with thresholds (Hosseini et al., 2021). However, in the MENA region, environmental regulation of desalination is quite weak, with largely no EMPs observed in Tunisia, UAE, Oman, and Algeria (Sola et al., 2021), while the GCC countries lack clear and enforceable regulatory frameworks (Amma and Ashraf, 2020; Barau and Al Hosani, 2015; Hosseini et al., 2021; van der Merwe et al., 2013).

Standards (i.e. required practices or processes) and thresholds (i.e. minimum levels or points required) represent classic instruments for environmental regulation, namely command-and-control regulation (i.e. setting rules and monitoring or enforcing them). There are also other options through economic regulation, which means providing incentives for desalination plants to optimize their costs, including the costs of environmental externalities. Economic regulations means monitoring the costs of the desalination plants and mandating performance-improving measures (including environmental performance) such as benchmarking (comparison with other plants), yardstick instruments (awarding a financial incentive based on the relative performance), and/or regulating the allowed price for desalinated water based on the cost function of the plant. However, these instruments (often implemented through independent regulators) are not widely used in the desalination industry.

Table 2. Environmental impact categories of desalination and solutions

Type of impact	Impact category	Issues	Remedies
One-off industrial impacts	Plant construction	Pollution and environmental damage to terrestrial and marine ecosystems	Careful site selection, compensation of arable land; minimization of associated waste
	Plant de-construction	Industrial waste; damage to artificial reefs	Waste disposal strategies; rehabilitation of soil and marine ecosystems through artificial reefs
Continuous industrial impacts	Energy consumption	Air pollutions; greenhouse gases	Energy efficiency measures; energy recovery; use of renewables; modernization of plants
	Noise pollution	Impacts of vibration and noise on humans and marine organisms	Noise minimization strategies through plant design
Continuous desalination-specific impacts	Water intake	Disruption and damage to aquatic ecosystems	Site-selection of water intake away from productive ecosystems; use of barriers and bypasses for marine organisms
	Water disposal	Damage to aquatic ecosystems mainly from the temperature, turbidity and salinity of the brine; damage to other receiving environments of the desalination brine, e.g., groundwater or soil	Reuse in other sectors; safe disposal; several brine minimization strategies towards materials' recovery and Zero-Liquid-Discharge (ZLD); brine treatment using methods such as dilution, evaporation, disinfection or adsorption

3.3 Accessible desalination: affordability and participation

The costs of desalination, namely capital costs plus operational and maintenance costs, represent a key issue that can drive or restrain local desalination. Closely related to this issue is the question of desalination finance (i.e., who owns assets, pays the costs and retrieves them from the consumer) and ultimately the desalination water tariffs. The parameters affecting the desalination costs are plenty, and can change depending on factors such as the scale of the plant, the type of treatment technology, energy input, and any environmental regulations (Ziolkowska, 2015b). Reviews of desalination costs provide varying ranges of costs, although small-scale desalination plants seem to have higher costs per unit of the produced water due to the lack of economies of scale (Al-Karaghouli and Kazmerski, 2013; Ziolkowska, 2015b).

Energy seems to be one of the key optimization points for determining desalination costs since it can account for 50% of the produced water cost (Al-Karaghouli and Kazmerski, 2013). In the case of remote or rural areas without access to national grids, renewable-energy-coupled desalination systems are recommended although the production costs of these systems is still much higher than conventional desalination systems. Particularly for small-scale systems, i.e., below 100 cubic meter per day, costs can range – depending on treatment technology and renewable energy source – between 1 and 16 USD per cubic meter (Al-Karaghouli and Kazmerski, 2013). Small-scale desalination using RO systems are the most economic systems with the cost estimated at up to 3 USD per cubic meter (Al-Karaghouli and Kazmerski, 2013). It is rather difficult to imagine that remote and often-poor areas in the MENA region, which previously depended on free groundwater, can afford to pay 10, 5 or even 2 USD per cubic meter for small-scale desalination.

