Chapter 9. Egypt[1]

François Molle

Abstract: In no other country, perhaps, is the identification between water, irrigation, and agriculture as strong as in Egypt. Several phases of agrarian and technical change throughout its long history have taken Egypt to a situation where farmers grow between one to three crops a year on 3.78 million ha after lifting water from canals and drains, and sometimes from aquifers. This chapter first reviews the extraordinary cost of maintaining the delta 'irrigation machine', the history of irrigated agriculture expansion, and the evolution of public policies. It then examines key issues and challenges, including irrigation modernization, the search for water savings, the multiple experiences with participatory management at various scales, inter-sectoral integration, the water-food-energy nexus, the recent masterplan, and finally transboundary threats.

Keywords: irrigation policy, efficiency, water reuse, water balance, Nile Delta

1 Introduction

In no other country, perhaps, is the identification between water, irrigation, and agriculture as strong as in Egypt. With the exception of the oases in the Western desert and the Red Sea coast, the 5% of Egypt's territory where the population is settled (divided between the Nile Valley and Nile Delta) corresponds to either irrigated agriculture or urban settlements, both sustained with Nile water. Like several other countries in the region, Egypt's irrigated agriculture is responsible for 76% of total water diversions and more than 85% of water *consumption* (NWRP 2017). Irrigated agriculture has played a crucial role in Egypt's history, social fabric, and national economy, as well as in the livelihoods and food security of a population of roughly 100 million. Hence, the intertwining of water and agricultural policies is key in understanding the country's evolution.

Egypt (as at 2015) boasts an irrigated area of 3.78 million ha (or around 9 million feddan[2] [Mfed]), while rain-fed agriculture is negligible (CAPMAS 2018). This includes 2.25 million ha of Old Lands, the traditional farm land of the Valley and Delta, and 1.53 million ha of New Lands, which include land reclaimed from the desert adjacent to the Old Lands or in the oases. The social landscape of the new lands east and west of the Nile Delta, as well as the oases, is a complex and intricate mix of investors and settlers, including small farmers coming from the Delta, landless tenants, previous state farm workers, high school and university graduates, small and large investors, large companies, and state and other army-operated large farms. All types of irrigation technology can be found, from gravity and sprinklers to drip and pivot, using water pressurized by individual pumps or collective pumping stations.

Following an historical overview of irrigation/agricultural development, this chapter focuses on post-WWII irrigation policy, and examines how irrigation in the Valley and Delta is sustained and how it is adapting to changing conditions. The next sections are devoted to analyses of "horizontal" agricultural expansion, the interactions between agricultural policy and water/irrigation, and finally the key issues and challenges currently faced by the irrigation sector, including technological and

[1] Pre-print version of Chapter 9 In Molle, F.; Sanchis-Ibor, C. and Avella, L. (Eds), *Irrigation in the Mediterranean: Technologies, Institutions and Policies*. Global Issues in Water Policy Series. Springer.

[2] One feddan = 0.42 ha, roughly one acre.

institutional innovations. The chapter closes with a reflection on the link between irrigated agriculture and the wider policy and geopolitical contexts.

2 Brief historical overview of the development of irrigation

For millennia, the water management and irrigation of the Nile Valley and Delta consisted of guiding the rising tide of the flood—and its load of fertilizing silt—into interconnected compartments or basins (*houd*). The success and hazards of cultivation reflected the (mis)match between the timing, duration, and height of the flood, partly reshaped through a system of dikes and the planting of particular crops. Between 1810 and 1840, during the reign of Mohammed Ali, the dikes were heightened along the two branches of the Nile in the Delta (Rosetta and Damietta) and the canals that branched off them, which served to spread the flood waters, were deepened in order to be able to convey water at low flows (these canals were then called *seifi*). Water had to be lifted from the canals, so, by 1844, 52,800 *saquya* (water wheels) had been installed (de Sainte Marie 1989). However, this system proved to be too demanding in terms of labor and lifting power, prompting the solution to reduce the depth of the canals while raising water levels through the construction of cross-barrages. The construction of a first delta barrage began in 1833 but was not completed until 1862; several similar diversion barrages in Upper Egypt and on the Damietta branch were added later under British rule. This system allowed the cultivated area to reach 1.3 Mfed by 1885. A barrage was constructed in Aswan in 1902 and a storage dam upstream of Khartoum in 1937 (de Sainte Marie 1989; MPWWR 1990), while steam pump stations were established in the first decade of the twentieth century. Considerable literature exists on the history of irrigation and water control (e.g. Linant de Bellefonds 1873; Barois 1911; Willcocks and Craig 1913; Hurst 1957) and the evolution of agrarian systems (e.g. Rivlin 1961; Richards 1982; Cuno 1992; Mikhai 2008), to which the reader can refer for further detail.

In his “Irrigation Policy” proposed in 1935, H. Sirry Bey (1935) unsurprisingly offered a picture of policy focused on issues of storage (raising the Aswan Dam, the planned Gebel Aulia Dam) and on the necessity of improving water supply to water-short or new areas through: the widening, deepening, opening, and connecting of irrigation canals, the conversion of *houd* in Upper Egypt to *seifi* (summer) irrigation, the building of pump stations and locks, and the strengthening or raising of river barrages. These measures aimed to make maximum use of the natural flow augmented by the releases from the Aswan and Sennar dams.[3] In addition, the expansion of cultivation was reasoned in terms of the available budget and labor force (expected to come from Upper Egypt) and improved drainage (redesigning the drains and installing 18 pump stations to drain land below the 2.5 m contour line). Likewise, the 1950 official report “Irrigation and drainage in Egypt” reviews the networks of main, branch, and distributary canals, headworks, regulators, siphons, culverts, and weirs, and discusses water requirements, irrigation rotations, and how to improve and extend water distribution. “Long-term storage” is shown to be necessary and is expected to be secured by dams in Sudan (Merowe) and upstream countries.

Despite successive raising works, the limited volume stored in Aswan Dam had long nurtured dreams of a high dam nearby. While options had been considered as early as 1946, it was after the 1952 revolution that Nasser rekindled the idea and preliminary studies were launched. When the UK, US, and World Bank employed loan conditionalities and tensions were raised following the nationalization of the Suez Canal in 1956, Egypt turned to the Soviet Union for assistance in building the dam (MPWWR 1990). The High Aswan Dam (HAD) was finally constructed between 1960 and 1968, with a capacity of 162 billion m^3 (Bm^3) (including 90 Bm^3 of live storage), completely eliminating the flood regime and allowing the wide-scale development of year-round cultivation. It promised to expand the irrigated area by 1.2 Mfed, converting the remaining basin irrigation (0.97

[3] The Sennar Dam is located in Sudan.

Mfed) to perennial irrigation and guaranteeing the irrigation of at least 0.7 Mfed of rice annually, as well as improving navigation, controlling floods, and generating hydropower (ibid.). The project's detractors pointed to the loss of natural fertilization through siltation, evaporation losses, the risk of malaria, and coastal erosion.

Various experiments were conducted in the 1960s to determine "water duties" and optimal rotations for the Valley and Delta, with a general system of 5 days on/10 days off, a 7/7 system in summer, and a winter closure period in January. The 1975 water policy had a target of 16.76 Bm^3 of additional supply, mostly though the reuse of drainage water (12.2 Bm^3) and Upper Nile conservation projects, envisioning up to 2.5 Mfed of horizontal agricultural expansion. The 1980 policy reduced these figures, but updates in 1986 and 1990 aimed at an expansion of 1.6-1.7 Mfed with an "available water" volume of around 10 Bm^3 (Fahmy 1996).

Optimistic projections of available supply banked on the Jonglei Canal project in Sudan,[4] various rates of drainage water reuse and groundwater abstraction (in the Old Lands and oases), and greater efficiency. Yet they were "rather unrealistic and have not been based on solid scientific studies. Estimates given by experts are very subjective and are used to satisfy the mismatch between resources and requirements" (Fahmy 1996), without considering the interdependency between some of these measures. As noted by Hvidt (1995), despite the 1979-88 drought period causing Lake Nasser to receive 99 Bm^3 less water than expected and reducing the reservoir to an all-time low of 6.8 Bm^3 in 1988, the response still reflected a supply/managerial bias in line with entrenched planning practice. Indeed, the turn of the century would see the acme of an irrigation/water policy obsessed with expansion plans, including projects in the New Valley and targets reaching 3.4 Mfed.

Different dynamics were brought about by the liberalization of cropping patterns and prices in the late 1980s, the "counter-agrarian reform" unleashed by Mubarak in the early 1990s, and changes in water management due to the spread of individual pumps and technical problems faced by farmers, such as drainage. A shifting demand/supply ratio and pollution problems also began to materialize. Irrigation was becoming a more complex issue than the basic idea that had hitherto dominated water policy in Egypt: "that any excess water available should be devoted to the extension of the irrigated area" (El Quosy 2006).

3 Sustaining the Delta 'irrigation machine'

The Nile's water is diverted through eight river barrages to a 31,000 km network of public canals and 80,000 km of private *mesqas* (tertiary canals) regulated by more than 22,000 water control structures (MWRI 2002) that distribute water to plots, while 16,700 km of drains capture the return flow that is generated. Water distribution and drainage are aided by 583 large pump stations, not to mention the 3.6 million diesel pumps used by farmers. This 'machine' was not only very costly to set up but must constantly be maintained and improved in the face of particular challenges, such as local water shortages or soil salinization.

