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‘Squeezing Out’ the Nile Delta’s Drainage Water to Irrigate Egypt’s Desert Land

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Abstract: Egypt’s quota of Nile River water has been constant since the 1950s, despite the continual agricultural land expansion. To facilitate land reclamation, Egypt has reallocated Nile water from downstream users, mostly smallholders in the ‘old lands’ of the Delta. As water demands have grown, more attention has gone to the reuse of waste/drainage water as a reliable source for irrigated agriculture in the “old lands”. 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 article scrutinizes this transformation of access to drainage water, examining who 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. It argues that more attention should be given to existing informal reuse arrangements and that smallholders’ access to water is guaranteed in light of new drainage water reuse projects.

Keywords: Nile Delta; desert land reclamation; informal water access; wastewater; drainage water reuse

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1. Introduction

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 [1]. 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. 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 [2,3].

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 the discharge of untreated domestic and industrial wastewater into agricultural drains [1–3]. Barnes (2014) [4], 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 a 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 resource management in Egypt [5]. 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' [5] (p. 16). In practice, this has led to the 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 [6]. 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 [5–7]. In some respects, the interests of these smallholders and their communities, which are often poor, have been obliterated, and hardships have been aggravated.

Within this context, in which almost no critical academic and policy discussions on the new water reallocation schemes in Egypt are there, this article aims to problematize the new reallocation schemes from a socio-economic and political lens. This will take place by answering 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 have not been problematized.

After this introduction, the following sections expand on the research methodology, followed by the theoretical framework informing the analysis. This is followed by 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 are analyzed. Following this analysis, the article presents and analyzes the El Mahsama project, which is one of three drainage water reclamation megaprojects recently put into operation. The article concludes 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 a 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'.

2. Materials and Methods

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 carried out 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.

Theorizing Drainage Water Access and Reallocation

While land grabbing in Egypt has been covered by various authors (e.g., [6–8]), their discussions have not problematized water access arrangements, specifically the reallocation of water to enable land reclamation projects [9,10]. 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 [11].

This section investigates access mechanisms for the 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 [1], based on the work of Uphoff (1986) [12], presented in Table 1. 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 1. Wastewater management and reuse activities (Source: own elaboration based on Uphoff, 1986 [12]).

Wastewater Flows	**Technological Management**				**Institutions and Practices**
Containment/collection Treatment Conveyance Discharge/reuse	Design	Construction	Operation	Maintenance	Regulation and norm Conflict management Resource mobilization 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 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 [13].

'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 [14]. 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 the legal and socially embedded entitlements of individuals and institutions to govern and control water flows within a specific territory [15,16]. While the right to utilize water resources is often a contested matter between bureaucratic, formal arrangements and socially embedded ones [17,18], this conceptualization of water resource 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 [1–14]. 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 [1]. 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) [13]. The latter are embedded in the social-material context and related 'bundles of power' [13] (p. 154). In contexts where informal access rights predominate, the theory of access, as developed by [13], 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 for the control of waste/drainage water flows.

Ribot and Peluso [13] 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 1. This suggests three pillars by which access arrangements for water reuse for irrigation can be studied.

The first pillar is infrastructure, both small-scale and large-scale. The development and management of infrastructure are influenced and shaped by politics and specific interests [19]. 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 [20]. 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 to 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 play a central and fundamental role in defining and shaping the formal institutional arrangements through which water is managed in the 'formal' state-recognized domain [21]. 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 [22]. 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 about 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 [20] 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 and economic considerations [23].

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.

3. 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 shaping 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 1) [21].

