The Contested Nature of Wastewater Reuse in Agriculture Insights from Egypt and Jordan

Mohamed Tawfik

Propositions

1. Failure of wastewater reuse projects in MENA stems from economic instead of health challenges.
   (this thesis)

2. Water reuse and reallocation are igniting societal inequality.
   (this thesis)

3. Migratory birds are excellent indicators for urban water quality.

4. Bedouins are expert land-use strategists.

5. Working for international development organizations makes researchers more cynical than optimistic.

6. Having toddlers is good for your PhD.

Propositions belonging to the thesis, entitled
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The Contested Nature of Wastewater Reuse in Agriculture:

Insights from Egypt and Jordan

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The Contested Nature of Wastewater Reuse in Agriculture: Insights from Egypt and Jordan

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Thesis

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Contents

1 Introduction

1.1 Research aim and background

This research critically analyzes the on-the-ground dynamics of wastewater flows, wastewater treatment infrastructures, and wastewater reuse policies, projects, and practices. It encompasses the formal, state-dominated policies, projects, infrastructures, and practices by which wastewater is reused for irrigated agriculture, as well as the informal, on-the-ground realities, infrastructures, and practices of smallholders for wastewater reuse, though these latter often fall outside the margins of state control and remain unrecognized by the state or in law. In looking at both spheres, this research aims to go beyond the dominant narrative on wastewater reuse, which mostly highlights the great potential of reclaiming wastewater streams as a means to tackle water challenges in water stressed contexts (Wessels, 2023). The dominant narrative in the reuse literature frames treated wastewater as an 'untapped resource' or 'new resource' that can be brought into use to offset shortfalls in supply, thus helping to fill the demand gap in countries where water is scarce (Mateo-Sagasta et al., 2022b; Qadir et al., 2020; Aleisa and Al-Zubari, 2017; Diaz-Elsayed et al., 2019; Jeuland, 2015). Within this dominant narrative, contexts with limited water resources are typically portrayed straightforwardly as suffering from an environmental shortage of water, which is steadfastly increasing with the growth of populations and the related economies (Amerasinghe et al., 2013; Okun, 2002; Bhattacharjee et al., 2020). This apolitical framing may lead to an understanding of the scarcity of water resources – both surface water and groundwater – as a limiting environmental factor. Such a framing, however, ignores the socio-political context and material factors that shape water resources management, allocation, and distribution among users and sectors (Molle et al., 2008). The mainstream narrative is often accompanied by a focus on the problem (i.e., the gap between water supply and water demand) and a promising solution (i.e., reuse of treated wastewater). This emphasis easily overlooks root causes of the supply-demand gap, such as the expansion of agriculture beyond the available freshwater budget limits. Furthermore, it may bypass the contested nature of freshwater (re)allocations and use, wastewater treatment and reuse schemes, and the associated on-the-ground institutions and practices. Within this context, the current research uses the term 'wastewater' as an umbrella concept that includes various wastewater streams, particularly domestic wastewater and agricultural drainage water, that are being reused with or without treatment for agricultural purposes.

There is a body of literature that highlights, often from a theoretical and engineering perspective, the economic, financial, environmental, and health benefits of treated wastewater reuse. In this literature, the failure of wastewater reuse schemes is often blamed on socio-cultural acceptance barriers (often referred to as the 'yuck' factor), which hinder the adoption and widespread use of treated wastewater, especially in the agricultural sector (Faria and Naval, 2022; Chfadi et al., 2021; Ghernaout et al., 2019). Little has been done to understand the politics of wastewater or drainage water reuse in local contexts in the Middle East and North Africa (MENA) region. Thus, there is scant research on how local and national socio-economic actors, factors, and political and institutional constraints shape on-the-ground, day-to-day practices (Wessels, 2023).

To fill this gap, the current research analyzes water flows, infrastructures, and institutions as well as how these interact in the formal and informal spheres through day-to-day practices in contexts of wastewater treatment and reuse projects. In these contexts, formal and informal waste/drainage water reuse arrangements are recognized as co-existing and mingling. Formal arrangements are those established by national laws and implemented, regulated, and controlled mainly by state agencies, though in some cases this is done via formally recognized private entities. Informal arrangements, in contrast, are not codified or structured according to written legal or contractual commitments (Cleaver, 2017). Informal arrangements are usually socially embedded and shaped by daily practices, negotiations, and discussions in very specific contexts.

This research was particularly interested in how state-led wastewater reuse projects may change water access arrangements, especially those of smallholder producers who have to deal with untreated and treated wastewater for supplementary irrigation. The role of infrastructure, its construction, and its use is, in this regard, theorized and analyzed as an important mediator through which particular actors – often the relatively more powerful ones – seek to rearrange existing water flows. Because of this, the analysis acknowledges infrastructure construction and its use and management via specific institutional arrangements as contentious and leading to water access 'winners' and 'losers'. This sometimes results in resistance responses. Within this research, practices and projects are understood as embedded in 'webs of social, political and power relations' (Barnes, 2017: 149). These manifest in various forms, such as in decisions on, for instance, what areas will (and will not) receive treated wastewater to enable expansion of cultivated lands (Barnes, 2014b), and in the framing of increased water productivity and modernization of agricultural practices as driving forces for change (Bush, 2007). These practices and relations derive from stakeholders' interests and their abilities to influence decision-making processes, in which less influential stakeholders may be muted. The current research sought greater insight into these processes and their outcomes based on case studies in Egypt and Jordan.

This introductory chapter starts with an overview of the ongoing debate regarding wastewater treatment and reuse in the MENA region. Section 1.2 examines the trend towards greater reuse of waste/drainage water in MENA, as advanced by the implementation of several research and development projects. Section 1.3 addresses the institutional embedding of the research, particularly, introducing the ReWater MENA project led by the International Water Management Institute (IWMI), which acted as host institute for this PhD project in Egypt and Jordan. Following this contextual mapping of the circumstances in which this research took place, section 1.4 sets out the thesis objectives and research questions, and section 1.5 presents the theoretical framework that informed the analysis in the chapters. Section 1.6 introduces the case studies in the two countries, and section 1.7 presents the methodological approaches employed to collect and analyze the data. Finally, section 1.8 provides an outline of the remainder of the thesis.

1.2 The wastewater reuse debate in the MENA region

Increasing pressure on freshwater resources has given rise to intensifying competition over scarce water supplies, particularly between the agricultural and domestic sectors, as well as efforts to mobilize, (re)allocate, and accumulate water resources more efficiently (Molle et al., 2010). This has led to the specter of 'water grabbing', either as an inherent aspect of 'land grabbing' or as a separate vehicle of resource accumulation (Mehta et al., 2012; Dixon, 2013, McMichael 2012; El Nour, 2019). However, little attention has been given to the role of waste/drainage water in these processes. This is explained in part by the fact that wastewater and agricultural drainage water are usually, and often officially, seen as water that is essentially 'waste', and thus cannot be used or reused without treatment and without formal arrangements decided by government (Tawfik et al., 2023). As a result, no formal water rights and entitlements are given to or recognized among those who do use these waters via 'informal' arrangements. On the contrary, these practices and users are relegated to the sphere of illegality and subject to fines and penalties. This lack of acknowledgement and illegalization of existing 'informal' waste/drainage water use practices has led many well-intentioned policymakers and practitioners to see this low-quality water as a promising 'new' water source for irrigation, once it has been treated and is 'clean again'. This latter is usually accomplished using heavy concrete and energy consumptive infrastructure for wastewater collection, treatment, and reallocation. As such waste/drainage water reuse practices have expanded, various forms of institutional arrangements, both formal and informal, have emerged to secure additional water for irrigation from waste/drainage water reuse while reallocating freshwater to other priority uses, such as for municipal water supply and irrigation for export agriculture (Liptrot and Hussein, 2020).

On a global scale, the quantity of formally treated wastewater reused in agriculture – referring to the volume of domestic wastewater treated prior to its reuse in agriculture in accordance with local, national, and regional regulations – is some 41 billion cubic meters (BCM) per year, out of 360 BCM of wastewater generated annually (Qadir et al., 2020). However, this quantity might be much higher if informal wastewater use were accounted for. Informal wastewater reuse refers to treated or untreated wastewater that is reused in agriculture through mechanisms or approaches that do not comply with or are outside the scope of local, national, or regional regulations. Treated wastewater reuse is expected to increase in the future as a result of advancements in treatment technologies, expansion of sewerage networks, and more positive attitudes towards the suitability of these waters for use in irrigated agriculture. This is reflected in increasing establishment of institutional and regulatory frameworks aiming to formalize and legally enable the use of wastewater in agriculture within the laws of numerous countries (Ait-Mouheb et al., 2020; Hern´andez-Chover et al., 2018).

As a nutrient-rich water source, waste/drainage water reuse in agriculture is expected to have production and financial benefits, too, as returns per unit volume can be greater than those of freshwater in traditional agriculture. Both globally and in the MENA region, agriculture is the largest freshwater consumer in most countries. Agriculture, moreover, is a significant contributor to gross domestic products (GDPs) – particularly in countries with agriculture-based economies – and in providing employment to the MENA region's, mostly youth, population (FAO, 2022a). However, water scarcity challenges in the MENA region are mounting, and represent a major threat to the ability of the region's agricultural sectors to maintain a foremost role in the future (Allan, 2008). Indeed, increasing water scarcity is destabilizing traditional agricultural practices and even leading to human displacement (Haddadin, 2001). These challenges add urgency to the search for reliable, non-conventional sources of water for irrigation. One such source, municipal wastewater and agricultural drainage water, has been put forward as having particularly high potential in reducing the gap between water supplies and demand. Waste/drainage water reuse could provide a new source for irrigation water, while freeing freshwater resources from the irrigation sector to supply domestic needs (ARD and USAID, 2001; Molle et al., 2010).

In developing countries, informal (often illegal according to the countries' own laws) reuse of untreated wastewater is prevalent, in addition to the planned and regulated reuse of treated wastewater (Scott et al., 2004; Kesari et al., 2021; Wessels, 2023). Regulated or planned reuse can be divided into two categories: indirect reuse and direct reuse. Indirect reuse of wastewater typically takes place after water has undergone one or more treatment steps (i.e., primary, secondary, and tertiary), in which the resulting flows are mixed with a freshwater source prior to their reuse (Tawfik et al., 2021). It is the most common formal form of wastewater reuse and usually recognized and promoted as having minimal health and environmental risk. Direct reuse of wastewater refers to wastewaters that are reused without being mixed with a freshwater source. Often the purpose of the reuse is to irrigate inedible crops (e.g., timber and biofuels) or fodder crops. Though these wastewaters are typically subject to full or partial treatment, relatively high health risks remain. This is especially so where the reliability of treatment processes is in doubt. Public acceptance of wastewater reuse in agriculture is low (Shakir et al., 2017). Direct reuse is only feasible when farmlands are in close proximity to wastewater treatment plants (Hosney et al., 2023). Despite the restrictions on waste/drainage water reuse in agriculture, treated wastewater reuse in the MENA region is expected to expand as governments embrace it as an adaptive mechanism to cope with water scarcity while enabling planned expansions of agricultural lands to achieve food security. Accordingly, a comprehensive analysis of the various policies and practices of wastewater reuse is crucial to understand and mitigate potential associated environmental, health, and socio-economic risks (El Moussaoui et al., 2019; Kesari et al., 2021).

Against this backdrop, Egypt and Jordan are two interesting countries in which to investigate waste/drainage water reuse policies and practices. Indeed, the two countries have formulated strategies to boost their water budgets through waste/drainage water reuse, and in both countries there is a strong dependency (especially in Egypt) and willingness (especially in the Northern Jordan Valley) to engage in formal and informal waste/drainage water reuse. In Egypt, agriculture is the main employer of the mostly young population, while also forming an important pillar of food security and economic revenue through agricultural exports (Omar et al., 2021). In Jordan, the agricultural sector supports a large number of producers, as well as an increasing number of foreign laborers (Hussein, 2018a). Hence, this research investigates the prospects of waste/drainage water reuse, drawing on Egypt and Jordan as representative low- and middle-income countries in the MENA region. In both countries, diverse approaches to wastewater reuse, direct and indirect, have emerged in recent decades. These differ in terms of scale, economic feasibility, institutional frameworks, and cost of implementation, operation, and maintenance (Tawfik et al., 2022). These mechanisms have been accompanied by policies advocating water substitution and reallocation (Jordan) and national water resources plans (Egypt).

1.3 Institutional embedding of this research

From 2020 to 2023, as part of international efforts to support the reuse of waste/drainage water in the MENA region, the ReWater MENA project, funded by the Swedish International Development Cooperation Agency (SIDA) and led by the International Water Management Institute (IWMI), was implemented in three countries of the MENA region, namely Egypt, Jordan, and Lebanon. The project's aim was to contribute to two key outcomes: (i) expansion of wastewater treatment and reuse projects so as to enable substitution of treated wastewater for freshwater in agricultural and industrial activities and (ii) improvement of treated wastewater reuse safety and acceptability through appropriate policies, standards, and strategies (https://rewater-mena.iwmi.org/). Although the project's objectives were similar to those of earlier initiatives and projects in the region, ReWater MENA aimed to achieve those outputs through a participatory project design (Figure 1.1). This was implemented by selecting two local case studies in each country, for a total of six case studies in the three countries. In each case study, field trials were conducted and local partners and stakeholders engaged in interviews, focus group discussions, and participation in knowledge exchange platforms. The platforms were a particularly important aspect of the project. They were designed to bring together various stakeholders under the umbrella of so-called 'national learning alliances' (NLAs). Thus, NLAs were initiated in each country – though plans to establish a regional learning alliance eventually failed due to the heterogeneity of the different MENA countries and challenging logistical arrangements.

At the design phase of the ReWater MENA project, social, cultural, institutional, political, and economic bottlenecks in the region were identified as the main obstacles hindering large-scale adoption of advanced wastewater treatment and reuse technologies. To overcome these challenges the project sought to bring about comprehensive 'changes' in knowledge, skills, values, and attitudes towards wastewater. At the same time, it sought to identify the 'right and appropriate' incentives, norms, policies, and institutional arrangements by which new practices and policies could be developed and put into practice.

The NLAs in Egypt and Jordan involved a broad range of official stakeholders. Egypt's NLA was state-dominated and included representatives from the Egyptian Holding Company for Water and Wastewater Treatment and Reuse, the Ministry of Water Resources and Irrigation, the Ministry of Agriculture and Land Reclamation, the Egyptian Water Regulatory Authority, and the Ministry of Planning. Similarly, in Jordan, the NLA was confined to representatives of the state, namely, the Ministry of Water Resources, the Jordan Valley Authority, and the Ministry of Agriculture.

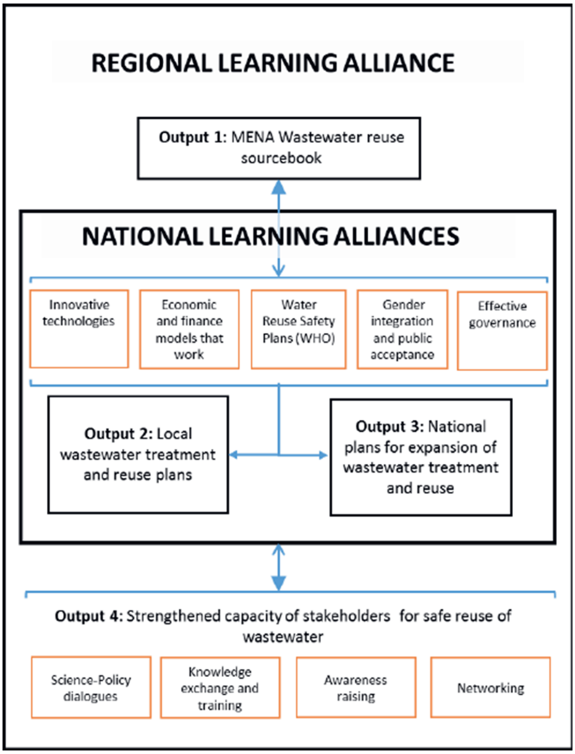

Figure 1.1 ReWater MENA project planned outputs (Source: project summary document).

In the context of the ReWater MENA project, the current research sought to develop a better understanding of the politics, policies, and practices that shape wastewater reuse projects. To understand these, the research studied and analyzed established practices, stakeholders' roles and relations, and actions undertaken to recreate or transform these, and with them, established power positions.

1.4 Thesis objectives and research questions

This research aimed to make a critical contribution to the scholarship on waste/drainage water reuse, especially in the agricultural sector. It began with a study of the regional context of waste/drainage water reuse policies and institutional arrangements, including reuse practices, in MENA. This was followed by an investigation of the extent of wastewater reuse at the national scale in Egypt and in Jordan. The research then narrowed to two case studies which considered both formal and informal reuse arrangements. One case study focused on Egypt's Nile Delta and the other on the Northern Jordan Valley. These served to map the most important actors, infrastructures, practices, and institutional arrangements for wastewater management in each of the two contexts. In doing so, the informal practices and arrangements through which communities and smallholders dealt with and reused waste/drainage water could be exposed and made visible.

The investigation of wastewater management and reuse in the two case studies was informed by an analysis of three 'levels' of management activities in the sector. The first level was constituted by formal and informal practices and arrangements for direct and indirect reuse of waste/drainage water in agriculture. The second level was that of technologies and infrastructures used to control and redirect waste/drainage water flows, allocation, and access. This included, for example, construction, operation, and maintenance of wastewater treatment, conveyance, and distribution structures. The third level was how institutions and practices organized the human efforts and interactions of the actors involved.

The insights gained by this research provide a better understanding of waste/drainage water reuse practices in Egypt and Jordan by documenting and recognizing smallholders' practices and perceptions around waste/drainage water reuse for irrigated agriculture. An associated aim was to demonstrate how these practices, perceptions, and arrangements relate to and interact with formal policies and new state-led projects seeking to expand the formal wastewater use sector. This was achieved by answering the following main research question:

> *How do state-led wastewater treatment and reuse projects and policies interact with and affect informal arrangements for wastewater and drainage water reuse and the associated water access of smallholder irrigators?*

This main research question was approached via four more specific sub-questions.

Research sub-question 1 – What are the current legal and institutional waste/drainage water reuse frameworks in the MENA region, and how have these been shaped by the historical development of water policies, regulations, and institutional arrangements? Answering this question set the legal and institutional scene for wastewater reuse in the MENA region. Five MENA countries were analyzed: Egypt and Jordan (the two focus countries), as well as Lebanon, Tunisia, and Saudi Arabia.

Research sub-question 2 – How is Egypt's current wastewater reuse sector operating through 'formal' and 'informal' institutional arrangements? This question shed light on the often-invisible role of informal reuse arrangements in the Nile Delta. Specifically, formal and informal wastewater management and reuse arrangements were investigated in two *ezbas* (small villages) in rural Egypt, where villagers were able to devise their own wastewater management mechanisms, including wastewater collection and discharge into the environment. Although these informal arrangements posed health and environmental risks due to the lack of treatment, they enabled farmers to reshape their access to sanitation services, as well giving them an additional source of water for use in agriculture. The two villages were analyzed using a novel socio-technical framework that highlights the different actors, management activities, and practices shaping wastewater collection, transfer, treatment, discharge, and reuse in different social, technological, and environmental contexts.

Research sub-question 3 – How are the newly constructed drainage water treatment and reuse infrastructures expected to change water flows and related water access of smallholders in the 'old lands' of the Nile Delta? With this question, implications were considered of several newly established mega plants for treatment and reuse of drainage water (i.e., El Mahsama, El Hamam, and Bahr El Baqar) in changing the traditional drainage water flows in the region. In particular, the new infrastructure is designed to reallocate drainage water flows to new agricultural frontiers in the desert.

Research sub-question 4 – Why have farmers in the Northern Jordan Valley (NJV) resisted treated wastewater reuse, and what implications does their resistance have for their access to water? Investigated here are the socially embedded root causes of an eight-year stalemate in a new water reuse and reallocation project in the NJV. This region is irrigated with freshwater from the King Abdullah Canal (KAC), and the government's plan to shift to treated wastewater for irrigation has met significant resistance from local farmers. Their resistance has translated into a refusal to use treated wastewater. By reverting to informal water access arrangements, local farmers have been able to continue irrigation using alternative sources of freshwater.

1.5 Theoretical orientation: Waste/drainage water reuse arrangements as a politically contested process

Waste/drainage water management and reuse is conceptualized in this research as a contested socio-technical process that takes place through control of water flows, infrastructures, technologies, practices, and institutions and the individuals who engage in the different stages of management of the reuse cycle. Herein, the different actors have varying degrees of interest, influence, and power. Through this dynamic process, formal state-led and recognized processes continually interact with and affect informal, usually illegal and not acknowledged, on-the-ground practices and realities of smallholders, who gain their livelihoods from and depend on access to untreated waste/drainage water flows (Figure 1.2).

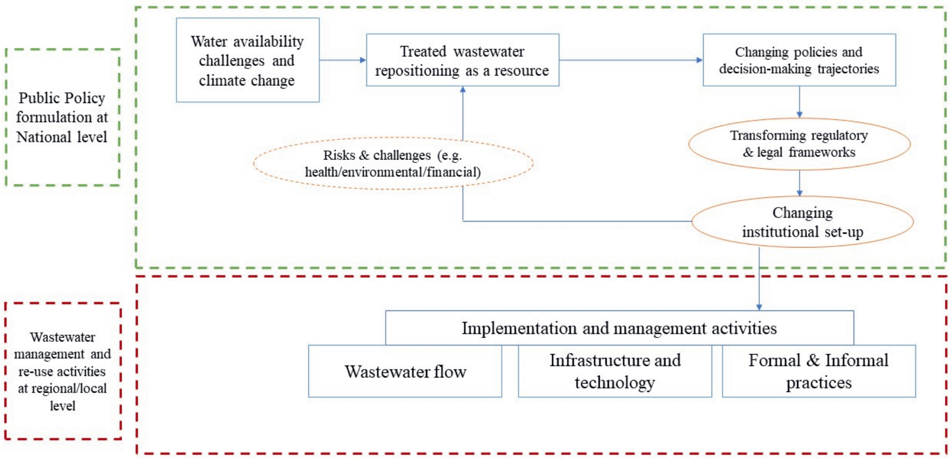

Figure 1.2 Conceptualization of reuse at the national and regional/local scales.

Our starting point for understanding interactions between formal and informal waste/drainage water reuse practices and institutions is the notion that the reallocation and reuse dynamics of treated wastewater (including agricultural drainage water) reflect power asymmetries and the political influence of the various stakeholders involved. These power asymmetries influence drainage water flows and access arrangements. In this regard, we follow Ribot and Peluso's (2009) definition of 'access' as the 'ability' to benefit from wastewater. This pertains, in most cases, to use of wastewater for irrigation. The ability to benefit from wastewater can be achieved by gaining, maintaining, and controlling access to this water by capitalizing on embedded social arrangements or what Ribot and Peluso (2009: 154) refer to as 'bundles of power'.

Thus, this research is based on the premise that waste/drainage water management and reuse cannot be seen as an apolitical process driven solely by a gap between water supply and demand – or freshwater scarcity. Rather, it is a product of the everyday political and power dynamics that shape decision-making processes (Robbins, 2019). It is within the everyday politics of wastewater reuse that infrastructure is built and used. This infrastructure changes water flows and related patterns and possibilities for different stakeholders to have access to (waste)water. As a result, there are water access 'winners' and 'losers', though all stakeholders seek to advance their interests using the strategies and networks at their disposal in the context of uneven power relations. This results in contestations in which the interplay between everyday politics and power dynamics are expressed. These dynamics shape the way 'different' waters, in terms of quantity and quality, are allocated and/or reallocated among users, spaces, and sectors (Joy et al., 2014; Perreault, 2014).

Accordingly, this research zooms in on the politics of waste/drainage water reuse. Yet, these 'politics' are not only those that are exercised at a 'macro scale', such as in global agendas, national strategies, and public policies. Rather, they also include the everyday practices and interactions between individual and institutional stakeholders (Barnes, 2014). These dynamics and interactions determine how wastewater is reused through formal and informal arrangements, who has access to what grade of water (i.e., allocation mechanisms for wastewater and freshwater), and how water access is obtained, denied, and perceived.

This conceptual orientation builds on Uphoff's (1986) work on participatory irrigation management. The analysis incorporates Uphoff's insights into a new model for investigating how waste/drainage water flows are controlled, allocated, and accessed by stakeholder groups (Table 1.1). The model divides waste/drainage water reuse processes into three components: (i) wastewater flows; (ii) technologies, infrastructures, and their operation; and (iii) the institutions and practices that regulate these wastewater flows and technologies. Though these components are separated for analytical purposes, it is important to acknowledge that they are intrinsically interrelated through webs of 'formal', legally recognized arrangements and 'informal', often illegal, 'invisible' arrangements. Together, these arrangements define the rules and regulations (and norms in the case of the informal arrangements) for wastewater reuse, as well as what stakeholders (institutions) are responsible for their implementation and control. These same institutions also regulate how resources are mobilized in waste/drainage water reuse processes.

Table 1.1 Waste/drainage water management and reuse activities in agriculture (Source: own elaboration based on Uphoff, 1986).

Wastewater flows	Technological management				Institutions and practices
Containment/collection	Design	Construction	Operation	Maintenance	Regulation and norms
Treatment					Conflict management
Conveyance					Resource mobilization
Discharge/reuse					Decision-making

Looking at waste/drainage water reuse and reallocation as an inherently political and contested process demonstrates that the same processes of collecting, treating, and reusing or reallocating waste/drainage water are, in many cases, tools to enable or deny particular groups of stakeholders access to a crucial source of water for irrigation. Through these tools, powerful actors – such as governments, agricultural investors, and donors – facilitate and influence allocations of treated waste/drainage water, according socio-economic advantages and in accordance with particular socio-economic development imaginaries. In doing so, they deny and, in some cases, even curtail less powerful actors, particularly smallholder farmers, from accessing water resources, whether in the form of treated or untreated wastewater or agricultural drainage water.

The theoretical framework in Table 1.1 highlights the role of infrastructures and technologies, particularly large-scale infrastructures, in reshaping waste/drainage water access mechanisms. In this regard, the current research builds on previous studies which have pointed out that politics and special interests influence the design, construction, operation, and maintenance of material objects, devices, and settings (Winner, 1980). As such, reuse infrastructures (i.e., large-scale treatment plants and pump stations) are employed deliberately to create certain forms of social order by directing and controlling water flows (Hommes et al., 2022).

Finally, we engage with notions from Mollinga's (1998) theoretical framework which positions water control activities within the agri-political context of the area under study. This context shapes producers' perceptions of the use of wastewater for irrigation, especially in relation to the agricultural production process and marketization of the outputs. This leads to contestations around the reuse of treated wastewater in irrigation. Implementation of waste/drainage water in irrigation is mediated by various social and physical intermediaries, such as water users associations (WUAs), on-farm water distribution technologies and infrastructures, crop selection, and the roles of donor organizations and governments in initiating and carrying out policies and projects for wastewater reuse.

1.6 Case studies informing this research

This section provides the rationale for selection of the case studies and contextualizes the selected cases.

1.6.1 Reuse and reallocation in Egypt's Nile Delta and new lands

Egyptian smallholder farmers in the Nile Delta rely on drainage water reuse to compensate for the water shortages the country suffers. Indirect reuse of wastewater in this region was estimated at 9.31 BCM in 2015, and the target of the Egyptian government is to increase that amount to 16.26 BCM by 2037 (MWRI, 2005). However, increasing amounts of untreated wastewater being discharged into drains has meant that drainage water quality is often too poor to be – formally – reused for irrigation (El-Agha et al., 2020). Quality issues hinder the reuse of an estimated 2.37 BCM per year (The Road Map, 2017). Farmers in the Nile Delta, however, access drainage water through individual water pumps, bypassing the Ministry of Irrigation's regulations and restrictions and thus rendering this practice illegal (Molle et al., 2019). Study of the situation this has created is highly relevant in the context of the ReWater MENA project. This is especially so as most informal practices have remained unrecognized and unacknowledged by those involved in the Egyptian NLA created by the project. Raising awareness and building bridges between the formal and informal 'worlds' of waste/drainage water reuse has the potential to open doors to more socially just water reuse policies and projects.

Academically, Egypt offers a unique case to study how formal water governance and informal, on-the-ground practices of waste/drainage water reuse are both at odds and interact with each other. Institutionally, Egypt's wastewater management is highly centralized. The country's formal bureaucratic institutions have overlapping roles and responsibilities, and farmers have little or no involvement in the decision-making processes that take place within state institutions at different levels. Farmers' exclusion from decision-making has rendered largely invisible and unacknowledged the many existing arrangements and practices for wastewater disposal, treatment, and reuse. At the same time, Egypt is adopting a 'novel' reuse and reallocation strategy that aims to 'rebrand' and reallocate agricultural drainage water from the Nile Delta for expansion of irrigated agriculture into reclaimed lands on Egypt's desert frontiers. This is to be achieved through centralized mega plants for wastewater treatment and a network of pump stations. Egypt's so-called 'novel' approach, however, can be construed as recreating a historical pattern of water reallocation that has gradually squeezed out – or 'squeezed dry' – the old lands of the Nile Delta.

1.6.2 Reuse and reallocation in the Northern Jordan Valley

Jordan suffers from severe water scarcity, a situation that has been intensified due to climate change and the unrelenting flow of refugees from Syria since 2011, resulting in steep drops in per capita water availability (MWI, 2009, 2016). Accordingly, successive governments have aimed to reallocate freshwater from agriculture to the domestic and industrial sectors (ARD and USAID, 2001). They have sought a path to achieve this while maintaining a 'resilient' agricultural sector, albeit with a 'lower quality' water source (i.e., treated wastewater) (Aljaradin, 2017).

The Jordan Valley is an important agricultural area, and farmers here rely on surface water for irrigation from the King Abdulah Canal (KAC). Farmers in the Northern Jordan Valley (NJV) receive freshwater from the KAC through individual pumps installed at the head of each farm. In 2017, the government, benefiting from a donor fund, proceeded with implementation of a pipeline network to transfer treated wastewater from three wastewater treatment plants serving Irbid governorate to the NJV for irrigation, while reallocating the NJV's share of freshwater to supplement the domestic water supply. However, NJV's farmers have resisted the plan, adopting various formal and informal arrangements to maintain their access to irrigation water from sources other than the treated wastewater. For example, they access groundwater via shallow and deep wells or abstract water directly from the KAC or Jordan River. Accordingly, the reuse-reallocation plan for the NJV has not been operationalized, despite the fact that the infrastructure was completed in 2017. This research was interested in why farmers have by-and-large resisted the use of treated wastewater for agriculture.

1.7 Methodological approach

The research presented in this thesis was carried out from 2018 to 2022 with the support of the ReWater MENA project, led by the IWMI MENA regional office. Data collection relied on various complementary approaches and tools, such as literature review, analysis of Google Earth images, participatory observation (especially taking part in and observing the dynamics of the NLAs), field visits (the visit to the Al Mahsama site in Egypt was allowed only once due to security restrictions, as discussed later), expert interviews, and semi-structured interviews.[1]

During the research period, information and facilities related to water and wastewater management in Egypt were subject to strict security restrictions, making it difficult for governmental and non-governmental researchers to work on the topic without strong collaboration and permissions from government authorities. Globally, too, the COVID-19 pandemic halted most local and regional mobility, especially in 2020 and 2021. In particular, pandemic-related lockdowns postponed the field visits to Egypt and Jordan. For these reasons, the research relied on primary data on informal wastewater management and reuse collected in Egypt in 2014, supplemented by video interviews and online meetings with key experts from Egypt and Jordan (during the COVID lockdowns), as well as field interviews at the two sites in Egypt and Jordan (post-COVID lockdowns).