3.1 Draining the lands

It is often mistakenly believed that drainage problems arose with the perennial irrigation allowed by the HAD. Yet drainage problems were first recognized when the original Aswan Dam (1870) allowed some land to be irrigated in summer, meaning the year-round application of water. This prompted the opening of the first drains but not enough to prevent the collapse of the cotton crop in 1909 (van Achthoven et al. 20014). In the 1920s, H. Sirry Bey noted that, "the most convincing evidence of this [problem] is the deterioration noticed in the lands of Menufia and Kaliubia Governorates, which, up to the time of the Great War, were the richest lands of Egypt." In the 1930s, massive investment in

[4] This canal drains the Sudd wetland in Sudan to reduce 'losses' from evaporation.

pump stations allowed water to be drained from the lower half of the Delta where it could not be drained by gravity ("free flow"). This drainage "service" was provided to land owners at no cost. In 1949 drainage was made the responsibility of the Ministry of Public Works and the area serviced by open drains increased from 2.2 Mfed in 1952 to 6.9 Mfed in 1968, with a network of 17,000 km of drains (van Achthoven et al. 2004).

With the development of year-round cultivation, water tables rose across the Delta. Resulting waterlogging and salinity problems were initially neglected because of the lack of funds to cover the costs of secondary drainage system. By the mid-1970s, some 80% of the most productive land in the country had been affected (Richards 1980) and the issues were being addressed by a major World Bank-funded program of investment in drainage launched in 1970. The Egyptian Public Authority for Drainage Projects (EPADP) was established in 1973 (Abdel-Dayem et al. 2007; Ritzema 2009). Surface drains were excavated or dredged in order to maintain a water table depth of 1.5 m and an ambitious project was launched to provide all cultivated land with subsurface drainage (i.e. a network of pipes and collectors buried at a depth of 1.5 m) by the year 2012. Farmers were to pay 50% of the capital costs over 20 years, with a grace period of four years. Maintenance (un-clogging pipes by injecting pressurized air) is theoretically available for free at the farmers' request and lasts 25 years. In 1990, however, further costs were induced when it was necessary to replace concrete pipes with PVC/PE. In 2007, around 85% of the cultivated area had been equipped, at an actualized value of around US$1.5 billion. In 2017, EPADP had installed collectors over 6 Mfed, rehabilitated another 1.9 million (www.epadp.org.eg), with around half a million kilometers of draining pipes buried in the soil.

Experiments have shown that subsurface drainage has a substantial impact on yields of major crops, such as cotton and wheat, with increases ranging between 10 and 30% (Abdel-Dayem et al. 2007). Although well appreciated by farmers, the technology has its drawbacks with regard to the cultivation of rice, as it increases the water demand by around 30-40%. This problem has prompted the proposal of the so-called "controlled drainage" technique, where farmers may obstruct their subsurface collectors (that are accessible through manholes) in order to better retain water in their soil profile, but it proved hard to implement.

Draining the land also requires that secondary and outfall drains are free flowing until they join the sea. Due to the very flat topography of the Delta, it is necessary to close its various outlets to the coastal lakes or the sea and to artificially lower the water level in the drainage systems by pumping water over these closure points (maintaining a typical difference in level of 2.5 m). This battery of around 40 large-scale pump stations currently discharges an average annual volume of 13 Bm^3 to coastal lagoons and the sea (Molle et al. 2018).

3.2 The cost of maintaining the machine

Following the construction of the HAD, the function of the canals changed from spreading the flood to supplying irrigation water to plots. The clear water released by the dam and the increased use of fertilizers promoted weed growth in irrigation and drainage channels. As a result, the focus of maintenance needs shifted from desilting channels to the control of aquatic weeds (MoI and USAID 1986).

In 1983, the annual cost of channel maintenance was 57 million Egyptian pounds (US$104 million at 2016 value) (World Bank 1986). With a World Bank loan injecting US$130 million over eight years, the project aimed to introduce "modern channel maintenance practices," replacing the traditional system of desilting by excavation with a mix of weed mowing, herbicide treatment, and desilting. It built on similar projects developed since 1978 with Dutch assistance (biological weed control, training of EPAD staff), US$140 million from various USAID projects, and a CIDA-funded project. Between 1973 and 1999, the World Bank funded seven drainage projects, as well as Channel

Maintenance Projects and a National Drainage Project. USAID also funded projects (in the 1990s, for example, the IMS project included “structural replacement” that built or upgraded 20,000 structures.

The “irrigation machine” also includes close to 600 large-scale pumping stations that deliver water to higher New Lands and drainage water into canals, or out to the sea and coastal lakes. Their construction and maintenance have been funded by various World Bank projects, most notably three successive "Irrigation Pumping Station Rehabilitation projects" (1983-1992/US$42M; 1993-1998/US$31M; 1999-2007/US$194M with KfW). The equipment is the responsibility of the Mechanical and Electrical Department. According to the World Bank (1999), the loans, "reduce the operation and maintenance costs of the pumping stations with related beneficial effects on the Government's recurrent budget." Irrigation totally depends on these pumping stations, which explains the attention and outlay continuously devoted to them. Achthoven et al. (2004) estimated that over the years US$3 billion has been spent on subsurface drains, remodeling and deepening open drains, and constructing and rehabilitating drainage pump stations, but a full accounting in present value has yet to be done.

3.3 Conjunctive use of water against shortages

The establishment of a system of year-round irrigation over 2.5 million ha in the 1970s was not achieved without problems. Due to the complexity and ramified nature of the hydraulic network in the Delta, certain areas faced water shortages. The simplest response to the insufficient discharge in some canals appeared to be the re-injection of water from the main drains into the main canals. A total of 28 pump stations were therefore planned and installed with the objective of supplementing the main canals with 12.2 Bm^3 of drainage water. Unfortunately, in the early 1990s, several of these stations had to be abandoned (some were never even used) because the low quality of untreated, or partially treated, municipal and industrial waste water that entered the drains was unfit for irrigation. By 2005 (APP 2005), only half of the 29 reuse pump stations that had been installed were functioning well or with only minor problems. Water reuse therefore remained limited at around 4 Bm^3. The plan to obviate the pollution problem involved “intermediate reuse” pump stations, as they came to be called. These would abstract drainage water from secondary drains and re-inject it into secondary canals before it joined the polluted main drains and the quality became degraded. In the 2010s, a large number of secondary drains were equipped with such reuse pump stations. The amount of drainage water reused in irrigation in 1996 was about 4.4 Bm^3, growing to 6.4 Bm^3 in 2014 (DRI, 2015) with a target of 8.4 Bm^3 in 2017, according to the 2005 National Water Resource Plan (NWRP). The new NWRP (2017) estimates total drainage water reuse to have been 9.31 Bm^3 in 2015 and sets a “most probable” target of 16.26 Bm^3 by 2037, including 6.14 Bm^3 of treated wastewater.

However, this undeniably sound and effective way of increasing the available water for irrigation is reserved for the ministry and officially prohibited to farmers. Yet there is no attempt to enforce this probably obsolete regulation, as the ubiquitous individual pumps set up along the drains of the Delta have been, and still are, the chief response to water shortages. Elsewhere, topography allowing, irrigation canals are supplied by direct gravity diversion of drains (e.g. the Nashart drain in Kafr el Sheikh governorate). In the command area of the Meet Yazid Canal, for example, which serves an area of 85,000 ha in the central part of the Delta, a survey has found around 2,500 pumps along main and secondary drains of the northern half (Molle et al. 2016). Intermediate reuse pump stations and individual pumps have each been found to provide (at times of peak demand) an additional supply equivalent to around 10% of the canal's maximum flow (IWMI and WMRI 2010).

Over the past 15 years, this combined use of irrigation and drainage water has coincided with a dramatic increase in the number of farmers resorting to groundwater to offset local shortages. Approximately 60% of the Delta is affected by this mushrooming of shallow wells tapping the superficial aquifer (that is replenished by seepage from waterways and irrigated fields), the salinity of groundwater being too high in the northern fringe of the Delta. As a response to shortages, individuals or groups of farmers generally invest in wells, and these have reached densities of over 1 well for 2 ha (El-Agha et al. 2017). This gradual, yet intense, development of conjunctive use is highly typical of irrigation systems experiencing growing water scarcity. However, the consequence of this process is increasing quantities of salts being transferred to agricultural plots through the use of saltier water from both the drains and the aquifer (in order of magnitude 1 dS/m and 0.7 to 2.5 dS/m respectively, against 0.42 dS/m for Nile water). This increases leaching requirements and can impact yield.

The mixing of fresh and drainage water is not only used to respond to local shortages. It has also been taken as the basis for expanding irrigation on the two sides of the Delta. The Salam Canal to the east receives water from the Damietta Branch of the Nile as well as from two main drains intersected on its way to the new lands developed in the Sinai. The intended 50/50 mix has not been achieved and only a third of fresh water was supplied for two thirds of drainage water (Mohamed 2013), keeping the salinity of irrigation water at around 1 g/l. To the west, the Umoum drain, which flows towards Alexandria, is also equipped with pump stations designed to transfer water to the Nubaria Canal that supplies the New Lands on the western edge of the Delta. But water salinity and pollution problems have so far worked against the full utilization of these schemes. In 1992-2000, more than US$3 billion was spent constructing wastewater treatment facilities. The cost of increasing the treatment capacity by 2 Mm^3/day by 2007 was estimated at US$2 billion (Bazaraa 2002).