The current economics of seawater desalination will probably hinder a wide and bottom-up participation in desalination activities, especially given that the current cost estimates often do not include the costs of environmental externalities. Therefore, desalination is recommended to be one of several supply options, while, for remote areas, the desalination of brackish groundwater can be more cost-effective than long-distance transport of desalinated water (Ziolkowska, 2015b). This is true for the severe cases of water shortages in large Yemeni cities such as Taiz or Sana'a. In fact, transporting designated water from coastal areas to the northern highlands seems "unrealistic" and "not viable," although this option is still debated due to the desperate water situation (Varisco, 2019; Weiss, 2015). In any case, some form of public support to make final water tariffs affordable is highly needed as pro-poor orientation has been a key objective of water pricing policies in Yemen (Al-Saidi, 2017b).

In the Gulf countries, desalination has often been rendered through large-scale desalination plants with increasingly more participation from the private sector. New desalination plants are built by independent (water and) power producers (IPPs or IWPP) established as public-private-partnerships (PPPs) with state companies owning some of the assets. In Qatar, for instance, the Qatar Electricity and Water Company (the national company for water and electricity production) was involved – often as a majority shareholder – in several joint venture desalination companies. Together, they built new plants in Um al Houl (ca. 620,000 cubic meter per day, commissioned in 2016) or Ras Laffan A, B and C (the three stations producing a total ca. 741 cubic meter per day, and commissioned between 2004-2011). These new companies sell water to a single buyer (SB) (namely Kahramaa which represents the national company for water supply) through long-term purchase agreements, in which the new companies receive buy-in-guarantees and subsidized fuel costs from the state. This PPP-model is popular in the Gulf and elsewhere in the MENA region since it allows for cost-sharing, and the participation of private sector, while maintaining state control and providing new lucrative jobs for the local population (Al-Saidi, 2020a; Tsai, 2018). The state remains highly involved in the provision of desalination water, which is often sold at highly subsidized prices despite recent attempts to decrease some of these market-distorting and price subsidies (Al-Saidi, 2020b).

3.4 Safe desalination: desalination as critical infrastructure

Due to finance and cost consideration, desalination is often rendered through large-scale plants, and, in the case of the Gulf, cogenerating both power and water. Often one or a few desalination plants can provide water supply for whole cities and towns. Al-Saidi and Saliba (2019) studied the case of increased risks to coupled and large-scale systems in the Gulf. A handful of desalination sites located on the Gulf coasts provide water supply to major cities in the Gulf, such as Riyadh, Doha, Dubai or Abu Dhabi. There are several risk scenarios threatening this mega-infrastructure, such as major operational disruptions, sudden fluctuations of demands, price instability of often-imported inputs, climate related events and attacks by state or non-state actors (Al-Saidi and Saliba, 2019). Therefore, it is highly relevant to conceive desalination infrastructure in water-scare countries as critical infrastructure that should be safe and resilient.

In the Gulf, desalination plants are protected through special police units (infrastructure security) and different layers of restricted access. Still, some of the risks to desalination plants – particularly in semi-closed seas with increased infrastructure development – are hard to protect against, e.g., those related to failures in other systems or external events. Heatwaves, oil spills, industrial or human errors, and security incidents can disrupt desalination operations with serious cascading effects. Resilience- and risk-based strategies for desalination supply security through detailed plans and anticipation of crises are needed (Al-Saidi and Saliba, 2019). In the Gulf, GCC governments are increasingly aware of these aspects and are mainly addressing them by ramping up their efforts to develop large reservoirs for maintaining supply for days and weeks in the case of a disruption. Besides, some desalinated water or treated wastewater is used to reinject groundwater which serves as water storage (Darwish et al., 2015).