The analysis of the 'formal' wastewater management and reuse sector in Egypt and Jordan was conducted via a review of the existing literature, official reports, interviews, and personal communications with sector officials, including ReWater MENA project partners. The analysis applied a theoretical framework developed for this research and reflected in the chapter outline in Figure 1.3. Due to the security restrictions in place, analysis of the 'informal' water management and reuse sector in Egypt's Nile Delta relied on data from previous fieldwork in selected villages in Beheira governorate of the Nile Delta during the 2012-2015 period. At that time, household and village representative surveys were conducted as part of a baseline study prepared by the Egyptian-Swiss Research on Innovation in Sustainable Sanitation (ESRISS) project.[2] I myself was part of that project team and a coauthor of the resulting report, which provides a detailed account of wastewater management practices in the Nile Delta. Findings from the ESRISS project were drawn upon and analyzed in the current research, applying the same analytical tools as used to analyze the formal sector. This procedure enabled the necessary consistency to be achieved to understand the interactions between the formal and informal sectors.

Analysis of the waste/drainage water reuse and reallocation plans of the NJV and Egypt's new lands was conducted after the end of the COVID-19 lockdowns in the respective countries. Accordingly, it became possible to visit both sites and conduct semi-structured interviews with farmers, operators, and officials from government institutions. A detailed overview of the data gathering and research methodology for each case is provided in the respective chapters.

1.8 Thesis outline

The thesis consists of six chapters (Figure 1.3). Following this general introduction chapter, Chapter 2 responds to the first research sub-question, fleshing out the regional context of the policy and institutional landscape of wastewater treatment and reuse in agriculture in MENA. This includes an analysis focused on five countries: Egypt, Jordan, Lebanon, Tunisia, and Saudi Arabia. Chapter 3 responds to the second research sub-question, analyzing the co-existing formal and informal wastewater reuse arrangements in Egypt's old lands in the Nile Delta. Chapter 4 responds to the third research sub-question, analyzing the implications of waste/drainage water reallocation for the accessibility of this water resource in Egypt. This examines, specifically, new drainage water reclamation projects in Egypt and offers an

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[1] During the international travel restrictions imposed during the COVID-19 lockdowns, some interviews in Jordan were conducted by colleagues from the IWMI-MENA office in Amman.

[2] For more information on the ESRISS project, see https://www.eawag.ch/en/department/sandec/projects/sesp/esriss-egyptian-swiss-research-on-innovations-in-sustainable-sanitation/.

in-depth analysis of the Al Mahsama mega treatment plant. Chapter 5 explores the challenges of wastewater reallocation in the NJV, where farmers have adopted informal practices to access freshwater for irrigation as a tool to resist the government's plan to expand wastewater reuse into their areas. Finally, Chapter 6 provides an overall synthesis of the research, recapping and discussing the main findings. In addition, I examine my own positionality in the research field, and present overall conclusions from the research.

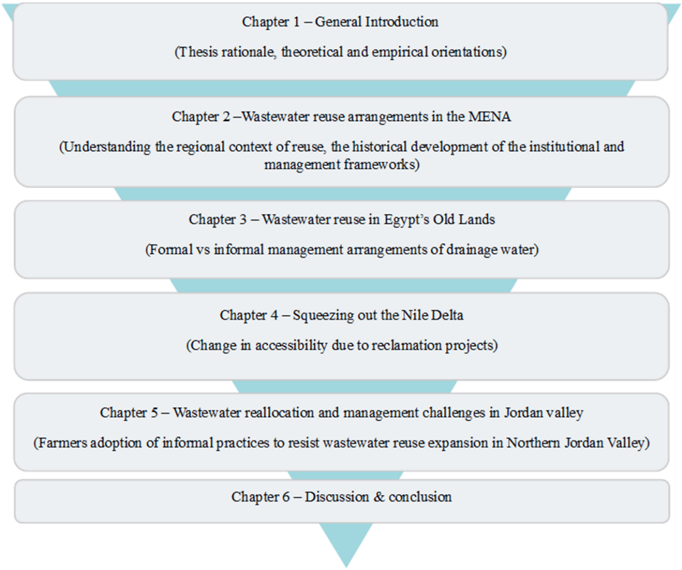


Figure 1.3 Thesis outline.

2 Water reuse policy and institutional development in the MENA region: Case studies from Egypt, Jordan, Lebanon, Saudi Arabia, and Tunisia

Abstract

Egypt – Food and water security are the key drivers behind Egypt's pursuit of 'new' water sources. Therefore, Egypt plans to optimize the use of treated agricultural and municipal wastewater to maintain its socio-economic development. However, due to increasing health and environmental concerns regarding water reuse safety, the country has maintained centralized control over the different aspects of wastewater management and reuse. This has led to overlapping responsibilities and legal mandates, which has challenged the expansion of water reuse in the country.

Jordan – Jordan's institutional and policy landscape shifted from a decentralized structure (i.e., with municipalities having the leading role in wastewater management) to a 'semi-centralized' structure, in which infrastructure development, operation, and maintenance are delegated to regional institutions and state-owned companies. This institutional landscape has enabled Jordan to lead the MENA region in water reuse. However, it has also created gaps in the decision-making process, and these have slowed down implementation of the current water reuse policy.

Lebanon – The water and wastewater management sector in Lebanon suffers from a lack of regulatory and institutional frameworks as well as lagging infrastructural development. This is due to various political and economic factors that have challenged Lebanon since the end of its civil war. However, progress has been made in creating an environment of collaboration between the Council for Development and Reconstruction (CDR), which has assumed a 'super-ministry' role since the end of the war, and the Ministry of Energy and Water (MEW), as well as regional water establishments (RWEs). These developments are creating an enabling institutional, legal, and financial environment for water reuse to take place.

Saudi Arabia – Saudi Arabia's experience in managing the water and wastewater sector (including water reuse) reflects a successful transformative shift towards the involvement of the private sector (and state-owned service providers) made possible by enabling policies and institutional reforms, while the government maintained its regulatory and monitoring role.

Tunisia – The water sector in Tunisia is highly regulated and institutionalized. However, the sector is characterized by competing interests between the institutions involved. This has undermined coordination between the different institutions, such as the National Sanitation Utility (ONAS) and the Ministry of Agriculture, Water Resources, and Fisheries (MAHREP), causing shortages of treated wastewater for reuse to satisfy the agricultural sector's needs. Yet, efforts to overcome these challenges have led to relatively flourishing water reuse arrangements for the irrigation of golf courses, for which there is collaboration between ONAS and the Ministry of Tourism.

Published as a book chapter: Mateo-Sagasta, J., Al-Hamdi, M., and AbuZeid, K. (eds) (2022). Water reuse in the Middle East and North Africa: A sourcebook. International Water Management Institute (IWMI). https://doi.org/10.5337/2022.225

2.1 Introduction

This chapter explores the policy and institutional landscape of wastewater treatment and reuse in Egypt, Jordan, Lebanon, Saudi Arabia, and Tunisia. It analyzes the key elements that contribute to, or hinder, the development of water reuse policies and institutional arrangements in the selected countries. To do so, it observes the different trajectories each country has followed in developing its water and sanitation sector over the years, focusing on the following aspects:

- country-specific contextual constraints (e.g., population growth, agricultural expansion, water scarcity, and dependency on transboundary water resources)
- institutional roles and responsibilities within the sector
- the historical development of water reuse governance and management modalities (e.g., from centralization to decentralization and privatization)

Each of the selected countries has faced a growing gap between water supply and demand, alongside a rapidly increasing population in need of socio-economic development. This has led to competition for already scarce water resources, particularly between the agricultural and domestic sectors (Figure 2.1). Governments have sought to reduce the gap by developing the reuse of treated wastewater. However, this shift has been problematic, as different technical, social, economic, health, and institutional problems have continued to challenge water reuse schemes.

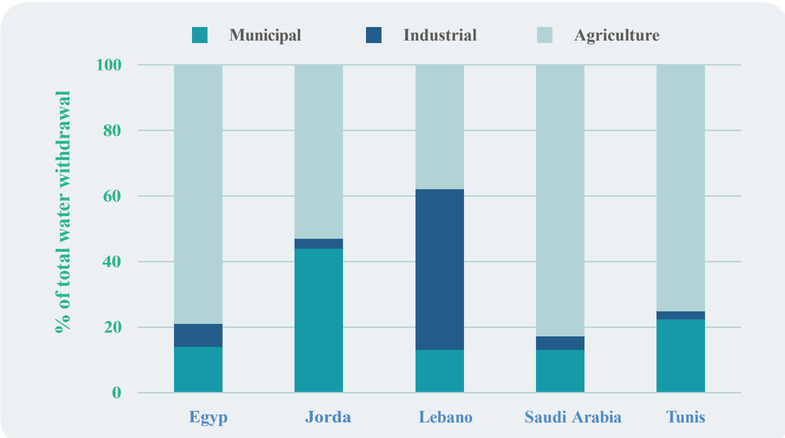


Figure 2.1 Water withdrawals by sector in the five studied countries in 2017 (Source: FAO, 2022a).

This chapter analyzes key policy and institutional milestones as well as bottlenecks that have stymied these developments over the years. It starts by identifying the foremost policies and institutional reforms (milestones) that have shaped the countries' water reuse institutions and arrangements. It then analyzes interactions between and the de facto functioning of the different governmental institutions operating in the sector.

2.2 Egypt

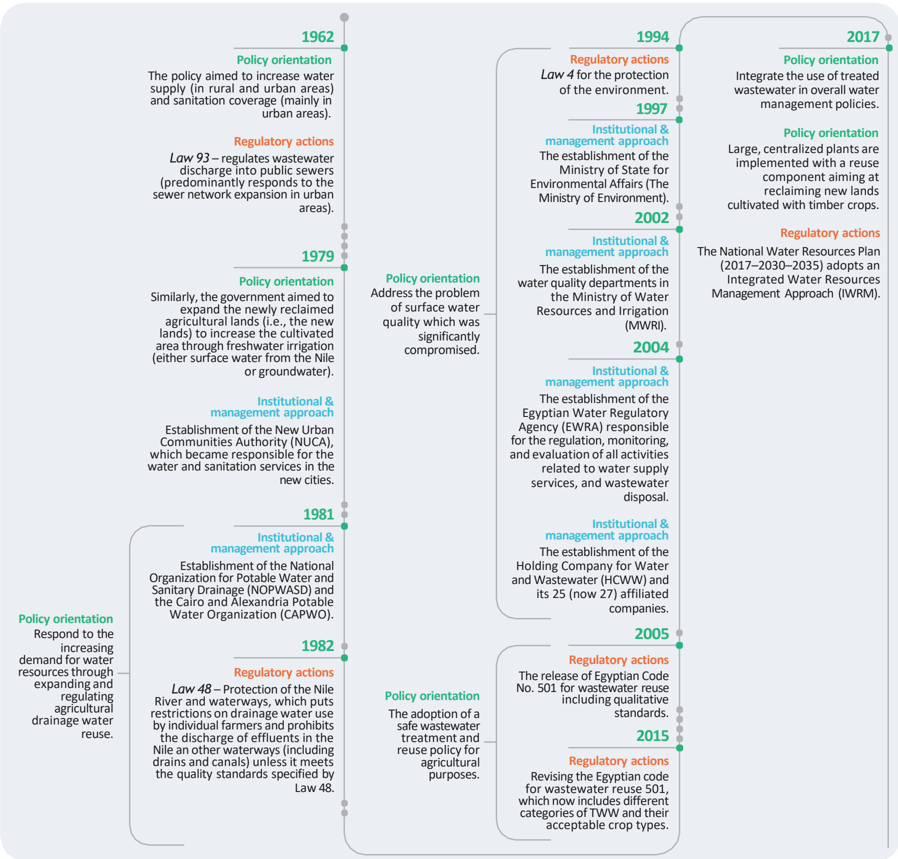
2.2.1 Toward water reuse development

Egypt's annual per capita water supply was 800 m^3 in 2017 (FAO, 2022a). This is below the 'stress' conditions threshold, which is considered to be 1,000 m^3 per person, according to the Food and Agriculture Organization of the United Nations

(FAO, 2022b). Nonetheless, the gap between water supply and demand is expected to increase with population growth, the impacts of climate change, and the development of the Grand Ethiopian Renaissance Dam (GERD), which is set to affect Egypt's annual share of water from the Nile River.

Egypt's government has responded to its dwindling per capita water supply by reallocating freshwater for priority uses, especially domestic drinking water, while seeking to maximize the amount of drainage water reused in the agricultural sector. Indeed, agriculture is the largest water user in Egypt and consumes around 76% of the country's water budget (Tawfik et al., 2021). The Egyptian government's policy orientation includes public investment in large-scale water reuse projects related to both treated municipal wastewater and agricultural drainage water. Increased use of treated wastewater is one of the mitigation measures that Egypt has adopted to maintain its socio-economic development in the increasingly water-scarce context (IWMI, 2019).

Table 2.1 The historical development of wastewater treatment and reuse in Egypt.



2.2.2 Historical development of water reuse: Policy and institutional milestones

Since the 1960s, Egypt's successive governments have worked to expand agricultural land area by desert reclamation projects to help the country achieve food self-sufficiency and create job opportunities (Molle et al., 2019). The resulting expansion of agriculture has relied on freshwater resources, obtained either from the surface waters of the Nile River or extraction of non-renewable groundwater. From the late 1970s to the early 1980s, this brought about a notable increase in drainage water reuse for irrigation (Molle et al., 2019). Many more farmers began to rely on agricultural drainage water as an important resource to reduce shortfalls in irrigation water supplies. Drainage water reuse also enabled the country to meet its land reclamation objectives.

However, due to lack of comprehensive sanitation coverage, particularly in rural areas, coupled with the continued low capacity of some wastewater treatment plants, illegal discharge of untreated wastewater into the agricultural drainage system became a growing problem (Tawfik et al., 2021). In response, beginning in the 1980s, the government started to regulate water reuse, implementing a set of institutional and organizational measures to prevent pollution of the agricultural drains. Among these measures were donor-driven reforms, such as establishment of the Egyptian Water Regulatory Authority (EWRA) and the Holding Company for Water and Wastewater (HCWW), Law 48, Code 501, an environmental law, and infrastructural mega projects, such as the El Mahsama and Bar El Baqar water treatment plants (Table 2.1). To achieve the desired quality and safe reuse of treated wastewater, top-down, centralized governance of the sector was implemented, reflected in the prominent role given to central state institutions in the different management activities associated with water reuse.

2.2.3 Institutional roles, responsibilities, and bottlenecks in water reuse

The institutional landscape of Egypt's water and wastewater sector is based on a form of institutional pluralism, in which the various responsibilities are distributed among different organizations with overlapping mandates though with limited coordination and communication channels. For instance, the state-owned HCWW was established in 2004 to improve the sector's performance and meet donor prerequisites (World Bank, 2016). However, HCWW's establishment resulted in an overlap of mandates with existing institutions, particularly the National Organization for Potable Water and Sanitary Drainage (NOPWASD). Overlap between these two institutions led to conflicts and disagreements regarding new water and wastewater projects, such as the Integrated Sanitation and Sewerage Infrastructure Project initiated in 2016 (World Bank, 2016; Tawfik et al., 2021). The overlaps became particularly evident in operation and maintenance activities. Table 2.2 maps the institutions responsible for wastewater management and reuse activities in Egypt.

Overlapping mandates also became evident regarding the Egyptian Water Regulatory Authority (EWRA). EWRA's role as a regulatory body started in 2004, but was challenged by overlapping regulatory responsibilities of other institutions, including HCWW, government ministries, and the cabinet itself (Ménard, 2022). Such overlaps in mandates diluted both leadership and responsibility for monitoring and enforcement, affecting the performance of treatment measures and facilities.

Table 2.2 Mapping of the responsible institutions for wastewater management and reuse activities in Egypt.

Wastewater management (Collection, treatment, discharge, and transfer)		Water reuse (License, approval, and allocation)			Codes, Standards, and tariffs	Monitoring
Infrastructure development	**Operation and maintenance**	**Industry**	**Agriculture**	**Urban (e.g., landscaping**		
Strategy and policy formulation: Ministry of Water Resources and Irrigation (for all aspects related to water allocation)						
National Authority of Potable Water and Sewage (NOPWASD)	The Holding Company for Water and Wastewater (HCWW) (25 affiliated companies in the different governorates)				Cabinet	Egyptian Water and Wastewater Regulatory Agency (EWRA)
Strategy and policy formulation: Ministry of Housing Utilities and Urban Communities (for all aspects related to water and sanitation services in urban and rural communities)						
	Construction Authority for Potable Water and Wastewater (CAPW), Cairo and Alexandria				Parliament Technical Committee	Ministry of Environment
Strategy and policy formulation: Ministry of Agriculture and Land Reclamation (for all aspects related to agricultural expansion)						
Hayah Karima project (national project to improve the livelihoods of rural communities in Egypt through infrastructural development in remote villages)	New Urban Communities Authority (NUCA), new cities					
	Suez Canal Authority (Suez Canal cities)					Ministry of Health

Such institutional bottlenecks compromised the sector's performance and stimulated the spread of 'informal' practices developed by local users, mainly agricultural water users, but also including water users in other sectors. For example, in the Nile Delta, informal drainage water reuse in agriculture was estimated at 4–6 BCM/year (Reymond et al., 2014). Oftentimes, drainage water was mixed with raw wastewater before its reuse. Given the underperformance and low rate of treatment and difficulty of enforcing regulations on the ground, the water reuse quality standards established by the Egyptian government have remained exceedingly ambitious (Reymond et al., 2014; section 5.1 returns to this).

2.3 Jordan

2.3.1 Toward water reuse development

Jordan's annual per capita water supply has continuously declined, reaching approximately 106 m^3 in 2018, which makes it one of the most water-scarce countries in the MENA region and the world (Hussein, 2018). Already in the 1970s, Jordan became one of the first MENA countries to consider reuse as part of its national water plan

Table 2.3). Jordan has increased the allocation of water reuse to the agricultural sector, where it serves as the primary water source for irrigation. This strategy has enabled Jordan to adapt, to some extent, to its water scarcity, as large volumes of freshwater have been reallocated to priority domestic needs (MWI, 2001). The strategy of water reuse for agriculture and allocation of freshwater for domestic uses relies on expanding sanitation services in urban areas in order to generate 0.184 BCM of treated wastewater annually (MWI, 2016).

Table 2.3 The historical development of the water reuse sector in Jordan.

Policy orientation

Aimed at expanding the sanitation services throughout the country and securing the water resources through a series of lawsthat established several governmental agencies.

1955

Regulatory actions

Law 29 – municipalities' mandates.

Institutional & management approach

Enables municipalities to be responsible for the construction, operation and maintenance of sewer systems.

1965

Institutional & management approach

Establishment of the Natural Resources Agency with a mandate to plan water resource development and irrigation policies.

1966

Regulatory actions

Law 79 – wastewater management regulation.

Institutional & management approach

Government agencies are responsible for the regulation of wastewater management activities (collection, disposition and discharge).

1971

Regulatory actions

Law 21 – treated wastewater quality. monitoring.

Institutional & management approach

The Ministry of Health became responsible for the regulation and monitoring of TWW quality.

1977

Regulatory actions

Law 18 – establish the Jordan Valley Authority.

Institutional & management approach

Establishment JVA as a regional agency responsible for the planning and implementation of all development aspects in the Jordan Valley, including water reuse in agriculture.

Policy orientation

The first wastewater reuse policy aimed to operationalize water reuse in agriculture.

1978

1982

Regulatory actions

Law 2 – first water reuse standards.

1983

Regulatory actions

Law 34 – establish the Water Authority of Jordan.

Institutional & management approach

Establishment of WAJ to manage, regulate and set policies for water and wastewater services (WAJ responsibilities were defined by Law No. 18 in 1988).

1992

Institutional & management approach

Establishment of MWI as a centralized body to manage water resources in the country.

1996

Regulatory actions

The Sewage Sludge Use in Agriculture Specification, Jordanian Standard, No. 1145 set by Jordan's Department of Standards.

Policy orientation

Policy recommendations to adopt water reuse plans in high priority areas (e.g., the Northern Jordan Valley).

1998

2001

Regulatory actions

Amendment of Law 18/1988 opens the door to the private sector to provide water and wastewater services.

2002

Regulatory actions

Law 893 – set standards for treated wastewater discharge into wadis.

Regulatory actions

Agriculture Law 44

Institutional & management approach

The Ministry of Agriculture regulates water reuse for irrigation and penalizes violators.

2006

Regulatory actions

Law 52 – the monitoring role of the Ministry of Environment.

Institutional & management approach

The Ministry of Environment takes part in monitoring and evaluating of environmental impacts of TWW on the environment through the issuance of regulations and permits for reuse.

2009

Policy orientation

Policies focused on regulating water reuse quality by adopting WHO and FAO.

Policy orientation

The promotion of a decentralized wastewater management approach.

Regulatory actions

Jordan's water strategy *Water for Life* (2008–2022) focuses on regulating environmental and health impacts by complying with the WHO and FAO water reuse guidelines (See Nassif et al. 2022 for more details on the WHO and FAO guidelines).

2013

Regulatory actions

Water substitution and reuse policies focused on the gradual substitution of freshwater with water reuse for agricultural use in priority areas.

Institutional & management approach

Establishment of National Framework for Decentralized Wastewater Management in Jordan (NICE), an interministerial committee established by MWI to develop a regulatory and administrative framework for implementing decentralized wastewater management.

2016

Regulatory actions

Jordan's water strategy (2016–2025) includes the following key policies: Water substitution and reuse policy, water reallocation policy and decentralized wastewater management policy.

2.4 The historical development of water reuse: Policy and institutional milestones

Table 2.3 traces the progressive inclusion of water reuse in the Jordanian water budget, particularly in allocations for irrigation. In the 1950s, Jordan relied solely on freshwater resources, particularly groundwater. By the late 1970s, however, it had started to shift toward large-scale water reuse in agriculture, with reallocation of freshwater to urban areas, as reflected in the large-scale water reuse and reallocation scheme in the middle Jordan Valley (Tawfik et al., forthcoming). In step with this shift, Jordan established several centralized governmental agencies, namely, the Jordan Valley Authority (JVA) and the Water Authority of Jordan (WAJ) under the umbrella of the Ministry of Water and Irrigation (MWI). These were mandated to control, operate, and regulate wastewater treatment and reuse activities.

Since the 1980s, Jordan has followed donor recommendations and further expanded water reuse in agriculture, so as to save freshwater for domestic uses. The country has identified key priority areas for implementation of the reuse and reallocation plans (MWI, 2001). To facilitate the expansion, it has sought involvement of the private sector.

2.4.1 Institutional roles, responsibilities, and bottlenecks in water reuse

From the 1950s to the 1970s Jordan's municipalities managed wastewater treatment and reuse activities. However, the municipalities' decentralized role was abolished in the late 1970s, when the government established the JVA, WAJ, and MWI. Table 2.4 maps the institutions responsible for wastewater management and reuse in Jordan.

Although MWI was the last to be established, in 1992, it became the central body for setting policies and strategies at the national level. WAJ was created in 1983 and performs a range of executive responsibilities related to the sector's operation and management. These include regulating and monitoring water and sanitation services through government-owned water and wastewater utilities in Aqaba, Amman, and North region governorates, as well as recommending tariffs based on the cost of providing water services (UFZ, 2022).

Table 2.4 Mapping of the responsible institutions for wastewater management and reuse activities in Jordan.

Wastewater management		Water reuse (License, approval, and allocation)				
Infrastructure development	**Operation and maintenance**	**Industry**	**Agriculture**	**Urban (e.g., land-scaping)**	**Codes, Standards, and tariffs**	**Monitoring**
Water Authority Jordan (WAJ) (regulates infrastructure construction and development)	WAJ (by supervising water utilities through its Program Management Unit (PMU))		Jordan Valley Authority (JVA) (in the Jordan Valley)		WAJ (tariff recommendations) Cabinet	Ministry of Water & Irrigation
					Jordan Standards and Meteorology Organization (JSMO)	Ministry of Health

JVA is responsible for the socio-economic development of the Jordan Valley. This broad mandate includes water resources management and irrigation water allocation (both freshwater and water reuse) (MWI, 2016). Due to its overarching role, JVA is often positioned at a superior level to the acting ministries (directorates) in the Jordan Valley. Recently, the JVA delegated some of its mandated responsibilities – mainly, irrigation water allocation and some maintenance tasks regarding irrigation water distribution networks – to the newly established water users associations (WUAs) in the Jordan Valley (Mustafa et al., 2016).

2.5 Lebanon

2.5.1 Toward water reuse development

The annual per capita water supply in Lebanon was around 260 m^3 in 2017 (FAO 2022a). Water scarcity in Lebanon is expected to worsen in the coming decades due to rapid urbanization, population growth, poor governance, and climate change. Despite worsening water scarcity, organized water reuse is still at an embryonic development stage (Eid-Sabbagh et al., forthcoming). Notwithstanding 30 years of massive financial investment in building sanitation infrastructure, less than 20% of treatment facilities in the country are operational.[3] The problem lies in a dysfunctional and fragmented institutional framework rooted in an entanglement of public and private interests, alongside a web of incompatible donor-driven institutional reforms (Riachi, 2013; Eid-Sabbagh, 2015; Nassif, 2019; Alles, 2019; World Bank, 2010).

2.5.2 The historical development of water reuse: Policy and institutional milestones

Wastewater regulations in Lebanon started in the 1930s, under the French Mandate, to provide for safe disposal of wastewater without polluting the surrounding water bodies (Table 2.5). This focus continued until the 1970s, when Decree 8765 prohibited the use of sewage water in irrigation and mandated that each municipality allocate specific locations for wastewater treatment and discharge.

Between 1975 and 1990, the Lebanese civil war weakened governmental institutions, including those managing water and sanitation services. Ripple effects of the civil war are still felt today. The large investments made to rehabilitate and construct water and wastewater facilities and the multiple institutional and policy reforms that have been established to reorganize the water and sanitation regulatory and organizational frameworks today remain unimplemented or only partially operational.

One of these restructuring attempts was Law 221, ratified in 2000, which merged the 22 local water authorities belonging to the country's municipalities into four regional water establishments (RWEs) with administrative and financial autonomy. Later, in 2002, the government issued Law 444 (also known as the Environmental Law), which elaborated an environmental code including standards for water and wastewater quality. In 2012, the government issued a national water strategy, which was the first official document to explicitly address the reuse potential of treated wastewater. In 2004, the government issued Law 77, also known as the *Code de l'Eau*, a comprehensive law governing both water and sanitation services. Law 77, however, was not ratified by parliament until 2018. The law was finally ratified on the eve of the CEDRE Conference (Conférence économique pour le développement, par les réformes et avec les entreprises), organized in Paris to help attract loans from the international community for the increasingly indebted country.

2.5.3 Institutional roles, responsibilities, and bottlenecks in water reuse

The main barriers to wastewater management and reuse in Lebanon relate to the governance framework, as this is characterized by a fragmentation of functions and institutional uncertainty which have hindered effective policy and project implementation (World Bank, 2010; Machayekhi et al., 2014). Officially, Lebanon's Ministry of Energy and Water (MEW) is responsible for wastewater planning, and the Council for Development and Reconstruction (CDR) manages funds and implements wastewater treatment plants according to MEW's plans. Upon completion, CDR hands the wastewater treatment plants over to the RWEs, which are in charge of their operation, under MEW oversight, including the levying of fees from citizens (Table 2.6).

In practice, since the mid-1970s CDR has been granted a large scope of powers in the planning of large infrastructural works and managing the associated international funds, in order to speed up bureaucratic procedures and accelerate post-civil war reconstruction. Thus, CDR expanded to play a super ministerial role, implementing decisions following approval of the prime

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[3] This number dropped further reducing starting in late 2019 due to the bankruptcy of both the Lebanese government and the banking sector (Eid-Sabbagh et al., forthcoming).

minister. This role, however, has been criticized, as it can be interpreted as a means to concentrate decision-making and associated financial benefits in the hands of political elites (Eid-Sabbagh, 2015).

Table 2.5 The historical development of the water reuse sector in Lebanon.

1974

Regulatory actions

Decree 8735 – Prohibits wastewater discharge into water bodies.

1976

Regulatory actions

Decree 8765 – Prohibits wastewater use in irrigation.

Institutional & management approach

Each municipality is mandated to assign a location for wastewater treatment.

1977

Institutional & management approach

Establishment of the Council for Development and Reconstruction (CDR) as an autonomous entity directly reporting to the council of Ministries, with the comprehensive task of planning, reconstruction, and rehabilitation of the country.

1999

Regulatory actions

Water Master Plan (2000–2009) by the Ministry of Hydraulic and Electric Resources (MHER).

2000

Regulatory actions

Law 221 – creating the regional water establishments (RWEs).

Institutional & management approach

Creates four RWEs with administrative and regional autonomy, responsible for the implementation, operation, and maintenance of water-related projects. The law was enacted in 2018.

2001

Regulatory actions

Law 337 – establishing the Ministry of Energy and Water (MEW).

Institutional & management approach

Transforms MHER to MEW.

2002

Regulatory actions

Law 444 – Environmental law.

Institutional & management approach

Environmental law to combat pollution, where the MEW and the Ministry of Environment have competencies in developing standards and imposing measures to monitor water quality in collaboration with relevant stakeholders.

2012

Regulatory actions

The National Water Sector Strategy (NWSS).

Regulatory actions

The National Strategy for the Wastewater Sector (NSWW).

2018

Policy orientation

The international conference in support of Lebanon's development and reforms in Paris (Paris IV - CEDRE) where the Lebanese government committed to implementing sectoral and multi-sectoral reforms that encouraged a large flow of soft loans and grants.

Regulatory actions

Water Code (*Code de L' Eau - Law 77*) – complements and/or operationalizes Law 221 (issued in 2000) by assigning the MEW the responsibility of developing sustainable strategies for water governance at a national level. It states that the RWEs should handle water and wastewater services within their regions and satisfy water demand through conventional and non-conventional sources (including TWW), also for RWEs. to propose water and wastewater tariffs.

Table 2.6 Mapping of the responsible institutions for wastewater management and reuse activities in Lebanon.

Wastewater management (collection, treatment, discharge, and transfer)		Water reuse (license, approval, and allocation)			Codes and standards	Monitoring
Infrastructure development	Operation and maintenance	Industry	Agriculture	Urban (e.g., landscaping)		
Strategy and policy formulation: Ministry of Water and Energy						
Council for Development and Reconstruction (CDR)	CDR				Ministry of Water and Energy	Ministry of Water and Energy
					Ministry of Environment	

Strategy and policy formulation: CDR						
	Municipalities					Ministry of Environment

Since 2012, a shift in political dynamics has put MEW in a better position concerning water sector planning and project implementation (Nassif, 2019). MEW issued the last National Water Sector Strategy in 2012, which includes a national wastewater master plan (MEW, 2010). In an April 2020 interview, an advisor from the Ministry of Energy and Water observed that coordination between the MEW and CDR had been improving, and that this was an important objective both within the ministry and for the upcoming update of the National Water Strategy.

Despite any improvements in coordination, the water sector has continued to face a number of vexing issues. The sector vision was reformed to comply with a prerequisite for World Bank funding of reconstruction works, rather than being initiated by the sector itself, based on its own needs and plans. The resulting vision led to creation of four regional water authorities (the RWEs), which were to be financially autonomous and capable of operating all water and sanitation services, as well as irrigation for three of the RWEs.

However, 20 years after the reform, the RWEs are still struggling to execute their mandate due to their weak political power on the ground. They are poorly staffed and subject to interference from the various political factions (World Bank, 2010; MEW, 2012; Eid-Sabbagh, 2015; Nassif, 2019). Currently, among the country's 166 wastewater treatment plants, only 10 are managed by the RWEs and five are operational. The rest are managed by CDR, with many of them funded by international projects and managed by the municipalities (Eid-Sabbagh et al., forthcoming).