4 Land expansion strategies

4.1 The old 'New Lands'

The idea of expanding cultivation in the desert on a wide scale was first proposed in 1952 by Magdi Hassanein, as the Ministry of Agrarian Reform and Land Reclamation was being created alongside that of agriculture (Springborg 1979). In 1954, Hassanein was placed at the helm of the newly created Tahrir Province Organization and started advocating the idea of establishing a model collective farm, in contrast with the model of private ownership of small plots promoted by the Ministry of Agriculture and Irrigation and the Higher Committee for Agrarian Reform. Hassanein's vision was that, "such reclamation undertaking implied that land should remain under public property, and that the state should not divest it. On these new lands, Egyptian socialism will firm its victory through the possession by its people of the whole of this land" (in Gumuchian 1975). New lands were "not merely an agricultural project […] but an entire social experiment, the nucleus and vanguard of Egypt's new rural society" (Voll 1980). Newly reclaimed lands were divided into sectors of 50,000 fed on average, which were further divided into plots farmed by individuals under the supervision of cooperatives (Gumuchian 1975).

Socialist ideology was beefed up in 1964, as Khrushchev visited Egypt and announced that the Soviet Union would assist in the reclamation of 10,000 fed in the northern part of Tahrir Province (Figure 1) and the establishment of a model State Farm (Springborg 1979). State policy on land reclamation and associated land tenure patterns remained a hotly debated issue until the 1967 war, when Nasser himself attempted to satisfy all sides by stating that reclaimed land could be distributed to peasants, rented to individuals or companies, or farmed directly by the state, based on rational cost accounting and the specificity of each case. Reclamation had become a real bonanza for private construction companies as well as for "branches of the civil service and public sector with responsibility for reclamation and utilization of reclaimed land [… which] were liberally stocked with officers" (Springborg 1979) and whose private interests had become associated with the continuation of reclamation and state control over land.

In the 1960s, the Tahrir Province area and the Mariut sector were developed by the state, but settlement of small farmers also took place in Abis (south-east of Alexandria), as part of the Egyptian-American Rural Improvement Service Project (1952-1963) (Figure 1). The bulk of the land developed during the 1960s was reclaimed by state companies, although some work was also done through private companies (Hopkins et al. 1988).

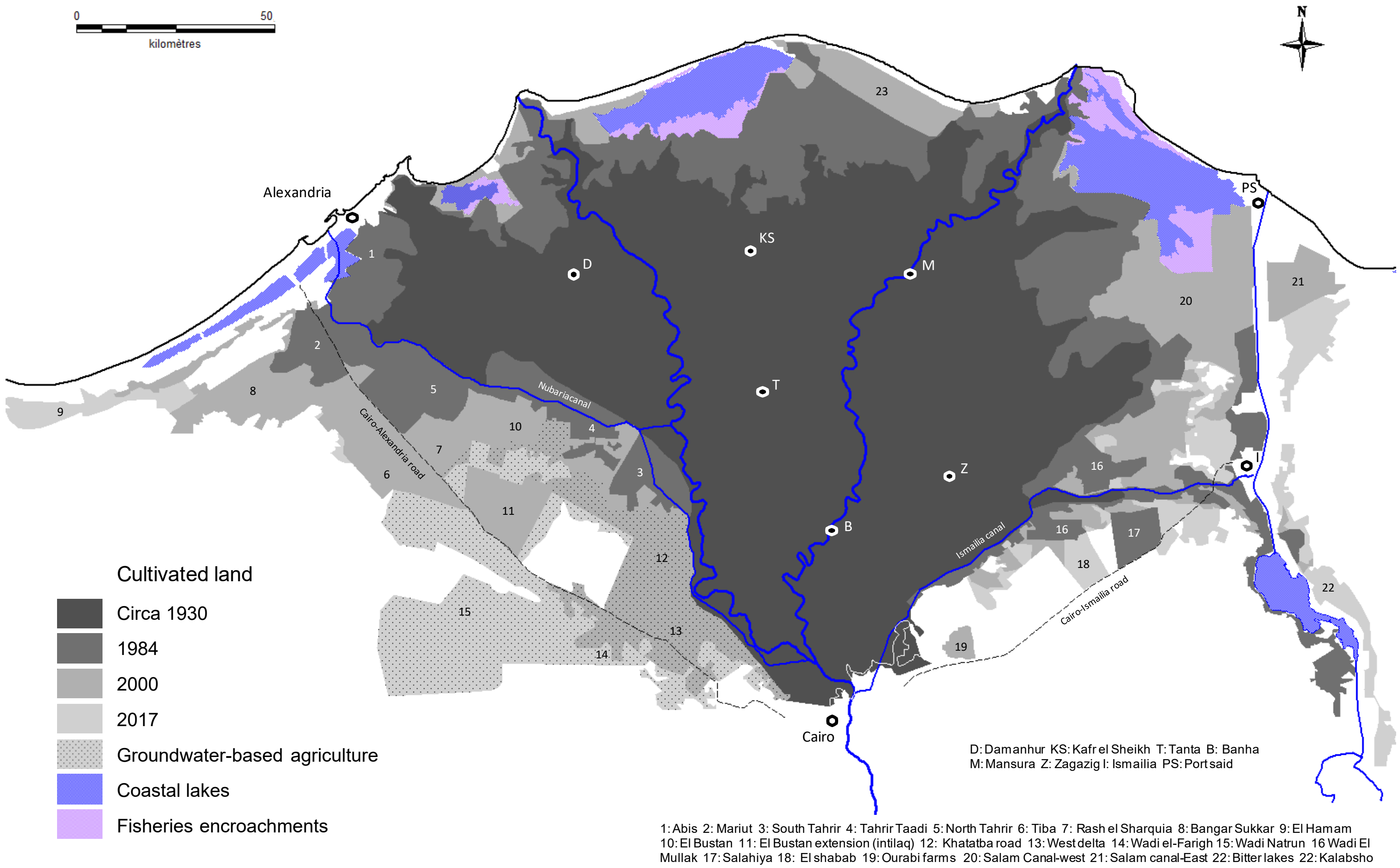
During the 1970s, land reclamation came to a halt (Meyer 1998) and political debates and decisions centered on the reorganization of the apparatus managing reclaimed land and on the redistribution of land. Many reforms were prompted by the disruption and financial difficulties associated with the 1973 war. Most of the new lands were partitioned between four independent companies established in 1973, which were given increased management autonomy, with an independent budget, in order to counteract excessive centralization and stifling bureaucracy. Peasants, however, remained integrated in the system of cooperatives, which set cropping patterns, provided seeds and equipment, and marketed production (Gumuchian 1975; Hopkins et al. 1988). In 1975, a decree organized the transfer of ownership of public land to the tenants who were farming it (Hanna and Osman 1995). A year later, a law was passed that widened the range of recipients of land to include new agricultural graduates, and, soon after, all graduates, as a way of compensating for the state's failure to keep its promise of providing every university graduate with a job (Hanna and Osman 1995).

4.2 The new 'New Lands'

In 1978, land reclamation was back on the agenda, with a target of 578,000 fed (242,000 ha). Most of this was to be to the west of the Delta (where new lands already totaled 200,000 fed in 1980: IFAD 1980) and supplied by the Nasr Canal, itself sourcing water from the Nubaria Canal (van Achthoven et al. 2004). In 1980, however, the World Bank (1980) stated that the performance of the reclaimed land was "sobering". It stressed the urgency of improving the selection and design of new land development projects. "Of the existing reclaimed land, less than 60 percent [was] under cultivation and possibly as little as 35 percent [was] being cultivated with profit. The principal difficulty had not been the unsuitability of the soils for crop production, rather it has been the deficiencies in technical design, such as inadequate drainage, and the 'company' approach to managing reclaimed lands." The Bank proposed a project that would introduce institutional change while making improvements to technical design, the small-farm settlement pattern, and agricultural services.

In 1981/82, reclamation works resumed with the Salhiya Project (~about 23,000 fed) (Meyer 1998) and the El Shabab Project (about 33,500 fed) on the eastern side of the Delta (Figure 1). On the western side, the World Bank funded a project to extend the Nasr Canal and expand cultivation in the area, which came to be known as Bangar Sukar. It was to be irrigated by gravity (basin), with the usual optimistic expectations that, "with good land leveling, training of farmers and adequate supervision, it is expected that the overall irrigation efficiency will be satisfactory" (World Bank 1980).

Figure 1. Historical expansion of irrigated agriculture in the Nile Delta



Notes: This map shows gross reclaimed areas. It does not show (expanding) urban, or small non-agricultural areas, such as airports, army camps, residual sand dunes, *kom* (mounds), etc. In some cases, the area indicated as fully reclaimed may only be partially cultivated (as in the case of El Hammam or Kalabsho). We have not shown areas under conjunctive use of surface and groundwater because this now virtually includes the whole Delta with the exception of its northern fringe. The agricultural area around Cairo has decreased: the map shows the extension in 1984 (not 1930) that covers the actual limit, which is indicated by a solid white line. Sources: Google Earth, Egyptian Survey maps.

It was originally conceived that the settlers of this land would be experienced farmers with families. However, given Egypt's swelling population of unemployed graduates it was decided that they too could be allotted land. In 1978, 3000 fed were distributed to settlers and 5500 fed to graduates in Nahda state farm, near Alexandria—a process that extended to South Tahrir (Tahadi area) (Corey 1978). In the mid-1990s, a third category of settler emerged: tenants who had been evicted under land reform, *mutadarireen* (more on this later), while some land was also earmarked for the "Mubarak graduate villages" (Adriansen 2009).

