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The Role of Sound Groundwater Resources Management and Governance to Achieve Water Security

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Groundwater Governance for Conflict-Affected Countries

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Abstract

Water security is critical in developing countries that face protracted crises, displaced peoples, food insecurity and climate vulnerability. Groundwater can help regions burdened with these issues; however, unregulated groundwater extraction can lead to unintended long-term consequences including aquifer depletion, decreased surface water flows and environmental degradation. This paper focuses on conflict-affected states in arid and semi-arid countries of Africa and the Middle East with selected case studies in Jordan and Kenya. Governance with best practices should include an array of stakeholders such as water managers, local policymakers, donors, investors and communities conversations as part of humanitarian/development work and should consider ongoing conflict, high numbers of cross-border refugees, displaced peoples, lack of financial resources and potential political corruption. Key outcomes include specific data and regulatory recommendations that incorporate present legal regimes, permitting practices, groundwater resources, and water tenure concerns. Recommendations include how communities and NGOs can proactively partner with government to develop and improve information and management systems in the face of the considerable challenges faced in these settings.

Keywords

Groundwater, food security, groundwater management, Africa

01
Introduction

In these days of pandemics and medical terminology, it may be possible to suggest that the challenge of social and economic development in many of the world's less developed countries has undergone a long, slow mutation – and not for the better. In areas with displaced people, prolonged periods of crisis and food insecurity, lack of water is often at the heart of the conversation.

Access to drinking and productive water is low across developing countries and efforts to meet Sustainable Development Goal (SDG) targets continue to fall short. Groundwater can solve many of these concerns while increasing food security; however, unregulated extraction can lead to unintended, long-term consequences including aquifer depletion, decreased surface water flows downstream and environmental degradation. Low rainfall in these areas and threats from climate change generate limited recharge capacity.

In some countries, large-scale groundwater development has led to short-term benefits, but dwindling reserves. In others, groundwater has yet to be tapped. The timing for review and creation of improved groundwater governance is ideal in both settings. Conflict-affected states in arid and semi-arid countries of Africa and the Middle East, such as Jordan and Kenya, provide examples of each of these realities.

With over 60% of the country's water supply coming from groundwater, Jordan is challenged by over abstraction and the need to move water from existing agricultural users to other sectors. In contrast, Kenya has untapped resources and large populations without sufficient access to water, particularly for productive purposes. While both countries have thoughtful aspects to their governance approaches, each could borrow missing aspects from one another. In both cases, management is imperative; however, structural realities including conflict, refugees, corruption and lack of capacity challenge the ability to implement policies successfully. Solutions may be found in partnerships between government, non-government organizations (NGOs), regional management, donor investors and community stakeholders as part of humanitarian and development work.

1.1. The Context: Triple Nexus and Groundwater Governance

In the 20th century, there were developing regions and there were natural disasters as there are now. The latter sometimes occurred in the former, but also occurred in developed regions. Similarly, there was conflict between and within states that manifested itself in regional conflict, civil war and other lower-intensity conflict. Perhaps hindsight is not 20/20, but it seems that back then each of these problems had a clear cause, a distinct geography and motivated specific expertise to find solutions. The development community – multilaterals, bilaterals, governments, and NGOs – took on the development challenge, the United Nations (UN) and humanitarian NGOs took on disasters and the UN and member states took on peace-building.

Over the past 20 years, rising levels of armed conflict and the protracted nature of this conflict – along with increasingly frequent and severe natural disasters – are layered on top of lackluster economic progress to create a particularly complex challenge. Practitioners have labelled this the "triple nexus", referring to the need to blend development, humanitarian and peacebuilding assistance and to do so in an intelligent, coordinated and effective manner in order to address what is now called amongst other names, "fragility" (Petryniak *et al*., 2020). In this new world the objective is often framed as building resilience, in order that communities and vulnerable populations might be able to absorb, adapt to and transform their circumstances in the presence of repeated complex and long-lasting stresses and shocks.

This paper examines the link between this strand of human history and the changing context of how to best govern, manage and use groundwater resources. It is common knowledge that the exploitation of groundwater resources is a perennial problem in arid and semi-arid areas of developed economies. The demand for water as populations grow and economies flourish drives the diversion, damming and extraction of surface and groundwater inexorably from low-cost to high-cost supplies. Moreover, as the saying goes, "water runs uphill to money" - meaning that higher value users of water ultimately deprive lower value users of that same water – either by administrative fiat, market transactions or corrupt behavior. That economic and political power drive water entitlements and allocations, just like other resources, is not a surprise and is not limited to developed regions.

The question addressed in this paper is how to achieve some measure of effective groundwater governance in the presence of the triple nexus. Given the context, governance solutions may not be first best options. The problem is not optimization of groundwater use but rather understanding its use and developing, albeit gradually, the ability to manage this use. A two-pronged approach consists of finding entry points to the measurement, monitoring and management of groundwater whilst promoting a governance framework that can evolve towards effective management as and when enabled by the surrounding context.

1.2. The Peacebuilding, Development, and Humanitarian Context

In this section, regional trends in conflict and development are examined, alongside prospects for future humanitarian needs based on vulnerability to climate change. Particular attention is given to the Middle East and North Africa (MENA) and Sub-Saharan Africa (SSA) regions. These two regions include numerous countries designated as fragile or conflict affected states (FCS) by the World Bank and form large portions of the portfolios of international humanitarian and development NGOs.

In 2019, global organized violence consisted of over 150 conflict events (at least 25 fatalities) for a total of 75,000 killings (Pettersson & Öberg, 2020). The trend in recent years is toward increasing numbers of conflicts, although fatalities have fallen from the 2011 peak during the outbreak of the Syrian civil war. These events are classed as state-based armed conflict, non-state violence and one-sided violence. State-based conflict, which accounts for two-thirds of fatalities, is particularly prevalent in Africa with the number of conflicts in the Middle East rising in recent years. Non-state violence (two-sided violence not involving the state) is now more prevalent (44% of total events) than state-based violence; these events have grown rapidly in the last decade, primarily in Africa and the Middle East. One-sided violence conflict events vary annually in number and made up 7% of total fatalities in 2019. Africa accounts for the overwhelming majority of one-sided violence, followed by the Americas and the Middle East. In sum, MENA and SSA are beset by growing levels of organized violence.

During the 2000 to 2010 period fairly rapid rates of improvement in the Human Development Index (HDI) were observed in many developing regions, including MENA and SSA countries (UNDP, 2018). During this period the regions further behind gained ground on those that were more advanced. Since 2010, however, progress has stalled. Annualized rates of increase in HDIs for SSA and MENA countries retreated significantly. For the eight MENA countries in which Mercy Corps is present, which include some of the worst conflict-affected countries, the HDI level actually decreased in absolute terms, since 2010. Conflict appears to be taking a toll on development.