2.6 Saudi Arabia

2.6.1 Toward water reuse development

Average annual water use per capita in Saudi Arabia was 278 m^3 in 2018 (GASTAT, 2018). The country has no natural surface water sources and extremely low annual rainfall.[4] Pressure on the already limited water supplies has continually intensified due to a high rate of population growth combined with a steadily increasing demand for water in the agricultural sector, which has grown at an annual rate of 7% and accounts for 84% of total water consumption in the country (MEWA, 2020).

Wastewater reuse is an integral component of Saudi Arabia's National Water Strategy 2030. That strategy points to wastewater reuse as a means to help the country save its non-renewable groundwater aquifers from ongoing depletion and reduce the country's electricity consumption by around 2% annually (Kajenthira et al., 2012). Water reuse would also provide for the industrial sector's growing water demand, as industry is a major contributor to Saudi Arabia's economy (Alkhudhiri et al., 2019).

In terms of Saudi Arabia's total water supply, treated wastewater contributed some 0.6 BCM (2% of total resources) in 2016, increasing to 1.9 BCM (15% of total resources) in 2020. In 2018, the Saudi Arabia produced around 1.46 BCM of treated wastewater, of which 17% was reused for agricultural purposes (MEWA, 2020).

Water reuse projects in Saudi Arabia have aimed primarily at conserving the country's non-renewable groundwater resources,

[4] Not exceeding 100 mm in most of the country except the southwestern region (Al-Zahrani and Baig, 2011)

while maintaining sustainable agricultural development and food security, improving the farmers' living standards, and maximizing environmental and economic benefits. These objectives have been pursued through national policies and institutional reforms which support privatization of the sector while providing for government subsidization of water and sanitation services and maintenance of a regulatory role for government (Ouda et al., 2014).

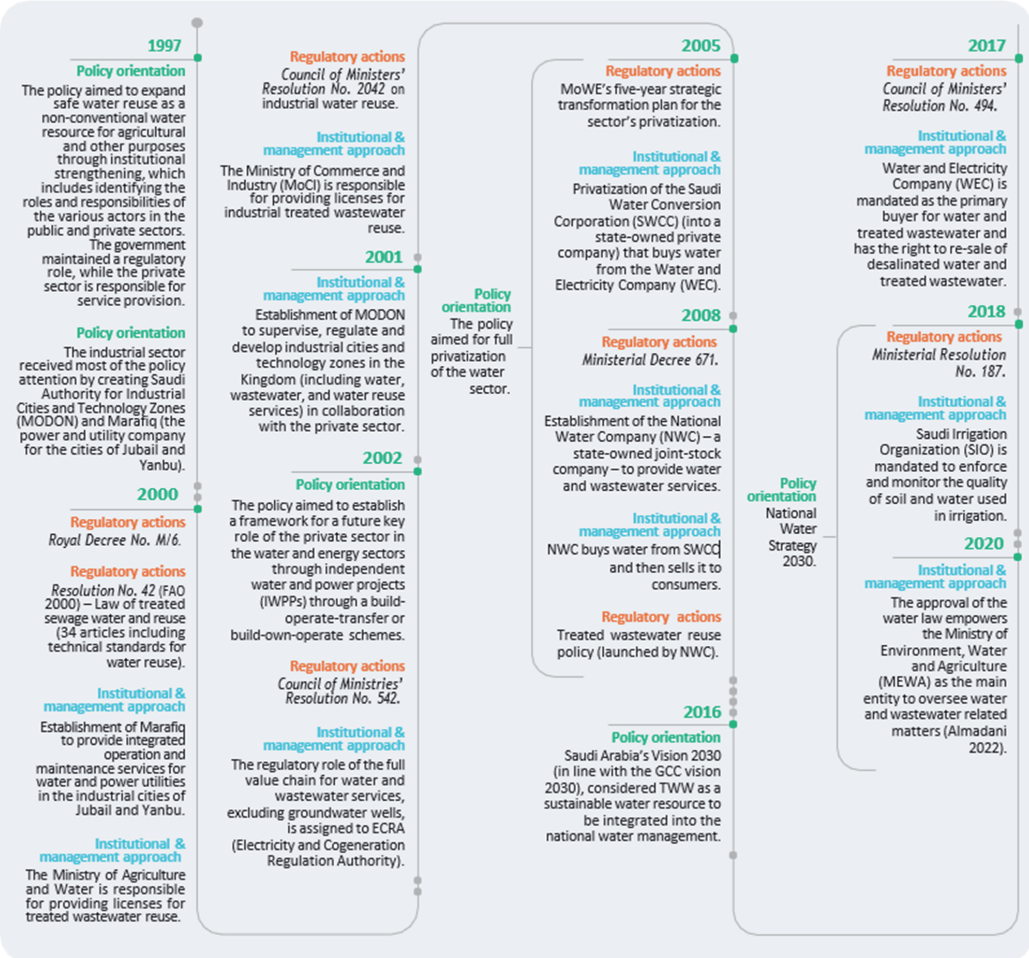
2.6.2 The historical development of water reuse: Policy and institutional milestones

Saudi Arabia began developing its water sector later than other countries in the MENA region (Table 2.7). This is explained by the kingdom's relatively recent agricultural development, which came later than that of Egypt, Jordan, and Tunisia. Historically, Saudi Arabia depended on groundwater resources, but in the 1950s it developed advanced seawater desalination capacities. In 2018, Saudi Arabia generates 18% of global stocks of desalinated water (Oxford Business Group, 2018). Saudi Arabia's efforts to expand safe water reuse, which is less energy demanding than desalinization, started in the late 1990s. In this regard, it has pursued greater involvement of the private sector in provision of water reuse-related services, while maintaining the regulatory role of government institutions.

2.6.3 Institutional roles, responsibilities, and bottlenecks in water reuse

Saudi Arabia has managed to integrate unconventional water resources, specifically, desalinated water and treated wastewater, into its water sector plan, while minimizing institutional overlaps and gaps between the involved agencies. It has clearly allocated roles and responsibilities between the public and private sectors (Table 2.7), which has helped to minimize competing interests between the various actors.

Table 2.7 The historical development of water reuse in Saudi Arabia.



The Saudi case can be considered an example of successful privatization, while maintaining the regulatory and monitoring role of government agencies to ensure the private sector's compliance with national codes and standards. However, well-established privatization does not mean that a transformative shift has been effected towards a decentralized sector. On the contrary, the water sector in Saudi Arabia is a centralized one that employs the vast experience of the private sector to increase efficiency and reduce the cost of providing services such as water supply, sanitation, and water reuse.

These transformative changes are reflected in the institutional structure of Saudi Arabia's water sector, in which state-owned companies and private investors play a key role in the water reuse value chain. This value chain starts with independent water and power project (IWPP) contracts (build-own-operate or build-operate-transfer) and ends with water provision to consumers through the state-owned companies, predominantly, the Water and Electricity Company (WEC), the Saudi Water Conversion Corporation (SWCC), and the National Water Company (NWC) (Biygautane, 2017) (Table 2.8).

Table 2.8 Mapping of the responsible institutions for wastewater management and reuse activities in Saudi Arabia.

<table>
<tr><th colspan="2">Wastewater management (collection, treatment, discharge, and transfer)</th><th colspan="3">Water reuse (license, approval, and allocation)</th><th rowspan="2">Codes and standards</th><th rowspan="2">Monitoring</th></tr>
<tr><th>Infrastructure development</th><th>Operation and maintenance</th><th>Industry</th><th>Agriculture</th><th>Urban (e.g., landscaping)</th></tr>
<tr><td colspan="7">Strategy and policy formulation: Ministry of Environment, Water, and Agriculture (MEWA)</td></tr>
<tr><td colspan="2">Independent water and power projects (IWPPs). These include the Saudi Water Conversion Corporation (SWCC), the Water and Electricity Company (WEC), and the National Water Company, in addition to the power and utility company for the cities of Jubail and Yanbu (Marafiq) and the Authroity for Industrial Cities and Technology Zones (MODON).</td><td>Ministry of Commerce and Industry (MoCI)</td><td>Saudi Irrigation Organization (SOI)</td><td>MEWA</td><td>Electricity and Co-generation Regulation Authority (ECRA)</td><td rowspan="2">MEWA</td></tr>
<tr><td></td><td></td><td colspan="3">MEWA</td><td></td></tr>
</table>

2.7 Tunisia

2.7.1 Toward water reuse development

Tunisia's per capita water supply was an estimated 440 m^3 in 2017 (FAO, 2022a), though this is expected to drop to 360 m^3 by 2030 (Chouchane et al., 2018). Water stress in the country has been exacerbated by increasingly variable rainfall and more frequent droughts. In addition, its conventional water resources are limited and degrading in terms of quality. This has led to a national push in regard to water to 'use every drop', including treated wastewater.

Water reuse in Tunisia got underway in the early 1960s, with the first such projects established in the La Soukra region, mainly to irrigate citrus trees. This major crop used to be irrigated from shallow coastal aquifers. Yet, the worsening depletion of these aquifers resulted in seawater intrusion and salinization of groundwater, making it unsuitable for irrigating crops as sensitive as citrus trees. The main objective of wastewater reuse was hence to protect groundwater resources from salinization and preserve the citrus orchards. This began well before 1975 promulgation of an overarching national water law, the so-called Water Code, which was established to regulate water reuse, among other objectives.

2.7.2 The historical development of water reuse: Policy and institutional milestones

Tunisia presents a unique case in which implementation of a water reuse project preceded institutional development for water reuse in the country. This contrasts with the other countries studied, as in those, project implementation steps came after regulatory and institutional ones. However, starting from the mid-1970s, Tunisia directed its efforts toward building institutional capacity for water reuse. It established the National Sanitation Utility (ONAS), a central government institution to manage the sanitation sector. From the 1980s onward, successive Tunisian governments issued a series of standards and laws to regulate effluent and influent quality and ensure compliance with national and international standards.

Starting in 2018, water reuse expansion gained momentum. In particular, it has been promoted under the flagship of the strategic study *Eau 2050*, which was accompanied by a national master plan for water reuse entitled Reuse 2050.

2.7.3 Institutional roles, responsibilities, and bottlenecks in water reuse

Wastewater reuse started in the early 1960s in Tunisia (Table 2.9), but policy and institutional settings were established only in the 1990s. The ministries and national agencies created as part of this institutionalization effort can be classified as producers, managers, users, distributors, controllers, and consumers of irrigation products and services).

Table 2.9 The historical development of the water reuse sector in Tunisia.

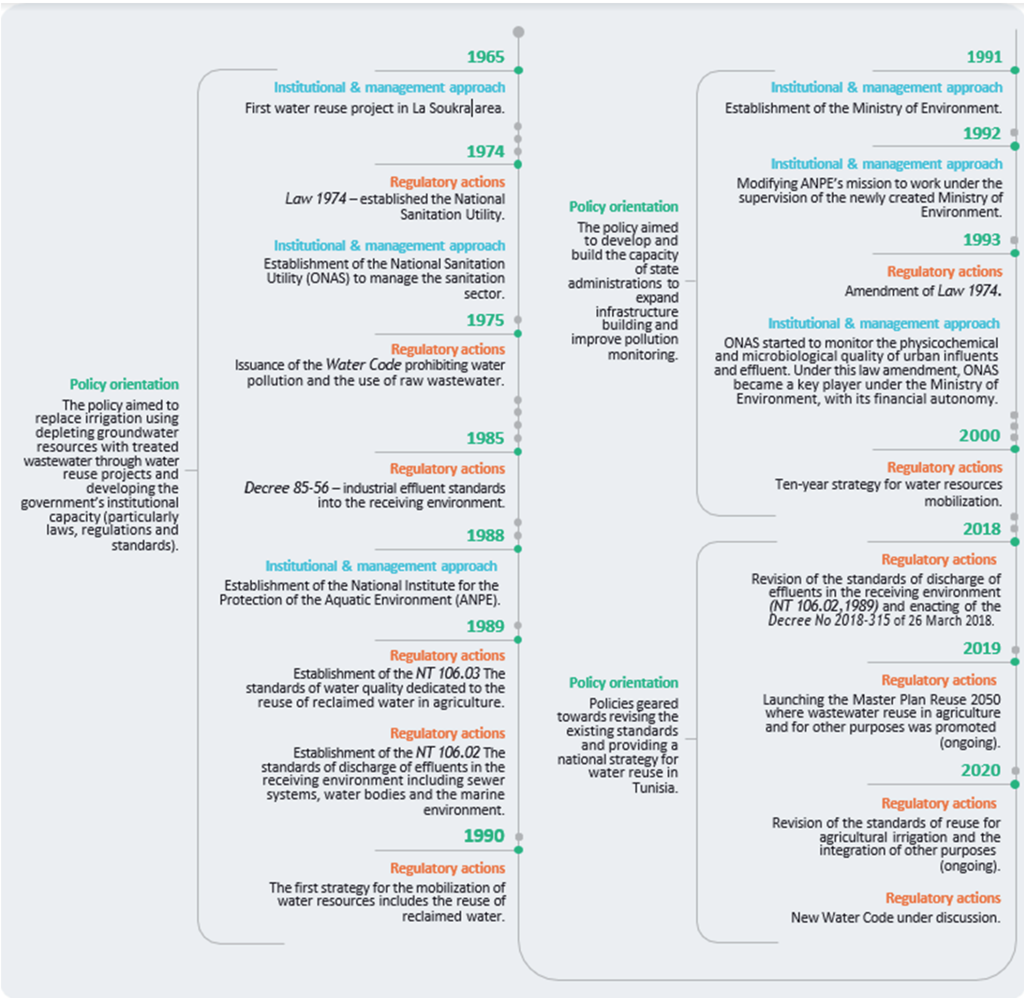


Table 2.10 Mapping of the responsible institutions for wastewater management and reuse activities in Tunisia.

Wastewater management (collection, treatment, discharge, and transfer)		Water reuse (license, approval, and allocation)			Codes and standards	Monitoring
Infrastructure development	Operation and maintenance	Industry	Agriculture	Urban (e.g., landscaping)		
Strategy and policy formulation: Ministry of Agriculture, Water Resources, and Fisheries (MARHP)						
Ministry of Equipment and Infrastructure	National Sanitation Utility (ONAS)		MARHP through the Regional Departments for Agricultural Development (CRDAs)		MARHP	Ministry of Environment through National Agency of Environmental Protection (ANPE) and ONAS (practicing self-evaluation)
			Farmers' associations (GDAs)			Ministry of Health

Within this value chain-like structure, the Ministry of Agriculture, Water Resources, and Fisheries (MARHP) plays a prominent role through its directorates and subsidiaries. MARHP's wide range of responsibilities includes water resources (mobilization and use) and agricultural production, as well as drinking water for urban areas, through the National Water Supply Utility (SONEDE), and for rural areas, through the Department of Rural Engineering and Water Exploitation and the so-called 'agricultural development groups' of water users' associations.

In the early 1990s, ONAS, established in 1974, and the National Agency of Environmental Protection (ANPE), established in 1988, were brought under the Ministry of Environment, which was being created at the time, though ONAS also operates under the Ministry of Local Affairs, as it has maintained its role as the main operator of sanitation services. Since the early 1990s, all wastewater reuse projects have had to submit an environmental impact study in order to be approved by ANPE. MARHP is the main manager, user, and distributor of treated wastewater. It intervenes only downstream of the treatment plant (the upstream aspects being managed by the Ministry of Environment), and it operates at both the national and regional level, in the latter through its representative regional departments (the Regional Departments for Agricultural Development, CRDAs) located in the country's 24 governorates.

Together with farmers' associations, CRDAs manage treated wastewater reuse and irrigated areas, including the operation and maintenance of irrigation networks, ensuring farmers' involvement and participation at the local and regional levels. For this purpose, the Agricultural Extension and Training Agency (AVFA) and its representatives in the regions (Extension Territorial Services, CTVs) are responsible for disseminating good practices in water reuse for irrigation and for offering extension services to end-users. The Ministry of Health and its regional affiliated agencies and departments are the main bodies controlling and monitoring treated wastewater quality and the quality of the irrigated environment and products.

In terms of governance and agricultural water reuse, Tunisia has in place the actors required for successful implementation. These include ministries, agencies, committees, and associations at the national, regional, and local levels. However, relationships between the actors have remained weak due to the lack of information sharing, which might reflect a certain mistrust. Currently, there are no mechanisms for reducing the existing overlap in missions, for example, by better defining the roles and responsibilities of the different actors. Non-agricultural water reuse, similarly, has continued to face weak governance due to a lack of specific regulations. An exception in this regard is the agricultural standards established in 1989, which are applied for water reuse on golf courses, for recreational activities, and for aquifer recharge.

A lack of collaboration between the many institutions from the different sectors is a major bottleneck. For instance, there are no institutional arrangements between ONAS and the regional departments of MARHP. This means there is no guarantee of treated wastewater production and distribution satisfying agricultural water demands. Creation of an independent multi-sectoral organization that would oversee water reuse has therefore been repeatedly suggested.

2.8 Conclusion

Regarding water reuse, the MENA region displays a lack of technological and infrastructural development, an absence of standards and regulations, and a weakness of institutional arrangements governing water reuse-related services (Ait-Mouheb et al., 2020; Mayaux and Ennabih, 2020). 'Decentralization' and 'private sector participation', for example, through public-private partnerships, are common policy recommendations. Nonetheless, the policy orientation informing the regulatory and institutional set-up and development of the water reuse sector has tended to be top-down and centralized in most MENA countries.

Within the five countries examined, the following key features can be identified as characterizing the policy and institutional development of wastewater management and reuse in MENA:

- Wastewater management and reuse appear to have been secondary priorities in the five countries examined. In these cases, increasing pressure on water resources has been a key driver in adopting water reuse as a new strategy, though primarily directed toward the agricultural sector.

- Policy and institutional measures to regulate wastewater reuse have often lagged behind other water-related projects, particularly supply management projects. Accordingly, an increased share of freshwater is being returned to the system as untreated wastewater.

- An absence of independent regulatory agencies, overlapping roles and responsibilities, and an absence of specialized institutions to monitor water reuse in the different sectors have been key factors leading to institutional weaknesses. The result has been to hinder governments' efforts to shift toward decentralization and private sector involvement (with Saudi Arabia being an exception).

- Institutional and policy reforms initiated by donors (e.g., in Egypt and Lebanon) have proven unable to achieve their goals of improving the sector's performance in the absence of country-driven reforms based on needs assessment and long-term planning.

- There is a trend toward centralization and increased regulation of water quality and water flows. This is logical in view of the expanding and competing demands for water alongside the weak institutional capacity to handle water, sanitation, and reuse services at the local level (e.g., in Lebanon the role of municipalities as service providers was reduced to avoid redundancy and mission overlap with the RWEs; in Egypt, provision of water and sanitation services was centralization with HCWW's establishment).

- In many countries, a lack or absence of policy enforcement and implementation has created 'gray zones' that are often filled by informal, often illegal, reuse arrangements (Tawfik et al., 2021).

The policy and institutional challenges and trajectories identified in the five countries point to a number of recommendations that could help MENA policymakers and decision-makers to overcome the policy and institutional bottlenecks their countries face:

- Create spaces for local stakeholders to participate in policy and institutional development concerning their localities.

- Establish an enabling environment to encourage private sector involvement. This should include clear roles and responsibilities for the various institutions in the sector, policy incentives, and long-term concession contracts.

- Entrench the concepts of transparency and collaboration within the different institutions to develop a multi-sectoral water policy that is inclusive of the various needs.

- Ensure that each policy item has a corresponding institutional action to avoid overlapping responsibilities.

- Understand that the transition from centralized to decentralized water management is not a 'silver bullet' for sector challenges. However, implementing this transition must be done in phases to avoid institutional 'shocks' and ensure financial, regulatory, and legal 'maturity' of newly created autonomous entities.

- Recognize that donor-driven policies and institutional reforms might hinder the sector's ability to define a clear vision that meets the country's own needs and long-term planning goals.

3 Unpacking wastewater reuse arrangements through a new framework: Insights from Egypt

ABSTRACT

Wastewater reuse has been identified as a strategy to ameliorate resource scarcity in water-stressed regions around the world. However, to develop it, there is a need to better understand the social, institutional, and technological contexts in which wastewater reuse takes place. This chapter develops a novel socio-technical framework to inform a sufficiently comprehensive context analysis and applies it to the wastewater reuse sector in Egypt. The analysis highlights the different actors, management activities, and practices that shape wastewater collection, transfer, treatment, discharge, and reuse in different social, technological, and environmental contexts in Egypt. It points out bottlenecks in existing wastewater reuse policies and programs.

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3.1 Introduction

Wastewater production worldwide has reached an estimated volume of 380 BCM per year, equivalent to five times the amount of water that passes through Niagara Falls (Qadir et al., 2020). Though not always accounted for, large quantities of this wastewater (treated and untreated) are directly and indirectly reused in irrigation around the globe, and this reuse is expected to increase. However, the actual role and future potential of wastewater reuse for irrigation at the global and regional scales is still an understudied topic (Qadir et al., 2020). Several authors have explored the economic, environmental, health, and social benefits of wastewater reuse, as well as the challenges that prevent the materialization of these potentials (e.g., Mateo-Sagasta et al., 2015; Otoo and Drechsel, 2018; Thebo et al., 2017). One obstacle is the neglect of informal reuse arrangements by formal institutions, thus limiting the capacity to strategically include and govern this wastewater reuse in a safe, sustainable, and equitable manner at different scales.

This chapter contributes to this discussion by first developing an analytical framework for analyzing wastewater reuse and then applying it to develop a better understanding of the different formal and informal wastewater reuse arrangements in Egypt. The analysis is guided by two main research questions:

- What theoretical framework can elicit a better socio-technical understanding of the wastewater reuse sector and its practices?
- What new insights does such a framework offer when analyzing the current wastewater reuse sector of Egypt?

The analysis presented is based on available official and unpublished documents, personal communications with national and international experts, and a baseline study prepared by the Egyptian–Swiss Research on Innovation in Sustainable Sanitation (ESRISS) project (2011–2015) (Reymond et al., 2014). For details on the data collection methodology, see the ESRISS project website.[1]

The remainder of this chapter is structured as follows. Section 3.2 sets out the theoretical framework and notions informing the analysis on wastewater reuse arrangements and their control. Section 3.3 considers the background of Egypt's water resources and its management challenges. Section 3.4 zooms in on Egypt's formal wastewater reuse sector, pointing to the drivers of increased demand for wastewater reuse and presenting the formal wastewater sector, which is managed by centralized state agencies with overlapping responsibilities. Section 3.5 concerns formal indirect and direct reuse arrangements in Egypt, while section 3.6 explores the case of formal direct reuse in the Marsa Matrouh project. Section 3.7 considers informal reuse practices in the Nile Delta. These are illustrated, in section 3.8, by case studies of two representative villages in rural Egypt. Section 3.9 presents findings within the developed framework for analysis. Its application indicates that in the formal, mainly urban sector, almost all tasks in the different wastewater reuse stages, technologies, and practices are dominated by state institutions. However, in the informal, mainly rural sector, all water flows and technologies are managed through household and community practices and institutions. This analysis confirms that in Egypt the formal (mainly urban) and informal (mainly rural) sectors coexist alongside one another, but with little or no collaboration between the two. Closer collaboration between the formal and informal sectors could yield safer and more socially just wastewater reuse practices. First steps in this direction could be recognition of the informal sector and decentralization of some state functions, to open new paths for collaboration in wastewater reuse. Finally, the chapter argues that the established framework offers a valuable lens through which to analyze wastewater reuse practices.

3.2 Theorizing wastewater reuse arrangements and their control

In the current analysis, wastewater reuse arrangements are conceived as socio-technical processes that take shape through water flows, technologies, practices, institutions, and individuals engaged in the different stages of the wastewater reuse cycle. These different stages are identified, as well as the processes that take place within and around them. In doing so, Uphoff's (1986) model for analyzing irrigation systems is adapted and applied in modified form to wastewater reuse systems. This adapted model is presented in Table 3.1.

The model divides wastewater reuse processes into three components: (1) wastewater flows, (2) technologies and their operation, and (3) the institutions and practices that regulate wastewater flows and technologies. Though these components are separated for analytical purposes, they are intrinsically interrelated to one another.

Table 3.1 Wastewater management and reuse activities (Source: own elaboration, based on Uphoff, 1986).

Wastewater flows		Technological management			Institutions and practices
Containment/collection	Design	Construction	Operation	Maintenance	Regulation and norms
Treatment					Conflict management
Conveyance					Resource mobilization
Discharge/reuse					Decision-making

The wastewater reuse cycle consists of four stages: containment, treatment, conveyance, and water delivery/reuse. These stages are not necessarily sequential and are not all necessarily present in wastewater reuse arrangements. The different stages are mediated through the use of diverse technologies at each stage. Usually, the first stages are wastewater conveyance and containment, through which wastewater is collected and/or transported away from the point of generation (e.g., households) to a point where it poses fewer health risks to those who generated the wastewater flows. This point is ideally a wastewater treatment plant where the social and environmental threats posed by polluted water are minimized by the removal of pathogens, parasites, and organic and inorganic elements. However, it may also be a water body, such as a river, an irrigation canal, a drain, a lake, or the sea. If and when wastewater is reused, it is redistributed, in treated or untreated form, through a conveyance network (e.g., a drainage network, as in the Nile Delta), which takes water flows to the place where these will be used, which in most cases is for agricultural purposes (Van Steenbergen and Dayem, 2007).

The abovementioned processes are mediated through formal and informal institutional, normative frameworks and practices. Institutional arrangements define the rules and regulations (norms in case of informal arrangements) for wastewater flows and reuse as well as what organizations are responsible for their implementation and control. These same arrangements regulate how resources are mobilized in the wastewater reuse process, how conflicts are mediated and resolved, and finally, how decisions are made.

It should be recognized that in these processes both formal and informal wastewater reuse arrangements coexist and mingle. Formal arrangements are those established by national laws and implemented, regulated, and controlled by state agencies and recognized by donor agencies. In contrast, informal arrangements are often socially embedded and shaped through daily practices, negotiations, and discussions in specific contexts. These are not codified or structured according to written legal or contractual commitments, meaning that in some spaces, informal arrangements may receive more compliance than externally imposed, formal regulations (Cleaver, 2017). The greater compliance with informal arrangements stems from their tendency to be socially embedded and shaped by daily practices, negotiations, and discussions in very specific contexts. Finally, technologies mediate social relations and resource flows between different institutions and actors (Pinch and Bijker, 1984; Latour, 1996). These play a key role in controlling, facilitating, or hindering specific wastewater reuse practices by delegating specific roles and attributions to specific actors. Social relations are embedded in specific local constellations. In such constellations, in many countries, there is a tendency for formal arrangements to discredit and render invisible informal arrangements (Boelens and Vos, 2014). This bypasses the crucial role of informal arrangements in providing sewerage and sanitation services to marginalized urban and rural populations, and may thus undermine the contribution of informal arrangements to the reuse of wastewater. This is of particular importance in water-stressed river basins. Here, informal arrangements can play a particularly important role in providing for irrigation demands and increasing wastewater reuse, as illustrated by the case of Egypt.

3.3 Egypt's water resources crisis and the increase of wastewater reuse

Egypt's water demand is 114 BCM/year, though only some 60 BCM/year is available, of which more than 90% is supplied by the Nile River (HCWW, 2011). The agricultural sector consumes around 76% of Egypt's water, whereas 13% is used for domestic purposes and 7% for industrial use (The Road Map, 2017). In this context, wastewater reuse could form a valuable practice to help deal with some of the country's future agricultural water demand and other water-related challenges.

At present, Egypt's 409 wastewater treatment plants serve 60% of the population, covering 90% of urban areas and 12% of rural areas (HCWW, 2011, 2019). The Nile Delta region has 289 wastewater treatment plants, with a total treatment capacity of 0.0087 BCM/day, an amount the government aims to increase to about 0.019 BCM/day by 2037 (The Road Map, 2017).

Egypt's water resources management, including the management of wastewater and its reuse, is characterized by strong centralized state control (Reymond et al., 2014). The irrigation and drainage system of the Nile Delta region was built and managed by centralized state agencies and constitutes a vast network of connected irrigation canals and drains. The drainage system was designed to collect and recirculate irrigation drainage water back to the irrigation canals, while discharging relatively small amounts into the Mediterranean in the lower basin (Nardini and Fahmy, 2005). With the lack of fully conventional wastewater collection and treatment schemes in the Nile Delta, this extensive drainage system has become a conveyance system that carries domestic and industrial wastewater – mostly untreated – along with irrigation drainage water (Figure 3.1). Accordingly, in this analysis, 'drainage water reuse' is considered a synonym for 'untreated wastewater reuse', since the quality of drainage water has been significantly deteriorated by wastewater flows in most of the Egyptian drains (JICA, 2016).

Delta farmers' reliance on drainage water for irrigation started in the 1950s and 1960s, first as a 'back-up' source for irrigation water. With time, drainage water reuse for irrigation increased as pressure on water resources became more acute. Drainage water quality dramatically deteriorated as the quantity of untreated domestic and industrial wastewaters increased starting in the 1970s. Much of this increase came from waste discharge from domestic (and, to a lesser degree, industrial) sources, which were expanding due to population growth and the related expansion of domestic water supply networks in the Nile Delta. This occurred in a context in which water supply networks grew much faster than sanitation services, and corresponding wastewater treatment plants were needed to treat the increased effluent flows. In relation to industrial effluents, small and mid-size industrial sources have been the main source of pollution, as large-scale industry is required by law to be equipped with industrial wastewater treatment units and assumed to be adequately monitored, though in practice this monitoring and related compliance is low.

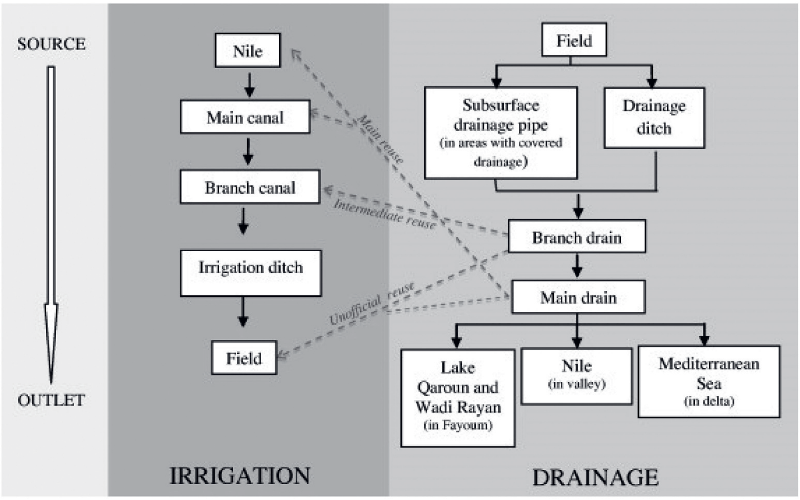


Figure 3.1 Schematic representation of the drainage water flows through the Nile Valley and Delta (Source: Barnes, 2014a: 185).

Despite the strategic importance and widespread use of polluted drainage water as a source for irrigation water, its reuse is an illegal practice in Egypt. To be legal, Egyptian Reuse Code 501/2015 prescribes that wastewater must be treated and mixed with freshwater in the irrigation canals, after which it may be used (officially) for irrigation purposes only. Similarly, the direct discharge of untreated sewage into drains is illegal unless the effluent abides by the strict standards of Law 48/1982. However, in most instances the state turns a blind eye to informal sewage and other wastewater discharge and reuse practices (Barnes, 2014a, 2014b), though this strategy carries serious health, environmental, and economic risks. In this context, it is alarming that the discharge of highly polluted agricultural drainage water back into the Nile north of Kanater Barrage is common practice. Examples include, but are not limited to, the El Rahawi drain discharging highly polluted water directly into the Nile Rosetta Branch and the Zarkoun Drain discharging into the Mahmoudiah Canal. This practice results in water with low levels of dissolved oxygen, high biological oxygen demand, and undesirable concentrations of nitrates, ammonia, phosphate, persistent organic micropollutants, and trace metal residues (JICA, 2016; El-Agha et al., 2020). These mixed waters are the source for water treatment plants that supply millions of people with domestic water. As many of these plants use conventional treatment processes, such as coagulation, sedimentation, filtration, and chlorination, they have limited capacity to remove the micropollutants that come from domestic, industrial, and agricultural wastewater discharges upstream (trace metals, pesticides, chlorinated hydrocarbons, trihalomethanes, etc.).