However attractive it may have been, the idea of reclaiming desert land encountered many technical and social difficulties that were not well anticipated. A severe problem experienced in many locations was that of waterlogging: large quantities of water applied to the soil resulted in perched aquifers, which in turn led to soil salinization and a subsequent rise in the water table that uplifted and destroyed the concrete linings of the main canals (IFAD 1980). Other problems included wind, which covered crops with sand and was combated through planted rows of casuarina trees, sandy soil with low fertility and limited water-bearing capacity, and the presence of undesirable minerals, such as calcium carbonates, gypsum, boron, and selenium (Hanna and Osman 1995). Technical difficulties included dysfunctional collective pumping stations and pipe networks serving 400 to 800 fed (Corey 1978), a costly and intermittent electricity supply, pump station breakdowns, maintenance difficulties, and a lack of qualified technicians (DDC 1997). Most collective pump stations broke down and were replaced either by smaller stations (for four or eight farmers) or individual pumps. These were funded by special projects (IFAD, Abu Dhabi Fund, etc.) or the farmers themselves.

Social difficulties also bedeviled the settlements due to transportation difficulties, a lack of infrastructure, medical services and schools (Hanna and Osman 1995; Hopkins et al. 1988; Ibrahim and Ibrahim 2003), a lack of capital, credit, extension services, and farm machinery (Corey 1978), and abuses of power by the cooperatives' officially nominated board members (Hopkins et al. 1988). Faced with a substantial rate of graduates abandoning their land (or renting it out to other farmers, more or less illegally), and in order to ease the land market, in 2002, the parliament passed an "Investment Law" allowing graduates to sell their land after a transition period of 10 years (Adriansen 2009). In 2003, according to Adriansen's (2009) calculations, 343,000 fed of land had been granted to a total of 69,962 beneficiaries, 64% of whom were graduates. This should not occult the fact that 60% of the newly developed land was sold off or auctioned to private investors in parcels ranging from 200 to 50,000 fed (van Achthoven et al. 2004).

Neither can it be ignored that the history of the allocation of new land was rife with stories of corruption—high-ranking military or police officers, officials, or large companies receiving land for nominal sums. Many urbanites were able to buy cheap land, for example in Wadi Natrun or along the desert road, on condition that it would be used for farming or industrial purposes, and then develop real estate or resell it (Ibrahim and Ibrahim 2003). Despite the setbacks and difficulties, New Lands – to the extent that they are supplied with water- have progressively established themselves as relatively productive areas, with a gradual shift towards drip-irrigated fruit tree crops (Alary et al. 2017).

Since the turn of this century, land reclamation has been mainly based on the use of groundwater by investors on the western and eastern fringes of the Delta (Figure 1). The best known area for corporate agricultural development is the so-called West Delta, located on the outskirts of Cairo, on both sides of the Cairo-Alexandria road. But these investors have now largely moved to other areas such as Wadi Natroun, Wadi el-Farigh but also East Oweinat et West Minyah (Acloque 2018).

4.3 The New Valley, Toshka, and recent expansion plans

The chain of oases—Kharga, Dakhla, Farafra, and Baharia—to the west of the Nile Valley forms a line often referred to as the "New Valley." In 1958, Nasser aroused people's imaginations by proclaiming its potential for 3 Mfed of irrigated land. Thirty years later, the state had developed a few hundred deep wells and allocated 19,000 ha of land (only half of which was actually irrigated). The administration, and its new laws regarding the control of land and water, had largely displaced pre-existing community water and labor systems, creating a new peasantry dependant on the state. Traditional wells had dried up because of falling water tables and salinity built up for lack of drainage facilities (Faggi and Maury 1987).

The "Ground Water Pilot Scheme, New Valley, 1972" prepared by the FAO assessed the cultivation potential to be 400,000 fed for 200 years (Abou-Korin 2002). But the situation at the turn of the century was disappointing, as all wells had lost their artesian characteristic and 30% of the land that was cultivated in 1965 had been abandoned due to the shortage of water (ibid.). As a result, the area currently cultivated in the oases does not exceed 120,000 fed (Sims 2015).

In 1997, the oases were grouped together with Toshka and East Oweinat in the "South Valley Development Project." This was backed by the first version of a new 20-year NWRP ending in 2017 that envisioned the reclamation and irrigation of 3.4 Mfed, with 1.4 Mfed in the South Valley Project. Located to the west of Lake Nasser and believed to be a former course of the Nile River, the Toshka depression is also the spillway of the HAD and received large amounts of excess water in October 1996, rekindling old projects to divert water to the “New Valley.” The project announced by Mubarak in 1997 consisted of a huge pump station that would abstract up to 5 Bm^3/year from the HAD and convey water through a 70 km-long canal to 540,000 fed of land to be reclaimed in the area (Wahish 1998). Toshka was presented as the "project of the new millennium," the "building of a new society" and a "new civilization." Accompanied by much fanfare and political propaganda, it was closely associated with President Mubarak's cult of personality (Deputy 2011).

Investors in the South Valley Development Project received a 20-year tax exemption and were exempted from import tariffs on capital equipment and machinery. They were able to buy the land for LE50/fed (~US$30/ha at current value) when the price of a feddan in the Delta could fetch over LE20,000 (Wahish 1999). Conspicuous among the (foreign) investors was Prince Al-Waleed Bin Talal, who acquired 100,000 fed of land. Diversely seen as a development plan destined to thwart extremism, as claimed by Mubarak, a presidential project under the army’s control and to its economic benefit (Warner 2013), or a strategy to claim prior use of Nile water and strengthen its position at the basin level (Waterbury and Whittington 1998), the project faced many difficulties and never developed as planned. Although internal dissenting opinions were initially silenced, the lack of a feasibility study or cost-benefit analysis nurtured critiques that surfaced after Prime Minister Kamal el-Ganzouri, the project's key supporter, was replaced in 1999 and the project faced its first obstacles on the ground (Al-Ahram Weekly 2000; Sowers 2003). The project was gradually shelved. With the weakening of the regime, and in the aftermath of its fall in 2011, sharp criticism appeared freely in the media, asserting that the deal struck with Bin Talal had been “illegal” and "Mubarak’s pyramids" a "mega-failure" (Egypt Independent 2014). Once in power, however, the Muslim Brotherhood—long-time critics of the scheme—unveiled a plan to settle one million people in Toshka.

Other flagship projects of the Mubarak era include East Oweinat (750,000 fed, close to the Sudanese frontier, which mainly seems to have benefited the army) and the Northern Sinai Agricultural Development Project (NSADP), which aimed to resettle 750,000 Egyptians on 92,000 ha of irrigated land west of Suez and 168,000 ha in the Sinai proper. The former area had been largely reclaimed from marshy land (and parts are now home to aquaculture), while the latter has been subject to very high salinity levels that could not be successfully leached. As a result, only part of the area is used, also for aquaculture. Other more distant areas into the Sinai have remained undeveloped for lack of water.

In a repetition of history, in 2014, President Sisi announced that the government was planning to reclaim 4 Mfed of desert land, a target that was soon reduced to a “first phase” dubbed the "1.5 million fed project" (Al Ahram weekly 2015). Ninety percent of the area, distributed over 12 governorates, would be irrigated with water from 3,500 deep wells. Unsurprisingly, the project has so far been mired in issues including the availability of water, insufficient logistical capacity, the lack of a feasibility study, a lack of transparency, uncertainty over the type of crops, and encroachment on the targeted land.

Verhoeven (2015) suggests that the logic of land expansion, whether cloaked in Malthusian narratives or nexus positivist thinking, primarily serves to sustain the clientelist practices that are at the root of state building and reproduction, notably by providing opportunities for capital accumulation in land reclamation and agricultural development (Dixon 2013; Roccu 2013). Springborg (1979), Sadowski (1991), Sowers (2003), and Dixon (2013), among others, have described the alliances between business interests and the government and its bureaucracies. While land expansion has overall been very costly, politically oriented, and has attracted much criticism, New Lands have come to represent a substantial proportion of Egyptian agriculture—one that grows as Old Lands are gradually urbanized. According to the MWRI (2014), the total expanse of New Land, complete with infrastructure, was 2.27 Mfed in 2012, of which only 1.49 Mfed were cultivated (0.6 Mfed with groundwater), while 0.24 Mfed were said to be “in progress.” But the reports also point to the “uncontrolled horizontal expansion” in the country. Estimated at 0.36 Mfed in 2010 (ibid.), this is irrigated by private initiative, mostly based on groundwater.