Against this backdrop of increasing conflict and waning development performance is the prospect of future increases in insecurity and crises attributable to climate change. According to the United Nations, climate-related disasters (including floods, droughts and storms) accounted for more than 90% of the world's disasters between 1998-2017 (CRED & UNISDR, n/d). Over US$ 2.2 trillion or 77% of total economic losses from these disasters were climate-related. While the absolute economic value of losses in low income countries is less than in high income countries – in part due to the value of their respective infrastructure – the portion of gross domestic product (GDP) that is lost to climate-related disasters (1.8%) for low income countries is much greater than in high income countries (0.4%) (CRED & UNISDR, n/d). The variation between regions in vulnerability to climate change, as measured by Notre Dame Global Adaptation Index (ND-GAIN), is quite stark (Chen *et al*., 2015). South Asia and SSA are by far the most vulnerable regions with MENA exhibiting somewhat less vulnerability. Notably, the conflict-affected SSA countries in which Mercy Corps is present are more vulnerable than other regions by a considerable amount, and show little improvement between 1995 and 2018. Clearly, as climate change proceeds the vulnerability of communities in these already conflict-affected and development-challenged regions is only likely to worsen.

1.3. Water Scarcity, Governance and the Challenge of Groundwater Management in the P resence of the Triple Nexus Challenge

Having established that the confluence of development, humanitarian and conflict issues is particularly acute in MENA and SSA, we turn to examine the extent of water scarcity in these two regions. Kummu *et al*. (2016) carried out analysis of water shortage (water available per capita) and water stress (portion of water available being consumed by humans) across the globe. The combination of these two factors constitutes water scarcity. Their results demonstrate that MENA, along with Central Asia, is one of the most water scarce regions of the world. A large portion of the MENA region has the highest level of water scarcity, recording both high shortage and stress. Countries in the Sahel, Horn and East Africa, as well as those in southern Africa display moderate and high water shortage, but not water stress – as their usage of available surface and groundwater remains relatively low. SSA and particularly MENA are thus also beset by the drivers of water scarcity.

What prospects do these regions have of managing their water resources, particularly groundwater? This will depend on the ability of nations to formulate, approve and implement laws, regulations and administrative policies, or the capacity of countries for self-governance. Governance indicators from the World Bank's Country Policy and Institutional Assessment (CPIA) framework and Transparency International's Corruption Perceptions Index (TI-CPI), provide a window into the likely capacity of regions and countries for successful management of a common resource like groundwater (World Bank, 2020, Transparency International, 2020). Across relevant indicators from these datasets, SSA, MENA, score poorly, lagging the other regions with the exception of South Asia. However, Jordan, and to a lesser extent Kenya, score well compared to their peers. Jordan and Kenya have relatively more governance capacity than their peers. The case studies in this paper investigate how this translates into the realm of groundwater governance.

This quick review of the challenges of the triple nexus, water scarcity and governance suggests that the most fragile and conflict-affected countries have low development levels, high conflict levels and high vulnerability to climate change and associated shocks, stresses and natural disasters. For the arid and semi-arid areas that make up MENA and large portions of SSA, there is a dependence on groundwater sources to meet human needs for food and drinking water.

In MENA, due to higher income and development levels, groundwater sources have already been tapped and are being used at levels well above their replenishment levels. This poses questions about the longevity of these resources and the costs of alternative sources and/or conservation measures. For SSA, with the exception of portions of the Horn and southern Africa, groundwater use remains relatively underdeveloped.

These two regions – exemplified by the cases of Jordan and Kenya – prompt the question of how best to govern and use the groundwater resource. In MENA the manifestation of this question is whether, and if so how, to scale back groundwater extraction. For SSA, the issue is where, and if so how, to increase groundwater extraction.
This paper does not address the question of whether groundwater extraction should or should not be scaled back or developed in these regions. This normative choice is for each country to make within the context of national policy. Here, we focus on the tools of governance in the context of the triple nexus.

02
Groundwater Governance

In practice, groundwater governance includes a system by which the permission to use groundwater is granted by the relevant authority, and this use is measured, monitored and managed against approved terms and conditions for groundwater extraction and use. A governance system may also include regulations related to other objectives such as recharge rates, human rights, water transfers, water conflict, water quality, surface water management and environmental uses.

Groundwater has long been regarded as a common pool resource, meaning a resource from which it is hard to exclude potential consumers, and the consumption of which by one consumer reduces the amount available to another (Ostrom & Ostrom, 1972). In the short-run groundwater better fits the definition of a public good given that there is plenty of water to meet all demands placed on the resource. However, in the long-run one person's use of groundwater will subtract from that available to another (Aylward, 2016; Hardin, 1968).

> *"Once usage exceeds the recharge rate, the over-draft on the aquifer will lead to the depletion of the resource if left unaddressed by collective action"*

As discussed later, the extraction of groundwater today for agricultural use in Jordan makes this water unavailable to meet urban demand for household water needs in the future. Common pool resources left to open access are prone to market failure and inefficient and inequitable usage, and thus call for collective action in their management (Randall, 1983). Once usage exceeds the recharge rate, the over-draft on the aquifer will lead to the depletion of the resource (and declining water table levels and water quality as it is drafted downwards) if left unaddressed by collective action.

Society has evolved a number of institutional arrangements to manage common pool resources. These revolve around establishing institutional mechanisms for excluding (and limiting) users from accessing and using groundwater. For groundwater, relevant arrangements include:

- Centralized arrangements – collective management by public authorities at the national or sub-national scale (e.g., state/province).
- Decentralized or devolved arrangements – delegation of management power and authority to a region, often at the scale of the groundwater basin
- Common property management regimes – user groups setting their own rules for managing the resource
- Markets – setting the scale for groundwater use (the "cap"),

distributing permits to users and then letting buyers and sellers trade to meet their needs (the "trade")

Finally, there are polycentric arrangements, in which authority and roles in groundwater management are distributed across different groups. For example, groundwater permits are managed centrally, or by individual regions, but market transactions are used to reallocate permits under a fixed or variable groundwater use limit (or cap). This system avoids hierarchical power structures in favor of distributing roles and responsibility in order to enhance accountability, transparency, legitimacy and public participation, which can be beneficial in the management of common pool resources such as groundwater.

Central questions in governing common pool resources are focused on: who controls the allocation of rights of access and use to the resource; how these rights are transferred; and who is charged with managing the resource (Schlager & Ostrom, 1992; Aylward *et al*., 2009). The answers to these questions often emerge from the governing institutional arrangement.

"Newer theories of governance, including integrated water management, advocate for a holistic approach that integrates planning for source water extraction with considerations of land, climate change and urban runoff with the goal of capturing co-benefits in related economic sectors"

Some countries, like Israel, opt for a centralized approach, where all waters belong to the state and are managed at that level. Other countries, like the United States, prefer a more localized approach based on the understanding that hydrologic and regional demands vary based on location. Within the United States, some jurisdictions manage groundwater at the state level whereas others, like California, manage it at the aquifer level and still others, like Texas, have adopted a hyper-regional approach where the lowest level of government regulates groundwater.

Generally, groundwater management is a process by which permission to use water is granted to users by the relevant authority. This permission most often takes the form of a right to use water, providing the rights holder with the legal right to access a quantity of water, but not vested ownership of the water itself. Gaining a water right can occur several ways. In most instances, someone desiring a right would apply to the regulatory authority. An application includes the quantity of water requested, where it will be used, for what purpose and during what times of the year. Some application systems automatically grant a groundwater right to the surface owner whereas others may treat them like any other applicant.