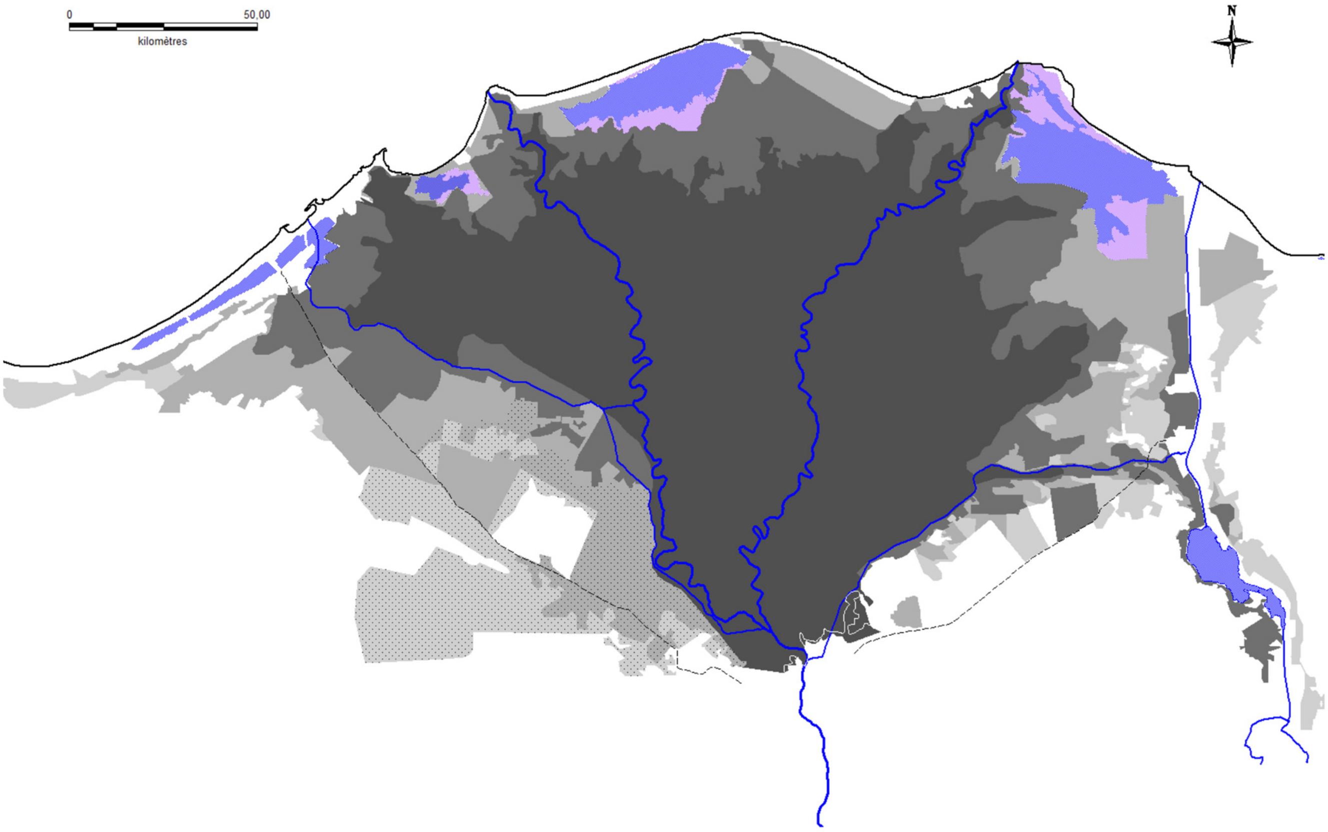

Figure 1. A dynamic delta with expanding land reclamation over time (dark grey color refers to the period of 1930; light grey color refers to the period of 1984–2000; blue color refers to the coastal areas; light pink color refers to the fisheries) (Source: [21]).

3.1. 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 [21]. At that time, water control projects were advanced for various socio-political and economic objectives [21]. 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 the construction of a barrage system to control by gravity the allocation of Nile River waters to agricultural lands downstream. Figure 1. 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 2). 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.

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 [24]. This was associated with agricultural 'modernization' and the development of large-scale infrastructure to control the flow of Nile water into the Nile Delta and Valley [24]. Later, this same infrastructure served to troubleshoot problems associated with hydraulic changes in the Delta, particularly salinity due to waterlogging [25]. Table 2 presents an estimate of the quantities of water secured for land reclamation by the various large-scale infrastructure projects 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) [26]. Thus, each reclaimed feddan (=0.420 ha) is assumed to be equipped with modern irrigation techniques and consume 4000–5000 m^3 of water per year [4–26]. 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 successive governments' level of ambition and persistence in working toward objectives of food security, employment creation, and urban development [8].