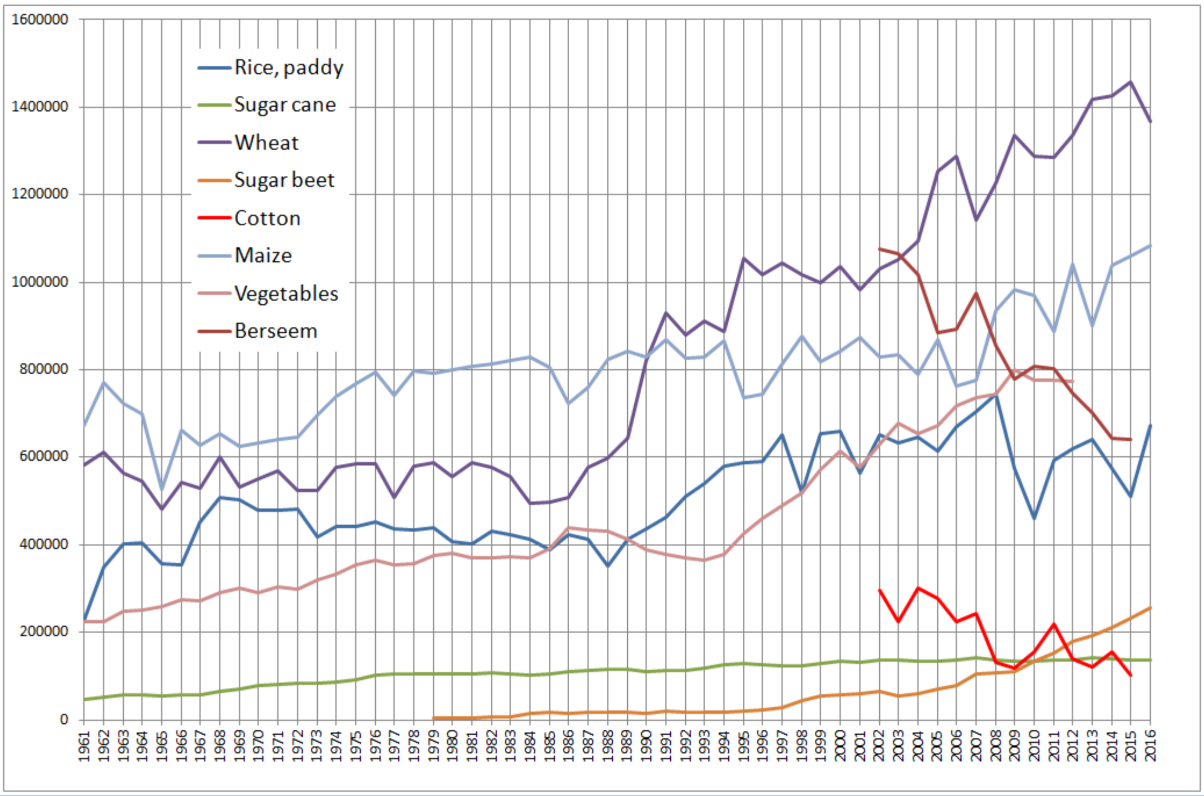
5 Irrigated agriculture and the policy context

5.1 Farming in the Delta and the Valley

Egypt's 3.78 million ha of irrigated land can be roughly broken down as 60% (2.25 million ha) Old Lands and 40% (1.53 million ha) New Lands (CAPMAS 2018). Although 37 million people live in cities, 55 million still reside in rural areas (Faostat 2015). While the agricultural sector only accounts for 11% of the national GDP, its contribution to employment is 29% (Tellioglu and Konandreas 2017).

The main crop is wheat, with around 1.4 million ha planted each year—a key commodity with regard to family- and national-level food security—followed by maize, berseem (clover), vegetables, and rice. Sugar cane, sugar beet, and cotton form a second group, each covering an area of around 200,000 ha (Figure 2). While the production of rice, wheat, vegetables, and fruit trees (in the New Lands) has been on the increase over the past 30 years, other crops, such as cotton and berseem have declined. Substitution within cropping patterns largely reflects the market and state subsidies, but the sheer dominance of wheat, rice, maize, and berseem gives a clear sign of the need to feed families and farm animals.

Figure 2. Evolution of main irrigated crop acreages in Egypt, in ha (source: FAOSTAT & CAPMAS)



In 2000, of a total of 3.21 million farms, 68% were under 2 fed in size (22% of the total area) and 91% less than 5 fed (50.6% of the total area). Farms over 10 fed represented less than 3% of the total number but a third in terms of total area (Ayeb 2010). This crudely shows a skewed distribution of land, although very large farms run by investors are only found in New Lands.

Labor in irrigated agriculture has been found to be dependent on macro-level factors, such as the government's absorption of labor and outmigration, in particular to the Gulf countries. This saw a hike following the inflation of the 1970s and a drop after the Iraqi wars and had a big impact on real wages (Meyer 1996). Shrinking land and a growing rural population have meant there is sufficient labor, although the cost of paying for it has led farmers to adopt water-saving techniques, such as the direct seeding of rice.

5.2 Market liberalization

Agricultural policy in Egypt was heavily influenced by American aid through the USAID-funded Agricultural Production and Credit Project (APCP) (1987-1995) and later the Agricultural Policy Reform Program (APRP) (1996-2002), as well as the World Bank (Agricultural Development Projects and Agricultural Modernization Project) during the same periods. In the 1980s and early 1990s, watchwords revolved around privatization and reform of the public sector (with the creation of "holding companies"), and the liberalization of agricultural markets and cropping patterns (El-Fellaly and Saleh 2004). In the mid-1990s, priorities shifted towards private investment and privatization in agribusiness, agricultural sector support services, and land- and water-resource investment and utilization.

Reforms of the agricultural sector in 1986 included the complete liberalization of producer prices for all products except cotton and sugar cane, the elimination of subsidies for input and credit, promotion of the private sector in processing and marketing, and the removal of barriers to imports and exports (Meyer 1996). In 1992, one year after Mubarak had agreed to an IMF and World Bank

Economic Reform and Structural Adjustment Program (ERSAP), a crucial law removed constraints on land rental and terminated all lease contracts by 1997.

There is no consensus on what these reforms really produced. International Financial Institutions (IFIs) and the state boast huge improvements in productivity and diversification, while other observers question the statistics and point to evictions of poor, landless tenants (Bush 2007). Oddly, no comprehensive or convincing study of agrarian change has ever been conducted. Opposition to the land tenure reform generated conflict, but it did not spread widely, either from fear of violent repression or because the effects of reform were weathered out.

IFIs ceaselessly lament the persistent under-performance of agriculture and its poor management and structural weaknesses. Inevitably they recommend further liberalization of Egypt's trade regime—a call backed by the US and EU, who, at the same time, lavishly subsidize agriculture. What seems less controversial, however, is that the obsessive promotion of capital-intensive, export-oriented agriculture in the New Lands by both the government and its foreign supports favors capital and does very little to provide jobs or address issues of land and market access in the Old Lands, not to mention food security (Bush 2007). The official discourse, and that of the IFIs, has promoted the idea that "Privatization has become an urgent necessity in water management projects in Egypt […] Many experts view privatization of irrigation projects as a step that will lead to rationalizing the use of water and relieve the government of the huge costs of giant irrigation projects required in the coming few years" (OOSKAnews 2013).

Export-oriented and capital-intensive agriculture has tapped markets with high certification standards (supermarkets and export), and donors, notably USAID, have entertained the hope that small producers could benefit from such linkages through contract farming in different guises. Yet there are few emerging success stories beyond the time span of specific projects, and investors are instead experimenting with different forms of externalization of risk and cost by providing small farmers with training and/or land and water to produce crops, such as potato and strawberry, for their export market (Acloque 2017).

5.3 Conflicting agricultural and irrigation policies

Egypt presents a typical case of an institutional setting where the responsibility for irrigation is divided between a Ministry of Agriculture and Land Reform (MALR) and a Ministry of Water Resources and Irrigation (MWRI). These administrations have different mandates and objectives that often translate into conflicting policies. The duty of the MALR is to expand agriculture and enhance its economic and social value, while the water administration tends to be more keenly aware of the limited availability of the resource, since overexploitation generates water shortages and management difficulties. A major policy fault line between the ministries is an understanding of how far it is possible to improve irrigation efficiency.

In its "Sustainable agricultural development strategy towards 2030" (ARC 2009), the MALR proposes "to achieve a gradual improvement of the efficiency of irrigation systems to reach 80% in an area of 8 Mfed, and to reduce the areas planted with rice from 1.673 Mfed (2007) to 1.3 Mfed by 2030, in order to save an [overall] estimated 12.4 Bm^3 of water." "Savings" would in turn allow the expansion of irrigation over 3.1 Mfed, with a cropping intensity estimated at 199%, and an increase in economic water productivity of 119% by 2030. This proposal is dismissed by most water decision-makers in private but rarely openly criticized in the media, revealing the perception of the power balance between the two ministries. Indeed, water savings of 12.4 Bm^3 would almost exactly match the quantity of water pumped out to the sea, which is absurd considering the importance of this drainage for the removal of salts and pollutants from the Delta. Such debates, sometime framed with disconcerting arguments that partly reflect the competition for budgets and megaprojects.

Many other tensions exist between the two ministries. Issues include their roles, remits, and budgets in the reclamation of new lands and who should be responsible for farm-level pressurized distribution systems in the framework of Irrigation Improvement projects (see next section) between the MALR's cooperatives and Branch Canal Water User Associations. Turf battles extend to the question of data, where assessments of rice areas differ, and even to crop requirements: a joint working group has met for years without settling the issue because the two ministries have vested interests in establishing either low or high figures.

6 Current water issues and challenges for the irrigation sector

6.1 Irrigation modernization policies: technology to the rescue?

Almost all irrigated land in Egypt (the few exceptions include Fayoum) uses machinery to lift water from waterways to the level of the fields. In ancient times, this was done by *shadoof*, *tanbur* (Archimedean screw) and the animal-powered *saquia* (water wheel). At the beginning of the eighteenth century, the saquia was enhanced so that the scooped water was collected and distributed at the level of the axis. In the early twentieth century, large-scale diesel pumps were introduced, allowing richer landowners to irrigate at higher elevations. In other locations, small farmers would form and share saquia rings, where water lifting and irrigation were determined by the location and capacity of the saquia. The advent of the HAD and the generalization of year-round agriculture generated the need for increased pumping capacity, and this was met by small diesel pumps (initially Indian models), which started to replace saquias in the 1980s. While initially these were shared (rented or borrowed), as can still be found in Upper Egypt, all farmers in the Delta now have one or more individual (fixed or mobile) diesel pumps. This has dramatically increased farmers' capacity to abstract water, and allows them to pump from any convenient location along canals or drains, although it has undermined the social arrangements of the saquia rings.