A permit generally refers to a vested property right that has limited ways it can be terminated; however, a license is revocable. Limitations on the right may also vary in relation to neighboring rights. Legal alternatives like reasonable use or correlative rights both seek to ensure that one user is not pumping to the detriment of another. Most water regimes are focused on human needs and neglect the environment as an essential water user. A key governance challenge is for regimes to be protective of the resource, while responding to societal objectives for water use.

Groundwater regulatory schemes will differ based on the desired outcomes. For some, the focus might be on the rights of the applicants, whereas others may set a total pumping cap to ensure aquifer longevity. Another alternative is to tie pumping limits to spring flow or environmental flows. Newer theories of governance, including integrated water management, advocate for a holistic approach that integrates planning for source water extraction with considerations of land, climate change and urban runoff with the goal of capturing co-benefits in related economic sectors.

A defined list of reasonable or beneficial uses will assist in allocation decisions, particularly if these uses are ranked by priority. A detailed understanding of quantity ranges for each use will assist with management. For example, agriculture is generally a high priority use; however, the reasonableness of water use can vary widely depending on factors such as type of crop, method of irrigation, and land preparation.

03
Case Studies

3.1. Kenya Case Study

3.1.1. Local Conditions

The Republic of Kenya straddles the equator on the eastern coast of Africa. Kenya is a parliamentary democracy, with a free market economy largely dependent on tourism and trade in agriculture products. Prior to the coronavirus outbreak in 2020, Kenya's economy was improving after a series of challenging events including the 2013 Westgate Mall and subsequent terrorist attacks, periodic droughts, and political unrest such as the 2017 Laikipia land invasions (The Guardian, 2013; 2017). Fifty-nine percent of Kenyans have access to basic water services and only 29% have access to sanitary services (WHO & UNICEF, 2019).

Rainfall is highly variable with 80% of the country categorized as arid and semiarid. Climate change models show 1°C increase between 1960 and 2003, with most warming taking place in the 'long rains' season of March (Thornton, 2010).

Conflict is common throughout the country, but is particularly prevalent in the Rift Valley, Nairobi, the peripheral pastoralist drylands, and the coast. Violence is often the result of ethnic conflict, poverty, restricted access to pastoral resources, border tensions, easy access to small arms, and cyclical political instability. These areas also see conflict associated with land and resource access and human/wildlife conflicts, which increase during drought cycles. The prevalence of conflict in Kenya inhibits the country's ability to progress economically and effectively develop resources in ways that benefit the larger community.

3.1.2. Kenya's Groundwater Resources

Geologically, Kenya is divided by the great Rift Valley and dominated by volcanic formations in many areas. Groundwater quantity and quality is greatly affected by subsurface chemistry and physical properties. Groundwater quality is a challenge in Kenya. In Central and Western Kenya, groundwater is generally soft with moderate alkalinity. Groundwater in coastal, eastern and northeastern regions is saline and of poor quality (Mwango *et al*., 2004)

Groundwater is used for public water supply, agriculture, domestic, industry, and livestock. Kenya is currently using a small fraction of the available groundwater. A 2004 study stated that "the total present groundwater abstraction rate in Kenya is estimated at 57.2 million m^3/year. Total safe abstraction rate in Kenya is estimated to be 193 million m^3/year" (Mwango *et al*., 2004).

One challenge in managing Kenya's groundwater is lack of knowledge about underground water resources. In 2013, UNESCO led a project that sought to better understand groundwater in the very arid region of Turkana. The Lodwar and Lotikipi aquifer basins were located using satellites and radar. The two deep aquifers (over 300 meters) are estimated to contain at least 250 billion m^3 of water (Radar Technologies International, 2013). This is over 4,000 times the entire country's annual groundwater abstraction rate as cited above. However, the water was subsequently found to have high salinity, limiting the usefulness of the aquifer. In 2019, a Saudi Arabian company was contracted by Turkana County to install desalination plants and there have been discussions about transporting the water to oil prospectors via pipeline.

The Merti aquifer in the northeastern part of the country extends from northeast of Habaswein into Somalia (Mwango *et al*., 2004). Although a portion of the aquifer is located in Somalia, there is no transboundary agreement in place. One of the most important sources of freshwater in northern Kenya, this aquifer is the primary water source for 350,000 to 450,000 refugees at the Dadaab camps. This water dependency has driven research about the aquifer in order to better understand its storage and recharge. In 2014, the aquifer was being researched as a municipal water supply for the city of Wajir, with drinking water to be supplied through a 120 km pipeline, which raised concerns about intrusion of bounding saline water.

Previous studies estimated groundwater recharge of the Merti aquifer to be quite low making it a "fossil aquifer". More recent studies proposed the recharge rate to be much higher than originally thought, underscoring the need for good science to enable effective management (Blandenier *et al*., 2016). In 2014, the International Groundwater Resources Assessment Centre (IGRAC) conducted a Managed Aquifer Recharge project on the Merti, which found that the aquifer could benefit from enhanced recharge using injection wells.

The Nairobi Aquifer System (NAS) is perhaps under the most stress of any of Kenya's aquifers. The NAS covers an area of 6,500 km^2, much of which is overlain by the city. While much of Nairobi is supplied by the Tana River, there were over 4,000 boreholes in 2009 making this the most abstracted aquifer in Kenya, also vulnerable to pollution and drought. Boreholes that used to be 80 meters deep now need to extend 400 meters to reach water (Reuters, 2018). In addition to the pumping, up to 50% of the water may be lost in transmission due to a deficient distribution system.

The Tiwi and Baricho are smaller coastal aquifers that supply water to Kenya's south coast, primarily for municipal water supply. Currently, neither aquifer appear to be over-extracted, but the Baricho has higher vulnerability to pollution due to its alluvial nature. Limited data is available for these. In addition to the coast, the cities of Naivasha, Nakuru, Wajir, Mandera, and Lodwarand as well as rural centers are heavily dependent on groundwater resources. Hand pumps are common in villages across the country.

Long-term sustainability of aquifers in Kenya is not solely controlled by careful pumping. Government authorities must also understand the linkage between land use and groundwater. Protection of recharge zones as well as water quality risks is essential. In 2014, the Kenya Groundwater Mapping Programme (KGMP) was launched. The goal of the project is to build local capacity to effectively and sustainably manage groundwater resources by improving the scientific knowledge about groundwater.

3.1.3. Current Groundwater Governance

In Kenya, water resources are vested in the state (Table 3-1). Water use is subject to approval and a water permit that typically defines type of use, the amount authorized, and the duration of use. Despite this legal structure, groundwater is often perceived to be a private resource that can be used by the surface property owner, which puts it at risk of being overused as a common pool resource with a focus on short-term gains.

Initially, national water management in Kenya focused on making potable water available to all households by the year 2000; however, the 1999 National Water Policy shifted the responsibility for water supply to the local level and focused the national government on regulatory management. The Water Act of 2002 further separated the obligations of supply from regulation, decentralized many functions to lower levels, shifted focus to implementation, and provided a role for non-governmental entities. The Act created the Water Resources Management Authority, which regulates the ownership and control of water and makes provisions for the conservation of surface and groundwater.