Table 2. Historical overview of land reclamation in Egypt (Source: [4,21–27]).

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	The 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	The 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 the 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) [21]. The sub-surface drainage system enabled the creation of nodes for control of drainage water throughout the Nile Delta.

The investment in drainage management infrastructure was accompanied by institutional development with 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 [27].

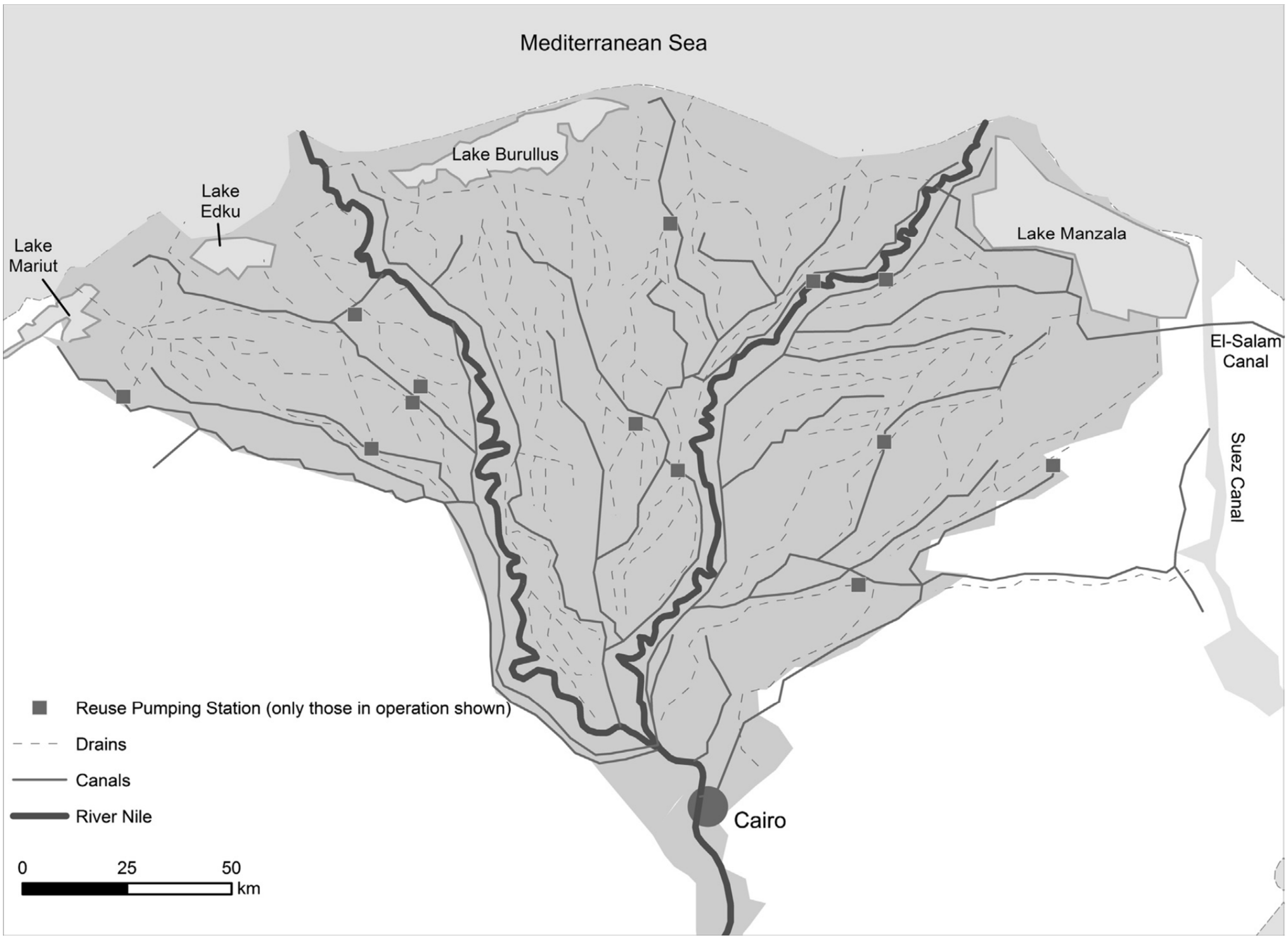

Figure 2. Pumping stations across the Nile Delta [1].