As a result of the ramified and inter-connected nature of the distribution network in the Delta, the typical 5 days on/5 days off summer rotation in secondary canals is hard to ensure. Unpredictability in the timing and quantity of available water results not only in a mismatch between supply and demand but also in risk-minimizing strategies on the part of the farmers, who over-irrigate as a means of storing water in the soil profile. In the 1970s, such problems of low efficiency and equity were analyzed by the Egypt Water Use and Management Project (EWUP, 1977-84) coordinated by the MWRI and researchers from Colorado State University. The two major and complementary recommendations were 1) to ensure *continuous flow* in secondary canals (through downstream control automatic gates and, later, baffle distributors at the head); 2) to establish *collective* pump stations at the tertiary (*mesqa*) level, serving buried piped distribution networks to deliver water to a number of valves and replace diffuse *individual* pumping from multiple points (canals and drains).

The IIP (Irrigation Improvement Project) was launched in 1984 with the support of USAID. It became a fully fledged program in 1989, and was expanded by the World Bank in 1995. The project was praised for having spearheaded the "modernization" of irrigation in Egypt; "the first step to bring the Egyptian irrigation system in line with the functional demands it will be facing by the turn of the 21st century" (Hvidt 1998). It was granted the status of a national project, with a dedicated "sector" within the ministry, and the long-term objective of being expanded nationwide. In 2006, it was renamed, and remains, the IIIMP (Integrated Irrigation Improvement and Management Project), with improved design criteria, including the use of electric pumps and the possibility of adding quaternary distribution pipes and farm-level hydrants (OFIDO and FIMP projects, implemented by the MALR). By 2007, the project had installed 2900 collective stations over an area of 200,000 fed (World Bank 2007), to which must be added 36,000 fed by IIP2 (funded by KfW), 67,000 fed improved by USAID before 1996, 66,000 fed improved by IIIMP until 2015, as well as areas improved with the national budget (around 50% of the cost is charged to farmers over 20 years), totaling around 0.4 Mfed. Yet Fahmy (1996) points out that the 1986 policy estimated that the IIP would cover around 2.5 Mfed, and that 2 Bm^3 of water would have been saved by the year 2000.

However, the implementation of the project has been bedeviled by a number of persistent problems. These include delays, high staff turnover and losses of trained personnel, inadequate career opportunities and salaries to attract new engineers (IRG 1998), escalating costs, faulty design and/or execution (e.g. pump inlet positioned too high, reversed canal slope) that "seriously undermined farmer confidence in the IIP and its abilities” (IRG 1998), difficulties faced by farmers in finding spare parts or the expertise to address technical problems.

The main shortcoming of the IIP projects has been the failure to establish continuous flow, "the key and lead technology of IIP" (IRG et al. 1998) and the main selling point to farmers. As a result, neither the pattern of water distribution to each branch canal nor the overall efficiency of the system has seen an improvement. Where mesqas have been filled in, farmers are now fully dependent on the collective pump station, but those located near the canal or drain have generally kept their individual pumps to abstract extra water. It is hard to make a definitive assessment of the IIP projects (see Molle et al., 2015): in the Meet Yazid area, 18% were found to be abandoned (either because the engine had been stolen or the group had been unable to manage conflicts or a technical breakdown), one third had shifted to electric engines, and many types of adjustment and transformation were observed. Farmers were found to be handling collective action in various informal ways and far removed from the formal, organizational mode that the project had originally imposed.

All in all, the farmers who see benefits in terms of reduced drudgery, equity in distribution, or pumping costs tend to be well situated in the upstream part of the branch canals. Environmental and social heterogeneity is very high and explains the contrasting situations observed. This, along with the fact that the 40% share of the investment to be paid by farmers was far from being fully recovered, suggests that investing in IIP programs is not a priority for the country and should be conducted on an 'on-demand' rather than subsidized basis (Molle et al., 2015). Tellingly, the new 2017 NWRP barely refers to IIP; nor does it set targets or discuss the future of the sector.

6.2 From the system to the farm: elusive efficiency gains

The question of whether improvement projects "save water" has been discussed since the start of the projects. While early studies claimed a reduction in the amount of water applied, years of monitoring and evaluation efforts were never able to substantiate this (Molle et al. 2015). In 1998, Merrey (1998) noted that "IIP has many other benefits, but the expectation that substantial water savings will occur is not realistic; and continued expansion of irrigation on the assumption that such savings will occur will lead to induced shortages in the Nile Valley [and Delta]."

There are several reasons for the failure to save water. First, continuous flow has not been achieved, meaning farmers still fully abstract whatever amount of water is delivered to their branch canal. Second, in the absence of a strict rotation within the branch canal, upstream farmers continue to abstract water disproportionately (in part as a protective strategy as supply remains unpredictable). Third, it is necessary to distinguish between applied and consumed volumes: where collective networks allow a more even and better distribution at the tertiary level, evapotranspiration, as well as yields, is likely to be enhanced. This would beneficially increase the depleted fraction and improve efficiency, but this small effect is impossible to evidence in a context where each season differs in terms of cropping patterns and available supply. Additionally, the corresponding reduction in return flows may affect the downstream farmers, who use drainage water, as well as increasing the salt concentration.

Regardless of the possible but unlikely effects of improvement projects on water use efficiency, the MALR, as part of its strategy for 2030 (ARDC 2009), is seeking to shift the average plot-level water efficiency from 50% to 80%. Aside from the huge investment required—which would exceed most farmers' financial capacities—and the fact that the technology is ill-suited to certain major crops, such as rice and berseem, this simplistic reasoning ignores the now well-established fact that plot-level efficiency cannot be extrapolated to the entire system. Ironically the Nile Delta was one of the key cases used in the 1990s to show that systems with substantial reuse of water require careful examination (Seckler 1996). The MARL's claim that savings could reach 12.4 Bm^3 and be used for land expansion (ARC 2009) is flawed, as it fails to understand the macro-level water balance of the Delta and the importance of the drainage outflow for 1) keeping water levels in the drains of the northern part of the Delta low enough to allow cultivation and 2) flush out the salt load and pollutants. It also neglects the importance of growing rice or farming fish at least a year out of two to maintain an acceptable level of salinity in the northern fringe of the Delta, which is subjected to upward seepage of groundwater (this practice necessarily generates outflow).

Questions of irrigation efficiency and agricultural expansion into New Lands thus depend on a thorough understanding of the Delta balance. This vexed issue has recently been revisited by Molle et al. (2018), who have found that, despite continuous growth in the net area irrigated with Nile water, the outflow to the sea has remained relatively, and surprisingly, stable over the past 30 years, at around 12 Bm^3, with higher values clearly associated with excess hydrologic years and higher releases from the HAD. This stability is extremely puzzling, since neither the expansion of rice cultivation in the late 1980s and early 1990s nor the overall expansion of cultivated/harvested areas (net of urban encroachment) seems to have had a significant effect on overall return flows. Data such as cropping intensity, yields, or the use of groundwater are too inaccurate to fully solve this riddle. More importantly, a 3-4 Bm^3 reduction in the 12 Bm^3 outflow to the sea is an ambitious target in itself, as it would involve significant change to water distribution and use, but also because it is generally accepted that the lowest possible value for the Delta outflow is 8.5 Bm^3 (IRG et al. 1998).[5] If we take this volume as a constitutive fact of water management in the Delta, then the current efficiency of the Valley/Delta system is 93% of its estimated potential, and any improvement would account for only around 5% of the Nile's water resources (ibid.).

There are benefits in reducing return flows through improving efficiency at the plot level (although this is not true in all parts of the Delta, particularly where return flows are recycled) because their quality degraded. This reduction would mean that farmer "demand" in terms of gross abstraction would be reduced, easing distribution at the secondary and main distribution levels. The main potential for this lies in improving farm-level irrigation practices and reducing soil evaporation and unproductive losses through laser land leveling, the lining of *marwas* (quaternary ditches), distribution of water through piped networks, mulching, and raised beds (Karrou et al. 2011).[6] These measures have been and are being implemented by the MALR and farmers but have not been systematized.

System-level irrigation management is complex and has not been adequately described or understood beyond the formal rotation system. For example, Roest (1999) estimated spillage from canals to drains in the eastern Delta at 23% of total supply. Yet, 20 years later, this phenomenon is rare at the extremities of secondary and tertiary canals (IWMI and WMRI), showing a shift in the demand/supply ratio and adjustments in management. (Better) matching water supply and demand has been a returning (often donor-funded) objective[7] of the past 20 years (Ismail et al. 2001; El Quosy 2006; Mott MacDonald 2011). Several attempts at attuning main and secondary canal discharges to 'real' water requirements that would be based on actual cropping patterns observed in the field have failed. This is partly due to an illusory idea that "demand" can be precisely computed based on theoretical parameters and partly due to foot-dragging by local managers who fail to imagine a shift from management based on water levels to one based on discharges, given the nature of the hydraulic infrastructure and the uncertainty in supply from higher levels.