Part II of the Act states that all water is vested in the state. The Minister, assisted by the Director of Water, is permitted to exercise agency over water in accordance with other provided provisions. Decisions about water must be focused on conservation and the "proper use of water." Groundwater does not have its own regulatory framework, but is managed as part of water resources generally. This can be problematic due to the unique nature of groundwater.

To assist with the goals of the Act, Part III establishes the Water Resources Management Authority (WRMA), which consists of a Chairman and ten appointed members. The WRMA is primarily tasked with development of guidelines and procedures for allocating water, water monitoring, issuing and enforcing permitting, protecting water quality, collecting and processing data. The Act goes on to specify the process through which the WRMA should develop a national strategy to manage, protect, use, develop, conserve, and control the water. Plans should be specific to each catchment area with stated goals. A groundwater conservation area can also be created in areas when there is a need to protect public or commercial water supply. The role of non-governmental entities and community groups (called water resources user associations) were greatly enhanced by the Act, but final decision making continues to be centralized.

The WRMA has the ability to grant a permit and ensure compliance with the requirements. They shall first give an authorization to construct the borehole or well. Additional regulations regarding the licenses for water providers were detailed in the Water (services regulatory) rules. Unfortunately, permits are often issued without a good understanding of the aquifer or the impacts pumping would have on it.

The 2002 Act was updated again by the 2016 Water Act. This Act provides for the regulation, management and development of water resources and water and sewerage services in line with Kenya's new Constitution promulgated in 2010, which declares that access to clean and safe water is

Table 3-1 Hierarchy of Kenya's water institutions (adapted from World Bank, 2016)

<table>
<tr><th colspan="4">Kenya Water Agencies Roles and Responsbilities</th></tr>
<tr><td rowspan="2">National Level</td><td>Regulation and Dissemination</td><td>Infrastructure</td><td></td></tr>
<tr><td colspan="2">Ministry of Water, Sanitation and Irrigation (WRA)</td><td>Policy Creation</td></tr>
<tr><td>Regional Level</td><td>Basin Water Resources Committe (BWRC)</td><td>Water Servies Regulatory Board (WASREB)</td><td>Regulatory Implementation</td></tr>
<tr><td rowspan="2">Local Level</td><td>Water Resources User Associations (WRUAs)</td><td>Water Service Providers (WSPs)</td><td>Direct Services</td></tr>
<tr><td colspan="2">Water Consumers and End Users</td><td>End User</td></tr>
</table>

a human right and tasks several counties with providing it, vesting the authority to manage water in those counties. The Act recognizes a shared responsibility between the national government and the county government and gives use of water for domestic purposes priority over irrigation and other uses. The Water Act continues to separate water resource management duties from water and sewage services. The Act created several new entities and redefined the roles of existing departments at national, regional and local levels.

On the resources side, the Water Resources Authority (WRA), formerly the Water Resources Management Authority, is focused on creating policies to protect, conserve, control and regulate use of water resources through the establishment of a national water resource strategy. The Basin Water Resource Committees (BWRC) are local catchment stakeholder groups under the WRA, which provides regional, transparent planning. At the lowest local level, the Water Resources Users Association (WRUA) manages the water for the community.

The Cabinet Secretary is obligated to create or revise a National Water Resource Strategy every five years with public participation. The goal of this strategy is "to provide the Government's plans and programs for the protection, conservation, control and management of water resources" (Kenya Water Act, Section 10(2), 2016). Groundwater is not specifically listed in the description of the strategy; however, it is likely included in some of the catch-all language. Further, Article 23 recognizes that the Cabinet Secretary may need to make special measures to conserve groundwater in the public interest to preserve water supply for the public or industry or to protect the aquifer. For policy implementation, Article 56 states that groundwater abstraction is dictated by the Fourth Schedule of the 2010 Constitution, which defines the distribution of functions between the national and county governments. While permitting is a national obligation, counties are responsible authorities for the "implementation of specific national government policies on natural resources and environmental conservation, including…water conservation" and water services (Constitution of Kenya, Fourth Schedule, Art. 56, 2010).

"Perhaps the largest challenge is lack of capacity including staff, technical, and financial resources"

As a result of these laws, Kenya has completed a National Water Master Plan 2030. This report is part of the larger Kenya Vision 2030 published in 2007, which includes water targets and references to the 1999 water policy. This water master plan includes national water policy and development targets and attempts to estimate sustainable groundwater yield for several catchment areas. Unfortunately, the plan ignores surface water/groundwater interaction and assumes uniformity across aquifers. It is highly unlikely that all aquifers would have comparable sustainable yields as recharge is highly variable across climates and lithologies. Additional data would provide greater accuracy.

Much of Kenya's groundwater is shared with other countries, which compounds management challenges. At least five significant transboundary aquifer groups are shared with neighboring countries: the Rift Valley aquifers, the Elgon aquifer, the Merti aquifer, the Kilimanjaro aquifer, and the Coastal sedimentary aquifers. Despite the amount of shared water, no cooperative use or protection agreements are in place.

3.1.4. Governance Challenges

Reviewing the situation in Kenya, several key challenges to effective groundwater management emerge. The first challenges are the current socioeconomic and conflict conditions throughout the country. Population is quickly increasing and much of the current population still does not have access to water. Groundwater development will be strongly tied to both of these issues.

Climate variability and predicted climate change uncertainties are currently not included in groundwater development decisions. Managing withdrawals towards sustainability (or any other target) requires considering the likelihood of longer droughts and heavier rainfall events. To do this effectively, one must first have knowledge of the resources involved. Critical scientific information related to recharge rates and connection to surface water needs to be understood in the context of a changing climate.

Perhaps the largest challenge is lack of capacity including staff, technical, and financial resources. "There is inadequate capacity in the WRMA offices responsible for the NAS. Between them—two geologists are deployed to Nairobi [sub-regional office] SRO, none in Kiambu SROs—groundwater staff must manage about 4,000 groundwater permits" (Mumma, 2007).

Lack of capacity often leads to lack of enforcement, which places the aquifer at the mercy of the commons. Common pool management of the resource negates interest in groundwater conservation. Implemented legal systems that include authorization protocols such as permits and water charges tend to improve compliance with larger goals. Currently, Kenya has moved away from centralized enforcement to a more localized approach utilizing aquifer-specific management plans and stakeholder/public participation. While this is a preferable governance structure due to the local character of water resources and demand, it is not effective without implementation support and consistent enforcement.

3.2. Jordan Case Study

3.2.1. Local Conditions

The Hashemite Kingdom of Jordan is a parliamentary constitutional monarchy made up of twelve governorates and ruled by King Abdallah II. As a small, largely desert, landlocked economy, Jordan has a relatively free market economy that depends on trade. Two-thirds of the economy is based on services, with the food industry and tourism being important contributors. Jordan is classed by the World Bank as an upper middle income country and plays an important geo-political role at the center of the Middle East. In particular, Jordan has absorbed waves of people displaced by conflict in the Palestinian territories, Iraq and Syria. Of Jordan's roughly 10 million people, some 2.4 million are classified as refugees by the World Bank.