The lack of compliance with formal regulations can be partly explained if one recognizes that 'illegal' sources of wastewater have served to quell the discontent of local farmers who have a drinking water supply, but as yet lack conventional sanitation systems and sufficient water for irrigation (Barnes, 2012; Helmke and Levitsky, 2004). Informal reuse has thus become part of a 'governance' strategy that 'stretches' Egypt's annual fixed quota of Nile water (Allam and Allam, 2007). As such, the livelihoods of smallholder farmers in the Nile Delta can be maintained, while preserving an otherwise contested – even weak – state control over wastewater resource flows and ability of the state to deliver basic needs through formal (bureaucratic) institutional arrangements.

3.4 Egypt's formal wastewater reuse sector

Before 2004, responsibility for domestic water delivery and sanitation services in Egypt was distributed among various organizations. Up to that time, the Construction Authority for Potable Water and Wastewater (CAPW) operated in Cairo and Alexandria, while the National Authority for Potable Water and Sanitary Drainage (NOPWASD) provided services to the other governorates. At the same time, in rural areas, local administration units (LAU) were responsible for water and sanitation services provision in their jurisdictions. Similarly, the New Urban Communities Authority (NUCA) provided water and sanitation services in new cities and industrial clusters. This fragmentation in the sector was linked to Egypt's financial woes (having a deficit of US $1.3 billion in 2003). The inadequacy of water and sanitation services, nonetheless, prompted calls for sectoral reforms. These got underway in 2004 with establishment of the Holding Company for Water and Wastewater (HCWW) (World Bank, 2016).

Since 2004, HCWW has held responsibility for collecting, treating, and safely discharging wastewater in Egypt through its 25 affiliated companies in 27 governorates (HCWW, 2019). Nevertheless, two other main entities (NOPWAS and CAPW) have also continued to operate as key players in the sector, particularly concerning investment and infrastructural development. This has resulted in project delays and increased cost of development projects and undermined the sector's efficiency (World Bank, 2016). Despite the transfer of responsibilities and assets to HCWW's 25 affiliated companies, its centralized authority has been entrenched and remained the only entity legally responsible for wastewater collection, treatment, and discharge/reuse. This has made all other arrangements for wastewater disposal, treatment, and reuse in the country illegal or informal.

The sectoral reforms were enacted to comply with prerequisites of donor agencies, particularly the European Union (EU) and World Bank, to secure their reinvestment in the water and wastewater sector in Egypt (see Cambaza et al., 2020, and Hoogesteger et al., 2017, for similar examples in the irrigation sector). The new investments were aimed at improving the sector's efficiency, for example, via cost recovery mechanisms, and at removing institutional bottlenecks (World Bank, 2016). However, these objectives were not achieved and HCWW has continued to operate in deficit conditions.

Nevertheless, these shifts in responsibilities gave HCWW and other state agencies a 'monopoly' position in the sewerage and wastewater sector. HCWW has received almost exclusive faculties in relation to the collection, availability, and accessibility of data concerning sewage and wastewater quantity, quality, and reuse potential.

Table 3.2 applies the developed analytical framework to the formal wastewater reuse sector in Egypt. It shows that HCWW as an institution is involved in all activities related to wastewater collection, treatment, and discharge/reuse through its affiliated companies in the different governorates of Egypt. While HCWW does not have a regulatory role, the limited role of the Egyptian Water Regulatory Authority (EWRA) has given HCWW more space to inspect and monitor the various wastewater management activities.

As such, HCWW has sought to ensure that effluent discharged into drains complies with Egyptian standards – though this standard may not be met by some treatment plants. HCWW has done this (i) via its role in treating wastewater discharges, as most wastewater from larger cities and urban areas undergoes treatment by an HCWW-affiliated company, and (ii) by overseeing other wastewater discharges through a system of permits and fines. However, both the former as well as the latter are poorly implemented and incomplete.

Table 3.2 Wastewater flow management analysis of formal indirect wastewater reuse: Mapping the involved organizations and their responsibilities.

<table>
<tr><th rowspan="2">Wastewater flows</th><th colspan="4">Technological management</th><th colspan="4">Institutions and practices</th></tr>
<tr><th>Design</th><th>Construction</th><th>Operation</th><th>Maintenance</th><th>Regulations/norms</th><th>Conflict management</th><th>Resources mobilization</th><th>Decision-making</th></tr>
<tr><td>Containment

/Collection</td><td colspan="2">Ministry of Housing, Utilities and Urban Communities (MoHUUC)

Wastewater is collected by the conventional sewerage network. It's design and construction are the responsibility of MoHUUC.</td><td colspan="2" rowspan="2">Holding Company for Water and Wastewater (HCWW).

Operation and maintenance (O&M) are carried out by HCWW</td><td rowspan="3">Egyptian Water Regulatory Authority (EWRA)

Responsible for the regulation, monitoring, and evaluation of all activities related to water supply services and wastewater disposal.

Although EWRA exists, it is not functional, and the regulatory role is partially filled by other organizations, including the Ministry of Environment, the Ministry of Health, and the Ministry of Agriculture.</td><td rowspan="3">No clear conflict management mechanism

Usually each institution refers to a law, code, or standard that supports its position and mandate. Often, these laws, standards, and codes are difficult to implement (e.g., Law 48/1982 and Reuse Code 501/2015) or contradictory.</td><td>NOPWASD

Construction Authority for Potable Water and Wastewater (CAPW)

New Urban Communities Authority (NUCA)</td><td>MoHUUC

PMU (Project Management Unit) part of the MoHUUC</td></tr>
<tr><td>Treatment</td><td colspan="2">National Organization of Potable Water and Sanitary Drainage (NOPWASD)

Carries out the investment component of designing and constructing new treatment plants. Overlapping with HCWW (World Bank, 2016).</td><td>Overlapping with

HCWW</td><td>HCWW</td></tr>
<tr><td>Conveyance</td><td colspan="4">Ministry of Water Resources and Irrigation (MWRI)

Design, construction, and O&M of the conveyance network (drainage network, main and branch irrigation canals, irrigation ditches, and mixing stations) are conducted by MWRI (Barnes, 2017).</td><td>MWRI

Through annual maintenance budget (Barnes, 2017).</td><td>MWRI</td></tr>
</table>

Delivery/Reuse	**Farmers and/or water user associations (WUAs)** Responsible for maintenance of irrigation ditches (*Mesqa*) (Barnes, 2017; Rap et al., 2019).			**Farmers** Are responsible for maintenance work (Barnes, 2017).	**Ministry of Agriculture**

3.5 Formal reuse arrangements in Egypt

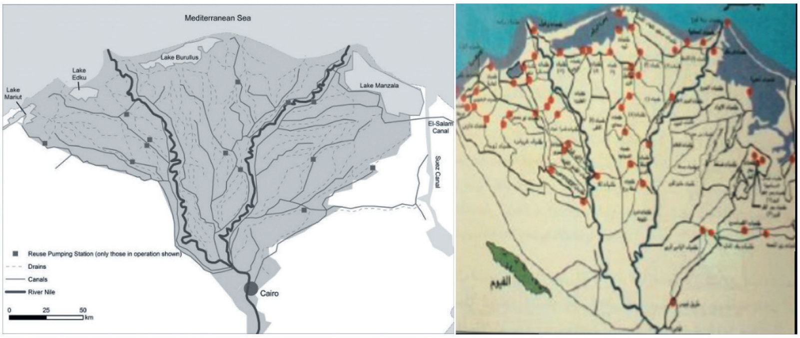
Formal indirect wastewater reuse policy has been in place since the late 1970s and early 1980s. The amount of wastewater indirectly reused in the Nile Delta was estimated at 9.31 BCM in 2015, though the target is to increase that amount to 16.26 BCM by 2037 (MWRI, 2005). This is to be accomplished by a number of mixing stations that transfer wastewater from the drains to feed the ends of the main (and branch) irrigation canals. The mixing process is managed by the Ministry of Water Resources and Irrigation (MWRI) to meet the needs of the agricultural sector (Barnes, 2014). However, high concentrations of pollutants have been measured in the discharged untreated wastewater, which has forced MWRI to close many mixing stations (Figure 3.2) and hindered the reuse of an estimated 2.37 BCM/year (The Road Map, 2017).

Indirect reuse of wastewater is not always economically feasible. Recent data estimate that treatment of 1 cubic meter of wastewater costs HCWW 2.6–3.0 Egyptian pounds (LE), which is approximately three times more than the water tariff for domestic use. Despite this high cost of treatment, there is as yet no investment strategy to maximize the benefit from treated wastewater. Particularly for treatment plants located far from agricultural drains, such as those in desert-front governorates, indirect reuse has proven unfeasible. These plants have therefore adopted direct reuse arrangements that comply with the Egyptian reuse code.

HCWW has been responsible for establishing projects for the direct reuse of wastewater, in accordance with the Egyptian Reuse Code 501/2015. It has focused its direct wastewater reuse mainly on growing timber – to enable reduced wood imports, which cost the country some US $1.7 billion in 2020 – and on growing other non-edible crops to produce biodiesel. As such, HCWW has expanded its timber plantations and prepared a list of potential lands for timber production in 18 governorates, spanning a total area of 42,250 ha. As of 2019, almost 4,500 ha were being cultivated using treated wastewater (Figure 3.3) (HCWW, 2019). The section below expands on one of these plantation projects, in the governorate of Marsa Matrouh, implemented by HCWW's local affiliate HCWW-Matrouh.

3.6 Direct wastewater reuse in Marsa Matrouh

Marsa Matrouh is a governorate at the desert frontier on the western border of Egypt. HCWW-Matrouh is the wastewater treatment plant responsible for treatment and reuse of wastewater within the governorate. It is a representative example of such facilities in Egypt. HCWW-Matrouh was designed to treat the urban wastewater from the coastal city of Marsa Matrouh at a processing rate of 25,000 m^3/day. However, in summer the plant often receives 60,000–70,000 m^3/day because of the increased water flows caused by the arrival of holidaymakers in Marsa Matrouh. An expansion of the treatment plant is expected to increase its capacity to 60,000 m^3/day in the near future.



(a) (b)

Figure 3.2 (a) Map showing functioning reuse (mixing) pump stations on the main drains/canals in the Nile Delta. (b) A screenshot from the preliminary Road Map for Wastewater Reuse (unpublished draft, 2017) showing the total number of drainage pumping stations in the Nile Delta (Source: Barnes, 2014a: 186).

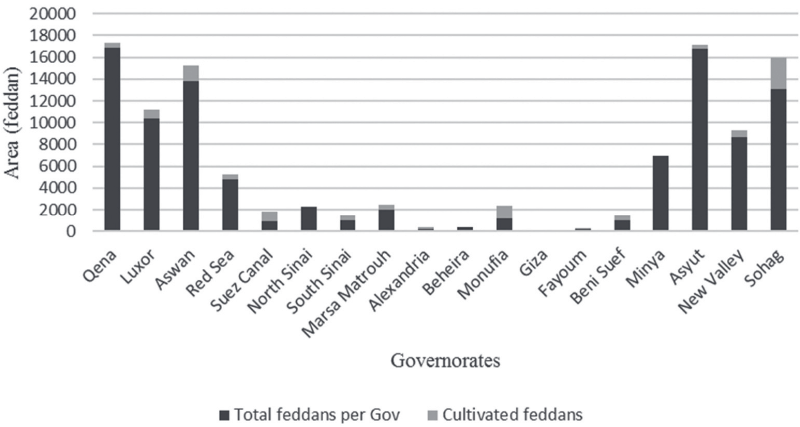


Figure 3.3 Formal wastewater reuse for timber production in Egypt (1 feddan is equivalent to 0.420 ha) (Source: HCWW, 2019).

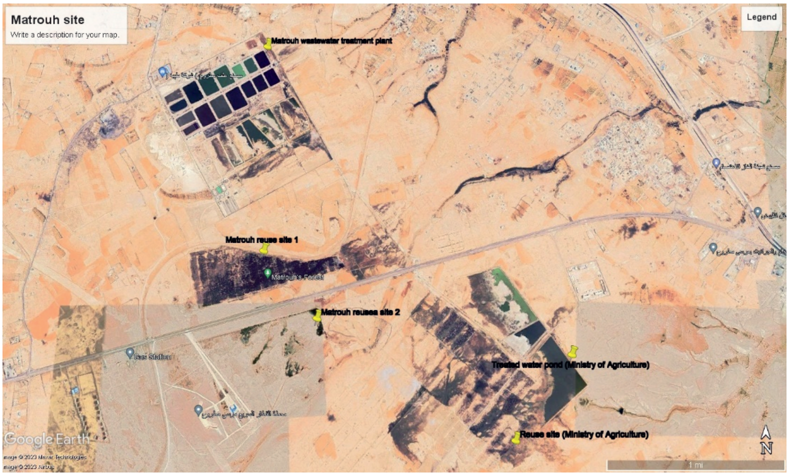


Figure 3.4 Matrouh wastewater treatment plant and its two reuse sites, Marsa Matrouh, Egypt.

According to operations staff, the treated wastewater is a burden for HCWW-Matrouh, as there are no agricultural drains nearby and the treatment plant's large distance from the sea hinders safe discharge of the treated effluent into this water body. Since 2015, the treated wastewater from HCWW-Matrouh has therefore been reused to irrigate two timber plantations on lands owned by the company. One plot is 63 ha and the other is 147 ha (Figure 3.4). According to interviewed staff, the two reuse plots are grappling with technical challenges due to the high salinity of the treated wastewater (3,000 ppm) alongside the shallow soil depth (the bedrock here is very close, leaving just 40 cm of arable soil to support tree growth). Staff reported that some trees had already fallen due to the shallowness of the soil layer. Additionally, the tree species to be cultivated in the project were chosen exclusively by HCWW headquarters in Cairo. Most of these species, however, have turned out to be either sensitive to the high salinity or require more soil depth. The centralized decision-making procedures leave little room for staff at HCWW-Matrouh to adapt to local constraints. The operations staff have concluded that there is no economic incentive driving this reuse model. Instead, the main objective is to get rid of the treated wastewater without violating the Egyptian code for treated wastewater reuse. The result is a very expensive wastewater treatment and reuse system that makes no contribution to closing Egypt's water supply-demand gap.

3.7 Informal wastewater collection and reuse in the Nile Delta

In rural areas and peri-urban settings in the Nile Delta, wastewater from different sources is often illegally discharged into the agricultural drains (Reymond et al., 2014; Soulie et al., 2013). This wastewater comes from a diversity of sources. Moreover, the various means used for collection and treatment render different concentrations of waste and contaminants in the resulting effluent. This poses a serious threat to public health. To deal with the sanitation challenges, local actors have developed and adopted various technologies to collect, convey, discharge, and reuse wastewater. The choice between the different technologies depends on users' financial situation, geographical location, village design, and the strength of social bonds to promote collective action in the villages. The technologies most commonly used to deal with sewage in the villages were locally built septic tanks and informal sewerage networks (Figure 3.5).

(a)

(b)

(c)

Figure 3.5 (a) A bayara *inlet from inside; (b) a villager responsible for informal sewer maintenance; (c) a* bayara-*emptying truck (Source: Reymond et al., 2014: 59 and 62).*

A *bayara* or *biir* is a locally built version of a septic tank, made of brick and concrete. *Bayaras* may be sealed or left unsealed, depending on the groundwater table. In areas where the groundwater table is low, *bayaras* are left unsealed so that wastewater can percolate into the soil. In areas with high groundwater, *bayaras* are sealed to prevent groundwater infiltration. The flexibility of the technology enables adaptation to accommodate different financial capacities in the villages. *Bayaras* require an additional service to transfer sewage to a discharging point (usually drains) by mechanized vacuum trucks (see Figure 3.5). Most of these trucks operate as private businesses, though a small fraction is owned by the village council (Reymond et al., 2014). Discharging wastewater from *bayaras* into drains is illegal. By law, trucks must discharge the collected sewage/septage at the nearest wastewater treatment plant. However, due to the long distances involved and often-inaccessible roads during winter, this is often unfeasible or less profitable for the operators. As a result, discharge is typically dumped into the nearest drain. This practice is sustained by a lack of law enforcement by local authorities (Verhagen and Scott, 2019).

Locally constructed, informal sewer networks are shallow and serve a whole village or part of one (Reymond et al., 2014: 3, appendix 2). These networks are composed of pipelines running through the village with a slope gradient to discharge wastewater (domestic and industrial) into the nearest irrigation drain. The networks are designed either by a villager with experience in the field, such as a former employee of HCWW, or by a private contractor. Villagers carry out the construction and installation work. The networks are maintained and unclogged through manholes constructed at intervals along the drainage lines. Informal sewer networks constitute an upgrade from the *bayara* system.

Wastewater pumped out from *bayaras* is more concentrated than wastewater discharged from informal sewer networks. Residents tend to limit the use of *bayaras* to blackwater, that is, wastewater from toilets, and sometimes liquid manure, while throwing away greywater, such as water from dishwashing and laundry, into streets or directly into canals and drains. The relatively low operational costs of informal sewers, alongside the subsidized water tariffs, encourage residents to discharge large quantities of greywater, which then dilutes wastewater concentrations (Reymond et al., 2014; Verhagen and Scott, 2019).

Despite the regular reuse of wastewater in irrigation, either directly or indirectly through the drains, farmers are reluctant to acknowledge wastewater as a water resource. This is because of the environmental and health impacts they have observed and effects on soil productivity, as well as the challenges they might face when selling their crops. Moreover, the region's long history of using fresh, high-quality Nile water to irrigate crops might spur farmers' reluctance to acknowledge wastewater as an irrigation water source. However, as availability of freshwater for irrigation decreases, many farmers are turning to the use of wastewater to irrigate, despite some reluctance (

Table 3.4).

3.8 Wastewater reuse arrangements in two villages in the Delta

3.8.1 El Hamamee

El Hamamee is a small village in Dmesna district, which includes five other villages overseen by an *Omda* (a traditional community leader with legal status recognized by the local government). El Hamamee is located on the banks of the Mahmoudiyah Canal, which carries Nile water north across the Delta. El Hamamee is densely populated. Its houses are separated by narrow lanes, with its neighborhoods situated between the drains, the Mahmoudiyah Canal, and agricultural lands (Figure 3.6).

The villagers here are low income and mostly reliant on income from labor on the lands of the *Omda* and his relatives, or other work or occupations in civil service outside the village. El Hamamee enjoys a stable irrigation water supply from the Mahmoudiyah Canal, which makes the direct reuse of wastewater unnecessary. All of El Hamamee's inhabitants are connected to a community-built informal sewer network. Each household pays a monthly fee for maintenance and extra fees to cover emergency maintenance work. Those who cannot afford it are usually exempted from fees or contribute labor instead.

Wastewater flows directly to small drains, from which it then flows 1 km downstream to a main agricultural drain (Figure 3.7). Although wastewater is not reused directly, its management poses a hurdle for the villagers. The wastewater flow reverses during the summer when water levels increase in the Nile and its branch canals and drains, which leads to wastewater flooding the village and flow obstruction in the sewer network (Reymond et al., 2014).

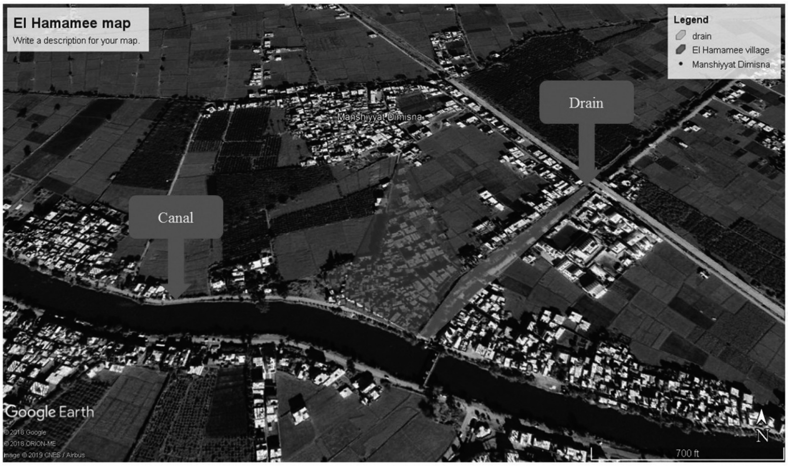


Figure 3.6 El Hamamee map (Source: Google Earth).

The ESRISS project's material flow analysis (MFA) provides an estimate of the volume of wastewater discharged from

El Hamamee's wastewater streams (Figure 3.7). As shown in Figure 3.7, almost all the discharged wastewater flows directly into the drain. There is no direct wastewater reuse in agriculture. However, as the Nile Delta Basin is semi-closed, the drainage water is inevitably reused for irrigation further downstream. According to the ESRISS study, 68% of wastewater flow from El Hamamee comes in the form of greywater, which dilutes the 11% generated from blackwater. The remaining 20% of flow is made up of infiltrated groundwater, which increases during the summer. Additionally, a small fraction of liquid manure is discharged into the drain, while another proportion is directly reused in agriculture.

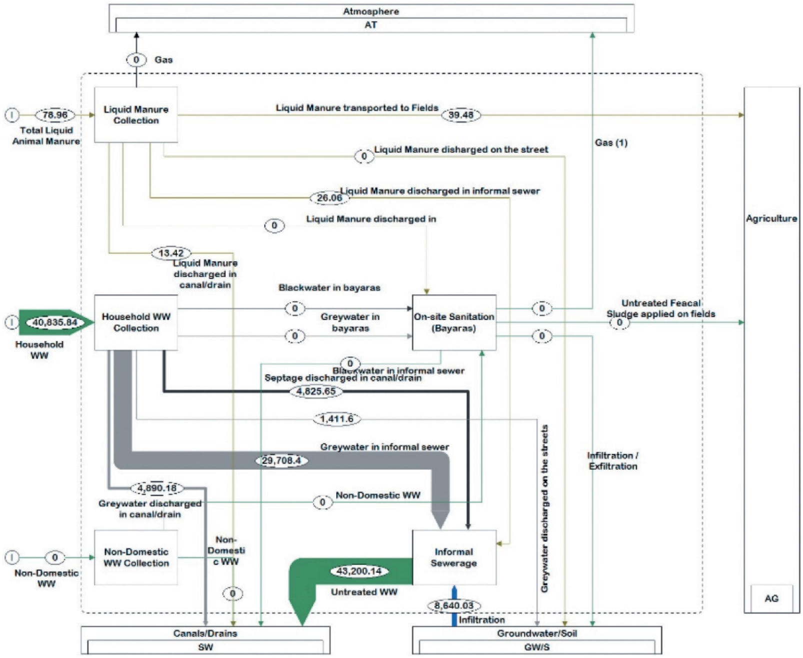


Figure 3.7 Volume of wastewater discharged from El Hamamee in different compartments (Source: Reymond et al., 2014).

3.8.2 Al Ashara

Al Ashara is a village in Abo Humous district of Beheira governorate. Most villagers here are smallholder farmers. Al Ashara is built on the bank of a small irrigation canal and surrounded by agricultural lands (Figure 3.8). The houses of Al Ashara are widely spaced.

All villagers in Al Ashara are connected to *bayaras*, often one *bayara* per house. Unlike villages served by informal sewer networks, *bayara*-served villages have reduced water consumption patterns, as villagers are highly aware of their daily water consumption and their discharge into different wastewater streams in the form of greywater and blackwater. Average water consumption in Al Ashara has been estimated at 60 l per person per day, which is roughly half the amount consumed on average in villages with informal sewer networks (i.e., 110 l per capita per day).

Greywater in Al Ashara is often discharged into the street, canal, or the drain, while blackwater from toilets is discharged into *bayaras*. These different discharging methods aim to reduce the frequency and cost of *bayara* emptying. *Bayaras* are emptied on average every 20 days during summer and every 25 days during winter. Six *bayara* emptying trucks operate in the village, and these also serve other places in Besentway area in rural Egypt. With these proportions, the demand for trucks exceeds their capacity. Some *bayaras* overflow during winter, as stormwater accumulates in the

Figure 3.8 Al Ashara map (Source: Google Earth).

unpaved streets of Al Ashara, making them muddy and inaccessible to trucks. In Al Ashara, 63% of greywater is discharged directly into the drain and on the streets, while 40% of the liquid manure is directly reused in agriculture (Figure 3.9).

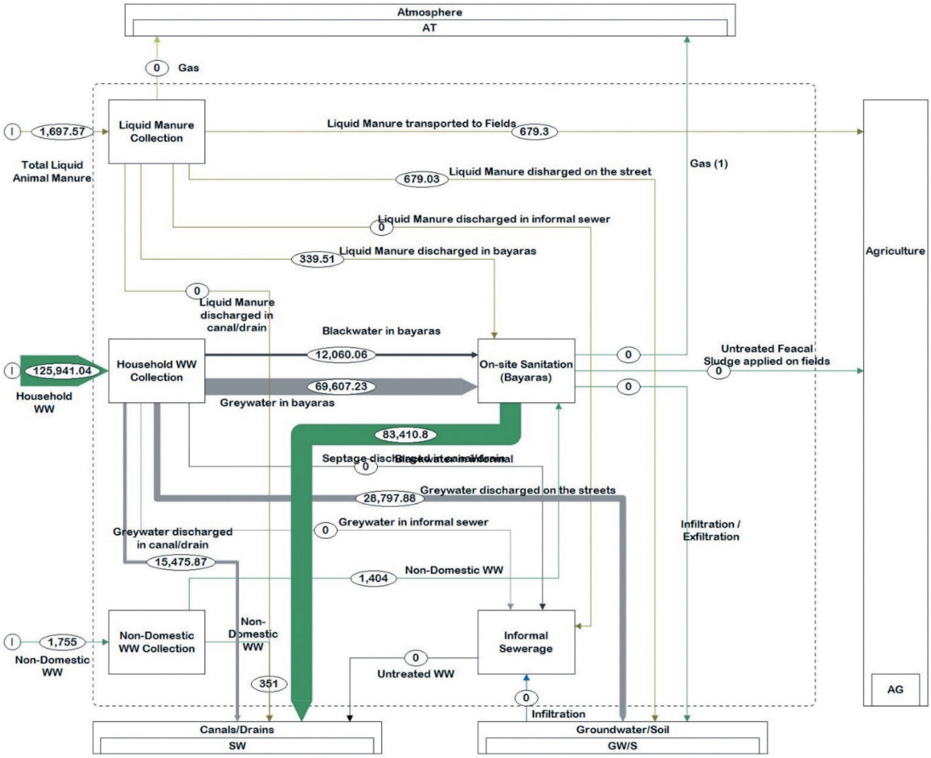


Figure 3.9 Volume of wastewater discharged from Al Ashara in different compartments (Source: developed from data in Reymond et al., 2014).

3.9 Discussion and conclusions

Wastewater reuse provides an important source of water for irrigation, helping to narrow the supply-demand gap experienced by many farmers in Egypt's Nile Delta. This chapter discussed two types of wastewater reuse arrangements. First were the formal wastewater collection, treatment, and indirect and direct reuse arrangements exclusively controlled by HCWW and its affiliated bureaucratic institutions. Second were the informal reuse arrangements managed by local actors who organize their activities through socially embedded arrangements which are illegal and unrecognized by the bureaucratic institutions (

Table 3.4). As plans to increase wastewater reuse emerge, it is necessary to understand the heterogenic arrangements that govern wastewater flows and reuse practices, as well as the technical and institutional arrangements that mediate these practices. Failure to understand the informal sector, its wastewater flows, and its reuse practices, while bringing wastewater collection, treatment, and reuse into the formal sphere, might, as this chapter shows, result in overlooking significant quantities of generated wastewater that could potentially narrow the gap between irrigation water supply and demand in a safe and environmentally friendly manner (see

Table 3.2 and

Table 3.3).

This chapter analyzed three cases, one in a desert-front governorate, where treated wastewater was directly reused at an HCWW timber plantation. This arrangement was found to provide little economic benefit, though it did constitute an 'easy discharging option' for the generated wastewater. Interestingly, this wastewater reuse model did not solve existing agricultural, domestic, or industrial water demand deficits or problems. It only generated a new water need by expanding the irrigation frontier with a plantation for the production of timber. Though this strategy fits within Egypt's strict wastewater reuse regulations, it raises important questions regarding social, economic, and environmental sustainability, especially in the context of growing water demand.

The two cases in the Nile Delta, where wastewater is often discharged and reused directly from the agricultural drains, show another reality. Here, irrigation drains provide a means to dispose of rural wastewater flows. These drains offer a cost-effective system for transporting wastewater within the Nile Delta and providing supplementary water for downstream users. Farmers, for example, benefit from these flows, gaining much-needed irrigation water to maintain their agricultural activities, albeit with high related health and socio-environmental sustainability risks.

In the Nile Delta, drains are shared by formal and informal reuse arrangements at different abstraction and control points. Formal arrangements include mixing stations at which reuse practices can be controlled. Informal arrangements, in contrast, rely on mobile pumping to abstract drainage water directly to agricultural fields at various points along the drains. This, however, leads to a system in which little is known about the quality of the water reused in the irrigation sector. Rural settlements dispose of their untreated domestic and industrial wastewater in the drains, and there is no monitoring or control of what contaminants might exist in what concentrations in the drains. This is especially concerning as farmers using water from these drains are constantly exposed to these pollutants, though without any means of assessing the quality of the water they are employing for production. Furthermore, polluted water from agricultural drains is pumped back into the main Nile River system north of Kanater Barrage, posing a serious risk to the domestic water supply of millions downstream.

The analysis in Table 3.2, 3.3, and 3.4 indicates that through informal arrangements, Nile Delta villages have been able to collect and manage sewage waters but have remained unable to treat and reallocate the flows in a socio-environmentally sustainable manner. This has led to a situation in which farmers use and sometimes depend on highly contaminated untreated wastewater pumped from agricultural drains, though this poses serious health, environmental, and economic risks at the local and national level. At the same time, treated wastewater is being used in desert governorates, such as Marsa Matrouh, for new, costly, and poorly functioning timber plantations that generate new water demands. Formal water reuse policies may thus be increasing pressure on Egypt's water resources, rather than using the potential of wastewater to ameliorate water stress.

Table 3.3 Wastewater flow management analysis of the formal direct wastewater reuse: Mapping organizations and their responsibilities.

Wastewater flows	**Technological management**				**Institutions and practices**			
	Design	**Construction**	**Operation**	**Maintenance**	**Regulations/norms**	**Conflict management**	**Resources mobilization**	**Decision-making**
Containment /Collection	**Ministry of Housing, Utilities, and Urban Communities (MoHUUC)** Wastewater is collected by the conventional sewerage network. Its design and construction are the responsibility of MoHUUC**.**		**Holding Company for Water and Wastewater (HCWW)**		**Egyptian Water Regulatory Authority (EWRA)** Responsible for the regulation, monitoring and evaluation of all activities related to water supply services and wastewater disposal. Although EWRA exists, it is not functional, and the regulatory role is partially filled by other organizations, including: Ministry of Environment Ministry of Health Ministry of Agriculture	**No clear conflict management mechanism** Usually each institution refers to a law, code, or standard that support its position and mandate, though often these are contradictory and difficult to implement (e.g., Law 48/1982 and Reuse Code 501/2015).	**Donors**	**MoHUUC.** **Project Management Unit (PMU)** Part of the MoHUUC
Treatment	**National Organization of Potable Water and Sanitary Drainage (NOPWASD)** Carries out the investment component of designing and constructing new treatment plants. Overlapping with HCWW (World Bank, 2016).						**HCWW**	**HCWW**
Conveyance	**HCWW** Treated wastewater is conveyed through pumps to the designated land for reclamation, which is often part of the treatment plant land area or close to the plant.						**HCWW** In addition to donor funding programs, such as the 'Life' program of the US Agency for International Development (USAID) in Luxor (HCWW, 2018).	
Delivery/Reuse	**HCWW** In collaboration with the Ministry of Agriculture and the Egyptian Environmental Affairs Agency (The Road Map, 2017). However, HCWW has not succeeded in attracting private investors or in selling treated wastewater outside its premises (personal communication).							