[5] The 2005 NWRP had targeted an outflow to the sea of 9.5 Bm3 by 2017. The new 2017 NWRP expected a value of 9.9 Bm3 by 2037.

[6] See www.icarda.org/sites/default/files/u158/Science%20Impact%20Raised-Bed_final.pdf,

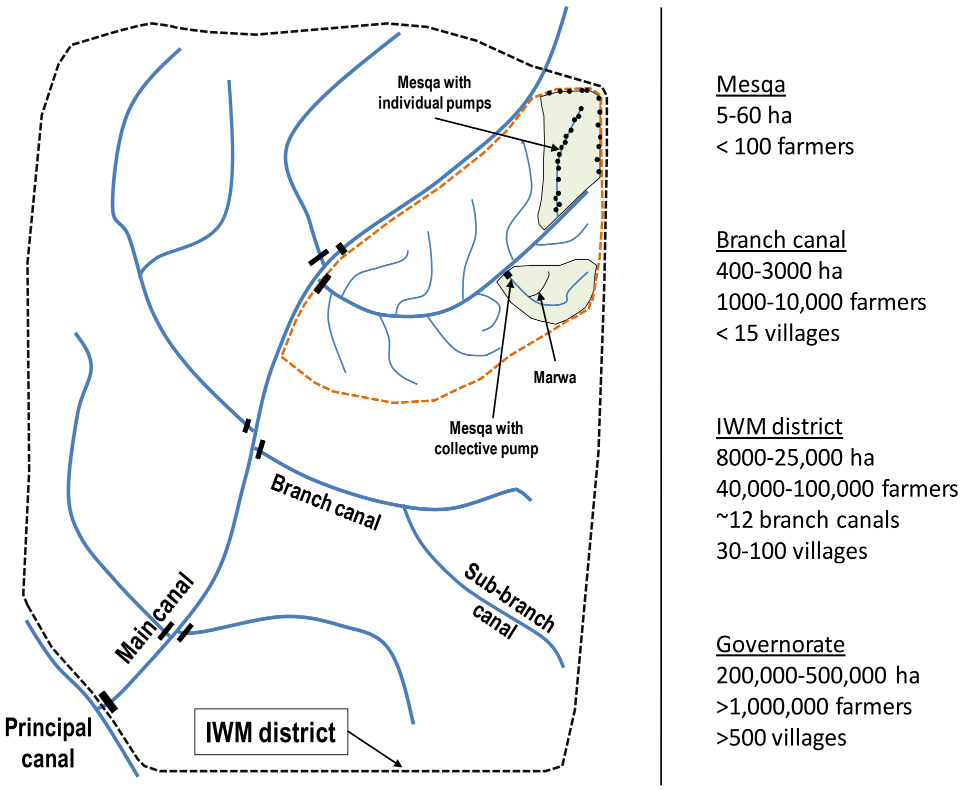
[7] For example, the MALR/USAID Agricultural Policy Reform Program (APRP) issued a policy brief announcing, "MALR and MWRI work together to deliver water to farmers at the right time and in sufficient quantities."

Another recurring theme with regard to the regulation of agricultural demand is water pricing. According to a former minister, “with the increasing scarcity of water from which the country is suffering […] it has become indispensable that farmers pay for irrigation services in an attempt to rationalize the use of irrigation water and establish sustainable drainage techniques” (OOSKAnews 2013). Contrary to this suggestion, however, successive reports have consistently concluded that, "water pricing under the present and expected near-term conditions may not be feasible in conserving water in the Old Lands" and advanced several arguments: the transaction costs would be tremendous and may exceed the revenue to the government (El Assiouty 1984); the price of water cannot exceed the cost of its delivery because, according to Islamic law, it is essentially free; it is impossible to relate the price to “demand” or actual volumetric supply; water pricing should only be seen as a cost-recovery mechanism through a flat tax (Perry 1996).

6.3 Institutional development and water users associations

Egypt has rich experience when it comes to developing water user groups in the field of agriculture. This includes a diversity of geographical situations (groups around tubewells in the oases, large-scale irrigation schemes in the Valley, Delta, and New Lands), water management arrangements (collective pumps for four to eight farmers in the New Lands, or at the tertiary canal level in the Old Lands), and various scales (from the tertiary [mesqa] and the secondary [branch-canal] to district level [around 10 branch canals] [Figure 3]). Over the past 30 years, several projects have attempted to organize farmers, improve the interface/coordination between farmers and irrigation managers, or develop district-level “water boards” to ensure the participation of all stakeholders (see Molle and Rap 2014).

Figure 3. Management levels in Egyptian irrigation (Delta) (Molle et al. 2015)



As early as the 1970s, the EWUP project recommended that farmers’ participation should be sought in the field of both irrigation distribution and maintenance, and called for the establishment of a specially trained cadre of professionals (Irrigation Advisory Service: IAS). A direct consequence of the collective pump stations proposed by IIP projects was that collective action was needed to operate and maintain the pump, organize water distribution, and pay the energy costs. This called for the establishment of mesqa-level Water Users Associations (WUAs).

However, WUAs initially had no legal status to act as independent bodies. This changed in 1994 with the modification of the 1984 Law 12, wherein WUAs were defined as legal organizations at the mesqa level in the improved irrigation systems (IIP) in the Old Lands, while Water Users Unions (WUUs) were made legal entities for the New Lands. The Bylaws of Law 213/1994 (Decree No 14900 of 1995) detailed the rights and duties of the WUAs and WUUs, and the recovery of capital costs of improved irrigation facilities (ICG 2009).

In 1995, the Dutch-funded Fayoum Water Management Project (FWMP) established the first user organizations at the branch canal level, known as "Local Water Boards" (Abdel-Aziz 2003). These were responsible for the operation and maintenance of irrigation intake structures of all mesqas and of secondary drainage infrastructures in their command areas, as well as weed control and domestic water use derived from canals and drains. All water users, whether farmers, residents, or industry, were obliged to become members of the Water Board. Between 1994 and 2009, Water Boards were tested at the district (*markaz*) level in the Fayoum governorate. They were conceived as small “water parliaments” consisting of civil society stakeholders. The project was expanded to other regions, until 900 Water Boards had been set up across the country.

Under USAID’s Agricultural Policy Reform Program (APRP) (1996-2003), strong support for various kinds of decentralization and Irrigation Management Transfer translated into several policy initiatives and changes. The MWRI introduced secondary-level Branch Canal Water User Associations (generically called BCWUAs) and “Integrated Districts.” Nine initial BCWUAs were formed by ministerial decree (IRG 2002b). In 2006, the IIIMP project took a much broader approach than the IIP by also considering the establishment of BCWUAs and a "From Mesqa to District" approach (APP 2007; World Bank 2005).

However, branch canal-level experiments have faced several setbacks (Rap et al. forthcoming). First, BCWUA board members were often appointed by the ISAs rather than being freely elected—a top-down approach that privileged traditional village leaders and power holders close to the government (Gouda 2016). Second, mechanisms to involve the BCWUAs in the establishment of maintenance priorities and monitoring the work of contractors, although welcome by farmers, often proved to be short-lived. Third, while BCWUAs could play a useful role in cost recovery and financial administration, the law does not recognize them as legal entities, meaning they have no authority to collect service fees or manage a budget. Fourth, BCWUAs were unable to enforce rotations without the approval of government engineers, since they lacked the legitimacy and resources to intervene, resolve disputes, or apply penalties in cases of infringement. Fifth, although farmers called for greater consultation and interaction with the district engineer (El-Zanaty & Associates 2001), some irrigation sector engineers were not convinced of the benefits of the increased involvement of the BCWUAs. They saw them as threatening to their prestige, power, legitimacy, and jobs (Hvidt 1998), and also recognized that they are unable to commit to a given supply pattern due to their dependence on higher level supply. The BCWUAs’ lack of legal empowerment is seen to result from the ministry’s reluctance to divest its discretionary power, and that of MPs to lose their vote-winning role in mediating occasional water crises.

General assessments of participatory water management reveal worrying trends (APP 2007; Molle and Rap 2014). Barakat concluded that user-group participation in water management is extremely low, that none of the actors properly understand their rights, and that WUOs and MWRI field staff do not see themselves as partners. Likewise, based on the monitoring and evaluation of 150 WUOs over several years, Bron (APP 2007) found user participation in water management to be very low, even when organized into water users' associations, and that "no water users' organization in Egypt [had] reached a level of institutional strength that [could] be considered sustainable.”

6.4 Institutional problems within ministries and the limits of reform

A diagnostic of institutional problems within the MWRI carried out 20 years ago (IIMI 1995; Merrey 1998) identified problems that are still considered systemic and "sticky." These include considerable duplication of functions (in part due to donors' insistence on the creation of autonomous entities to manage their projects, producing, for example, the EPADP[8] as well as the Irrigation Improvement Sector), insufficient cooperation and information sharing between, and even within, ministries, low salaries leading to "seepage" of the best professionals to the private sector or Gulf countries, a highly centralized structure with power concentrated in the hands of a few, and a lack of transparency.

A further major problem has been a multiplication of, and lack of consistency between, operational units (directorates). Vertically linked to their respective sectors, these deal with irrigation, drainage, or mechanical/electrical issues (as well as groundwater, once it was promoted to a separate sector in 1999). Irrigation and drainage administrations have separate buildings, equipment, and work schedules (Merrey 1998).