3.2.2. The Water Context in Jordan

As an arid country with limited surface water, Jordan is heavily dependent on groundwater. Jordan suffers from both water shortage, with a very low availability of water per capita, and from water stress, with water usage exceeding the renewable supply. Jordan's efforts to address water scarcity are tied to the country's unique geography, as well as regional hydro geopolitics, the vast majority of the population and economic activity is situated in northwest Jordan, along with most of the surface and groundwater sources. Northwest Jordan is divided into a lowland and a highland portion, with the agricultural Jordan River Valley making up the former and the larger cities of Amman, Irbid and Jerash sitting atop the plateau that extends into eastern Jordan. The Jordan River and its tributaries provide the bulk of Jordan's freshwater supply, water that historically was used by the Jordan Valley Authority to supply a narrow corridor of irrigated farms stretching from the Syrian border south to the Dead Sea.

In Jordan, groundwater use and surface water use are tightly connected as the country strives to use and reuse its limited water supply. The Jordan Valley Authority's water supply is gradually being transitioned from freshwater to treated wastewater from the highlands. The highlands, home to most of the industry and population of the country rely heavily on groundwater extraction for water supply. Thus, the country is effectively turning groundwater pumped in the highlands for municipal and industrial (M&I) purposes into treated wastewater for irrigation in the lowlands. As urban demand grew and as the input of freshwater to the system was reduced by Syria and Israel, the wastewater systems were put in place for Amman's effluent, later to be follow for other cities located to the north. As wastewater replaces surface water in the Jordan Valley, the freed-up surface water is to be pumped up to the highland for M&I purposes, relieving the pressure on the groundwater resource.

Further to the east in the highlands, in the more sparsely populated Azraq and Mafraq governorates, large quantities of groundwater are used for irrigation, as well as for M&I purposes. This water usage is not connected to that in the western highlands and groundwater not consumed by crops is lost to evaporation or percolates into the groundwater table. Climate change in Jordan is bringing with it higher temperatures, less precipitation and more intense bouts of precipitation. The implication of these changes in such arid areas is that a larger portion of the annual water budget will go to satisfying atmospheric demand, i.e. as evapotranspiration. Thus, it is expected that groundwater recharge rates in the highlands will decrease, even as the incidence of flooding increases.

3.2.3. Groundwater in Jordan

There are eleven aquifers in Jordan, of which a few play a major role in the country's water supply (JMWI, 2018a) The A7/B2 aquifer with outcrops in the heavily populated northwest region makes up one-quarter of groundwater usage. A highly productive aquifer with pumping depths on the order of 50 to 250 meters, this aquifer provides high quality water. However, due to the intensity of use the aquifer is declining at rates of 1 to 12 m/yr with the highest declines in the area of Irbid and Mafraq near the Yarmouk River (JMWI, 2018a).

The Alluvium aquifer in the Jordan Valley and the Basalt and B4/B5 aquifers in the Azraq basin are relatively more shallow (5 to 150 m) and heavily used for urban centers, Syrian refugee camps and commercial groundwater irrigation.
These aquifers are declining at rates from 1 m/yr to 5 m/yr with the highest rates of decline noted in the Jordan Valley (JMWI, 2018a). In Azraq, groundwater temperature and salinity are also increasing and a shallow wetland has dried up, indicative of the declining water table. The Ram Aquifer, primarily located in Saudi Arabia, has been tapped for some 20% of the country's water supply with this water being pumped all the way to Amman. The Disi Aquifer, shared with Saudi Arabia, has very low recharge rates and is considered as non-renewable. Jordan pumps Disi water all the way to Amman for M&I purposes. This aquifer is declining at rates of from 0.6 to 5 m/yr (JMWI, 2018a).

Analysis by both the Ministry of Water and Irrigation and the USGS conclude that for basins with large withdrawals, the trend is towards increasing declines and worsening water quality (JMWI, 2018a, Goode *et al*., 2013). The United States Geological Survey (USGS) forecasts a decline in saturated aquifer thickness in the principal basins of about 30-40%, and falling to zero (i.e. no water available) in 5% of the locations by 2030 (Goode *et al*., 2013). As water levels fall, an increase in total dissolved solids and worsening of water quality in these aquifers is also observed (Al-Karablieh & Salman, 2016, Goode *et al*., 2013). Economic analysis for a number of key agricultural basins forecasts that these declines will lead to increasing costs of accessing groundwater for irrigation, rendering many of the low value crops unviable in ten to thirty years, crops that account for a large proportion of current area planted in these basins (Rosenberg & Peralta, 2012).

3.2.4. The Groundwater Management Challenge in Jordan

Jordan has 710 million m³ of renewable water supplies, of which 40% is the groundwater safe yield, 30% is the Jordan River freshwater and the remainder is treated wastewater, local surface water and desalinated sea water (JMWI, 2018b). An additional 143 million m³/yr are estimated to be available from nonrenewable groundwater for fifty years, for a total time-limited sustainable supply of 853 million m³/yr.

In 2017, the demand for water in Jordan was 1,412 million m³ and the amount actually used, once shortfalls are taken into account, was 1,047 million m³. This amount does not include 225 million m³ of undocumented pumping from wells without permits, first documented in 2014 (Al-Karablieh & Salman, 2016). Comparing water use in 2017 with that in 2000, the observed increase is 30% with a compounded annual growth of 1.5% (JMWI, 2018a; 2018b). This growth incorporates the water deployed to meet the influx of refugees since 2011.

"As the surface water resource in Jordan is fully used and a significant portion of the groundwater is used twice, first for M&I and second as wastewater for irrigation"

As the surface water resource in Jordan is fully used and a significant portion of the groundwater is used twice, first for M&I and second as wastewater for irrigation, the deficit in renewable supply is made up from groundwater. Nationally, groundwater depletion is 22% of total usage if the drawdown of non-renewable groundwater is excluded. If mining of this fossil water is included, the depletion amount rises to 36% of total use (or 379 million m³/yr). However, even these sums are based on the official records of water usage, which does not take into account the aforementioned undocumented and illegal water use of approximately 225 million m³. Therefore the total unsustainable groundwater extraction may be on the order of 600 million m³/year, representing 60% of the official usage or 220% of the country's safe yield for groundwater.

Of further concern is that the draw on groundwater continues to grow. From 2000 to 2017, M&I water use grew by 69% or an annual rate of 3%. In theory, this allows for the production of higher amounts of wastewater for irrigation, which will eventually result in the pumping of surface water supplies to the highlands to alleviate this draw on groundwater. This shift is underway, but it is unclear if it will be sufficient as long as water use increases at such a rapid pace in the highlands.

3.2.5. Current Groundwater Governance

Jordan's legal regime to manage water is dictated by three sources: The Water Authority of Jordan (WAJ) law 18 of 1988, the Jordan Valley Authority (JVA) law 30 of 2001, and the Ministry of Water and Irrigation (MWI) law 54 of 1992.
In Jordan, all water resources are considered property of the State and are not able to be used or transferred outside of limited legal parameters, although there are exceptions for domestic water needs. Although water is not owned by individuals, private water use rights can be obtained. Criminal and financial penalties can result if a non-authorized groundwater well is drilled.

The MWI is the governmental agency tasked with creating water strategy, policy and planning. It was created to pursue a more integrated approach to national water management throughout the country. "MWI aims to upgrade, develop and regulate the water sector and enhance the quality of water services" (Centre for Environmental Research, 2020).
In addition to planning, implementing and overseeing a national water strategy, it is also tasked with executing international water agreements and developing private sector partnerships with support from international donor organizations.