3.2. 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 [28]. 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 on the old lands [7]. 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 [29]. 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 access to subsidized fertilizers and pesticides [29]. However, this policy has not been operationalized and enforced as yet due to uncertainties surrounding the 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' [4] 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 are 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 MWRIs mixing stations (Figure 2). 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 farmers in the Delta, who are obliged to use drainage water as the main supply for their fishponds). Accordingly, drainage water, from a legal and formal perspective, cannot be claimed by farmers on the old lands.

3.3. Changing Access to Drainage Water

Drainage water access control and regulation play 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 [3], while other sources suggest that informal drainage water reuse provides for some 15% of crop water requirements in the Delta [30]. 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 [21]. 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 3). 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.

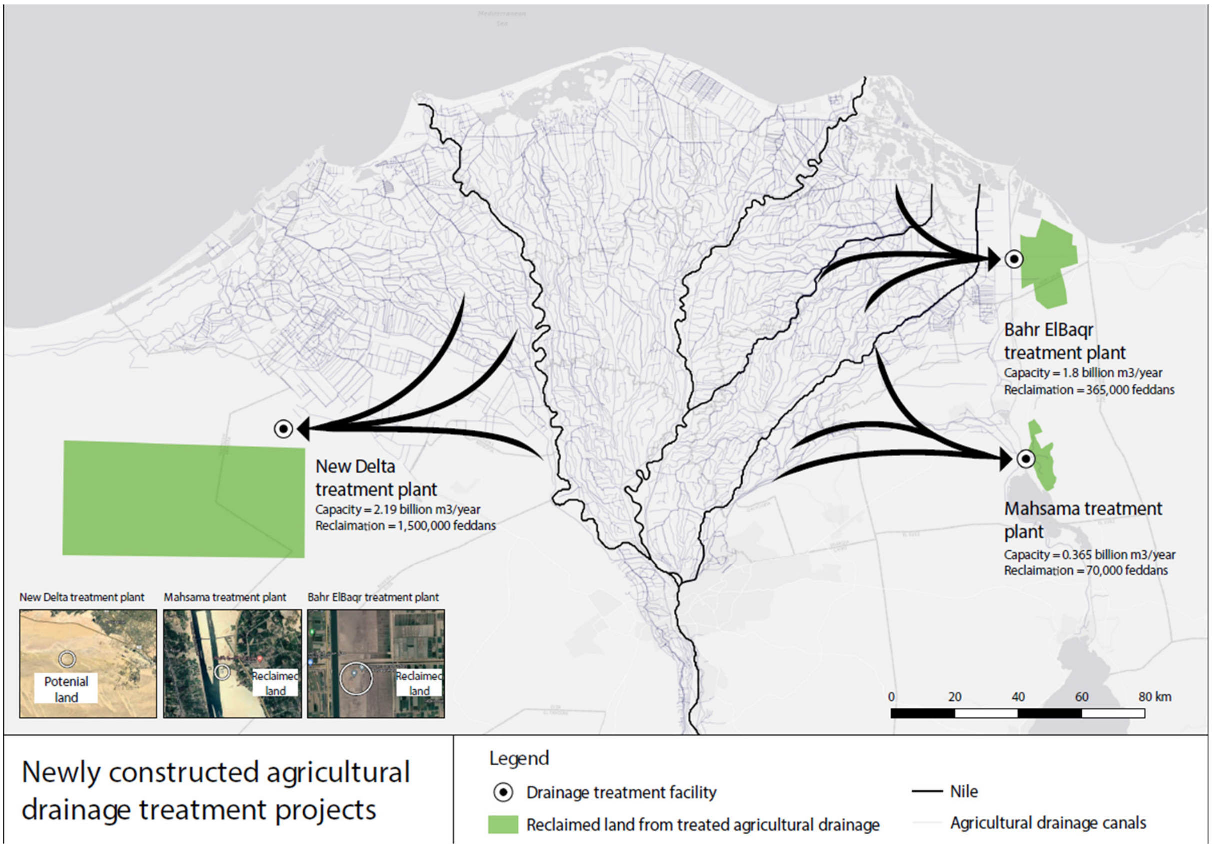

Figure 3. The locations of the three large-scale drainage water treatment plants (Source: author's own elaboration) Background tiles: Esri grey, 2022.