At the same time, regional cooperation can mitigate some of the risks through supply diversification, regional contingency plans, integrated infrastructure and exchange of knowledge (Al-Saidi, 2021; Al-Saidi and Saliba, 2019). In the Gulf, most desalination activities rely on the Gulf waters, which are increasingly becoming vulnerable due to rising salt levels, climate change, and the impacts arising from the expansion of coastal development. Gulf countries can collaborate on sharing knowledge and experiences related to the protection of coastal infrastructure and ecosystems. There have been regional cooperation initiatives such as the establishment of Marine Emergency and Mutual Aid Center (MEMAC), which is a part of the Regional Organization for the Protection of the Marine Environment (ROPME) established by the Kuwait Convention of 1982 and adopted by all the Gulf littoral countries. Current GCC-based plans include the establishment of a regional climate research center, and increasing science-based collaboration. Future regional cooperation efforts should explicitly address the cross-boundary impacts of desalination, and develop knowledge and plans to mitigate risks through contingency plans, including studying the option of joint water storage and transfers.

4. Discussion: Collaboration towards a sustainable and circular desalination

4.1 Desalination's success as a broad management aim

For many decades, the ability of the desalination industry in the Gulf to provide reliable water supplies for the domestic sector has been dependent on professionalism and good management of the desalination industry. Desalination has grown significantly since the 1950s in the Gulf, and, despite existing environmental impacts, can serve as a reference case for the wider Arab region, which can invest in low-energy and green desalination technologies (Son et al., 2021). The success of desalination in the Gulf in terms of a good coverage of water services at a reasonable cost is also a function of strong public investments in both desalination infrastructure and human capital (Saif, 2012). However, the desalination industry in the Gulf results in important environment impacts and lacks regulation, particularly in issues such as brine (Hosseini et al., 2021; Le Quesne et al., 2021). Academic literature on the environmental impacts of desalination often suggest that the desalination industry can solve issues such as brine management through better technologies and practices (Al-Absi et al., 2021; Jones et al., 2019). However, it is important to understand that desalination plants operate within a narrow managerial perspective of day-to-day operations. Moreover, desalination managers (plant-level operators and decision-makers) are sometimes unwilling or unable to tackle some of desalination's environmental impacts. This is due to costs associated with monitoring impacts of desalination activities on the environment, mitigating these impacts (e.g., reducing emissions or treating the brine) and reporting actions. If there is no clear and enforceable legal frameworks mandating environmental protection measures, desalination operators might not take action.

Figure 2 shows that for a sustainable desalination, it is important to bridge the gap between the managerial perspective of the water supply executives and the governance perspective of the water sector regulators and policymakers. As mentioned earlier, sustainable desalination can be guided by four broader sustainable development aims, namely efficiency, environmental sustainability, equity, and security. However, these aims have different interpretations from a managerial or a governance perspective. For example, desalination managers are more concerned with technical efficiency of desalination plants, and associated distribution networks. In the Gulf, water supply managers are investing in infrastructure to minimize water losses, revising building codes to encourage water and energy efficiencies (e.g., through building certification), and encouraging behavioral change to reduce water consumption (Saif, 2012). Gulf countries exhibit some of the world's largest ecological footprints (i.e., water, energy, food and carbon use per capita), and environmental awareness is largely lacking. It is therefore highly relevant to encourage responsible consumption through awareness campaigns, role models, and environmental education. Pricing water adequately can also play a role in making citizens appreciate its value. Considering the current water price compared to household income in the Gulf, affordability of water services – which should not exceed 5% of monthly expenditure as an international standard – has not been an issue.

At the level of desalination plants, improving performance through managerial oversight, incentives, maintenance, and monitoring systems are important efficiency considerations. Besides, desalination managers understand environmental sustainability through interpreting existing regulatory frameworks and seeking to comply with them – in case they exist. In Saudi Arabia for example, the lack of specific environmental requirements and clear criteria (e.g., quality thresholds and clear procedure for water intake and disposal) means that some desalination plants might not have transparent data and monitoring systems (van der Merwe et al., 2013).