Two agencies report to the MWI. The WAJ is the direct services provider tasked with planning, construction, operation and maintenance of water and wastewater systems. The second institution directly subordinate to the MWI is the Performance Monitoring Unit (PMU), which manages private sector participation projects.

To meet its obligations as service provider, the WAJ is tasked with mapping water resources, developing policies to provide water to citizens; preventing pollution of water resources; and regulating the uses of water, preventing waste, and conserving water. WAJ sets policy for use and management of resources through a board chaired by the Minister of MWI and including the Secretary Generals of JVA, ministries of Planning, Agriculture, Municipal and Rural Affairs, Environment, Health, Industry & Trade, Finance, Energy and Natural Resources and an expert member.

The MWI/WAJ grants for drilling licenses and abstraction permits in accordance with the effective groundwater legislation (Al-Karableih & Salman, 2016). Tariffs are placed on all wells, calculated based on volume of water use; however, this system has been criticized for lack of enforcement and as being too inexpensive. A survey of farmers in the JVA disclosed that billing efficiency was only 82% and collection efficiency only 75% (van den Berg & Al Nimer, 2016). Despite this allowance, many illegal wells remain (Al-Karableih & Salman, 2016).

The Jordan Valley Development Law of 1988 established the JVA to manage the socio-economic development of the Jordan Rift Valley. The JVA accomplishes this by studying the resources, planning and building projects, continued operation and maintenance of irrigation projects and monitoring of public and private wells in the region. Specifically, they are mandated to plan, design, construct, operate and maintain irrigation projects, dams and hydroelectric power stations in the region. In 2011, the national government realized the challenges of a fully centralized groundwater management approach. To disperse some of the responsibility for municipal water supply, three additional utility companies were created to assume a more localized responsibility to distribute water through the authority of the WAJ (Al-Karableih & Salman, 2016).

Groundwater policy is centralized in the National Water Strategy 2016-2025, the 2016 Groundwater Sustainability Policy, and the Irrigation Water Policy. The Groundwater Sustainability Policy was released by the Minister of Water and Irrigation as part of a suite of policies related to the National Water Strategy (JMWI Groundwater Sustainability Policy, 2016). In the policy, the importance of groundwater and the significant over abstraction in the country are noted. The goal of the policy is to effectively manage these scarce resources. The document includes a list of policy benchmarks and assumptions about groundwater by which implementation decisions should be guided.

Many of the policies are value driven to ensure that water used is going to its highest value use. For example, the water strategy states that agriculture should reduce its demand on water to allow for a higher value use, such as M&I, to have access. There is also the opportunity for funding and incentives for agricultural projects that increase efficiency resulting in reduced abstraction. The use of appropriately-treated wastewater is encouraged as is development of groundwater models for regional aquifers. Finally, it calls for a comprehensive groundwater basin management plan to be included in the National Water Master Plan and all legislation to be strictly enforced against all users acting in contravention of the rules.

The document also states principles upon which all policies should be shaped. These include an understanding of the importance of groundwater as a resource in Jordan and the need to use it efficiently. The adoption of Integrated Water Resources Management (IWRM) to ensure management based on principles of sustainable use, economic efficiency and social equity is a goal. As part of this, there is a stated objective of managing groundwater in relationship to surface water, incorporating climate change adaptation, and developing new water sources through desalination, wastewater treatment, water harvesting, improved aquifer storage and recovery, as well as enhanced recharge.

Stakeholder participation can educate users, particularly farmers, as well as focus on data needs and collection. Current data systems should be closely monitored and additional data sets should be included. A comprehensive national water data bank could be managed by MWI. As in Kenya, comprehensive data sets are a challenge as many water resources are not well studied.

Like Kenya, Jordan has internationally shared groundwater; however, more efforts have been made to collaboratively manage these for the good of both countries. The 2016 National Water Strategy commits Jordan to cooperating with neighboring nations and jointly managing shared aquifers. Some evidence of this in practice can be found in the Disi Aquifer, shared with Saudi Arabia, which is a fossil water aquifer that is being significantly dewatered in some areas. The estimated withdrawal of 1,000 million cubic meters (MCM) of groundwater per year near the Saudi Arabian town of Tabuk created a large cone of depression, which affects many wells (Müller *et al*., 2017). In April 2015, the two counties entered into an agreement for the Management and Utilization of the Ground Waters in the Al-Sag/Al-Disi Layer focused on the protection and management of the system.

3.2.6. Governance Challenges

Due to its strategic national importance, Jordan has focused policy attention on a framework for groundwater management and protection. However, challenges remain in ensuring that the desired outcomes become a reality. Despite the agencies appointed to manage water in Jordan, there is still no dedicated manager of groundwater. In addition, jurisdictional overlaps exist between the WAJ and WMI. Exemplified by irrigation as a major use of water, which is managed through the Minister of Agriculture, increased inter-governmental coordination is also needed.

Further, other than the JVA, there are no smaller, regional authorities managing the aquifers. Lack of local implementation and oversight limits stakeholder management and education of the end user.
Central to Jordan's goals is partnering with users and stakeholders throughout the nation, and outside for shared resources. In particular, the education of agricultural stakeholders is critical. There is still a need for widespread involvement of farmers in order to meet the stated goals.

Similar to Kenya, there is a gap between written policies and clear, consistent implementation. Laws are needed to better define what use rights are available, for which purposes and how they can be accessed. Permitting rules need to be developed and implemented consistently for all users.

On the funding and incentive side, there are few tools in place to meet stated goals, such as moving water to higher value uses and reducing water used by agriculture. Tools created for this purpose, such as tariffs, need to be used consistently to achieve desired results. Financial shortfalls often inhibit progress. More funding needs to be available to pursue projects such as incentivizing efficient irrigation technologies, or preparing wastewater for reuse. Further, although the policies state that a goal is to reduce groundwater use for agriculture, water pumping is still heavily subsidized through inexpensive pricing and lack of fee collection.

04

Best Practices for Groundwater Governance

4.1. Policy Frameworks: Regulation, Implementation and Oversight

The increasing reliance on groundwater to meet the needs of growing populations, coupled with the risks of over-abstraction, necessitates proactive management of aquifers. In many cases, water laws and implementing authorities have historically focused on surface water with little specialized attention to the groundwater resource, either on its own or as it interacts with surface waters; however, integrated water management that provides climate change resiliency cannot happen without the inclusion of groundwater. Degradation associated with common-pool resources is likely without concerted legal and managerial oversight.

There are many ways to structure these systems, but some considerations should be present to maximize outcomes. Much has been written about groundwater governance and among the recommendations several aspects are consistent (Megdal, 2018). Common elements include: the use of science and data; functioning and effective governmental authorities; a clear legal framework; the need for public participation; and, sufficient funding to support programming. Many of these goals can be challenging in countries with restricted public budgets, protracted crises, or struggles with corruption. In these contexts, attaining so-called “good” governance is difficult if not impossible; actual practices should be adapted to the local situation and local capacities.