4. 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 are pumped upstream to the Al Mahsama treatment plant on the eastern bank of the Suez Canal. 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 [31]. 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 of 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 (Table 3).

Table 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 is 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 Mahsama (full capacity)	1 million m^3/day
	Drainage water is available to tail-end farmers downstream of Al Mahsama	0 m^3/day

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) 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).

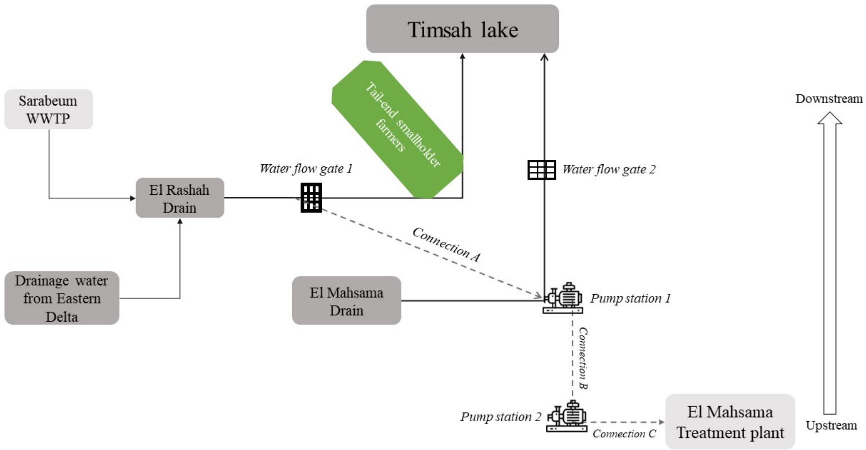

Figure 4. Water flow diagram in the study area of Al Mahsama.

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 (Figure 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 6).

Similar infrastructural developments have been reported at the Bahr El Baqar treatment plant and at 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 (The reallocated treated drainage water will also support the irrigation of the already reclaimed lands in those areas) around 1 million feddans (420,000 ha) of new agricultural lands (Figure 7 and Table 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. (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). It was thus easy to acquire these lands for the 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 5. Flow gate 1.

Figure 6. Direct abstraction of drainage water using a high-power pump to irrigate several large land plots.