Desalination costs are an important parameter for the desalination industry to determine its ability to provide affordable supply or to invest in technology with better environmental performance. Minimizing desalination costs is at the heart of the social responsibility of the desalination industry, although the ability of this industry to provide affordable water and to minimize environmental impacts depends on many external factors, including the availability of subsidies. The economic feasibility of many of the environmental technologies, including those towards materials' recovery and brine minimization, will depend on the level of the water tariffs (regulated by governments) and the availability of some capital subsidies (for purchasing the rather expensive technologies) or subsidies for the brine industry for the development of more cost-effective technologies (Kumar et al., 2021). While subsidization of the desalination industry might not be required in the case of affordability (full price including environmental externalities acceptable relative to households' consumption and monthly income), it is a common policy in the MENA region, and particularly advised for countries with a large proportion of poor households.

Desalination operators and plant-level managers can work towards more transparency using sustainability and/or financial reports in order to display responsibility and good performance. Instruments such as benchmarking or environmental ranking of desalination plants have been suggested as a way for the Gulf to improve its competition and performance (Al-Sharrah et al., 2017). Besides, desalination plants are less concerned with the diversification of the different water supply options and the resilience of the water supply to shocks. For them, the key concerns are plant-based security, the avoidance of errors and the availability of affordable production inputs as well as contingency plans. For example, the desalination industry in the Gulf is increasingly dependent on innovative technologies (e.g., membranes), which are so far not produced locally (Al-Saidi and Saliba, 2019). On the other hand, Gulf countries have accumulated a great deal of technical knowledge in operating desalination plants. This knowledge can be shared with other countries in the MENA region that desire to construct new plants to compensate water scarcity.