Although water resources have regional considerations, clear goals regarding groundwater should be set and committed to at the national level. These can include selecting from broad policy objectives such as the technical and/or economic efficiency of resource use, equitable access through moving water to underserved or disadvantaged sectors, or protecting the environment through limiting drawdown and safeguarding groundwater quality, or, providing widespread access to water on a first-come first-served market basis. A good example of framing a national vision can be seen in Jordan’s Groundwater Sustainability Strategy. While many of the goals listed in that document could be considered general, there is a clear goal to ensure that water is going to new users by ensuring efficient use of water in more traditional sectors.

While Kenya has a vision for water access driven by the 2010 constitution, it does not have a detailed policy framework to guide management of groundwater. Kenya has not faced the challenge of over abstraction seen in Jordan. Jordan’s dependence on groundwater coupled with the need to free up water to meet new demands encourages efforts to address illegal withdrawals and cascade the use of groundwater from urban uses in the highlands to treated wastewater use in irrigation in the lowlands. Countries, like Kenya, that have not yet experienced overdrafting, have the opportunity to establish goals and mechanisms for managing groundwater before issues arise.

Generalized outcomes can be specified as national policy; however, detailed regulations and management are needed to reflect local physical and economic circumstances. For example, management criteria for a non-recharging aquifer will differ significantly from a quickly recharging water source. Local authorities, on an aquifer or sub-aquifer scale, should be empowered to interpret and apply the national vision to their areas. Local management also has the facility to coordinate with related sectors, such as agriculture or municipal, and can lead to a multi- sectoral approach.

With the exception of the JVA, which manages surface water for irrigation, Jordan has maintained water policy at the national level. Due to the challenges of over-abstraction already present, local management could focus on obtainable goals for given aquifers and their recharge basins. While Kenya recently moved away from the national-only model by creating counties and promulgating regulations that delegate authority to local groups, sufficient support has not been provided to render the management measures effective. Many offices have very limited human capacity or funding to effectively administer the resource and implement regulations. Financial investments should be aligned with the stated outcomes. Without sufficient support, even the best written policies cannot be effected.

Decentralization can be very effective for implementation but, typically, it will only be partial. There are many authorities, functions and roles that need to be carried out to govern and manage groundwater successfully. Which of these are held by the central government and which are delegated can vary. Typically the trade-off will be between satisfying the central government’s desire for control and the regions’ desire for autonomy.

Crafting a system that allows elements of subsidiarity is generally advised with a local and common resource like groundwater. Certain functions though –particularly the scientific and technical elements – may most efficiently be provided from the center. Pitfalls to vesting authority and functions locally certainly exist as well. Regional actors may be more susceptible to corruption or selective enforcement and local administrators may also be impacted by political shifts. To ensure trust, expectations of consistent and transparent management should be set and overseen by the federal or national authority to which the regional groups report. In fragile contexts, the need for oversight may be considerable. Given the top-down nature of traditional engineering approaches to water infrastructure and management, the challenge in these countries is likely to be to open up venues for local participation in planning and decision-making, which allows for administrative decentralization as regional capacity and appetite evolves.

Government entities should involve local stakeholders at all levels. Public, private and civil society actors should be involved in developing and implementing localized goals, implementation and data sharing. Education will be an important factor for success. Local users need to understand the laws as well as basics about the groundwater system and its relationship to surface water and land use challenges. This is particularly important in pastoral communities, as seen in northern Kenya, where common pool damage of land resources is prevalent. With attention paid to governmental structure, clear policy initiatives and involvement of affected parties, local management of policies that represents a range of users and their objectives can be developed.

For any of the management structures outlined above, several overarching considerations need to be included in the creation and implementation of groundwater rules. Perhaps the most important of these is science. One of the biggest challenges to effective management is lack of understanding. The invisible nature of groundwater resources poses the largest challenge to its protection. Lack of scientific and technical knowledge challenges proper governance.

Achieving sustainability first requires a sufficient understanding of the system's features including recharge, transmissivity, storage and extent. Without a full understanding of the subsurface dynamics, an issue may not be discovered until there is a crisis such as reduced well yield or a communal health problem, at which point mitigation options are more limited. Lack of financial capacity exacerbates the inability to collect data to measure and monitor the resource; therefore, crowd sourcing of data collection and utilizing information collected from diverse partners including NGOs diversifies information available.

Understanding the resource not only guides withdrawals to avoid unintended consequences, it can also be used to develop innovative systems to assist the natural environmental processes. A good knowledge of an aquifer's recharge system can pave the way for protection of sensitive areas as well as the development of enhanced recharge projects. The ability to view groundwater as part of a system also allows for the integration of projected climate change impacts.

In addition to understanding the relationship of surface water to groundwater, water must also be considered as part of the land use protocols. There is a direct relationship between land management and water resources. This can clearly be seen in Kenya, where pastoral lands often reflect land degradation caused by overgrazing. The land compaction coupled with minimized vegetation increases the volume of run off and prevents seepage into aquifers. Overland flow of precipitation that reaches surface water bodies often has more sediment load compared to water flowing across lands with heavy grass cover.

4.2. Local Strategies for Groundwater Management in Fragile Contexts

As alluded to in the prior sub-section, having an agreed-upon objective for groundwater use and management, along with the laws, regulations and administrative capacity to implement such, is essential to good governance of groundwater. And yet, in countries with low levels of development, ongoing conflict and recurrent humanitarian crises – as well as low levels of administrative capacity and most likely limited citizen-state relations – the likelihood that the state is going to reach out and govern groundwater in rural areas strains credulity. Jordan provides an example here, as even with a demonstrated need for good management and in the presence of an ambitious set of water policies and considerable centralized capacity, the existence of un-accounted groundwater use totaling over one-fifth of all water use in the country went unreported and un-addressed for many years. Perhaps, had involvement in groundwater governance been devolved to the governorate or to basin authorities, this might not have persisted for so long. But even in Kenya, a relatively prosperous and well-governed country in SSA, where certain functions have been devolved to the county level, there is little known about the state of the groundwater resource. This is not surprising as Kenya has yet to develop it. To expect Kenya to have a functioning system for administering groundwater seems unlikely. The difficulty with groundwater is that waiting to implement governance and management until the resource is already on its way to exhaustion means it will likely be hard to manage its decline, or stave off decline, if that is the objective.

As the saying goes, "you can't manage what you can't measure". This section flips the question from what can centralized authorities do to successfully govern a local resource to the question of what needs to be done at the local level to enable successful governance. Principally, this task involves understanding existing resource use and tenure arrangements associated with this use. Developing this set of information is an activity that international NGOs (INGOs) and their local development partners are ideally situated to perform, given their involvement in communities and their participation in the provision of water supply, sanitation and hygiene (WASH) in communities and camps. Of course, any voluntary effort directed at gathering, compiling and making such information publicly available will be partial in nature and faces myriad challenges (Thomson *et al.*, 2012). Given advances in information technology and the increased use of crowdsourcing for developing detailed raw data for later aggregation, a central task is to ensure that there are standards for collecting, recording and uploading data.