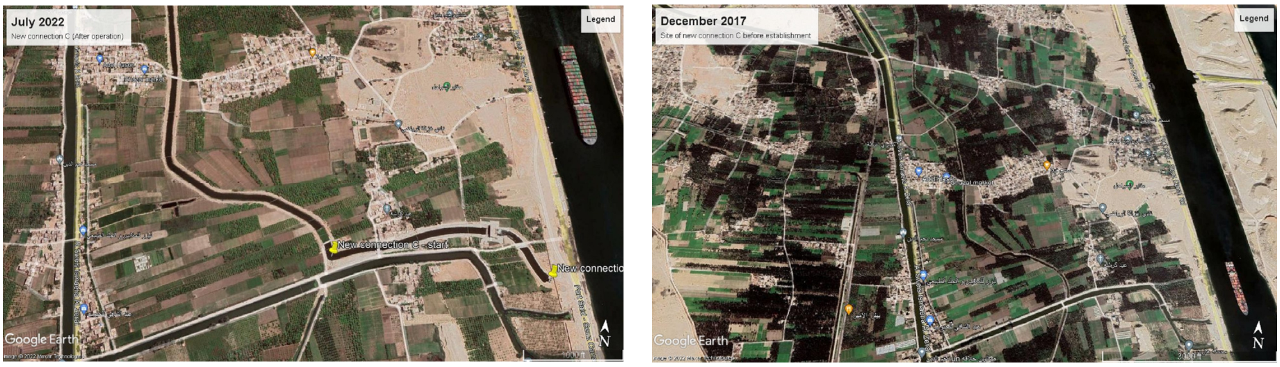

Figure 7. Land use before and after the establishment of the last connection, C.

Table 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	

5. Discussion and Conclusions

Water flow control and reallocation in Egypt is an old practice dating back to the establishment of modern Egypt during Mohamed Ali's time 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 reclaiming and irrigating lands outside the Delta region through the use of drainage water. Yet, this article demonstrated that these waste/drainage water reclamation schemes do not only tap into unused water but actually reduce the water access of tail-end smallholder farmers in the Delta. This article looked specifically at the predicament of tail-end farmers downstream of the Al Mahsama plant. 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. This 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 [1]). 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 8).

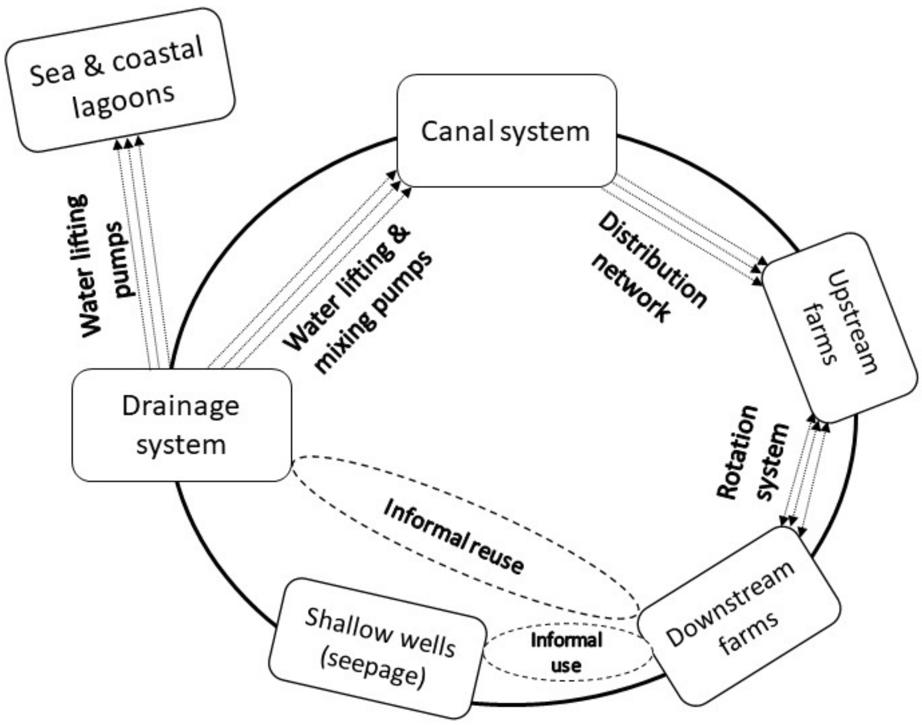

Figure 8. Formal and informal reuse arrangements as part of the irrigation water management system in the Delta.

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 [4–7]. 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, 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 9). Tail-end smallholders in the old lands of the Delta may soon be wholly deprived of access to waste/drainage water. Indeed, the operationalization of the new modern irrigation policy, which stipulates a shift to drip irrigation, would cause a significant reduction in drainage water flows.

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.