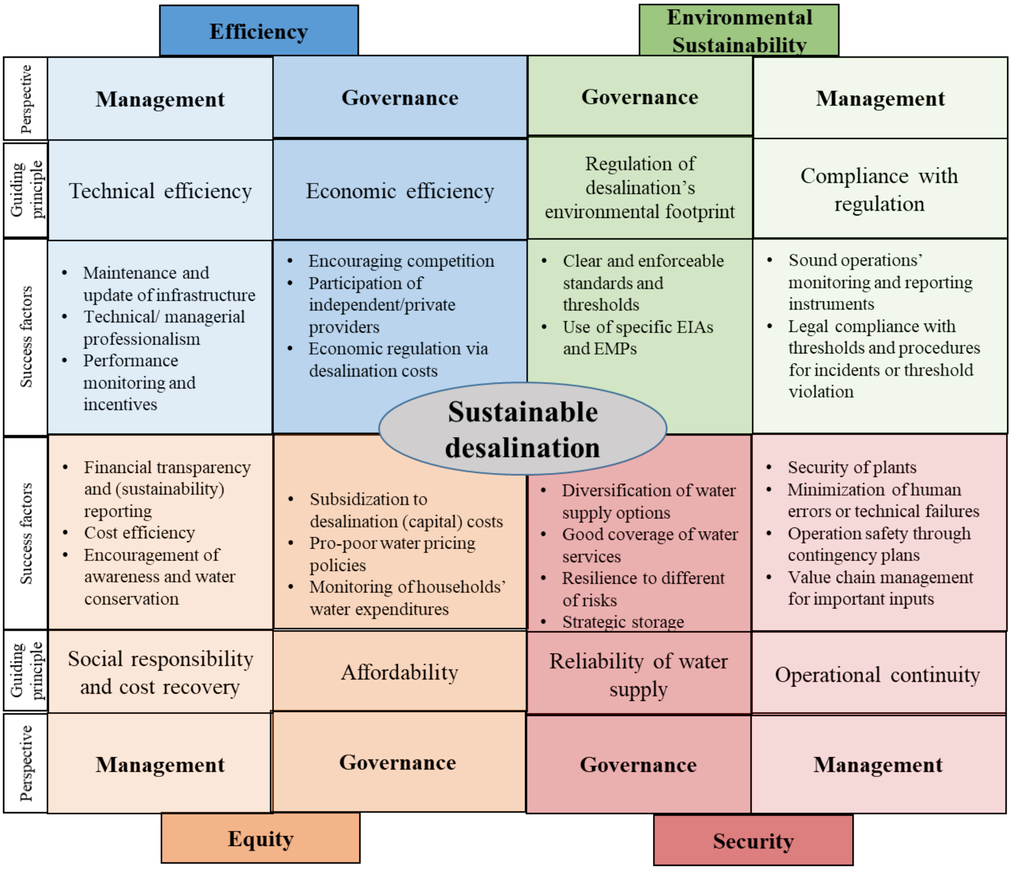

Figure 2. Sustainable desalination from management and governance perspectives (NOTE: figure to be redesigned professionally).

4.2 Desalination's sustainability as a multi-level governance task

Desalination governance is a complex task embedded within legal frameworks and policy choices regarding the sustainable development of the whole water sector. Using the key success factors for desalination governance depicted in Figure 2, one can highlight three overarching recommendations. First, economic and environmental regulation of desalination activities should be pursued at the same time. Economic regulation is a comprehensive approach for closely monitoring and improving the performance of the water sector (Hernández-Sancho, 2019). In the desalination case, it means working more closely with desalination plants towards monitoring costs, improving competition and the provision of incentives and instruments for performance improvements. There are several soft and hard instruments for economic regulations, ranging from benchmarking and "naming and shaming," yardstick measures for monitoring costs and providing incentives or disincentives, to the installation of independent economic regulators. Environmental regulation can be embedded within comprehensive regulatory frameworks (e.g., independent regulators), but the goal of economic regulation is basically to closely work with service providers in order to improve their cost function and minimize environmental impacts (Nour and Al-Saidi, 2018). Regardless of the shape of the regulatory framework, environmental regulations for desalination activities need to be revisited in the Gulf and the Arab region. Procedures and quality thresholds for brine discharge are needed as a "lowest common denominator" in regulation. Internationally, the quality of regulatory frameworks in the MENA region seems lower than in other regions such as Europe, the USA, or Australia (Sola et al., 2021).There are also good practices from the region such as in Israel, where public support enabled the desalination plants to invest in expensive brine transport infrastructure, special monitoring systems and the rehabilitation of coastal aquifers (Shulman et al. 2011).

Second, public leadership and industry-government-science collaborations are essential for making sustainable desalination possible. Public leadership is important for making desalination affordable through subsidizing some capital costs (particularly for expensive small-scale desalination), encouraging private sector participation (e.g., through purchase agreements and cost sharing), and setting up appropriate pricing policies. This does not mean providing unnecessary subsidies or providing expensive (especially considering environmental externalities) desalinated water for free or at a low-cost despite affordability in terms of the household income. Some forms of "smart" pricing policies with discounts and rebates for certain groups might still be needed for guaranteeing equity in countries with large poor populations (Al-Saidi, 2017b). Besides, many of the new environmental technologies for lowering the impacts of desalination activities stem from industry-science collaborations, which will still depend on public Research & Development (R&D) funds prior to commercialization, e.g., the case of Zero-Liquid-Discharge techniques or emergent circular desalination strategies (Bello et al., 2021; Le Quesne et al., 2021). Third and finally, large-scale desalination as a sole or dominant supply option needs to be scrutinized in the wake of rising risks and increasing environmental damage. Alongside strategic storage, encouraging conservation practices and cooperating with desalination plants on emergency and resilience plans, policymakers should study options to encourage supply diversification and desalination at different scales. In the near future, decentralized desalination can become more accessible in terms of technologies and costs. The reliance on mega-desalination projects can create path dependences and rigidities that are both risky and irreversible.