A simple first step is to geolocate existing wells and boreholes. This may be easier for boreholes if drilling permits are required by the state and records are kept. For example, in Mali the national directorate maintains a data set of more than 16,000 boreholes throughout the country. Information recorded includes the coordinates, whether water was found, depth of water, yield of the well and water quality (Díaz-

Alcaide *et al*., 2017). Documenting boreholes is probably a first priority as they are likely to serve larger users and thus represent a large portion of water usage. But in many less well-off areas where groundwater is relatively close to the surface, hand dug wells for human or livestock use may be the rule. For example, in one village in central Mali, a total of 57 wells serve the needs of a community of 1,500. Knowing where these are – given that rural households will be largely dependent on these wells – may not be that important in terms of understanding total withdrawals, but may be very important in terms of protecting these households as larger, commercial uses of groundwater are developed.

Once wells are located, a range of information can be collected and associated with these points on the map. Basic information simply replicates the information that would be required on an official permit to use water (Aylward *et al*., 2016). This information includes the name of the person, household or community that controls access to the water source and is responsible for its upkeep (nominally the well/borehole "owner"). Other basic parameters surrounding use of the source include:

- the amounts of withdrawal specified as one or more of the following:
  - a maximum instantaneous flow withdrawal rate;
  - a total volume per year; and
  - for irrigation, a volume per unit area per year
- the period of the year during which the withdrawal occurs or a 'season' of use;
- the type of use (e.g., domestic, irrigation, commercial);
- the place of use (i.e., the fields on which irrigation water will be used, or the community service area)
- for irrigation, the extent of use in terms of the area to be irrigated (e.g., in acres).

Of course if there are multiple uses and users of a given well/borehole then this information would ideally be collected for each. It may also be useful to define the maximum use that would be made by users for each use, as this amount would be the amount for which a user would need an official permit. Due to seasonality, this maximum amount is not necessarily equivalent to the total amount used and, thus, actual measurements of water extracted is another useful set of annualized data. For boreholes, meters measuring and aggregating flow rates are ideal, but are not often installed or functioning properly. An alternative or supplemental method is to record the energy consumed in pumping and convert this using an established power/flow curve for the pump.
For hand pump systems or open wells from which water is extracted manually, approximations will be needed including of typical use during wet/dry season days and/or of estimated uses based on household numbers and outdoor area irrigated in the dry season. Of particular interest in rural, dryland settings will be how the use (including yield of the source) and water quality vary from dry to wet season.

Beyond these fundamental data points is additional information about the behavior of the groundwater source, which would come from:

- estimating peak yields from the source, for dry and wet seasons and at the end of drought years and wet years;
- tracking of the water level in the well to obtain an understanding of its diurnal fluctuation in both dry and wet seasons; and
- documenting periods of time when the yield is overwhelmed by demand and whether the shortfall is made up elsewhere and from which sources.

With respect to well function and the local hydrogeology, further steps are to document clusters of wells/boreholes and assess how they perform over similar time frames.
A key question to examine is whether the use of nearby wells impairs yield and/or water levels at peak use during the dry season.

With respect to permits and tenure for the water source, the working assumption is that the sources are unlikely to be required to register for a permit due to a lack of permitting regulations or due to exemptions for small-scale household or livestock uses. If a permit is required then the information collected above can be used to register the water source. Regardless, a primary concern in terms of establishing the right to access and use groundwater will be the status of customary rights to water in the country. Efforts are under way to better understand water tenure and document the extent of these rights across developing countries (Hodgson, 2016, RRI & ELI, 2019). Documentation of customary uses is therefore another potentially useful preparatory step towards effective groundwater governance. Information that may be gathered includes answers to the following questions:

- When were the wells/boreholes constructed and in what year were they first used?
- What changes in tenure have occurred over time, documenting the chain of tenure back to construction and first use?
- What changes in access, usage and type of usage have occurred over time?
- Is there a priority order for the use of the water source or rules for how the burden of shortage is shared/distributed among users or uses?

This type of tenure information is just an entry point to documenting how rights of access, use, exclusion, transfer and management are, or are not, specified for this water source, or for groups of water sources that locals understand as tapping in to the same aquifer.

In fragile countries, policy reform and putting in place the building blocks of good governance (generally, but specifically for groundwater) is a necessary but not sufficient condition for success. Policies, laws and regulations need to be implemented to have effect and this can be very difficult in fragile contexts. This second section, therefore attempts to identify proactive steps that communities and local officials, supported by INGOs and local development partners, may take to prepare for active governance of the resource. While these are practical and unexciting tasks, the reality is that there is nothing glamorous about the laborious process of

achieving good governance and water management. However, if this work is not done and the information not available, then the risk faced by communities is magnified when officials arrive from the capital with laws and regulations in hand, or when the resource starts to dwindle in the face of overwhelming and growing demand.
Further, such efforts can be used as a way to increase communities' technical understanding of an invisible resource and to build their internal capacity to measure, monitor and manage groundwater.

"A proactive effort by communities and local government, and supported by INGOs, to gather, compile and share data on groundwater use"

05
Conclusions

The need for social and economic development and the difficulty of making headway on this challenge appears worse in 2020 than it has been for many decades.
Even before the COVID-19 global pandemic, there was an increase in the occurrence of armed conflict and natural disasters in countries already lagging in development and self-governance indicators.

For water professionals and those addressing the risks and opportunities associated with groundwater resources and their usage, these developments make an already difficult job even more so. Persuading governments, the private sector and communities to adopt forward-looking regulations and management practices for an invisible, common pool resource before it is too late has always been a vexing task.

The review and analysis in this paper suggest that there is reason to cheer in that some of the more advanced and progressive countries in this cohort of conflict and fragile countries – in this case Kenya and Jordan – do have sensible policies, laws and regulations in place. Still, the dedication of sufficient resources to, and participation of civil society in, planning, implementation and enforcement of existing governance frameworks remains a challenge for these countries. Meanwhile, away from capital cities in communities that are often outside the grasp of formal government structures and processes, there is an opportunity to pursue another avenue to advance the cause. A proactive effort by communities and local government, and supported by INGOs, to gather, compile and share data on groundwater use and tenure systems would help prepare for the day when governance is critical in terms of allocating and managing supplies and when countries are strong enough to engage with regions on groundwater governance. For INGOs, merely drilling boreholes is not enough. Much can be done to raise community awareness and capacity to manage groundwater, while at the same time promoting effective and equitable access to this critical resource.

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Groundwater supplies nearly half of all drinking water globally and is a key resource for basic livelihood from irrigated agricultural purposes to industrial purposes. It highly influences to ecosystems by maintaining the baseflow of rivers, preventing seawater intrusion, and many other benefits, which will be affected by the impacts of climate change. Despite the critical role of groundwater, often it is less considered in decision-making processes due to lack of awareness.

There are approximately 300 transboundary aquifers, supporting many of the 2 billion people who depend on groundwater according to UN-Water. Mismanagement of transboundary groundwater can cause potential national and international conflicts. Cooperation is essential and appropriate groundwater resources management based on proper legal and institutional frameworks is primarily required for achieving the 2030 Agenda for Sustainable Development as it highlights peace and prosperity for people.

This GWSI Series, the role of sound groundwater resources management and governance to achieve water security, aims to highlight the critical role groundwater to achieve water security. The beneficial use of groundwater should receive more attention since it plays a critical role in water resources management. This series explores various case studies, literature reviews, tools, and protocols for groundwater resources management and governance.

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