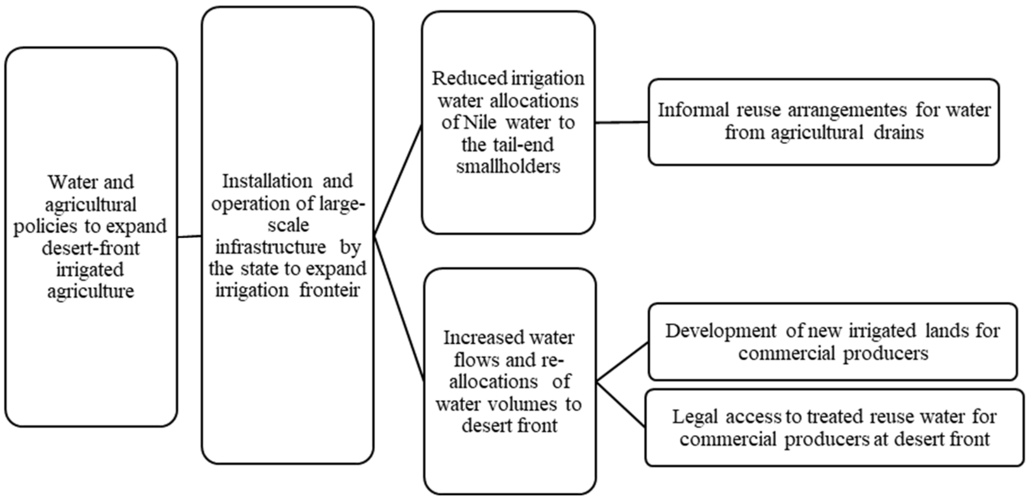

Figure 9. Two interlinked water access trajectories.

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 [1]. However, the use of all available wastewater from domestic and industrial sources might secure only a fraction of the irrigation needs of farmers on the old lands [14]. 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 [4], 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 [32] (p. 365), 'signs of defeat', rather than approaches to ensuring agricultural sustainability in the Delta.

On the other hand, if drainage water (mixed with treated wastewater) use practices are recognized as rights or entitlements of smallholders in the Delta, then it would be important to first warrant that these existing rights to access (drainage) water are met and protected. A second step would be to ensure that these rights or entitlements are warranted not only in quantity but also in quality. If the latter applies, then the water from the wastewater treatment plants should be used first and foremost to warrant these water uses and related rights (in quality and quantity) in the Old Delta Lands. This implies making more water of good quality available there, where it ought to be used in the Old Delta Lands. Technically, this would imply that water treatment capacity must be increased in the Old Delta Lands themselves and not at the fringes of them, as is now stipulated by current wastewater reuse policy and practice (e.g., Al Mahsama treatment plant). It would also require rigorous monitoring and evaluation procedures to ensure that agricultural drainage water quality meets safety standards prior to reuse for irrigation.

Such a shift would imply curtailing the ambitions for expanding new agricultural desert fronts through current water treatment and reuse policies and practices. This results from the fact that it would imply that only after existing water use demands and entitlements are met (in quantity and quality) in the Old Delta should water be allocated to newly developed or to develop desert front lands. In this way, the production and related livelihoods of producers in the Delta can be warranted. This means that less water would be 'available' for the expansion of the agricultural frontier and related development imaginaries. However, given the latter, it is politically very unlikely that strategies will be developed that defend and enhance the existing water rights of generally politically marginalized producers in the Old Delta Lands.

Likewise, the wished-for shift in focus and attention of policies to center existing water users and producers in the Old Lands as right holders and as political subjects seems far away as long as the existing power relations remain the way they are. Particularly, the current model of agricultural cooperatives in Egypt—farmers' representatives—is limited to tasks related to selling and distributing agricultural inputs (e.g., fertilizers, seeds, pesticides, etc.); which are often performed with low efficiency [33]. Those cooperatives have very limited bargaining and political power, and it is highly unlikely that agricultural cooperatives would be empowered to play different roles in the current political context. These existing power constellations and related interests will most probably continue with the existing policies, paradigms, and interests aimed at expanding the desert front agricultural frontiers for commercial agro-export agriculture.

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 are needed on 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.

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