Table 3.4 Wastewater flow management analysis of the informal indirect wastewater reuse.

Wastewater flows	Technological management				Institutions and practices			
	Design	**Construction**	**Operation**	**Maintenance**	**Regulations/norms**	**Conflict management**	**Resources mobilization**	**Decision-making**
Containment /Collection	**Local actors (villagers/farmers)** Design and construction depend on local actors' needs and constraints.		**Individual household** Each household is responsible for operation and maintenance, through either labor or monetary contributions.		**Community leader(s)** Norms are set to organize the collective effort of the community to build containment structures.	**Community leader(s)** Socially embedded norms. For example, it is not acceptable to discharge blackwater in the streets, but such disposal of greywater is acceptable. However, farmers have little power to challenge national projects.	There are **diverse resources** that community taps into, such as labor power, money, land, and expertise.	Either **consolidated within one family** or one person (a **community champion**), or a **group of proactive** actors in the village.
Treatment	**No treatment before discharge**				**Do not exist**			
Conveyance	Wastewater from *bayaras* is conveyed by **vacuum trucks**. While wastewater collected by informal sewerages is discharged directly into drains.		**Owners** (for private vacuum trucks) **Village council** (for public trucks)		Regulations set by the Egyptian Water Regulatory Authority (EWRA), Ministry of Environment, Ministry of Health, and Ministry of Agriculture are rarely enforced.			
Delivery/Reuse	**Farmers** Delivery of wastewater for reuse takes place through the existing drainage network. Farmers abstract wastewater directly from drains before it reaches the mixing stations.		**Farmers** Operation and maintenance of abstraction pumps are carried out by farmers.		**Farmers' pumps** Informal reuse from drains is carried out by farmers' who pump water from the closest point to their fields.			**Farmers** They decide the amount of irrigation water based on crop requirements. Some farmers have shifted to inedible crops, due to the impact of drainage water on edible crops' taste and soil productivity.

Reuse of wastewater and agricultural drainage water appears to hold considerable potential for reducing pressure on Egypt's limited water resources. Already, the reuse sector is expanding. This could be facilitated by improving and supporting informal wastewater disposal and reuse practices (e.g., rehabilitating existing structures such as *bayaras* and informal sewerage networks); by providing greater regulatory support (e.g., easing the stringent treatment and reuse regulations); and by more adequate monitoring of the discharged effluent's quantity and quality (e.g., through inspection and enforcement). To advance this agenda, innovative participatory approaches are needed. These should cross the formal-informal divide and include the already involved stakeholders, including those often considered illegal.

Formal arrangements have succeeded in providing sanitation coverage of the majority of urban settings, while lagging in rural areas. Recognizing and supporting the informal arrangements present in rural areas could significantly improve wastewater collection and treatment, as well as ameliorating the quality of treated wastewater reused in agriculture. This suggests that a critical bottleneck is the formal wastewater sector, particularly its inability to recognize the informal sector. This is reflected in slow progress in adopting less stringent regulations (e.g., an amended Law 48) and in the continued reliance on a single institution for operational activities surrounding wastewater management and reuse. The management activities presented in Table 3.1 demonstrate that the obstacles facing recognition and regulatory inclusion of the informal sector are not only technical or institutional, since formal and informal actors are aware of each other and interact in the dynamic flow and control of wastewater. The obstacles can be attributed mainly to the stringent regulations and absence of political will to redistribute responsibilities and power between formal and informal arrangements. This is apparent from

Table 3.4, which demonstrates the lack any enforced regulations for informal arrangements. This hinders rather than supports the efforts of local actors in managing wastewater. Future studies are recommended to identify and propose specific regulatory tools that could go hand in hand with a well-planned expansion of the existing collection, treatment, and distribution infrastructure to enable better management to take place. Such an approach should be transparent and participatory and lead to new forms of wastewater governance in Egypt. A related topic for future research is to investigate the long-term and short-term impacts of recognizing and empowering the informal reuse arrangements on social, economic, and political life in Egypt. This chapter demonstrated that to arrive at safer wastewater reuse practices, it is important to understand the different components and actors engaged in wastewater reuse, including the often-ignored informal sector. Furthermore, use of the developed analytical framework helped to identify technical and institutional bottlenecks that need to be addressed in order to facilitate improved wastewater reuse flows.

4 ‘Squeezing out’ the Nile Delta’s drainage water to irrigate Egypt’s desert land

4.1 Introduction

ABSTRACT

Since the 1950s, Egypt’s quota of Nile River water has been constant, although near continual agricultural land expansion has been in progress. To facilitate reclamation of desert lands, Egypt has reallocated Nile water from downstream users, mostly smallholders on the irrigated ‘old lands’ of the Nile Delta. As agricultural, industrial, and domestic water demands have grown, more attention has gone to the reuse of wastewater and agricultural drainage water as a reliable and untapped resource for irrigated agriculture. However, agricultural drainage water, usually mixed with domestic and industrial waste streams, has been reused for irrigation since the 1950s. Recently, new mega plants for drainage water treatment have been built to promote reclamation of ‘new lands’ in desert-front governorates located outside the Nile Delta. Through these plants and the related water conveyance infrastructure, drainage water from the ‘old lands’ is now being collected, treated, and reallocated to these newly reclaimed areas. This chapter scrutinizes this transformation of access to drainage water, examining who it benefits and what implications it holds for smallholder farmers in the old lands. The analysis suggests that waste/drainage water reclamation schemes do not tap into unused water but actually risk depriving smallholders in the Nile Delta of water access. The chapter argues that more attention should be given to existing informal waste/drainage water use arrangements and that existing smallholder users need to be recognized and their access to water guaranteed in light of new drainage water reuse projects.

Tawfik, M. H.; Hoogesteger, J.; Badawy, M.; Hellegers, P. Squeezing out the Nile Delta: Reallocating drainage water to create new agriculture frontiers in Egypt’s desert land (not published).

Severe water scarcity and increasing competition for limited water resources have shone a spotlight on water reuse arrangements in Egypt, especially the reuse of agricultural drainage water mixed with treated or untreated wastewater (Tawfik et al., 2021). Despite its potential for reducing the gap between irrigation water supply and demand, drainage water reuse has brought major challenges. Key among these is the continued deterioration of water quality due to illegal discharge of raw or partially treated wastewater and excessive use of pesticides and inorganic fertilizers (JICA, 2016; Khairy and Ghany, 2021). The result has been economic (e.g., health and environmental losses) and financial (monetary losses) losses in the ‘old lands’ of the Nile Delta due to increasing soil salinity and diminished land productivity (Hosney et al., 2023).

One of the most pressing challenges for smallholders in the ‘old lands’ of the Nile Delta is the decreasing quantity and quality of water for irrigation. This deterioration of water resources is the result of a gradual and continued reallocation of Nile River water to develop commercial agriculture in desert-front governorates, as well as increasing urbanization and discharge of untreated domestic and industrial wastewater into agricultural drains (Tawfik et al., 2021; Khairy and Ghany, 2021). Barnes (2014a), for example, reported on the expansion of agriculture in Fayoum governorate. Here, newly reclaimed areas competed with the old lands for the fixed irrigation water quota allocated for the governorate. This led to a loss of total agricultural lands in Fayoum, as many farmers abandoned their fields due to lack of adequate irrigation water. Such reallocations of water have, in recent decades, ‘squeezed out’ the old lands, imperiling the centuries-old tradition of irrigated agriculture.

Within this context, Egypt’s National Water Resources Plan 2017 foresees the ‘efficient’ use of agricultural drainage water as a pillar to improve overall water resources management in Egypt (MWRI, 2005). The plan, however, acknowledges the need to improve the quality of drainage water and proposes to accomplish this by establishing centralized treatment facilities that are 'attuned to investments' (MWRI, 2005: 16). In practice this has led to construction of several mega plants to treat drainage water collected from the old lands. The 'new and clean' water produced by these plants is then used to irrigate newly reclaimed irrigated lands on the desert frontier. Discursively, these 'treatment and reuse' projects are being developed to 'maximize the value' of drainage water reuse in agricultural investments. The assumption in such treatment of waste/drainage water is that water quality standards will be met for growing various lucrative commercial export crops. Such production takes place, by and large, on newly developed irrigated lands owned by medium- and large-scale investors and individuals or cooperatives with political power (Dixon, 2014). However, these water reuse plans largely bypass the socio-economic needs and challenges of smallholder farmers and communities in the 'old lands' of the Nile Delta (Barnes, 2012, 2014b). In some respects, the interests of these smallholders and their communities, which are often poor, have been obliterated and hardships aggravated.

Within this context, this chapter aims to answer the following question: How is access to waste/drainage water being transformed in the old lands of the Nile Delta, particularly, to whose benefit and to whose detriment? To do so, it presents and scrutinizes new mega schemes for drainage water treatment and related policies. The treatment plants assessed collect and treat wastewater and drainage water from the old lands, and provide the treated water to newly developed irrigation schemes in the desert. Up to now, these schemes have been praised for their potential economic success, but not problematized.

After this introduction, section 4.2 expands on the research methodology. Section 4.3 then develops the theoretical framework informing the analysis. Section 4.4 presents a brief historical overview of the dynamic changes that have affected irrigation water availability in the old lands and land reclamation projects. Within this context, Egypt's latest drainage treatment and reallocation strategy is analyzed. Section 4.5 presents and analyzes the El Mahsama project, which is one of three drainage water reclamation mega projects recently put into operation. Section 4.6 concludes the chapter by discussing challenges facing smallholders in relation to the evolving drainage water reuse arrangements. Indeed, reallocating drainage water and denying smallholders access to a vital source of water for irrigation has undermined informal water access arrangements, leading to loss of agricultural viability in the Nile Delta. As currently formulated, the wastewater and agricultural drainage water reallocation and reuse plans can be seen as a continuation of the historical approach of water reallocation from the old lands of the Nile Delta to new irrigated lands on the desert frontier. This suggests that more attention should be given to the position of smallholders and access to water in the old lands, which are increasingly being 'squeezed dry'.

4.2 Methodology

Data on the historical development of land reclamation was collected from existing literature. The topics of the reviewed literature varied from land grabbing and dispossession to food security, irrigation water management in the Nile Delta, competition over desert land ownership, and agricultural reforms in Egypt. This diversity of topics helped to clarify the context in which water access and reallocation have taken place.

Regarding challenges in the reuse of wastewater and drainage water in Egypt, data were collected over the course of four years, from 2018 to 2022, as part of the ReWater MENA project led by IWMI-Egypt. This was done through a series of workshops with decision-makers, consultants, and researchers in the water and agricultural sectors. In addition, extensive fieldwork was conducted at two sites in the Nile Delta: in Kafr El Sheikh governorate and at a location on the fringes of the Nile Delta, in the area of Sarabeum near the Suez Canal. At the latter site, water from one of the main agricultural drains was diverted to feed into the Al Mahsama mega plant for waste/drainage water treatment. At both sites, semi-structured interviews and focus groups were conducted with farmers.

Finally, data on the Al Mahsama water reclamation mega project was provided by interviews with the pump station operations engineer and the reclamation plant operations engineer, as well as a field visit driving upstream along the new drainage connections to reach the Al Mahsama plant. Additional information on the Al Mahsama plant was obtained from government publications on the official website, as well as from news outlets and official reports on the project.

4.3 Theorizing drainage water access and reallocation

While land grabbing in Egypt has been covered by various authors (e.g., McMichael, 2012; Dixon, 2013; El Nour, 2019), their discussions have not problematized water access arrangements, specifically, the reallocation of water to enable land reclamation projects (Mehta et al., 2012; Franco et al., 2013). In recent years, with increasing water scarcity and competition for available water resources, the reallocation of water resources in Egypt has become more visible and contentious. Mounting scarcity and competition have given greater weight to notions such as water productivity, which have been more prominently discussed by researchers and practitioners in the water sector (Karrou et al., 2012).

This section investigates access mechanisms for reuse of waste/drainage water for irrigation purposes. It theorizes such waste/drainage water reuse as a socio-technical process that takes place within a water balance, thus bringing the technical and social aspects of water reuse into a single framework. The starting point for this approach is the model of waste/drainage water management and reuse developed in Tawfik et al. (2021), based on the work of Uphoff (1986) presented earlier in Table 1.1 and in Table 4.1 below. This analytical framework divides wastewater and drainage water reuse processes into three components: wastewater flows and uses, infrastructures and their management, and the institutions that regulate wastewater flows and technologies. Though these components are separated for analytical purposes they are intrinsically interrelated, as these arrangements direct and redirect water flows and related capabilities of water access for different groups of users.

Table 4.1 Wastewater management and reuse activities (Source: own elaboration based on Uphoff, 1986).

Wastewater flows	Technological management				Institutions and practices
Containment/collection	Design	Construction	Operation	Maintenance	Regulation and norms
Treatment					Conflict management
Conveyance					Resource mobilization
Discharge/reuse					Decision-making

Water flows and access are controlled and mediated by arrangements that are shaped by interdependencies between wastewater streams, infrastructure and its management, and the related institutions and practices. These different arrangements and constellations can bring about influential changes in who can access and benefit from waste/drainage water reuse through either formal or informal arrangements. This section analyzes this process by looking more closely at access theory and how it may be applied (Ribot and Peluso, 2009).

'Access theory' provides a suitable theoretical framework for investigating the ability of different actors to benefit from the reuse of waste/drainage water, primarily for irrigation. The notion of 'ability' is especially useful in contexts where there is no clear, institutionalized, or legal regulatory framework that designates specific use rights for reuse of agricultural drainage water and other wastewater flows (Tawfik et al., 2022). In Egypt, the context in which much water reuse takes place is neither legally nor institutionally recognized, that is, it is informal. This renders water reusers and their practices officially non-existent and illegal, though water reuse is often the basis, or an important supplement, for smallholder production and related rural livelihoods, especially in the 'old lands' of the Nile Delta. For this reason, it is important to look beyond legal frameworks and water rights-based notions and analyze on-the-ground water access and use.

The 'right' to utilize, share, and trade water resources has been extensively covered in the literature. Various authors have examined legal and socially embedded entitlements of individuals and institutions to govern and control water flows within a specific territory (Vos et al., 2006; Hu, 2015; Macpherson, 2019). While the right to utilize water resources is often a contested matter between bureaucratic, formal arrangements and socially embedded ones (Boelens et al., 2014; Hoogesteger et al., 2016), this conceptualization of water resources allocation among stakeholders falls short in understanding who 'benefits' from resources and through what mechanisms. This is particularly so in contexts that lack defined property rights to water resources, or where 'informal' collective and individual access to water prevails (e.g., Tawfik et al., 2021, 2022). This is the case in the reuse of wastewater and agricultural drainage water in Egypt, since these two forms of water resources are considered a 'waste' product that is discharged outside the hydraulic system and can be reused only in accordance with state regulations and reuse mechanisms (Tawfik et al., 2021). Yet, in this same context, state regulations have ignored and rendered invisible the many informal arrangements and practices of water reuse that exist on the ground. In doing so, the water reusers are officially non-existent, concealed, and placed in the sphere of illegality. Furthermore, their water reuse and related practices go unrecognized and unaccounted for in official statistics, despite the fact that many livelihoods depend on them.

The theory of access is concerned with the 'ability' of stakeholders (individuals, groups, and institutions) to benefit from a resource by gaining, maintaining, or controlling access to that resource through both material arrangements (e.g., infrastructure) and social arrangements (institutions and practices) (Ribot and Peluso, 2009). The latter are embedded in the social-material context and related 'bundles of power' (Ribot and Peluso, 2009: 154). In contexts where informal access rights predominate, the theory of access, as developed by Ribot and Peluso (2009), offers a valuable entry point for analyzing arrangements for wastewater and drainage water reuse. It directs our focus to who benefits from water reuse practices and how, as well as who is affected by changes in arrangements of control of waste/drainage water flows.

Ribot and Peluso (2009) identified seven mechanisms of access: infrastructure, capital, markets, knowledge, authority, social identity, and social relations. The current analysis builds on this categorization, adapting it by combining these seven access mechanisms with the conceptualization of wastewater management and reuse elaborated in Table 4.1. This suggests three pillars by which access arrangements to water reuse for irrigation can be studied.

The first pillar is infrastructure, both small-scale and large-scale. Development and management of infrastructure are influenced and shaped by politics and specific interests (Winner, 1980). Thus, hydraulic infrastructure is used deliberately to create certain forms of social order by directing and controlling water flows in a particular way, depending on how, by whom, and for what purposes the infrastructure is designed, built, and operated (Hommes et al., 2022). Infrastructure allows certain groups to control where, how, and to whom water flows are directed and under what conditions. As such, infrastructure can be construed as expressing a material 'fix' which reflects and advances specific relations of power, authority, and hierarchy. Given that infrastructure sizes and scales vary greatly, specific attention should be given to how large-scale and small-scale infrastructure and related water flows relate and influence one another in specific contexts. The current analysis of water reuse infrastructure considers how water flows are regulated and controlled at the different stages of collection, conveyance, treatment, discharge, and actual reuse, in this case for agricultural purposes.

The second pillar is institutions, including both formal and informal arrangements. Formal institutional arrangements aim to create order and the hierarchies of power by which water flows are directed and infrastructure managed. The 'state' and its related hydraulic or water bureaucracy often plays a central and fundamental role in defining and shaping the formal institutional arrangements through which water is managed in the 'formal' state-recognized domain (Molle et al., 2019). Formal structures thus reflect the state bureaucracy that governs water flows, allocations, and distributions by means of decision-making, policies, regulations, investments, standards, and laws. Formal institutional arrangements are often used to advance specific interests, ideologies, power relations, and economic objectives. In contrast, socially embedded or informal arrangements concern on-the-ground practices and actions that individuals and collectives undertake, in this case, to direct and redirect water flows for reuse in irrigation (Hoogesteger et al., 2023). Through these arrangements, farmers access waste/drainage water to irrigate their fields. Oftentimes, these mechanisms circumvent the state's regulations. Furthermore, these arrangements are often makeshift, unrecognized by state entities, or defined as illegal by the state. As a result, the associated water users and uses are by and large unacknowledged, despite the fact that these arrangements co-exist and interact with formal arrangements.

The third pillar is agricultural production requirements, encompassing mainly the labor force, capital, and agricultural market availability and viability. In the current research, this component mainly reflects the changes taking place in the agricultural landscape of Egypt, particularly the expansion of new agricultural frontiers and the shrinking of old ones. This process has brought changes in flows of both freshwater and waste/drainage water. Water flows and their control shape agricultural activities by determining the types of crops farmers can grow, the markets these crops can access, and the resulting socio-economic status of agrarian communities.

The three pillars must be understood as complementary and cross-cutting. As such, access arrangements are part of a dynamic socio-technical and political process of water resources management within the defined context. In this research, the role of large-scale hydraulic infrastructure in redefining access to water resources and reshaping policy and institutional arrangements (Hommes et al., 2022) is framed as a key leverage point to enable or constrain stakeholders' ability to benefit from water resources for irrigation. As an access mechanism, large-scale hydraulic infrastructure is controlled primarily by the state, which seeks to allocate water flows based on political economy considerations (Mollinga, 2014; Tawfik et al., 2023).

The section below sketches the historical development of irrigation water reallocation and distribution projects in Egypt. These are gradually 'squeezing dry' the Nile Delta. This is followed by an analysis of arrangements to access drainage water for irrigation and how those mechanisms have been altered by the socio-infrastructural changes taking place in the lower Nile Basin.

4.4 Squeezing the Delta dry: A brief historical overview

Egypt has a long history of freshwater and drainage water reallocations for land reclamation projects. Indeed, these projects have contributed to shape the current boundaries of the Nile Delta. It is therefore important to look back at Egypt's history of 'mega' irrigation schemes, land reclamation, and water control infrastructure, as well as freshwater availability.

Early land reclamation in Egypt involved the reallocation of large volumes of surface freshwater from the Nile River to new agricultural lands on the fringes of the Old Nile Delta. This created a 'dynamic' delta with expanding frontiers over the decades (Figure 4.1) (Molle et al., 2019).

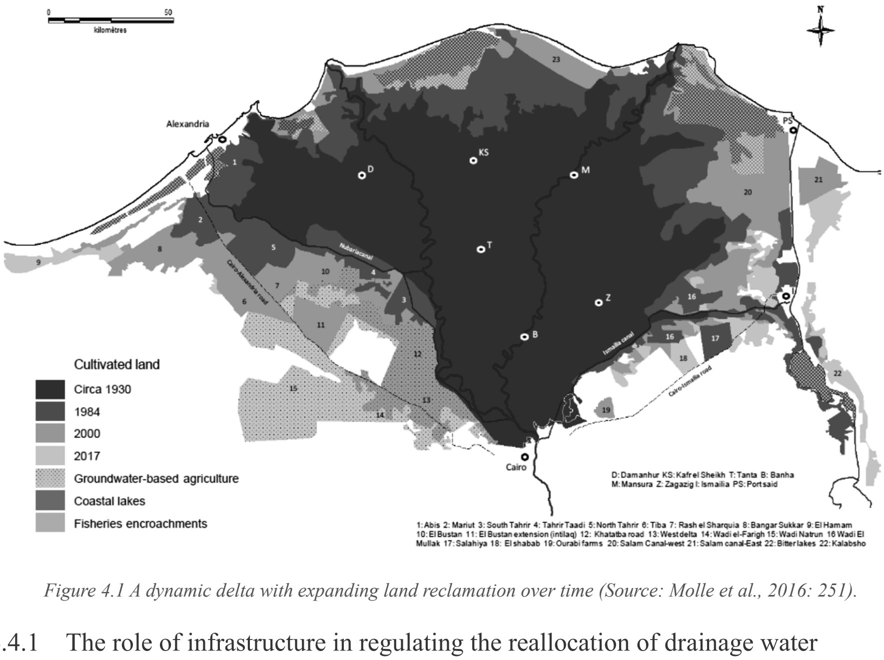


Figure 4.1 A dynamic delta with expanding land reclamation over time (Source: Molle et al., 2016: 251).

4.4.1 The role of infrastructure in regulating the reallocation of drainage water

The construction and expansion of hydraulic infrastructure in the Nile River and the Nile Delta started as early as the 1830s (Molle et al., 2019). At that time, water control projects were advanced for various socio-political and economic objectives (Molle et al., 2019). Primary among these were to achieve food security, create job opportunities, and develop new urban centers outside the narrow strip of the Nile Valley. The development of large-scale hydraulic infrastructure started with construction of a barrage system to control by gravity allocation of Nile River waters to the agricultural lands downstream (Figure 4.2). The first barrage was completed in 1861. However, with increasing water scarcity and supplies falling short of demand, a paradigm shift took place. Instead of developing hydraulic infrastructure for managing and reallocating river water by gravity, successive governments invested in electricity-powered pumping stations to bring drainage water back into the irrigation system (Figure 4.3). In addition, a rotation system was devised to regulate the allocation of water among irrigation canals through a series of water flow gates distributed along the irrigation canals of the Nile Delta.

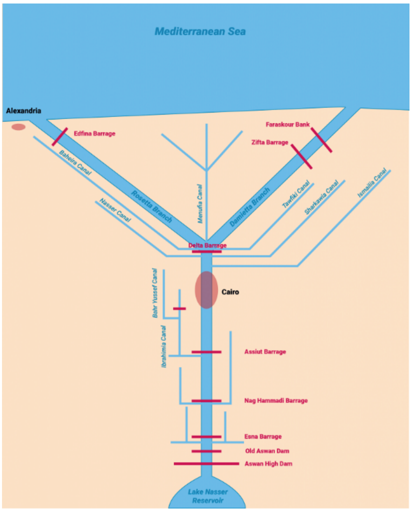


Figure 4.2 Water barrages in Egypt (Source: Water.fanack.com).

Figure 4.3 Pumping stations across the Nile Delta (Source: Water.fanack.com).

From the late 1950s through the 1960s, a series of agricultural reforms abolished the feudal agricultural system in Egypt and allowed landless peasants to own agricultural plots (Bush, 2007). This was associated with agricultural 'modernization' and development of large-scale infrastructure to control the flow of Nile water into the Nile Delta and Valley (Bush, 2007). Later, this same infrastructure served for troubleshooting problems associated with hydraulic changes in the Delta, particularly salinity due to waterlogging (El-Agha et al., 2020). Table 4.2 presents estimates of the quantities of water secured for land reclamation by the various large-scale infrastructure project since the 1950s. The calculations – based on official estimates of water requirements and land areas to be reclaimed – employ 'optimistic' estimations of water quantity requirements for land reclamation in sandy soil, as given by the Ministry of Water Resources and Irrigation (MWRI) (Barnes, 2014b). Thus, each reclaimed feddan (= 0.420 ha) is assumed to be equipped with modern irrigation techniques and consume 4,000–5,000 m^3 of water per year (Al-Bultagi and Abu Hadeed, 2008; Barnes, 2014a). Although the figures in the table do not reflect the actual area of reclaimed lands (since some projects were not completed or ceased operation shortly after their inauguration), they do reflect the successive governments' level of ambition and persistence in working toward objectives of food security, employment creation, and urban development (El Nour, 2019).

Table 4.2 Historical overview of land reclamation in Egypt (Source: Bush, 2011; Barnes, 2012, Molle et al., 2019, Negm et al., 2021).

Year	Water control and drainage infrastructure	Land reclamation projects/programs	Planned reclamation area (feddan)	Estimated water reallocation potential (in BCM)
1950s – 1960s	1952: 2.2 million feddan (Mfed) served by drainage infrastructure (preceded by the installation of drainage pump stations in the 1930s)	Tahrir project	10,000	0.045
	1968: 6.9 Mfed served by drainage infrastructure			
	Construction of the High Aswan Dam	Egyptian–American Rural improvement service project	37,100	0.16
		First five-year plan	390,000	1.75
		Second five-year plan	300,000	1.35
1970s	1975: Launch of the sub-surface drainage project	Launching of the Green Revolution	Aimed to reclaim 1.2 Mfed before the year 2000	4.5
1980s	1984–1995: Irrigation Improvement Project (IIP)	Salhiya project	23,000	0.1
		Shabab project	33,500	0.15
1990s	Expansion of IIP into a national project which later became a permanent program of the Ministry of Water Resources and Irrigation (MWRI)	Third five-year plan	189,000	0.85

		Fourth five-year plan	656,000	2.6
		Toshka project	540,000	9
		Fifth five-year plan	469,000	2.1
2000s	Reframing of the IIP project as the Integrated Improvement and Management Project (IIIMP)			
	2007: Some 85% of the 'old lands' of the Delta were equipped with sub-surface drainage infrastructure			
	2017: the Egyptian Public Authority for Drainage Projects (EPADP) rehabilitated 1.9 Mfed of sub-surface drainage infrastructure and installed 6 Mfed			
	Establishment of mega plants for drainage water reclamation in El Mahsama, Bahr El Baqar, and El Hamam	1.5 million feddan	First stage to reclaim 4 Mfed in Egypt's desert	The project relies on mixed streams of groundwater and treated drainage water

The shift from seasonal to perennial agriculture following construction of the Aswan High Dam meant that the Nile Delta was prone to waterlogging due to intensive agriculture and continuous flood irrigation. Thus, drainage water management became necessary to maintain soil health. This was accomplished by large-scale implementation of sub-surface drainage infrastructure, under the Irrigation Improvement Project (IIP) and the Integrated Improvement and Management Project (IIIMP) in collaboration with the US Agency for International Development (USAID) (Molle et al., 2019). The sub-surface drainage system enabled creation of nodes for control of drainage water throughout the Nile Delta. The investment in drainage management infrastructure was accompanied by institutional development in the establishment of the Egyptian Public Authority for Drainage Projects (EPADP) in 1969 and the Drainage Research Institute (DRI) in 1976, both under the umbrella of MWRI. These entities have since been responsible for managing the expanding network of sub-surface drainage in the Delta, performing operation and maintenance work, conducting research on drainage water quality and quantity, and regulating farmers' practices in relation to the networks (Abdel-Dayem et al., 2007).

4.4.2 Policy transition and institutional arrangements

In addition to the visible role of infrastructure, there has been a less visible role of policy and institutional arrangements in regulating the reallocation of drainage water in Egypt. Since the beginning of modern irrigation, under Mohamed Ali, it was – and still is – the state that controls irrigation water flow, diversion, and allocation, while farmers are subject to state decisions on water quota allocations and management strategies (Rap et al., 2022). Control of access to water is a longstanding, yet hardly visible component of Egypt's water resources management. Herein, the state has the role of 'controller' and 'provider' of water. Unlike freshwater for irrigation, farmers have no access rights to drainage water. Neither do they have a fixed quota of drainage water for irrigation purposes. In fact, drainage water is supposed to be discharged directly into the Mediterranean Sea, but due to the severity of water scarcity, drainage water has for decades been widely reused, both formally and informally, particularly by tail-end smallholder farmers on the fringes of the Nile Delta.

Throughout the country's history of land reclamation and water allocation to new lands, successive governments have ensured the use of water-saving irrigation techniques on the new lands in order to reduce the impacts of water reallocations on existing agriculture in the old lands (Barnes, 2012). Mounting water scarcity, however, has led to a new policy, issued by MWRI in 2022-2023, aiming to reduce water consumption in the old lands by forcing farmers to shift from surface irrigation to drip irrigation (Akhbarelyom News, 2022). The policy stipulates that farmers who fail to comply with the shift will be penalized with a monetary fine (approximately US $146 each) and also lose their access to subsidized fertilizers and pesticides (Akhbarelyom News, 2022). However, this policy has not been operationalized and enforced as yet, due to uncertainties surrounding impacts of the shift. Of particular concern is the potential for biophysical changes in the Nile Delta, such as rising soil salinity, seawater intrusion, and most importantly, a potential reduction in volumes of drainage water generated from surface/flood irrigation in the Delta.

The risk of a reduction in drainage water due to this policy is already a point of discussion among water and agriculture experts in Egypt, as the design capacity of the new drainage treatment plants requires a certain volume of drainage water availability (discussed in the next sections). Although these concerns are valid, there are no clear answers to them as yet, in part because the treatment plants are implemented and operated by high-level actors, specifically, the Armed Forces Engineering Authority (AFEA) and private enterprises. Indeed, they are 'sealed off' from the public (even from researchers and experts in the field). Accordingly, information such as drainage water availability and treatment qualities cannot be accessed, disputed, or even shared between different MWRI departments.

Despite the uncertainties surrounding the new policy, MWRI has moved to exempt agricultural lands in the northern Delta region from the requirement to comply, as this region already faces high rates of seawater intrusion, which could be exacerbated by the use of drip irrigation. Overall, the official rhetoric has linked the shift to drip irrigation to greater 'efficiency' in agriculture and 'modernization' of irrigation in the Delta. Promulgation of the shift reaffirms Barnes' (2014) observation that the government doubts the feasibility of agricultural activities within the current contextual constraints of the Delta and prefers instead to reallocate water resources to other locations and activities that may be capable of securing a higher return on investment per cubic meter of water.