5. Conclusion

The rise of desalination in the MENA region is expected to continue due to its improving economic feasibility and rising water demands. Desalination has become relatively affordable partly because environmental externalities are not priced. While desalination is necessary in many areas of the MENA region, it can produce serious environmental damage in terms of pollution, emissions and the damage of coastal ecosystems. Academic and policy debates often focus on questions related technologies, which are perceived to "solve" some of desalination's negative impacts. The experience of the Arab Gulf countries show that desalination can indeed provide a reliable and clean water supply over the long-term, but it is not a technical panacea for water scarcity since environmental impacts should be tackled. The desalination discourse needs to include broader governance and regulatory issues, alongside emergent topics related to the security and the diversification of water supply. In the following, some interrelated recommendations are presented in order to advance sustainable desalination in the wider MENA region using some lessons learned from the Arabian Peninsula.

1. *Desalination as a broader good governance task (not only techno-managerial issue):* Good desalination governance is oriented towards several normative principles grounded in a broader understanding of

sustainable development. There is a need to tackle desalination beyond technical or managerial solutions and adopt several solutions to make desalination low-impact, accessible and safe. As to be explained in the next points, this also means incorporating softer issues related to governance, regulatory policies, and finance and cooperation among stakeholders (e.g. public planners and regulators, private investors, managers of desalination plants, water distributors, users, and the civil society).

2. *Environmental regulation as a key gap:* Low-impact desalination means tackling environmental problems across the life cycle of desalination. At the core of such an endeavor is a clear and enforceable environmental regulation that includes standards for improving water quality, required thresholds, specific impact assessments and/or monitoring plans. Environmental regulation is the missing link in the often technology-driven debate on the management of the desalination brine, a highly important topic for lowering desalination's environmental footprint.

3. *Public leadership for disseminating green desalination technologies:* Public leadership is important for lowering desalination costs, including any necessary investments in R&D of green desalination technologies. Alongside supporting environment-friendly desalination technologies through public investments, public support to brine mitigation strategies (e.g. infrastructure for brine transport) might be necessary. The private sector needs also to be involved in co-developing and piloting these technologies.

4. *More participation for increased desalination's access:* Accessible desalination often requires public investments, while new Public-Private Partnerships can lead to a sharing of costs and risks. Private companies are increasingly active in joint ventures with state companies through long-term agreements to build and operate desalination plants. This leads to increased investments in desalination activities, while the state can retain control and ownership of most of the desalination assets (e.g., as a majority asset owner in the desalination joint ventures).

5. *Considering desalination at different scales:* While large-scale desalination remains a dominant option due to its cost efficiency over the long run, it can enlarge desalination risks and should be accompanied by resilience-based contingency planning. Although small-scale desalination remains rather expensive, it is considered as an option for remote areas, particularly using the nowadays-affordable renewable energies.

6. *Broader engagement of developmental actors:* The engagement of development aid, civil society and local government can help deliver desalination even for poorer communities with depleted water resources. Local level actors from the civil society and development cooperation can work together to provide financing schemes and capacity building programs for remote communities and/or small-scale farmers in order to utilize desalination technologies to provide additional water supplies for irrigation and domestic supply. Cost sharing through community-based ownership or through special subsidy programs for purchasing assets can help disseminate desalination. Such support programs exist

in other areas such as solar-based irrigation, and can provide important lessons for promoting decentralized desalination.

7. *Collaboration and co-development for more sustainability in the desalination sector:* From a macro-perspective, a sustainable and circular desalination joins the two perspectives of desalination management and water governance. Desalination managers have a more short-term view that is focused on daily operations, compliance, costs per unit and internal management. They should be encouraged to adopt more sustainable practices with regard to their technical efficiency, monitoring practices, transparency, reporting or contingency planning. For this to happen, broader desalination governance should focus on collaboration and co-development between different stakeholders at different levels. Sector regulator, planner and policymakers should encourage more instruments towards more integration among economic and environmental regulation. Sustainable desalination will be an outcome of collaborative efforts among desalination stakeholders, and the increased attention to environmental and non-technical impacts of desalination can encourage closer coordination and collaboration.

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