This points to the importance of the policy, regulatory, and legal landscape in the 'old lands' and its role in facilitating or hindering access to drainage water in the 'new lands'. Drainage water abstraction and use for irrigation is controlled by Egyptian laws and standards, particularly Law 48/1982 and Reuse Code 501/2015, which prohibit direct abstraction of drainage water unless it is mixed with canal water at one of MWRI's mixing stations (Figure 4.3). This means that before drainage water is mixed with canal water, it is not officially a water source for irrigation and cannot be claimed by farmers (excluding aquaculture famers in the Delta, who are obliged to use drainage water as the main supply for their fishponds). Accordingly, drainage water, from a legal, formal perspective, cannot be claimed by farmers in the old lands.

4.4.3 Changing access to drainage water

Drainage water access control and regulation plays a crucial role in Egypt's irrigation water management. This is demonstrated by successive governments' extensive investment in the development of the sub-surface drainage network throughout the different stages of the Improved Irrigation Project (IIP), which later became a program under MWRI. That drainage infrastructure enabled the creation of collection points for drainage water across the Delta's agricultural lands.

MWRI estimated drainage water reuse at 20 BCM per year in 2018 (Khairy and Ghany, 2021), while other sources suggest that informal drainage water reuse provides for some 15% of crop water requirements in the Delta (El Quosy, 1989). Nonetheless, these figures cannot be taken as accurate or realistic estimations of drainage water reuse, due to farmers' widespread, often daily, use of mobile water pumps to abstract water directly from agricultural drains (Molle et al., 2016; Barnes, 2014b). The lack of accurate estimations is indicative of the dynamic nature of drainage water reuse in the Delta. There is a particular lack of clarity regarding informal arrangements, which provide smallholders flexibility to abstract drainage water on-demand, without relying on the rotation system that characterizes the formal arrangement.

This dynamic nature of drainage water reuse means that as crop water requirements increase and freshwater availability decreases – due to climate change impacts, reduced allocations to the old lands of the Delta, and changes in the rotation system between farmers in the different command areas – greater variety is expected in drainage water reuse, both spatially and temporally, as a form of adaptive management. Accordingly, farmers' dependence on drainage water as a source for irrigation has increased in recent decades and is expected to expand further as freshwater allocations from the

Nile River to the Delta's irrigated sector diminish. Thus, any reduction in drainage water availability would directly impact farmers' ability to maintain land productivity and their livelihood conditions.

In spite of this, drainage water availability is expected to decrease in the old lands of the Nile Delta under the influence of a 'new breed' of large-scale drainage water treatment plants. Three such plants have been constructed in the region, one of which was completed and brought into operation in 2018. These large-scale water treatment plants and the related hydraulic infrastructure are designed to collect, convey, treat, and discharge water for use in newly reclaimed lands on the eastern and western boundaries of the Delta (Figure 4.4). The three mega plants for drainage water treatment are the following:

- Al Mahsama, located on the east bank of the Suez Canal with an annual drainage water treatment capacity of 0.365 BCM/year to support the reclamation of 70,000 feddans
- Bahr El Baqar, located on the northeast of the Nile Delta and expected to support the reclamation of 365,000 feddans by generating 1.8 BCM/year of treated drainage water
- The 'New Delta' or El Hamam treatment plant, which is expected to generate 2.19 BCM/year for the reclamation of some 1.5 million feddans in the western desert

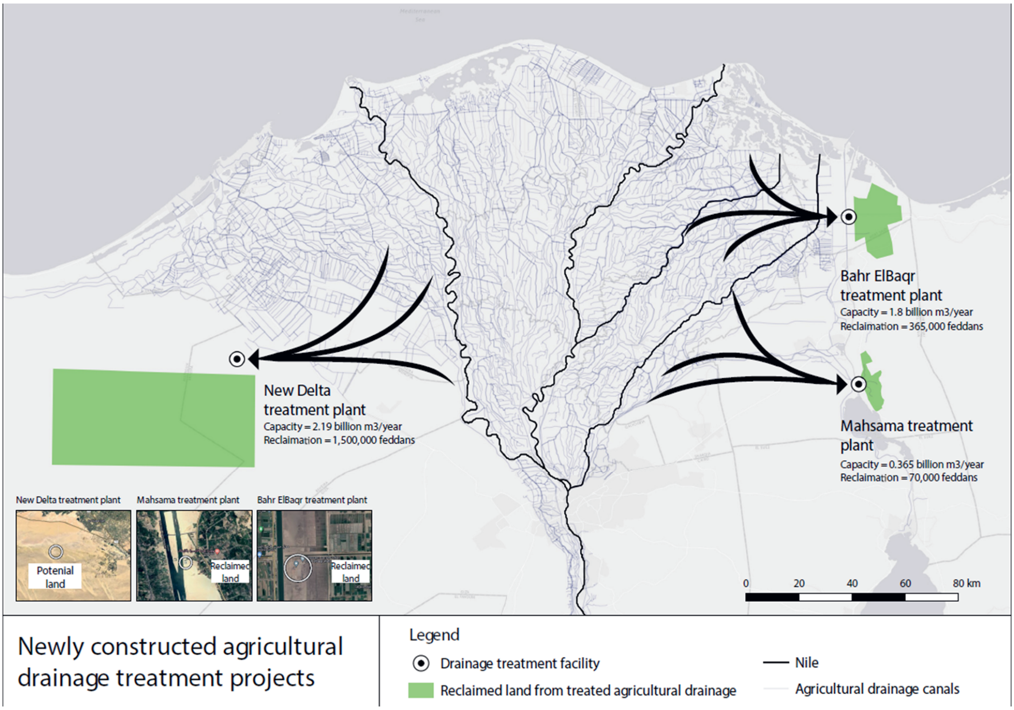


Figure 4.4 The locations of the three large-scale drainage water treatment plants (Source: author's own elaboration. Background tiles: Esri grey, 2022).

4.5 Al Mahsama plant: Large-scale hydraulic infrastructure

The Al Mahsama treatment plant was selected for study based on its close proximity to another research site where formal and informal reuse practices were investigated, that being the Sarabeum forest plantation in Ismailia, Egypt. From here waste/drainage water is pumped upstream to the Al Mahsama treatment plant on the eastern bank of the Suez Canal (see Hosney et al., 2023). Additionally, Al Mahsama provides an interesting study case because it has garnered substantial attention in the local media, in which it is framed as an 'engineering success story' that will promote agricultural development in Egypt. Indeed, the local media hailed Al Mahsama after it was named the best international wastewater recycling project in 2020 by Capital Finance International (CFI), a UK-based entity that gives awards for infrastructure projects. Al Mahsama was also named the best infrastructure project in MENA in 2019 by the Construction Innovation Awards (Ahram online, 2020). The plant treats up to one million cubic meters of drainage water per day. The main sources supplying the Al Mahsama plant are the same drains that are used to discharge agricultural drainage water (mixed with treated or untreated wastewater) into El Timsah Lake, namely, Al Mahsamah, Alwadi, Alforsan, Albahtimi, and Abo Gamous drains. These drains have a total capacity of two million cubic meters per day, that is, double the required capacity for operation of the Al Mahsama treatment plant.

According to the pump station operator (stations 1 and 2, west of the Suez Canal in Ismailia governorate) (interviewed in October, 2022), 'the current drainage water flow exceeds the treatment plant's capacity, so we let the water flow downstream when the treatment plant is full or if there is maintenance work'. Tail-end farmers downstream of the Al Mahsama plant (before Timsah Lake) access this drainage water to irrigate approximately 108 ha of land.

The interviewed operations engineer added, 'this is expected to change when farmers [in the Delta] shift to drip irrigation' in line with the new policy mentioned earlier. The engineer estimated the current volume of drainage water flowing into the Al Mahsama plant at around 700,000 m^3 per day, which allows around 1.3 million m^3 of drainage water to flow downstream in its natural course. The operations engineer expected the shift to drip irrigation to cut in half the amount of drainage water flowing from the Delta into the El Rashah and El Mahsama drains (i.e., yielding a total drain flow of 1 million m^3 per day). According to this estimation, the amount of water available for downstream users who have informal access would be some 300,000 m^3/day instead of the current 1.3 million m^3/day, assuming a constant rate of water abstraction by Al Mahsama, at 700,000 m^3/day. If the Al Mahsama plant operates at full capacity and the new policy becomes operational, only 1 million m^3 per day is expected to be available in the drains. This would leave downstream users without access to any drainage water at all (Figure 4.5Table 4.3).

Table 4.3 Drainage water availability and access scenarios in Al Mahsama.

Surface/flood irrigation in the Nile Delta	Drainage water availability in El Rashah and El Mahsama drains	2,000,000 m^3/day
	Drainage water reallocation to Al Mahsama (current capacity)	700,000 m^3/day
	Drainage water available to tail-end farmers downstream of Al Mahsama	1.3 million m^3/day
Drip irrigation in the Nile Delta	Drainage water availability in the El Rashah and El Mahsama drains	1 million m^3/day
	Drainage water reallocation to Al Mahsama (current capacity)	700,000 m^3/day
	Drainage water available to tail-end farmers downstream of Al Mahsama	300,000 m^3/day
Drip irrigation in the Nile Delta	Drainage water availability in the El Rashah and El Mahsama drains	1 million m^3/day
	Drainage water reallocation to Al	1 million m^3/day

	Mahsama (full capacity)	
	Drainage water available to tail-end farmers downstream of Al Mahsama	0 m^3/day

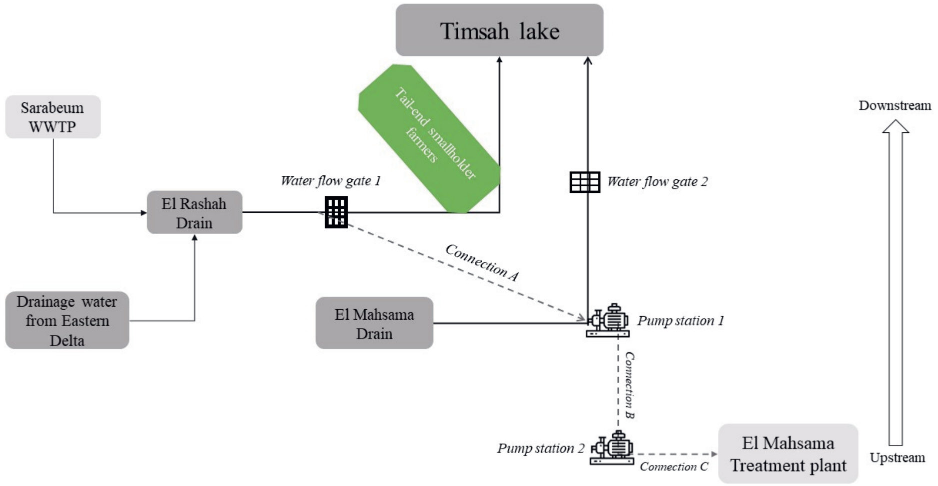


Figure 4.5 Water flow diagram in the study area of Al Mahsama.

In order to shift the drainage water flow upstream to the Al Mahsama plant, various drain connections have been established since 2018. The length of each connection (A, B, and C in Figure 4.5) ranges from 1.5 to 2 km. Three pumping stations have also been established to abstract drainage water upstream to reach the Al Mahsama plant, using pipelines to pass underneath the Suez Canal. Each pumping station has a capacity of 43,000 m^3 per hour (interview with the operations engineer). Two of the pumping stations are located at the ends of connections A and B (Al Mahsama I and II, respectively), and the third pumping station is located within the Al Mahsama plant on the east bank of the Suez Canal (see Figure 4.5).

This pumping capacity and shift of water flow will almost certainly impact farmers downstream of the pumping stations, particularly those who abstract water directly from the drains (see Table 4.3, Figure 4.5). That water provides for necessary supplementary irrigation, as the farmers here do not have enough freshwater to irrigate their lands or they might prefer to use drainage water due to its high nutrient content. One farmer who abstracted drainage water just beyond flow gate 1 said that it improved the yield of the mango trees which are Ismailia's main product (Figure 4.7)

Figure 4.6 Flow gate 1.

Figure 4.7 Direct abstraction of drainage water using a high horse-power pump to irrigate several large land plots.

Similar infrastructural developments have been reported at the Bahr El Baqar treatment plant and in the future New Delta treatment plant, which is under construction. Infrastructure development for the three plants collectively will enable the diversion, treatment, and reallocation of around 4.3 BCM of drainage water annually from the western and eastern Delta. This reallocated drainage water, according to the government's plan, is to be used to reclaim and irrigate[5] around 1 million feddans (420,000 ha) of new agricultural lands (Figure 4.8 and Table 4.4).

In terms of land availability, the operations engineer for flow gates A, B, and C mentioned that all of the lands next to the site were owned by the military or were state lands.[6] It was thus easy to acquire these lands for implementation of the connections to enable drainage water flow upstream. This demonstrates the role infrastructure can play as an 'enabler' of water access. Most farmers in the study area cultivated these lands without formal contracts or rental agreements (however, a few farmers were found to own or rent lands close to the study site).

Figure 4.8 Land use before and after establishment of the last connection, C.

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[5] The reallocated treated drainage water will also support the irrigation of the already reclaimed lands in those areas.

[6] No one can utilize land owned by the state unless the state decides to open it for tender and development. By contrast the military can utilize the land it owns for whatever purpose it deems appropriate.

Table 4.4 Drainage water allocation and land reclamation potential of the new treatment plants.

Treatment plant	Drainage water treatment capacity (BCM/year)	Potential land reclamation (feddan)	Location of the newly reclaimed land
Al Mahsama	0.365	70,000	North Sinai
Bahr El Baqar	1.8	365,000	North Sinai
El Hamam/New Delta	2.19	500,000	Western desert
Total	4.3	935,000	

4.6 Discussion and conclusion

Water flow control and reallocation in Egypt is an old practice dating back to the establishment of modern Egypt during Mohamed Ali's times in the 1880s. The waste/drainage water reuse and reallocation plans that began to come into operation in 2018 can be regarded as a novel approach to reclaim and irrigate lands outside the Delta region through the use of drainage water. Yet, this chapter demonstrated that these waste/drainage water reclamation schemes do not tap into unused water but actually reduce water access of tail-end smallholder farmers in the Delta. This chapter looked specifically at the predicament of tail-end farmers downstream of the Al Mahsama plant (see Table 4.3). In this case, waste/drainage water reallocation has arguably been facilitated by (i) the establishment of large-scale infrastructure to treat and reallocate drainage water to the new lands, (ii) a policy transition stipulating water-saving irrigation techniques in the old lands to reduce water consumption, and (iii) institutional arrangements that promote the roles of new – yet powerful – actors in the water resources management domain (i.e., the military and the private sector).

Studying the existing arrangements, both formal and informal, through the lens of the presented theoretical framework, which is based on access theory, provided a better understanding of what waste/drainage water flows are accessed and used by whom. The study found that tail-end smallholders in the old lands of the Nile Delta were accessing waste/drainage water directly from the drains for use in agricultural production. Their water reuse, though formally illegal, tended to be facilitated by informal reuse arrangements (see Tawfik et al., 2021). The water obtained in this manner may be of poor quality, but nonetheless it is oftentimes used to complement formal irrigation quotas, which in recent decades have been gradually reduced, as the Nile Delta is 'squeezed dry' in favor of agricultural land expansion projects. Smallholders use water from the agricultural drains as a matter of necessity, rather than as a preferred source (Figure 4.9).

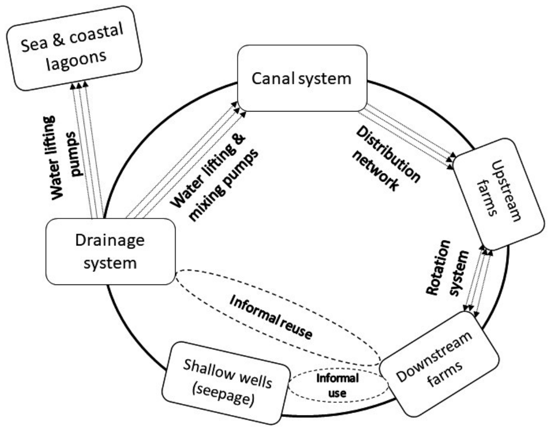

Figure 4.9 Formal and informal reuse arrangements as part of the irrigation water management system in the Delta.

Tail-end farmers are being gradually deprived of access to waste/drainage water through two mechanisms. The first one is the reallocation of waste/drainage water for reuse by new users, often medium- to large-scale agricultural investment projects in newly developed agricultural lands in the desert. Such reallocations have been supported by an active role of the military in developing large-scale infrastructure, and backed by national policies aiming to increase the irrigated land area in the country under the objectives of increasing food production, stimulating economic growth, generating jobs, and spurring land reclamation projects (Barnes, 2012, 2014a). Though in the past, such new users obtained water from deviations of Nile River water through irrigation infrastructure, the lands being reclaimed and developed at present rely on large-scale infrastructure and state institutions and investments for reuse of water, framed as 'waste', from agricultural drains in the Nile Delta. That water on paper is now lost to coastal lagoons and the sea (Figure 4.10, see also Figure 4.9). Tail-end smallholders in the old lands of the Delta may soon be wholly deprived of access to waste/drainage water. Indeed, operationalization of the new modern irrigation policy which stipulates a shift to drip irrigation would cause a significant reduction in drainage water flows.

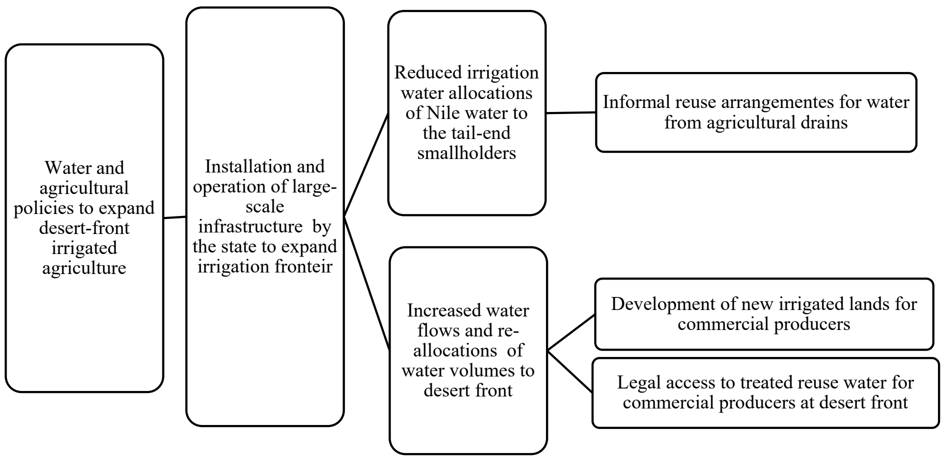

Figure 4.10 Two interlinked water access trajectories.

The analysis suggests that this process is supported and advanced by notions of irrigation efficiency, agricultural profitability, technological development, and modernity. However, these notions veil the deeply political nature of water flow reallocations and changes in access to drainage water for its reuse in irrigated agriculture. This narrative characterizes agricultural practices in the old lands as 'backward' and incapable of increasing productivity and profitability. However, this ignores the historical role of agriculture in the old lands in creating job opportunities, contributing to economic growth, and securing food for millions of people over hundreds of years. Additionally, this approach accepts the disappearance of the Nile Delta as an agricultural center instead of providing solutions to overcome the biophysical and socio-economic challenges affecting the smallholder farmers who operate there. Drainage water reallocation can be construed as 'squeezing dry' the Nile Delta, depriving it of one of its last and major sources of water for irrigation and jeopardizing the future of subsistence agriculture in Egypt's old lands.

The case study of the Al Mahsama treatment plant is indicative of the future trend of water reallocation in Egypt. In this case, only a limited area downstream of the Al Mahsama plant would be affected by the reallocation of waste/drainage water (around 108 ha). However, the full realization of waste/drainage water reallocation to the new lands would leave many more downstream and tail-end smallholders in the Delta without enough water for irrigation. Informal use of wastewater, whether treated or untreated, can thus be expected to increase, since it will be the only source of water that will remain available (Tawfik et al., 2021). However, the use of all available wastewater from domestic and industrial sources might secure only a fraction of the irrigation needs of farmers in the old lands (Mateo-Sagasta et al., 2022a). In this context, farmers would either abandon their lands and seek alternative sources of income, such as performing agricultural labor in the new agricultural areas, moving to urban areas, or emigrating (Barnes, 2014a), or they might develop informal practices to access freshwater from irrigation canals or groundwater. The feasibility of the latter depends on farmers' geographical location, such as their proximity to irrigation canals, as well as their influence within their local network and MWRI monitoring and enforcement. Whatever the case, such informal practices are, according to Lieven (2013: 365), 'signs of defeat', rather than approaches to ensure agricultural sustainability in the Delta. Finally, although this research has emphasized the risks to smallholders posed by the new reallocation scheme for drainage water in Egypt, it must be acknowledged that further investigation and quantification is needed of the impacts on smallholder farmers in terms of their crop production, soil characteristics, socio-economic status (or farmer livelihoods), and local and national food security.

5 Shifting waters: The challenges of transitioning from freshwater to treated wastewater in the Northern Jordan Valley.

ABSTRACT

Jordan's water scarcity prompted a national plan whereby treated wastewater is utilized to amend agricultural irrigation water so as to reallocate freshwater to urban/domestic uses. The policy, however, has engendered farmers' resistance in the Northern Jordan Valley (NJV), causing a stalemate in putting the new infrastructure into operation. This chapter investigates the socio-economic causes of farmer resistance and contestation and examines the government's institutional approach to overcome the challenges. It finds that the perceived risks of wastewater reuse, such as salinization and restrictions of international markets, figure prominently in the farmers resistance. As yet, farmers have managed to avoid the shift to treated wastewater use by employing the political agency of elite farmers who control water users associations (WUAs). These same farmers have adopted informal water access practices to overcome freshwater shortages. At the same time, small producers who lack possibilities to access extra water and have less political clout seem more willing to irrigate with treated wastewater. The chapter concludes that understanding the heterogeneous context in which the envisioned wastewater users operate is key to predicting and solving conflicts that arise in treated wastewater reuse projects.

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5.1 Introduction

The MENA region is facing a growing gap between water supply and demand (Ait-Mouheb et al., 2020). Urban water demand is increasing, with cities often being granted priority in freshwater allocations, at the expense of irrigated agriculture. Given that agriculture is the MENA region's largest water consumer, though it also has the lowest economic return on water use, this sector faces a looming challenge in sustainably meeting its current and future water needs (Drechsel et al., 2022; Molle et al., 2019). Governments in the MENA region are attempting to amend the gap in irrigation water availability by promoting the reuse of treated wastewater (Qadir et al., 2020; Mateo-Sagasta et al., 2022a).

Over the past decades, Jordan has experienced a drastic reduction of surface water availability, growing water demand, especially in agriculture and for urban uses, and over-abstraction of groundwater resources (Bens et al., 2016; Hussein, 2018a, 2018b). By 2025, the country's overall water shortage is expected to reach 1.521 million m^3 (MCM) per year (Hellegers et al., 2022). This scarcity is aggravated by geopolitical challenges, which have stood in the way of a fair distribution arrangement for transboundary water (Bens et al., 2016; Hussein, 2018a).

Against this background, Jordan is seeking to maximize its treated wastewater reuse capacity to reach 80% reuse of the generated wastewater by the year 2050, up from 30% at present (Hellegers et al., 2022). Treated wastewater reuse in agriculture would also provide a nutrient-rich source of water for fertigation that could help reduce the negative impacts of inorganic fertilizers on the environment (Ouoba et al., 2022; Mainardis et al., 2022). Reaching this target, however, will not be easy, as it requires huge investments in infrastructure, a willingness of actors in the agricultural sector to adopt water reuse practices, and the ability to cope with the high running costs of wastewater treatment plants, especially as a result of their energy consumption (MCC, 2018).

In practice, substantial steps are still needed to achieve the shift towards greater water reuse capacity. However, Jordan's institutional landscape has been evolving towards this goal since the 1970s, when the government issued its first treated wastewater quality standards under Law 21 (Tawfik et al., 2022). In the early 2000s, Jordan's water reuse policy was placed under its 'Water for Life' strategy, a key focus of which is assuring the quality of treated wastewater and its safe use in terms of public health and environmental protection (MWI, 2023). The strategy targets the expanded use of treated wastewater in agriculture to help meet the water demands of major irrigated agriculture schemes. Under the more recent 'Water Green Growth Action Plan 2021–2025' (MoEnv, 2020) water reuse expansion is also a key target.

With two new policies, the Water Substitution and Reuse Policy and the Water Reallocation Policy (National Water Strategy 2016-2025, MWI, Jordan), Jordan's government aims to reallocate part of the agricultural sector's share of freshwater to the municipal sector. This will provide drinking water for city residents while at the same time providing nutrient-rich treated wastewater from cities to amend the water deficit in agriculture. However, farmers in the Northern Jordan Valley (NJV) – one of the country's foremost agricultural areas – view the plan as a threat to their traditional agricultural practices and livelihoods. Farmers' resistance has continued to stall the further implementation of the water reuse–reallocation scheme. Though the needed hydraulic infrastructure has been in place since 2017, the scheme has not been operationalized. This delay jeopardizes the plan's potential to contribute to solving Jordan's severe water and agricultural sector challenges.

This chapter builds on the works of Mollinga (1998) and Uphoff (1986) by advancing a holistic understanding of the coexistence of formal and informal practices as integrally intertwined components that shape and are shaped by the socio-economic context governing irrigation water allocation and management in the Jordan Valley. Adopting this theoretical lens, the analysis aims to understand the role of informal practices in facilitating farmers' access to water for irrigation while they resist the government's plans. At the same time, the study is interested in how stakeholders perceive the plan to reuse treated wastewater in agriculture and reallocate freshwater resources.

Following this introduction, section 5.2 presents the qualitative research methodology employed to collect and analyze the available data. Section 5.3 discusses the theoretical orientation of the analysis, and section 5.4 introduces the study area. Section 5.5 presents the results of the analysis, discussing findings from the interviews with farmers and formal stakeholders regarding irrigation water availability, access to water, and formal and informal institutional arrangements by which irrigation water is allocated, as well as current practices to access irrigation water. Farmers were asked about their perceptions regarding the shift to the use of treated wastewater for irrigation, whether they would accept the shift, and why or why not. Section 5.6 discusses the results, zooming in on how farmers have managed to resist the reuse–reallocation plan. The chapter concludes, in section 5.7, by recommending an inclusive and participatory approach to bridge the trust gap between farmers and government and help build an inclusive water reuse plan with minimized risk to farmers in the NJV.

5.2 Materials and methods

This study of irrigation water allocation and management practices in the Jordan Valley draws on qualitative methods involving document review and interviews with key informants and farmers. The reviewed documents included academic literature and official reports addressing water resources management challenges in Jordan from both a technical and an economic perspective. Reports from donor organizations and government water policy documents were key to understand the government's plans for water resources management and reuse expansion. The informant and farmer interviews were semi-structured and involved representatives from Jordan's water and agricultural sector (including professors, researchers, and government officials), farmers from the NJV, and members of one water user association (WUA) in the NJV.

As in previous chapters, stakeholder identification and interviews were conducted under the umbrella of the ReWater

MENA project, which was implemented in the NJV by the Royal Scientific Society (RSS) in coordination with IWMI. Selection of farmers for interviews was facilitated by a local community-based organization (CBO) that was active around farm units adjacent to irrigation lines 11, 12, and 13. The selection process was random, based on farmers' availability and their willingness to participate in the interviews. This resulted in interviews with 18 NJV farmers, including WUA board members of irrigation lines 12 and 13.

The key informant (expert) interviews were conducted in Amman with representatives of relevant governmental and non-governmental institutions, such as the Jordan Valley Authority (JVA) (specifically, the director of the division in charge of WUA organization was interviewed), the RSS, and the IWMI office in Amman. The semi-structured interviews were conducted over three months, in June, July, and August of 2021. Their focus was to understand stakeholders' views on irrigation water challenges in the NJV, the on-farm practices of farmers to manage irrigation water quotas and overcome scarcity, the presumed role of water reuse in the agricultural future of the NJV, and the role of WUAs in irrigation water allocation in the NJV, as well as whether or not WUAs would have a role in facilitating treated wastewater reuse expansion and acceptance in the NJV.

5.3 Theorizing water reuse and reallocation in the NJV

Irrigation water transfer and allocation among users (henceforth 'irrigation water management') often takes place through top-down formal arrangements in which various technological, infrastructural, institutional, and organizational interventions are established to control water flow from source to user, according to codified rules and agreements (MWI, 2023). Parallel to and intersecting with those formal arrangements, there are co-existing informal arrangements that local communities adopt as adaptive mechanisms, to adjust to the impacts of formal arrangements for access to irrigation water (Cleaver, 2001). Informal arrangements are often labelled as illegal practices (Cleaver, 2017), although this is not always the case. Informal arrangements represent socially embedded practices that have been forged by the local context (both socio-economic and everyday political factors), and they are frequently shaped by the formal arrangements themselves (Mollinga, 1998).

The interaction between formal and informal arrangements reflects the complexity of the irrigation water management process. That process encompasses government strategic plans, infrastructure projects, donor interventions, organizational and institutional reforms, and farmers' acceptance of or resistance to all of these. It also includes farmers' interest in maximizing their profitability by accessing more irrigation water through various informal practices which many governments fail to codify or regulate.

To grasp this complexity and dynamics, this analysis combines Mollinga's (1998) and Uphoff's (1986) frameworks in order to understand interactions between formal and informal irrigation water management practices in the NJV. Both frameworks have in common the concept of water control and the understanding of irrigation as an inherently political and thus highly contested practice. In a context of scarcity, as in Jordan, irrigation water becomes a contested resource between various stakeholders, with these stakeholders typically having asymmetric power and influence on access to irrigation water. In such cases, each stakeholder group aims to maximize their profits, either through formal arrangements (e.g., new rules and regulations or construction of water control infrastructure) or by adopting informal arrangements to resist and circumvent those formal interventions. Uphoff's (1986) framework would have been sufficient for this analysis if the aim was to understand the dynamics of water control activities and the role of farmers in managing those activities, regardless of the agricultural arrangements in the study area. Combining Uphoff's framework with Mollinga's enables us to position water control activities in the NJV within the existing agri-political ecology context of the Jordan Valley (Figure 5.1). Indeed, this context shapes perceptions of irrigation water quality, quantity, reuse, and reallocation mechanisms among the different stakeholders and users within and outside the NJV.

In the framework in Figure 5.1, the left-hand side represents interventions and activities that take place through formal arrangements initiated either by donor organizations or governments. Those activities reflect the material and social conditions that enable irrigation water management in the NJV, as well as the water flow control that takes place through organizational or institutional means and infrastructural or technological means.

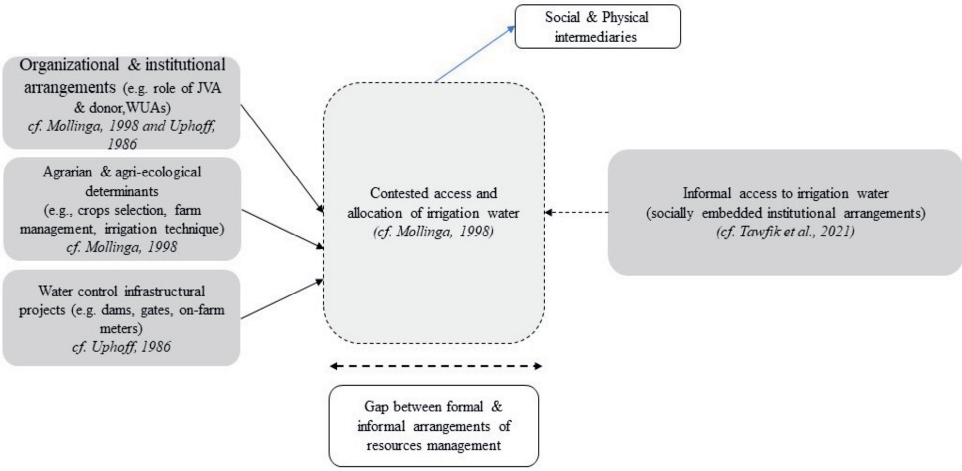

Figure 5.1 Combining Mollinga's (1998) and Uphoff's (1986) analytical frameworks.

The right-hand side of the framework represents the various informal (socially embedded or socio-normative) practices that farmers in the NJV adopt to circumvent and resist the formal arrangements (Tawfik et al., 2021). Similar to the formal arrangements, informal practices can target either the physical or the social conditions of possibilities for irrigation water management.

Finally, at the center of the framework there is a social space where the formal and informal arrangements interact over the contested irrigation water resource in terms of water quantity, quality, and water quota allocation timing (as in the case of the NJV). According to Mollinga (1998), this interaction is mediated by various social and physical factors at different scales, represented by the dashed border of the central block in the figure.

5.4 Study area

The Jordan Valley is one of Jordan's three agro-ecological zones, the other two being the desert and highlands. These zones are heterogenous in terms of biophysical characteristics (water sources and quality, micro-climate, soil types, and crops), as well as the local social, economic, and political context that shapes agricultural activity in each area (Hosney et al., 2023) (Table 5.1). The Jordan Valley is the largest among the three zones in terms of surface area and irrigation water consumption. It consumes around 25% of the country's available water resources and is considered Jordan's breadbasket thanks to its close proximity to water sources, its altitude (200–400 m below sea level), and its soil fertility (Venot et al., 2008).

Table 5.1 Agricultural activities in the Jordan Valley (Source: Hosney et al., 2023).

Agro-ecological zone	Crops	Source of irrigation water
Northern Jordan Valley (NJV)	Citrus Banana	Surface water: King Abdullah Canal (KAC)

	Vegetables	Rainfed
Middle Jordan Valley (MJV)	Vegetables (greenhouses)	Mixed water: treated wastewater + freshwater from KAC
Southern Jordan Valley (SJV)	Vegetables Date palm trees	Groundwater wells

The NJV is divided into agricultural basins that receive weekly irrigation water quotas through a pressurized or gravity pumping network. The Jordan Valley Authority (JVA) oversees irrigation water flow management and allocation processes. Each basin consists of a group of agricultural units sharing the same irrigation pump and water distribution network. The units vary in size from 30 to 40 donums (3–4 ha), with farmers owning or renting one or more agricultural units in the same or in different basins.

Despite its prominence as one of the country's foremost irrigated agriculture areas, production in the Jordan Valley is threatened by severe physical water scarcity as a result of climate change impacts, transboundary water allocation challenges, and increasing demand for water resources in other sectors (Bens et al., 2016; Shammout et al., 2018). Concurrently, the agricultural importance of the Jordan Valley is affected by the government's perception of the agricultural sector here as being a 'wasteful' consumer of water resources, as it usurps 50–70% of the country's freshwater withdrawals (Hussein, 2018b). Furthermore, primary agriculture's contribution to GDP is falling, having dropped from 8.1% in 1991 to 3.6% between 2011 and 2016 (excluding activities in the broader agrifood sector) (Molle et al., 2008; World Bank, 2018).

Treated wastewater from the As Samra wastewater treatment plant has been used to partially substitute for freshwater among farmers in the MJV, complying with the Jordanian reuse standards. Here, treated wastewater is collected and mixed with freshwater at the King Talal Dam reservoir, followed by another mixing stage with freshwater from the Yarmouk River, Peace Conveyor, and Mukheiba wells, before water reaches farmers to meet their irrigation needs. This has facilitated the reallocation of freshwater to help meet increasing urban water demand through water conduits linking the rural MJV with urban settings, including Amman. This has served to counterbalance rising water demand in the nation's capital and major cities. Some 50 MCM per year of freshwater were transferred from the Jordan Valley to Amman in the early 2000s, and plans are in place to increase this amount to 90 MCM per year by 2025 (Venot et al., 2008).

Treated wastewater reuse and freshwater reallocation plans for the NJV date back to 2001, but these have not been operationalized – despite the area being identified as a top priority for water reuse and freshwater reallocation (ARD and USAID, 2001). Instead, irrigation in the NJV has continued to rely on freshwater from the King Abdullah Canal (KAC). Farmers in the NJV have a long tradition of citrus plantations, with the fruits destined for export to regional markets in Syria and the Gulf States, analogous to the earlier practices of farmers in the MJV before the shift to reused water for irrigation there. Farmers in the MJV have since lost their citrus trees, attributing that loss to the poor quality of the treated wastewater from the As Samra plant, particularly before the plant upgraded to mechanical treatment in 2007 (Shatanawi and Fayyad, 1996; Salman et al., 2018). The shift to treated wastewater reuse and the corresponding change in water quality thus appears to have led to a shift in crop selection within the MJV to crops that are more resilient and less sensitive to salinity (Ammary, 2007). Despite significant improvements in the quality of the treated wastewater from the As Samra plant, NJV farmers have continued to reference the MJV case as justification for their fear and resistance to receiving mixed treated wastewater for irrigation.

5.5 Results

This results section explores water allocation and access in the NJV in a structure corresponding to the aspects of irrigation water management presented in the theoretical framework (see Figure 5.1).

5.5.1 Irrigation water organizational and institutional arrangements

The JVA is responsible for water quota allocation from the KAC to farmers across the Jordan Valley, either directly through the JVA's canal operators or through WUAs. In 2001, farmers' involvement in irrigation water management was facilitated by support from the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The first WUA involving farmers was established in 2002. Called 'the Jordanian corporation', it was chaired by Jordan's minister of agriculture. The idea of farmer involvement was further developed based on examples from different countries which delegations from Jordan visited over time. The first visit was to Damanhur, Egypt, in 2004, followed by Syria and Turkey in 2005.

Until 2007, work in the corporation was voluntary and unpaid. In 2008, two 'entrepreneur' locations were selected in the NJV, near pumping station 33. Here, a transfer of responsibilities agreement was signed, including both water distribution and 'censorship' responsibilities (monitoring for violations and reporting these to the JVA). In an interview, the director of the JVA division in charge of WUA organization stated that the 'observed positive impact of WUAs on irrigation water management' had encouraged the JVA to expand the number of such agreements, which reached five in 2009. Later, in 2015, a new transfer of responsibilities agreement was signed in which WUA employees would receive payment from the JVA. They were also made responsible for regular maintenance, although emergency maintenance and repairs remained the responsibility of the JVA. The agreement also included definitions of technical and geographic regions in which the contract was valid and the precise responsibilities of both the JVA and the signatory associations. WUA responsibilities included water distribution, pumping station operation, and irrigation water network maintenance.

In 2020, 18 WUAs had active agreements with the JVA. In that year, WUAs covered 18% of the area served by irrigation in the Jordan Valley as a whole. Despite the increasing number of WUAs, they had not developed into the fully financially and legally autonomous entities that were initially foreseen (Mustafa et al., 2016). The challenges the WUAs faced were reflected in the responses of the interviewed WUA members, as they noted the associations' limited capacity to take a leading role in irrigation water management due to their financial and legal dependency on the JVA. Fourteen of the farmers interviewed also commented on the WUAs' lack of capacity for conflict resolution and their inability to ensure that farmers received their allocated water quotas. They stated that the WUAs had had little positive impact on irrigation water management in the NJV, and they mainly benefited rich farmers and WUA board members (the majority of whom were rich farmers). In this context, they used the word 'rich' to refer to farmers with access to financial means (e.g., through inheritance or side jobs other than farming) and access to knowledge regarding new farming technologies (e.g., water storage in fishponds, drip irrigation, and the use of solar-powered water pumps).

The interviewee from the JVA WUA division agreed that the associations faced challenges and there was room for improvement. Improvements were said, however, to be taking place. For example, in North Shuna (in the NJV) six associations had been incorporated into one association called the 'Water Users Association in North Shuna'. It was established as a non-profit voluntary organization under the Ministry of Social Development. This restructuring reduced the cost of the WUA, as its establishment as a commercial association would have required a payment of 360 Jordanian dinars (JOD) (US $514). The Ministry of Water and Irrigation managed the association through a service agreement instead of an employment agreement.

In addition to the JVA and WUAs, donor agencies (particularly USAID) have had an influential role in irrigation water management and water allocation in the NJV. In 2001, USAID's Water Resource Policy Support Project identified the NJV as one of three priority areas in the Amman–Zarqa Basin for implementation of a reuse–reallocation plan (ARD and USAID, 2001). A USAID report states that the NJV provides 'very attractive' potential to divert large amounts of freshwater to Amman at a relatively low cost. Some 57 MCM was estimated as the amount that could potentially be transferred annually, slightly exceeding Jordan's freshwater allocation under the 1994 peace treaty with Israel (Transboundary Freshwater Dispute Database, n.d.).

Despite the organizational and technical potential to secure a more sustainable water supply for rural and urban users, the USAID report acknowledges that the reuse–reallocation plan would have 'considerable' socio-economic impact on farmers in the NJV. Particularly, the shift to reused water would affect cropping patterns, due to the change in water quality. Farmers, therefore, faced potential losses or reductions of income, especially if they lost their traditional citrus plantations (ARD and USAID, 2001), as had occurred in the MJV. The interviewed farmers, indeed, mentioned this as a key concern.

Other than the KAC, alternative sources of irrigation water in the NJV were limited to shallow groundwater wells (farmers call these 'springs') and deep groundwater wells, though closer to the Jordan River these were often saline. Moreover, all alternative sources were regulated by the JVA through the issuance of permits for groundwater wells and fines in cases of violations (e.g., illegal wells). Obtaining permission for a groundwater well cost JOD 10,000–12,000 (US $14,000–28,000), in addition to the cost of digging the well (some JOD 20,000 or US $28,000), making this an unaffordable option for ordinary farmers, most of whom were poor.

5.5.2 Agrarian and agro-ecological determinants

The key agrarian and agro-ecological determinants are crop selection, farm management, and on-farm water management, including irrigation technique and the farm water quota according to the regulations in the NJV. Most of the interviewed farmers in the selected basins (12 farmers) owned citrus plantations, though five interviewees were hired operators with long experience in farm management. One interviewee was a 'guarantor', an arrangement similar to a rental agreement in which the farm owner receives a fixed monetary sum and the guarantor takes over farm management and crop marketing.

The interviewed farmers stated that many farm owners in the NJV would prefer managing their farms through guarantors, to avoid the increasingly challenging marketing conditions and other uncertainties that threatened agricultural productivity and farm revenue. Table 5.2 presents the characteristics of the farms selected for this study in the NJV regarding crop selection, on-farm irrigation water management, water allocation mechanism, and alternative sources of water for irrigation through informal access.

Irrigation water quotas in the NJV were crop-based, in which larger quotas were allocated to farms growing citrus and bananas compared to farms growing vegetables (Table 5.3). Vegetables were mainly grown during the winter season under rainfed conditions. Citrus and banana farmers received roughly twice the water allocation of vegetables. The JVA managed these allocations. Among its responsibilities, the JVA issued permits to farmers who were willing to grow high-water quota crops (mainly citrus and bananas). Despite stimulus policies being in place to reduce irrigation water consumption, the JVA had legalized several unregistered citrus plantations that had begun operating between 1991 and 2002 (Liptrot and Hussein, n.d.). These farms consequentially became legally entitled to receive the higher water quotas for citrus farms.

Table 5.2 Characteristics of farms operated by the interviewed farmers in the Northern Jordan Valley (NJV).

Farm management	
- Ownership	12 farm owners; 5 managers/operators, 1 guarantor.
- On-farm irrigation water storage	11 farms had on-farm water storage structures (i.e., earthen or concrete ponds). The rest (7 farms) irrigated directly without storage.
- Irrigation technology	15 farms used irrigation hoses. 3 farms used drip irrigation.
Irrigation water allocation mechanism	

- Jordan Valley Authority (JVA) (canal operators)	14 farms received water quotas through the JVA.
- Water users associations (WUAs)	2 farms received water quotas through WUAs.
- Other	2 farms did not have access to a formal water quota (their land plots were not officially registered as agricultural lands).
Alternative source of water for irrigation (informal access)	11 farms reported having no access to water sources other than their water quotas. 4 farms reported using alternative or additional water sources either sporadically or continuously, such as shallow or deep wells, water abstracted from the Jordan River, and illegal abstraction from the KAC. 3 farms requested extra water quotas (extra hours of irrigation) from the JVA when water shortages arose.
Crop types	12 citrus farms 3 vegetable + citrus farms 1 grape farm 1 citrus + grape farm 1 citrus + date palm tree farm
Average agricultural units per interviewed farmer	1–2 units per interviewed farmer (average unit size in NJV was 33 donums, equivalent to 3.3 ha).

Table 5.3 Crop-based water quota allocations in the Northern Jordan Valley (NJV), citrus versus vegetable farms (Source: Venot et al., 2007).

Period	Citrus farm water allocation (average m^3/ha/day)	Vegetable farm water allocation (average m^3/ha/day)
High water demand (April to October)	30	15
Low water demand	20 (extra water allocated upon request)	15

Increasing water scarcity and diminishing water quotas in the NJV affected farmers' selection of irrigation techniques, corresponding to variations in farmers' knowledge and their financial means to address the problem. Rich farmers were more capable of shifting to advanced irrigation techniques. Unlike their poorer counterparts, they could gain access to knowledge and financial means to reduce the impacts of water scarcity. Among the interviewed farmers, only three (two from rich families, and one who was a retired JVA employee) had shifted from surface irrigation to drip irrigation with filtration units to avoid system clogging. These three farmers (all growing citrus) reported significant water savings after installation of the drip irrigation. The remaining 15 farmers were using traditional water distribution hoses fixed at the base of each tree.

Half of the interviewees stated that the water scarcity problem in the NJV was the result of mismanagement of the country's water resources, which interviewees said, had affected farmers across the entire Jordan Valley. However, they also noted mismanagement of water quotas by NJV farmers and NJV farmers' continued use of traditional irrigation techniques. Half of the interviewees stated that Jordan was indeed suffering from a reduction in physical water availability.

Farmers' perceptions of the potential of treated wastewater reuse for irrigated agriculture were largely influenced by experiences in the MJV. Half of the interviewed farmers based their views of reused water for irrigation on these experiences. As noted, farmers in the MJV attributed loss of their citrus plantations to the low quality of treated wastewater from As Samra (particularly, the water's high salinity). Additionally, three farmers reported they had had access to treated wastewater during a trial conducted by the JVA in 2014, in which treated wastewater was mixed with freshwater from the KAC. Those farmers said the water smelled bad and some field workers had suffered a skin rash. The trial continued for two weeks before it was discontinued due to farmers' complaints. Despite this, 11 of the interviewed farmers expressed interest in discussing the potential of treated wastewater reuse for crops such as vegetables and date palm, but not for citrus, as these trees were sensitive to salinity.

5.5.3 Water control infrastructure

Jordan Valley level. The Jordan Valley is part of the Lower Jordan River Basin (LJRB), a semi-closed basin in which water demand exceeds the current supply (Venot et al., 2008). As noted, intensive irrigated agriculture here has been facilitated by availability of water from the King Abdullah Canal (KAC), which was constructed in the 1960s. The KAC receives its water from the Yarmouk River, the Peace Conveyor (in accordance with the 1994 peace treaty with Israel), and groundwater wells.

The NJV receives freshwater for irrigation from the KAC, which extends a few kilometers into the MJV. Freshwater from the KAC is then conveyed to Amman for domestic and industrial use (including for the tourism industry). After the diversion point, the KAC receives a different water flow, that from the King Talal Dam (KTD) to the east. The source of this water is the As Samra wastewater treatment plant, which collects and treats Amman's and Zarqa's wastewater. The treated wastewater flows to the KAC through the valleys and enters the KAC at a junction point in the MJV (Figure 5.2). Accordingly, the rest of the MJV relies mainly on treated wastewater for irrigation (the ratio of treated wastewater to freshwater is 6:1) (Figure 5.2).

Figure 5.2 Diversion point in Middle Jordan Valley.

Table 5.4 Water allocation to the Northern Jordan Valley (NJV) and Middle Jordan Valley (MJV) (Source: Hosney et al., 2023).

Water source	Distributed to	Volume (Mm^3/year)	Water control infrastructure
King Abdullah Canal (KAC) (from Yarmouk River, Peace conveyor, groundwater wells	NJV	55	KAC + Pump stations
Imported from northern wadis		15	Pump stations
Treated wastewater from As Samra treatment plant	MJV	60	King Talal Dam (KTD) + pump stations
KAC		10	KAC + Pump stations
Total water allocated to NJV + MJV	140 million m^3/year		
Total water allocated to Amman from the Jordan Valley	50 million m^3/year		

Additionally, new water control infrastructure was developed in 2017 to reallocate freshwater from the NJV to the city of Irbid for domestic use, while supplying farmers in the NJV with treated wastewater for their agricultural activities (in a 6:1 ratio, similar to the MJV) (see Figure 5.3). This arrangement, however, has not been made operational due to farmers' resistance.

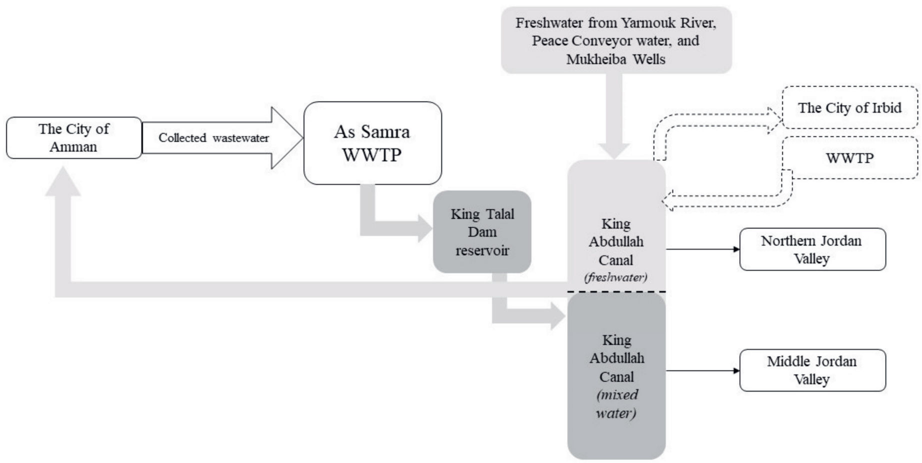

Figure 5.3 Current and proposed water reallocation in the Jordan Valley (dashed lines indicate proposed water reallocation scheme).

Farm level. On-farm irrigation water management and distribution in the NJV is regulated by the JVA through installation of a 'farm turn-out assembly' (FTA) at the head of each agricultural unit (i.e., one FTA releases water for 30–40 donums). The JVA equips the FTAs with flow meters to regulate and limit water flows to a rate of 6–9 l per second for an average of 12 h per week for each farm, while also measuring water consumption. The interviewed farmers reported annual irrigation water bills ranging from JOD 80 to JOD 200, in which 'annual' refers to the summer months when farmers rely on pumped irrigation water in the absence of rainfall. Variation in the water bills depended on the number of units each farmer owned. Hence, water bills did not reflect the volumetric water consumption per agricultural unit, but rather, the number of irrigation units each farmer had.

5.5.4 Informal access to water for irrigation

Freshwater availability and accessibility through informal practices and arrangements were key in sustaining agricultural productivity in the NJV, and this augmented farmers' resistance to the plan to introduce water reuse for irrigation. According to interviewees, farmers' social network and influence affected their ability to access irrigation water through formal and informal practices. Those farmers who were unable to access additional freshwater, through formal or informal means, were mainly poor farmers with weak connections (e.g., links with either the canal operators or WUA members). For them, water shortages had caused a significant diminishment of crop productivity, as reported during the interviews. To adapt to the reduced water quotas, some of these farmers had cut back on the number of citrus trees per farm unit. Farmers with more than one farm unit often chose to combine and reallocate all of their water quotas to a single unit, to meet the irrigation water demand there. At the same time, the rich farmers interviewed reported little or no complaint regarding access to water quotas. They blamed 'other' farmers for mismanaging their water quotas and faulted their continuing use of low-efficiency, traditional irrigation techniques. Some of the rich farmers did report at times requesting an extra irrigation water quota from the JVA, which they said would be 'promptly' provided. However, less influential and poor farmers did not report this practice (i.e., requesting and receiving extra water quotas from the JVA). Despite the ready provision of the extra quotas, even these were said to be shrinking due to the diminishing availability of water in the Jordan Valley. Rich farmers tended to fill gaps by abstracting water from deep wells, though these were often saline and required the use of desalination units. Many refrained from applying for formal permission for these wells or registering them, likely considering their social and political influence sufficient to protect them from the 'strict' government fines on unregistered wells (Hussein, 2018b).

One of the most common practices reported was tampering with FTA units, leading to inequity in water quota distributions between farmers at the beginning (upstream) of the irrigation line and downstream. Such practices had drastically affected the gravity-operated irrigation lines (i.e., unpressurized lines not equipped with pumping stations), as farms at the beginning of these irrigation lines or at a lower slope could receive more water than the rest. One of the interviewed farmers at the beginning of a gravity line said that besides tampering with the FTA, he had replaced the pipes receiving water from the FTA with wider pipes – allowing larger volumes of water to flow to his farm. This, however, deprived farmers downstream of access to their designated water quotas. The resulting inequities in access to water at the farm level served to amplify the immediate water scarcity problem at certain farms, which also explains why some of the interviewed farmers did not suffer irrigation water shortages, while counterparts located downstream on the irrigation lines did. This issue had become particularly acute since the JVA had reduced the water quotas in the NJV. The interviewed farmers reported that their water quotas had been decreased from 48 h to 12 h (or less) per week. Other farmers abstracted water directly from the heavily polluted Jordan River. These farmers also reported use of desalination units to reduce the salt content of the water. This, however, imposed an additional cost, making it an unaffordable option for poor farmers, many of whom were solely dependent on the water quota allocation. They faced dire financial consequences due to the worsening water scarcity.

5.6 Discussion

Social and physical intermediaries were identified as playing an important role in enabling or hindering access to and allocation of irrigation water in the NJV (see Figure 5.1, top right). These intermediaries were found to be interlinked and, furthermore, a result of contestation and conflict between formal and informal arrangements, as described above. Table 5.5 presents the main social and physical intermediaries observed in the study area. The sections below discuss some of these.

Table 5.5 Social and physical intermediaries of irrigation water access and allocation in the Northern Jordan Valley (NJV).

Social intermediaries	Physical intermediaries
Water users associations (WUAs) in the NJV.	Informal practices to access water.
Crop selection and access to national and regional markets.	Formal freshwater reallocation infrastructure.
The role of the Jordan Valley Authority (JVA) (through canal operators).	On-farm water distribution devices (FTA).
Experience of Middle Jordan Valley (MJV) farmers with treated wastewater.	On-farm irrigation technology.
Perceptions of donor agency, government, and farmers in the NJV on water allocation and treated wastewater reuse.	New treated wastewater reallocation infrastructure (developed in 2017).
NJV farmers' social networks, influence, and financial status.	Farms' geographical location upstream or downstream on an irrigation line.
Government's commitment to secure water supply for urban settings.	Physical water scarcity in Jordan.

5.6.1 Perceptions

The experience of MJV farmers with treated wastewater reuse, particularly loss of their citrus plantations, was a key social intermediary that shaped the perceptions of the NJV farmers interviewed in the current research. However, the views of donor agencies (particularly USAID) and of government regarding the great potential of the water reuse–reallocation plan in the NJV pushed forward the construction of infrastructure and implementation of a few pilots. Understanding perspectives on both sides is instrumental to understand the current stalemate, which has halted progress towards putting the reuse– reallocation plan into effect. Table 5.6 summarizes the drivers of the different stakeholders' perceptions of the reuse–reallocation plan in the NJV.

Table 5.6 Risks and benefits of water reuse as perceived by key stakeholders in the Northern Jordan Valley (NJV).

	Stakeholder	Perceived risks	Perceived benefits/opportunities
Technical/infrastructural and organization-oriented perception	Donor organizations.	Impacts on current crops and agricultural practices, potentially undermining farmers' livelihoods.	The plan would secure large volumes of freshwater for priority domestic uses in urban settings.
	Government (e.g., the Ministry of	Considerable resistance exerted by the influential	The plan would help the government to demonstrate its efforts for better water

	Water, the National Agricultural Research Center, and the Jordan Valley Authority).	agricultural lobby (Mustafa et al., 2016)	resources management to international partners and donors, and it would contribute to secure freshwater for priority urban/domestic uses. Additionally, the plan would enable the government to increase the water supply for agriculture through treated wastewater.
Socio-economic oriented perceptions in the NJV	Small-scale, poor and less influential farmers.	Risk of losing productivity because of limited knowledge and resources to shift from traditional agricultural practices and crop patterns to new techniques and crops, which may be needed due to the shift in water quality.	The plan would provide a reliable irrigation water source, allowing for sufficient water quotas to boost production. For these stakeholders, the perceived benefits outweigh the risks.
	Rich farmers.	Risk of losing access to regional and global markets due to health restrictions on crops irrigated with treated wastewater or mixed water streams, thus diminishing financial and economic power.	At present, the plan would provide no additional perceived opportunities or benefits for rich farmers.

5.6.2 The WUAs and JVA

The roles of the WUAs and JVA have been interlinked, as the WUAs' very establishment is dependent on the JVA. Moreover, JVA regulations govern the WUAs. One such regulation is the stipulation that for a fully functional WUA, representation of at least 86% of the agricultural units in the affected area is required. The representation requirement is based on the idea that the local WUA would then represent most landowners in the area. In practice, however, WUA membership rules have favored conditions in which leadership can be usurped by rich farmers, enabling them to entrench their political influence and potentially consolidate greater access to irrigation water. Hence, WUAs have become yet another form of top-down control over irrigation water, with control of allocations in the hands of the JVA through the JVA's financial and administrative authority over the WUAs. For instance, in case of a breach of water quotas and management stipulations, WUA employees must report the violation to the JVA, as they themselves have no legislative capacity to act. Mustafa et al. (2016) observed that this institutional dependency of the WUAs on the JVA and the current restrictive rules are favored by many JVA staff, who are concerned they might lose their powerful social and political positions in the Jordan Valley if the WUAs were fully empowered.

5.6.3 Access to irrigation water and access to markets

Various uncertainties accompany the planned transition from freshwater irrigation to mixed freshwater and treated wastewater for irrigated agriculture in the NJV. The impacts of such a transition could well determine farmers' access to various markets, affecting their local and regional competitiveness, their market share, and the financial and economic viability of the agricultural sector overall. As highlighted by the heterogeneous perceptions of stakeholders (see Table 5.6), poor and less influential farmers exhibited greater openness to discussing water reuse as a potential source of irrigation water. This was mainly due to their desperate need for additional water to irrigate their lands – as they could not meet this need with the formal freshwater quotas from the KAC or through available informal arrangements, which were either too costly or required social and political influence.

Rich farmers, however, were mainly concerned about losing their access to regional and international export markets, due to the risk of residual contaminants being transferred from treated wastewater to agricultural produce. Fears were raised that the use of treated wastewater for irrigation could trigger a wave of boycotts of Jordan's agricultural products in export markets. Such markets have been known to impose strict regulations on products irrigated with treated wastewater (Scott et al., 2004). One example is the ban on agricultural products (particularly tomatoes) from Jordan imposed by Saudi Arabia 21 years ago (National News, 2011). The earlier-mentioned USAID report (ARD and USAID, 2001) terms the 'considerable resistance' of local farmers (mainly rich farmers) to the government's water reuse–reallocation plan as a justifiable and predictable response. It also observes that the Jordanian government might be unable to implement such a plan in a top-down way unless further significant reductions in freshwater availability force local farmers to accept water reuse as an inevitable solution to maintain agriculture in the NJV.

Resistance has persisted, however, and translated into various forms of informal irrigation water access. This has resulted in a complex, socially embedded system with practices that have developed independently from those of the formal system (Boelens et al., 2019). The current study identified two main forms of informal water access for irrigation purposes. The first, used predominantly by poor and less influential farmers, is the adoption of illegal practices to access water for irrigation. These practices were dependent, however, on the availability of alternative water sources (e.g., shallow wells and direct access to the KAC) near a farm's location. The second form of informal water access concerns institutional arrangements exclusive to rich and well-connected farmers and involving multiple actors from governmental institutions in the water sector. Although these informal institutional arrangements were not illegal, they were beyond the reach of poor and less politically and financially influential farmers, who lacked the requisite connections to institutions such as the JVA. Hence, institutional arrangements indeed enabled rich farmers to circumvent the bureaucratic arrangements with impunity (Hüttl et al., 2016).

5.7 Conclusions

Many NJV farmers viewed treated wastewater as a lower quality water resource with many potential negative impacts on agricultural practices and farmers' livelihoods. Similarly, the reallocation of freshwater from the NJV to urban centers (e.g., Amman) is seen as a threat to farmers' identity, power, and culture, in favor of 'external actors' (Manosalvas et al., 2021). Conducting semi-structured interviews and analyzing the local dynamics that have shaped agricultural practices in the NJV and access to irrigation water, the current research found that the involved stakeholders had different and often conflicting perceptions of treated wastewater reuse and its associated risks and benefits (see Table 5.6). This variation in perspectives mirrored the stakeholders' different socio-political and economic standpoints, and has led to the current stalemate blocking the reuse–reallocation plan from being put into operation in the NJV, despite the readiness of the infrastructural component since 2017.

This research supports the hypothesis that the current stalemate is due to the reuse–reallocation plan focusing primarily on the infrastructural and organizational water control aspects, with less attention being given to the local socio-political and economic context in the NJV. As a result, farmers have continued to resist the formal plans, while co-creating informal solutions to access freshwater for irrigation as an adaptive mechanism to overcome immediate water scarcity and maintain agricultural productivity. Although most of the 'informal' practices identified were illegal, the financial gains from increased water availability outweighed the costs incurred, in the form of fines or bribes paid to JVA or WUA staff, particularly among rich farmers, who feared losing their access to regional and international markets.

At the same time, poor and less influential farmers – who were in desperate need of water – viewed the treated wastewater reuse plan as an opportunity to address the water scarcity problems they faced on a daily basis, though they too had concerns about the quality of the treated wastewater and its long-term impact on their crops, especially citrus trees. These farmers were open to discussing treated wastewater reuse as a potential source for irrigation water in the NJV. However, their voices have continued to be marginalized, as the current socio-political and economic context empowers rich farmers and their representation through long-established networks and their prominent role in the WUAs. NJV farmers' adoption of informal practices and institutional arrangements to access water for irrigation has remained beyond the government's capacity to monitor, regulate, or prevent. Yet, the potential impact of these practices and arrangements on freshwater consumption is grave and could accelerate water scarcity in the NJV beyond the government's already dire predictions. Continuation of the current stalemate would undermine the government's plan to reallocate freshwater to priority urban and domestic uses, and thus reduce Jordan's options for addressing severe water scarcity in the future. There is an urgent need for the government to develop an inclusive plan addressing farmers' concerns regarding the short- and long-term impacts of wastewater reuse in agriculture. Primarily, policies need to be developed to protect crop exports to regional and international markets and avoid bans on Jordanian agricultural produce such as the one imposed by Saudi Arabia 21 years ago.

In conclusion, this study indicates that understanding the heterogeneous socio-political and economic context – as well as climate change impacts, which are outside the scope of the current research – is key in formulating water reuse and reallocation policies. Finding a path forward in the NJV will require building a strong alliance with 'ordinary' farmers. The government could, furthermore, consider restructuring the WUAs to better represent the heterogeneity of NJV farmers' perceptions and needs.

6 Synthesis and conclusion

This thesis has investigated formal and informal waste/drainage water reuse arrangements and how these have shaped or reshaped access to water for irrigation in the MENA region. In particular, two cases, in Egypt and Jordan, were examined in more detail. Increased competition for limited freshwater resources throughout the MENA region has led many farmers to devise novel, socially embedded approaches – in other words, informal arrangements – to access irrigation water. In this context, non-conventional water resources, such as treated and untreated wastewater, agricultural drainage water, and groundwater from shallow and deep wells, have played a critical role in bridging the existing supply-demand gap. In light of increasing scarcity of water resources, leading to intensified competition over freshwater resources, governments in MENA countries have pursued new 'formal' arrangements for access to non-conventional water resources. These have included adoption of new regulatory and institutional frameworks, as well as construction and management of large-scale hydraulic infrastructure through which wastewater and drainage water of low quality is collected, conveyed, treated, and discharged for use mostly in new irrigation areas – oftentimes mixed with higher quality water. Though this process is formally presented as a win-win proposition in which 'underutilized' water resources are made available for irrigation purposes, this research found that many of these processes are in fact contested, as this water was already in uses and is being reallocated by the new arrangements.

In Egypt, wastewater and agricultural drainage water is formally treated and reused by and large for the expansion of irrigation at the desert frontiers, either for the production of timber or for commercial agriculture. To accomplish this, drainage water was being pumped out of drainage canals in the 'old lands' of the Nile Delta, despite the fact that some of this water was already being used informally by smallholders to supplement their diminishing freshwater irrigation turns. As such, the new infrastructures and related policies have in practice reallocated waters from the old lands of the Nile Delta to new agricultural projects in desert-front governorates. This has undermined water availability for smallholders' informal wastewater reuse. In the Northern Jordan Valley (NJV), well positioned farmers have by and large resisted the use of treated wastewater for irrigation, as they fear that due to the lower quality of this water their production will decrease, crops will die, and export markets will close. To overcome water shortages within the formal irrigation system, these farmers have resorted to informal use of other water sources, such as accessing groundwater via shallow and deep wells or abstracting water directly from the KAC or Jordan River. Both cases point to important challenges and unintended consequences that arise in and around projects that aim to reclaim wastewater and drainage water for use in irrigated agriculture.

This final chapter returns to the research questions, setting out answers them based in the research findings. I reflect on how my perspective regarding the research topic evolved throughout the different stages of my PhD investigation and ith participation in the ReWater MENA project.[7] Following this discussion, I reflect on the local context in Egypt and Jordan and then look back at how the research questions for the current study evolved, from the start of proposal writing until formulation of the research questions in their final form. Finally, some conclusions are drawn.

6.1 Answering the research questions

The research questions posed were formulated to provide insights into the repercussions of top-down decision-making processes regarding access to wastewater and agricultural drainage water for reuse in irrigation, based on cases in Egypt and Jordan within the broader context of the MENA region. In contrast to the dominant, top-down technical and regulatory narrative surrounding wastewater treatment and reuse, the questions posed are more empirical in nature and centered on stakeholders' perceptions of wastewater reuse plans and how these perceptions have informed stakeholders' acceptance or resistance to such plans. To analyze wastewater reuse and reallocation mechanisms, a socio-technical and political lens

[7] https://rewater-mena.iwmi.org/ funded by the Swedish International Development Cooperation Agency (SIDA) and led by the International Water Management Institute (IWMI)

was used,[8] with which the role of large-scale hydraulic infrastructure (including advanced wastewater treatment plants) and wastewater access control mechanisms could be better understood. The overall main question posed in the research was the following:

> *How do state-led wastewater treatment and reuse projects and policies interact with and affect informal arrangements for wastewater and drainage water reuse and the associated water access of smallholder irrigators?*

This main research question was approached by means of four research sub-questions. The first inquired into the legal and institutional waste/drainage water reuse frameworks in place in the MENA region, and how these have been shaped by historical developments in water policies, regulations, and institutional arrangements. In fact, substantial heterogenicity was found between the MENA countries, though they did share in common a foremost role of the state's hegemonic power to impose reuse through policy, institutional, and infrastructural tools. In Egypt, where increasing amounts of untreated wastewater were being discharged into drains, agricultural drainage water was often of too poor quality to be formally reused in irrigation (Molle et al., 2013). Nevertheless, drainage water reuse was widely practiced here through 'informal arrangements', often contravening the formal policies regulating drainage water reuse in place since the 1970s. Formal drainage water reuse in Egypt was accomplished through a network of mixing stations which transfer drainage water, mixed with treated and untreated wastewater, from agricultural drains to feed the tail-ends of main and branch irrigation canals (Barnes, 2014a). The mixing process is organized by the Ministry of Water Resources and Irrigation (MWRI). However, farmers in the Nile Delta accessed the drainage water informally for irrigation, using privately owned mobile pumps to abstract the water, though this infringes on MWRI regulations and restrictions which illegalize this practice (Molle et al., 2019). Recently, new mega plants for drainage water treatment have been constructed to facilitate reclamation of 'new lands' for irrigated agriculture outside the Nile Delta. Through these plants and their related water conveyance infrastructure, drainage water from the 'old lands' of the Nile Delta is now being collected, treated, and reallocated, in a process that this research termed 'squeezing dry' the Nile Delta. This latest drainage water reuse policy, alongside the related infrastructure and resulting changes in water flows, can be understood as a continuation and deepening of a century-old process by which freshwater from the Nile River that used to flow to the Nile Delta is increasingly reallocated for expansion of the irrigation frontier. Due to this process, less water is available to irrigate the old lands. Now that the freshwaters from the Nile can no longer be stretched and 'squeezed out' of the Nile Delta, drainage waters from the old lands of the Delta have become the latest water resource to be targeted as a potential source to foster expansion of irrigated agriculture into the desert. These reallocations have hit smallholders in the old lands of the Nile Delta. These smallholders have already been compelled to complement their dwindling freshwater irrigation turns with drainage water, but now risk losing access even to that drainage water due to the new drainage treatment and reuse policies and infrastructures. Moreover, these smallholders have little voice and political weight to safeguard their access to water.

In Jordan, severe water scarcity has led to significant reductions in per capita water shares (see MWI, 2001, 2009, 2015). This predicament has been intensified by climate change and the continuous flow of refugees from Syria since 2011. Jordan's water resources policy and strategy, set in 2016, deprioritized the agricultural sector in favor of the domestic and industrial sectors. Agriculture, in this context, was to be made more 'resilient' by switching to treated wastewater, which represents a lower quality resource than freshwater from the Jordan River. In 2017, the government, benefitting from a donor fund, proceeded with the implementation of a pipeline network to transfer treated wastewater from three wastewater treatment plants serving Irbid governorate to the Northern Jordan Valley (NJV). That water was to be used for irrigation, while the NJV's share of freshwater would be reallocated to cover the increasing domestic water demand in the growing urban centers. Yet, from 2017 up to the time of this writing, NJV's farmers have resisted operationalization of this reuse–reallocation scheme, despite completion of the water reallocation infrastructure. In an attempt to break the stalemate, the government has reduced the freshwater quota of NJV farmers. This has prompted a number of these farmers to adopt 'informal' water access practices in order to maintain their agricultural productivity.

[8] Here we address the everyday politics of wastewater reuse arrangements that are embedded in formal and informal practices.

The second research sub-question was interested in the formal and informal institutional arrangements through which Egypt's wastewater reuse sector operates. Zooming in on two Egyptian *ezbas* (villages), a novel socio-technical framework was employed to analyze wastewater reuse practices. The findings reveal these practices to be embedded in specific social constellations. Moreover, within these constellations, a tendency was found for formal arrangements to discredit and render invisible informal arrangements. The analysis demonstrates that, in the absence of functioning formal arrangements, farmers in the Nile Delta have been able to fill the supply gap by establishing informal arrangements for wastewater management and disposal. However, to achieve safer wastewater reuse practices with fewer negative environmental and health impacts, these informal arrangements need to be recognized, empowered, and regulated, and farmers enabled to access better quality water for reuse in agriculture.

The third research sub-question centered on the role of infrastructure for wastewater treatment, reuse, and reallocation and thus in 'squeezing dry' the old lands of Egypt's Nile Delta. Specifically, the new infrastructure was designed to collect waste/drainage water from the old lands and reallocate it to new agricultural areas. Here, access theory was drawn on to analyze the role of large-scale infrastructure in enabling and reshaping access to waste/drainage water for reuse in agriculture. The investigation found that operationalization of infrastructure undermined smallholders' access to water to irrigate their crops in the context of severe freshwater scarcity. Indeed, many farmers relied on informal arrangements whereby they accessed drainage water for irrigation, though they could not claim formal access rights to this water. In this context, the analysis explored the shift in control of access to drainage water due to the state's development of large-scale infrastructure that facilitated this water's allocation to irrigate newly reclaimed lands in the desert. It revealed the socio-technical and political implications of hydraulic infrastructure in disrupting socially structured hydrological cycles, in this case by diverting drainage water flows in order to realize the state's development imaginary. The analysis indicates that the new reallocation mechanism emerged from notions of maximizing 'agricultural profitability' and 'water use efficiency' through 'modernization'. Governments and donors have long characterized surface irrigation in the old lands as 'wasteful' and 'sub-optimal', while agricultural expansion in the desert has been framed as the 'future' for profitable agriculture.

The fourth research sub-question explored the reasons for farmers' resistance to treated wastewater reuse in the NJV and the implications of that resistance for their access to water. The aim was to understand the multiple perceptions of the different farmers' groups and how these perceptions were formed by the socio-economic and political interests of those who defended them. The investigation revealed that farmers' perceptions of wastewater reuse were not always negative. On the contrary, farmers who lacked social and political influence in their localities expressed a willingness to explore the reuse of wastewater for irrigation, unlike richer and more influential farmers who had a vested interest in securing their quota of freshwater for irrigation so as to maintain their access to agricultural export markets, which are highly restrictive towards agricultural products irrigated with treated wastewater. The analysis revealed that potential health and environmental impacts of wastewater reuse in agriculture – and ways to mitigate those impacts – can only be understood within the socio-political and economic context that shapes farmers' perceptions of wastewater reuse in agriculture. Furthermore, bottom-up organizational structures, especially, water users associations (WUAs), played an important role in representing the diverse socio-economic and political statuses of the different farmers' groups and in determining their willingness to accept wastewater reuse in agriculture.

6.2 Positionality

Prior to my involvement in this PhD trajectory, my main academic interest was the 'informal' practices by which agrarian communities remediate their water supply and sanitation services. Specifically, I was interested in the challenges in this respect faced by communities in which governments are unable or unwilling to invest in expanding or improving these services due to, for example, their commitment to other priorities, mainly being urban settings. This background played a crucial role in shaping the general lines of this PhD project, as the socially embedded arrangements that bring together water resources management, sanitation, and agriculture were at the core of the research question. In addition to my background in the field of water and sanitation, my positionality in this research was shaped by the different research stages and factors that figured in the research (Figure 6.1).

6.2.1 Four stages that shaped my positionality

This section highlights four research stages that were key in shaping my positionality in the investigation. The four stages are the research proposal stage, my engagement with the ReWater MENA project partners and stakeholders, security restrictions and COVID lockdowns, and the field interviews in Egypt and Jordan.

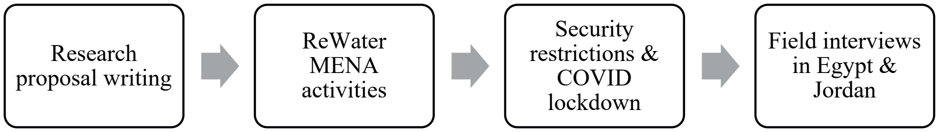

Figure 6.1 Research stages that shaped my PhD project trajectory.

The research proposal writing stage took place on campus at Wageningen University in the Netherlands before the official start of the ReWater MENA project. It was characterized by identification of potential research questions based on the theory of change for the ReWater MENA project which had been approved by the donor (section 1.3 introduced and described the project). The theory of change emphasized the role of participatory project implementation as an important element of the project. At this stage, the focus of the research was to be understanding the dynamics of the 'learning alliance approach' and how these donor-funded multi-stakeholder platforms, in the specific contexts of Egypt and Jordan, transformed the formal-informal dichotomy, existing politics and policies, and institutional practices in the water reuse sector. Therefore, the research initially aimed to better understand how the national learning alliances (NLAs) in Jordan and Egypt were constructed and facilitated, and what outcomes these 'spaces' of change and inclusion had for the water reuse sector. The research was set to critically examine the process design of the multi-stakeholder platforms with a special focus on the politics of participation within these platforms.

The second stage started with the official implementation of the ReWater MENA project in Egypt and Jordan. During the inception phase, I took part with the project partners in designing the participatory process and identifying the roles and responsibilities of each. During this stage, my main concern was how to design an 'effective' participatory process; that is, one that is inclusive and can lead to practical changes on the ground. (The next section provides further details on the 'participatory approach' process design.) At this stage, the debate around how to address 'wastewater' came to the surface, as the word 'wastewater' proved to elicit sensitivity in many stakeholders. Thus, the project team set out to find a 'better' word that was more acceptable (I elaborate on this in the coming sections). It was at this stage that I realized that the purpose of my PhD research could not be the promotion of wastewater reuse as a 'silver bullet' for water scarcity in Egypt and Jordan, but rather it should explore local socio-economic and political contexts surrounding waste/drainage water reuse.

The third stage was one in which I was confronted with several disappointments resulting in my inability to conduct field interviews as I had foreseen. This was due first of all to restrictions associated with the 'securitization' of the water sector in Egypt. This securitization was aggravated by the ongoing political debate between Egypt and Ethiopia on rights to Nile River waters. Accordingly, all water-related projects in Egypt, and other donor-funded projects, were required to obtain security approval to ensure they were aligned with the country's political stance in relation to water security. Though this already made access to the field more difficult, the situation became more onerous with the onset of the COVID-19 lockdowns, which brought the project and the PhD activities to a standstill. At this stage, I started to question the relevance of studying participatory project implementation in a context in which this 'participation' is technically selective of one group of stakeholders and excludes others. This view was affirmed during the lockdowns, as the 'participatory' engagement continued online and through hybrid means, which entrenched the exclusion of farmers from the discussion. As will be set out in the next section, analyzing a 'participatory process' that excludes a key stakeholder (i.e., farmers) from the start could produce only results similar to previous research, which has criticized the very notion of 'participatory processes' as a tool to implement development projects.

The final stage of conducting several field visits and interviews in Egypt and Jordan was an eye opener, as the gap between practice and the formulated policy and institutional arrangements (access arrangements to water) became clear. These visits also shed essential light on the socio-economic and political dimensions of water reuse and reallocation that had shaped farmers' acceptance of or resistance to wastewater reuse for irrigation. For instance, Egypt's wastewater sector is highly centralized, with overlapping roles and responsibilities. Whereas formal bureaucratic institutions here have an entrenched the centralized position of the state in wastewater management and reuse, farmers have continued to be excluded from decision-making processes (with the exception of those involved in the WUAs). This exclusion renders 'invisible' the practices that farmers adopt to access water for irrigation. This exclusion has long blurred and de-emphasized all non-formal arrangements for wastewater disposal, treatment, and reuse in the Nile Delta. In the NJV, farmers have long relied on freshwater for irrigation. Yet, in 2017 the government, facilitated by a donor fund, proceeded to implement a pipeline network to transfer treated wastewater from three wastewater treatment plants serving Irbid governorate to the NJV for irrigation, while reallocating the NJV's share of freshwater to cover the increasing domestic water demand in the growing city of Irbid. From the start, up to the time of this writing, NJV farmers have maintained their resistance to this plan and the government's systematic reductions of their weekly water quotas by adopting various informal water access arrangements to sustain their agricultural practices.

6.3 Factors shaping my positionality

During the stages, a number of factors contributed to shape my research positionality. I refer to these here as 'participatory project implementation', 'formal and informal arrangements', 'the term wastewater reuse and reallocation', and 'the unprecedented circumstances through which the research was conducted'.

6.3.1 Reflection on participatory project implementation

The proposal for this PhD research was initially directed towards investigating the role of citizen participation in wastewater reuse arrangements and the role of multi-stakeholder platforms in strengthening this role or overcoming the state's hegemony. Answering this question would have been achieved by evaluating the participatory processes established within the 'learning alliance platforms' of the ReWater MENA project in Egypt and Jordan. However, after the inception phase in which the project and management were designed and implementation agreements signed between IWMI, as the lead organization, and local partners, I realized that participation would be limited mainly to state actors with no real power in decision-making. It became clear to me that the 'participatory platforms' in the project were included in order to fulfill donor prerequisites, rather than as a tool to democratize the decision-making process.

This observation was based on how those platforms were designed, who were invited to participate, and who were left out. Similar observations are echoed in previous research, though the literature establishes that participatory processes are efficient when citizen engagement is 'as far up the ladder as possible' (Reed et al., 2018). The 'ladder' here refers to Arnstein's (1969) seminal work, *A Ladder of Citizen Participation*. Arnstein argued that 'there is a critical difference between going through the empty ritual of participation and having the real power needed to affect the outcome of the process' (Arnstein, 1969: 216). In the ReWater MENA project, the former situation was dominant, as all six NLA meetings which took place throughout the project's four years were designed to include high-level policymakers, former ministers, and experts. They were invited to provide input, while key stakeholders, such as farmers, mid-level bureaucrats, and wastewater treatment plant operators were excluded.

Faced with this reality, which I was not eager to investigate further, I turned to look for research questions that could contribute new or in-depth insights on the day-to-day challenges that shape wastewater (including drainage water) reuse practices, their acceptance or resistance, and the everyday politics that are often invisible in multi-stakeholder platforms such as those described above. On that last topic, I elaborate below.

6.3.2 Formal and informal arrangements

The main research question and tailored sub-questions aimed at understanding wastewater and drainage water management and reuse arrangements in Egypt and Jordan. To do so, a comprehensive lens was applied to discern the coexistence of two types of reuse arrangements within the same space. The first type is the 'formal' state arrangements regulated by state policies, standards, and laws. The second type is the socially embedded 'informal' arrangements practiced by farmers in rural areas to manage, enable, and in some cases, resist access to wastewater and drainage water as a source for irrigation.

While researching the local case studies, I learned that 'informal' water access arrangements reflect what the community values (i.e., water quality and/or quantity), what their real challenge is (i.e., health, environmental, and/or economic aspects of wastewater reuse), and how they find solutions to avert or mitigate that challenge. Formal arrangements, in contrast, reflect the state imaginary about fixing the current challenges and paving the way for future development. My analysis found that state institutions often perceived the coexistence of formal and informal arrangements as a 'zero-sum' game in which there was no place for the 'informal' or socially embedded arrangements in the development of water and sanitation services or in managing access to wastewater for irrigation. However, in reality, informal arrangements complemented the efforts of the state's formal arrangements by improving wastewater management and reuse in rural areas where formal arrangements have failed to progress as fast as in urban areas. However, the informal arrangements of wastewater management in rural areas do pose environmental and health risks, due to the lack of wastewater treatment infrastructure. Nevertheless, I would posit that water quality is not the real concern in a context of severe water scarcity. In such a context, farmers must compromise on water quality and irrigate with whatever source of water they have available in order to guarantee a successful crop at the end of the season, as crop production is for many farmers their only source of income.

6.3.3 The term 'wastewater' in regard to reuse and reallocation

Wastewater reuse in the MENA region, including the reuse of agricultural drainage water, is inevitable in many countries in order to successfully bridge the gap between water supply and demand in the context of intensified competition between and among different water use sectors and increasing physical water scarcity. In addition, the MENA region is witnessing exponential growth in urbanization and mounting competition over freshwater resources between the agricultural sector (the foremost water consumer) and urban water users. However, wastewater reuse potential in agriculture differs across the MENA region, where countries are at different levels of advancement in terms of their capacity to collect, treat, and reuse wastewater. These discrepancies are largely the result of socio-economic factors that enable or hinder national capacities and willingness to expand wastewater treatment and reuse – such as infrastructure development, social acceptance or resistance, and establishment of reuse standards and regulations.

In many arid and semi-arid regions, including MENA, freshwater scarcity will remain the undisputed driver urging governments to shift to treated wastewater reuse in order to reduce the supply-demand gap and boost the water budget. The formal shift towards reuse has been paralleled (and sometimes preceded) by 'informal' reuse arrangements that farmers have adopted out of necessity, though this informal reuse is hardly quantified. Farmers' 'adaptive management' approaches to ameliorate the impacts of freshwater scarcity (from a quantitative point of view) have long masked the economic and financial value of treated wastewater. Nevertheless, by looking at treated wastewater reuse beyond the notion of scarcity, other motives emerge for countries, even those with abundant freshwater, to consider treated wastewater as an integral part of their water resources management plans. These motives arise, for example, under the notions of circular economy, resource recovery, nutrient management strategies, and nutrient mining (Drechsel et al., 2015). To avoid pollution due to poor quality water entering the environment, these concepts have been adopted to promote sustainable economic growth, particularly in the agricultural sector, while reducing resource depletion and energy consumption.

Beyond this technical narrative, and as this research has demonstrated, 'wastewater' is still a contentious word (Wessels, 2023). It carries different meanings for different stakeholder groups and is a locus of socio-technical as well as political debate between groups of stakeholders with differing interests. Accordingly, this section reflects on wastewater reuse as an epistemological frame that lies at the core of this research.

One of the key objectives of the ReWater MENA project was to overcome the social and cultural obstacles that hinder wastewater reuse at scale in the target countries and in MENA. Accordingly, one of the key recommendations was to avoid using the word 'wastewater' and instead use more acceptable words such as 'reclaimed water', 'treated water', or 'recycled water' (Drechsel et al., 2022). This is justified by acknowledging that if wastewater is treated then it is no longer 'waste'. Also, the word 'wastewater' triggers a natural human aversion to products irrigated with this source of water. Reflecting on 'wastewater' as a terminology that is accepted by some and frowned upon or rejected by others became a key driver shaping my research questions as well as one of the findings of my research.

The debate over the 'wastewater reuse' terminology is even reflected in countries' decision-making regarding wastewater reuse arrangements. The analysis presented in this thesis found that Egypt and Jordan, for water quality reasons, have prioritized indirect reuse arrangements (in which treated wastewater is mixed with freshwater prior to its reuse in irrigation) over direct reuse arrangements. Consequently, indirect reuse in both countries is labelled the use of 'mixed water' in agriculture, not as 'treated wastewater reuse'. Furthermore, farmers' direct reuse of drainage water or treated wastewater in Egypt and Jordan is strongly condemned by the governments. When it is exposed it is framed as an individual violation rather than as common practice.

These different ways of perceiving the term 'wastewater reuse' have created multiple views that originate within the debate on wastewater treatment and reuse in agriculture. The first is the optimistic view, which considers treated wastewater as the only sustainable source of water, as it increases as population increases. This source of water can enable arid countries to expand their arable land, create job opportunities, and boost economic development. This framing is common in the literature (see Drechsel et al., 2022; Mainardis et al., 2022). Additionally, this optimistic view posits reuse of wastewater (even if not treated) as a water source that can quell farmers' discontent at the state's inability to fulfill its commitment by delivering an adequate supply of water for irrigation (Chapter 3).

The second view, however, is a more pessimistic one. It foresees the mainstreaming of wastewater reuse (even if treated) in agriculture as propelling the agricultural sector towards accelerated soil degradation, loss of productivity, loss of market reach (as in the case of NJV farmers who seek to export their agricultural products to the EU and Gulf States), and unpredictable health outcomes. This view, alongside the optimistic view, has dominated decision-making processes within bureaucratic institutions from the inception of wastewater reuse in agriculture up to the current day (Chapter 5). However, the first view currently seems to be prevailing, particularly with the support of donor funds, realization of large-scale infrastructure, and the 'rebranding' of wastewater as a new, safe, and reliable water resource that can be used for unrestricted agricultural activities (Chapter 4).

Although these two views are well justified, the analysis of the current research suggests that neither the optimistic nor the pessimistic view fully grasps the complexity of reallocating domestic and agricultural wastewater for reuse in agrarian communities where several stakeholders' interests are at stake. In fact, farmers in Egypt and Jordan, particularly those in the two case study regions, were heading towards severe water shortages that their governments appear ill-prepared to address by traditional water supply and demand management approaches. Accordingly, farmers in the two countries have adopted various forms of informal water access arrangements to maintain their agricultural activities. Moreover, they expressed willingness to expand wastewater reuse, regardless of short-term and long-term environmental and health impacts (Chapter 2). However, the current political economy context is decisive in enabling or constraining farmers' ability to access waste/drainage water for irrigation. For instance, Egypt's powerful agri-business stakeholders and the state were treating drainage water and reallocating it to expand the agricultural frontiers into the desert, while smallholders on the 'old lands' of the Nile Delta were set to lose their access to drainage water, though that water has maintained their agricultural productivity for decades. In Jordan's NJV, powerful farmers who sell their produce on export markets have resisted the introduction of treated wastewater to boost the irrigation water quota in the NJV, while less powerful farmers have indicated a willingness to reuse treated wastewater if it enables them to maintain their agricultural activities.

6.3.4 Unprecedented circumstances

This research was conducted during the unprecedented circumstances presented by the COVID-19 pandemic and lockdowns, as well as the securitization of water-related topics in the countries of interest. Both these circumstances affected my ability to conduct extensive fieldwork in Egypt and Jordan. As a result, questions remain regarding waste/drainage water reuse in the two case study countries. The following five are of particular interest from my own perspective as researcher: (i) quantification of the volumes of waste/drainage water reused through informal arrangements in the Nile Delta, (ii) quantification of the impacts of informal access to freshwater for irrigation on overall water availability in the Northern Jordan Valley; (iii) the potential impact of waste/drainage water reuse on agricultural productivity, particularly in Egypt and Jordan; (iv) the impact of waste/drainage water reallocation on smallholders' livelihoods; and (v) the impact of waste/drainage water reallocation in creating new forms of informal water access arrangements in marginalized agrarian communities.

6.4 Conclusions

From this research, we can conclude that policies on waste/drainage water treatment and reuse and the reallocation of water flows (both drainage water and freshwater) are influenced by political drivers that seek to close the gap between water supplies and demand and achieve governments' imaginaries of agricultural development. Though this is a politically driven process, it is supported and advanced by notions of irrigation efficiency, agricultural profitability, infrastructure development, and modernity that work to depoliticize reallocation mechanisms.

In the context of the two case studies, we observe two types or levels of drivers of water reuse and reallocation: the political drive at the national level and the drive of everyday practices. Although these two operate at different scales, both shape waste/drainage water flows and access through various instruments and mechanisms. The national-level political drive is linked to the state's development strategies in which expansion of agricultural frontiers plays a crucial role in realizing imaginaries of development and advancement (Chapter 4). At this level, the irrigation water needs of smallholder farmers are marginalized (or even 'dwarfed') by the scale of newly developed large-scale infrastructure (e.g., the Al Mahsama mega plant for drainage water treatment and the three pump stations by which drainage water is reallocated for reuse upstream). This is further supported by the promotion of national policies that aim to reduce farmers' irrigation water needs (e.g., compelling them to replace surface irrigation with drip systems). At this level of state control, the involvement of powerful actors, such as the Armed Forces Engineering Authority and agri-business enterprises, works to propel the implementation of reuse and reallocation schemes beyond the government's usually slow bureaucratic pace.

The second type of drive is that of everyday practices which shape access to and distribution of irrigation water among farmers. The NJV case study demonstrates that despite national political interest in implementing wastewater reuse and reallocation, rich and influential farmers in the NJV have remained able to resist (and as yet block) this plan. In their perception, the plan would negatively affect their access to agricultural export markets in the EU and the Gulf States, due to restrictions imposed on crops irrigated with treated wastewater (Chapter 5). In contrast to this group, less powerful 'ordinary' farmers in the NJV expressed willingness to accept wastewater reuse in agriculture in order to alleviate the conditions of water stress that hindered their agricultural productivity. Yet here, access to and reuse of treated wastewater was shaped by the influential farmers, who erected a barrier preventing operationalization of such a plan.

The analysis found that waste/drainage water reuse had a significant role in ameliorating the impacts of water scarcity and maintaining the agricultural productivity of smallholders in both Egypt and Jordan (Chapter 4 and 5). Drainage water provided for an estimated 15% of crop water requirements in the Nile Delta. To maximize this contribution, needs-driven reuse and reallocation plans should replace politically driven ones. In addition to empowering smallholders by strengthening their role within decision-making processes, WUAs should be restructured to better represent the heterogeneity of farmers' perceptions and needs (Chapter 5).

The analysis, furthermore, demonstrated that formal and informal reuse and water access arrangements coexist within the same geographical, social, and political spaces (Chapter 3). However, the formal bureaucratic system often renders informal arrangements invisible, by framing them within the sphere of illegality and violation of the formal system. On the ground, however, the formal bureaucratic system creates an enabling space for informal arrangements to flourish, since these latter arrangements provide smallholders sanitation services (Chapter 3) and irrigation water (Chapter 4 and 5) that formal arrangements have been incapable of providing.

The presence of informal arrangements in Egypt and Jordan is not solely because the two countries' governments allow them to exist. On the contrary, governments' traditional focus on infrastructural and organizational water control aspects, with less attention given to the local socio-political and economic context, has resulted in farmers' adopting informal arrangements as a form of resistance to the formal plans (Chapter 5). Farmers have thus engineered informal arrangements as an adaptive mechanism to access water for irrigation and overcome immediate water scarcity, so as to maintain their agricultural productivity.

In the NJV, informal arrangements were further divided into two forms. One form was practiced by richer and more influential farmers, and included such strategies as requesting extra water quotas, which were 'promptly provided' from the Jordan Valley Authority (JVA). Such a practice was not reported by 'ordinary' farmers who were experiencing reductions in their regular water quotas. Additionally, richer farmers had the resources to abstract water from deep, often saline, groundwater wells, which required the additional step of desalination prior to use for irrigation (Chapter 5). Yet, 'ordinary' farmers had fewer options in accessing irrigation water through informal practices. One of these was tampering with the farm turn-out assembly (FTA) units that regulated the volumes of water entering a farm unit. Other farmers replaced the pipes receiving water from the FTA with wider diameters – to allow larger volumes of water to flow into their farms, though depriving farmers downstream of access to their designated water quotas (Chapter 5).

Most of the 'informal' practices identified by this research in Egypt and Jordan were illegal; that is, farmers using them could face financial penalties or even jail if exposed. However, the financial gains from increased water availability through informal access arrangements outweighed the costs incurred, in the form of fines or bribes paid to local bureaucrats. Particularly, farmers who feared losing their access to regional and international markets and were well connected to existing power networks could practice informal access arrangements with impunity.

The ongoing dynamic between the formal and informal arrangements highlights the important role of large-scale infrastructure in shaping wastewater reuse, reallocation, and access mechanisms. The current analysis points to state-controlled, large-scale infrastructure such as mega plants for wastewater treatment (e.g., El Mahsama in Egypt) and reallocation pumps, pipes, and canals (e.g., NJV reallocation infrastructure) as a key leverage point through which the state enables or constrains farmers' ability to benefit from informal wastewater for irrigation (Chapter 4). Although the development of large-scale infrastructure is overseen by government, the two cases in Egypt and Jordan demonstrate that other powerful actors may also be involved, such as the military and donor organizations. Their contributions play a vital role in enabling such infrastructure to be established at a faster pace than allowed by traditional bureaucratic processes.

More broadly, this analysis found the development of large-scale infrastructure was associated with a reformulation of the formal institutional arrangements governing water allocation and distribution among farmers. However, formal policies, regulations, standards, and laws did not always favor existing farmers and farming regions. The new irrigation water quotas for NJV farmers and the new policy imposing water-saving irrigation techniques for smallholders in several parts of the Nile Delta in Egypt are just two examples of the implications of state control over water reuse for smallholders and their future livelihoods.

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