This has prompted the MWRI, with considerable persuasion from donors, to adopt "a policy to integrate all water management functions at the district level to support decentralized management" (IRG 2002b). The goal was to merge into one integrated district the various sectors (irrigation, drainage, mechanical) that are defined with different boundaries (neither of them corresponding to administrative districts). This was intended to: 1) reduce the number of staff and put all of them under the authority of a single district engineer, 2) do away with the intermediate layer of the inspectorate, 3) integrate the various functions of water management for coordinated planning and management. The pilot IWMDs of Zifta and Ibrahimia in the Delta were recognized in 2001 by Ministerial Decree No. 506, and, by 2007, 27 districts had been established.

The implementation of the IWMDs faced several obstacles and issues, including (IRG 2002a): 1) setting the new boundaries (often taken as those of the irrigation district), 2) selecting the officers (with conflict arising between the three departments over who would head the IWMD), 3) allocating budget and determining operational procedures (with finances coming from different departments), 4) a lack of water monitoring programs (needed for improved management but requiring funding for equipment), 5) a reluctance to delegate authority and decision-making from the general directorate to the IWMD, 6) limited cooperation from the Drainage and Mechanical equipment sectors, which maintained or shifted their best equipment and staff within the directorate (above the district) where such rationalization has not been attempted.

The USAID-funded LIFE-IWRM Project (from 2004 to 2012, in two phases) provided technical assistance to the MWRI to implement decentralized and participatory IWRM over an area of 485,000 ha (15% of Egypt's irrigated area) (El Atfy et al. 2007). The project's stated achievements include the establishment of 45 districts in 8 irrigation directorates, with the formation of 622 BCWUAs (covering 2 Mfed and 1.3 million users), trained to participate effectively in decision-making.

BCWUAs should be involved in the annual planning, prioritization, and selection of maintenance and minor works, with inspection of the canals and drains to be carried out jointly with the IWMD staff. They should also participate in the monitoring of progress and quality control during the execution of works (Barakat 2009). BCWUAs are expected to monitor, measure, and record the water levels at key control points to detect and report anomalies and shortages. The participation of all BCWUAs in the management system of the IWMDs was found to have a positive influence on the quality and the equity of water distribution among in the IWMDs (El Atfy et al. 2007).

In 2005, the MWRI set up an Institutional Reform Unit (IRU), which issued a first Institutional Reform Vision and Strategy document that included the formation of water users' associations at branch canal, district, and directorate levels, the transfer of O&M management and financial responsibilities

---

[8] Other semi-autonomous authorities include, among others, the High Aswan Dam Authority, the Egyptian Shore Protection Authority, a holding company responsible for North Sinai and the South Valley, and another for the Western Delta.

to WUOs, and the restructuring of MWRI local administration into public bodies known as Regional Water Management Authorities. The strategy proved to be overambitious. A review carried out in 2010 (Salem 2011) again identified problems with the politicization of staff recruitment, the brain drain generated by low salaries and incentives, and the permanence of a structure of sector-based silos where communication is almost exclusively vertical.

There have long been discussions about introducing a degree of privatization into water management (APP 2001), mostly at the instigation of donors. One issue is whether special authorities should be dismantled when their role comes to an end. For example, when the EPADP's drainage program is complete, its virtual monopoly of drainage must give way to a more service-oriented and demand-driven mode of operation. Drainage *services* would be provided to private drainage users—investors or water boards—for new development, rehabilitation or maintenance, possibly by operators other than, or in competition with, EPADP (van Achtoven et al. 2004).

Overall, institutional reform within the ministry has not been able to displace entrenched cultural and bureaucratic models, whose hyper-centralization, believed to date back to Ottoman times (Salem 2011), is associated with problems of transparency and knowledge-sharing.[9] Efforts to rationalize and integrate irrigation and drainage, and reduce the number of and inconsistency between operational units, were discontinued in 2014, when the minister decided to halt the IWMD reform. Sector leaders had understood that reform would result in loss of power, discretion, and prestige, and consequently were resistant to it (ibid). Even the participatory definition of maintenance priorities with farmers has been sidelined, as these are often dictated "by powerful figures who used to belong to the ruling party or the Local Popular Councils or other affiliates of power corridors" (Salem 2011).

Inter-ministerial committees and other bodies set up to facilitate coordination or integration are numerous, but, "in many cases they are either not functional or leave little trace due to unclear mandates, lack of permanent supporting structures, and ineffective feedback mechanisms" (Luzi 2010). They are often established at the insistence of donors, who, although sometimes serving as catalysts, produce an overkill of institutional initiatives and programs that may promote fatigue and inertia.[10]

6.5 The water-food-poverty nexus and policy linkages

At least since Nasser's time, food self-sufficiency has always featured as an unquestionable policy objective. This is understandable when one considers both the high population growth and the political vulnerability associated with a dependence on food imports and world market food prices. However, by the early 1980s, Egypt was importing around half its food requirements (MoI and USAID 1986), and this is still more or less the case.

The three "sacred cows" of water and agricultural policy—namely, food security, job creation, and limited per-capita land endowment in the Old Lands—are constantly used as an indisputable rationale for the expansion of irrigation. This is well illustrated by an MWRI policy document, which stated that "unless a very ambitious and serious plan to expand land resources, rationalize the use of limited water resources, and increase the efficiency of using both land and water in agricultural production to its maximum, food security in basic crops can never be achieved" (MWRI 2002).

---

[9] The National Water Resources Plans (2005 and 2017) are not available on any official website; some theoretically public annual reports can only be accessed through personal relationships, even within the ministry; the ministry website is poor, out of date, etc.

[10] Between 2003 and 2005, for example, Egypt was involved in the NWRP with the Dutch, the Water Policy Reform Program (WPRP) supported by USAID, the Integrated Water Resources Management (IWRM) Action Plan supported by the World Bank, the National Environment Action Plan (NEAP) supported by UNDP, the European Union Water Sector Reform Program (EUWSRP), the EU Water Initiative (EUWI), the EURO-MED Partnership in Egypt, and so on.

Yet the rhetoric of the expansion of irrigation for food security purposes (Acloque 2017) is squarely contradicted by the promotion of the New Lands as a frontier of modernization devoted to high-value, export-oriented agriculture. It may be dictated by a need to maximize the return on private investment or improve the balance of payments, but it will do little to improve food security in the Old Lands (Ayeb 2008) and will even worsen it where the New Lands divert water from them (such as the Toshka project).

Since Egypt is the world's largest wheat importer, special attention and governmental support is extended to its production. Leaders are mindful of the food riots of 1977, when Sadat tried to impose an IMF deal in Egypt, and of those in 2008, when the Government of Egypt (GoE) attempted to reduce subsidies after the international wheat price had tripled (Ayeb 2008; Bush 2010). More than half of Egypt's population lives below the poverty line and the price of bread is a key parameter of social stability.

Rice is also important for food security, and its profitability has made it a favorite crop of farmers, despite its high water demand and the government's attempts to discourage it. In August 2016, the cabinet issued a decree aimed at limiting the extension of rice to 1.1 Mfed to avert water shortages (Daily News Egypt 2016), but it was later overruled by the prime minister under pressure from MPs. In 2017, the government defended the idea in parliament and secured an agreement for a quota of 0.7 Mfed for 2018: a tall order when the balance of 2017 was 1.87 Mfed against an allowable area of 1.08 Mfed. It is unlikely that command-and-control measures will have much effect, although, in 2009, the ministry claimed to have reduced rice acreage from 2.2 to 1.2 Mfed by cracking down on violations (Al Ahram Hebdo 2013).

Even with optimistic projections in terms of land expansion and productivity, any potential gains will be largely nullified by population growth, and food security is set to remain a moving target. Allan (2003) has proposed viewing cereal (foodstuff) imports as transfers of embedded "virtual water" as a means to virtually increase the country's water supply. But the idea of relying on global trading systems to provide food and solve water deficits proved to be a "no-go area in public discourse" (ibid.), something that can be understood in light of the destabilizing impact of global food price hikes and of Egypt's political dependence on the US.

6.6 Planning ahead: the new National Water Resources Plan 2037

In 2017, the MWRI issued its new NWRP for the next 20 years. The plan includes a series of notable discursive shifts. Most importantly, it stresses that, however necessary they may be, supply- and demand-oriented approaches have *limited scope*, and that, "Government agencies, the private sector, and civil organizations—as well as individual farmers and users of domestic water—will have to find ways to adapt to increasing scarcity" (NWRP 2017). It projected a 10% reduction in the amount of water available for crops. Combined with a predicted rise in crop evapotranspiration, this means, "that farmers will have to choose crops or cultivation systems that consume less water, reduce cropping intensity, or accept suboptimal production" (ibid.).

The unrealistic land expansion targets of the 2005 NWRP now give way to a scenario where, "the total agricultural area including New Lands will remain fairly stable: gains in cultivated area due to land reclamation projects will be offset by loss of arable land due to urbanization, construction of roads, etc.". The NWRP (2017) gently dismisses MARL's 2030 strategy and its expansion target of 3.1 Mfed allegedly made possible by an increase in the average plot-level irrigation efficiency from 50 to 80%. But the fast-track measures to tackle Egypt's future water needs delineated by a committee set up by prime ministerial decree in 2016, and which again include a strategy "to save 10 Bm^3 by 2030," show the lingering political attractiveness of grand but unrealistic promises.

A further noteworthy change is the attempt to decentralize water management towards the governorates by assigning them specific amounts of water through a bulk allocation system. With the IWMD reform shelved, a continuing brain drain, and no sign of the political will to enact significant reform, the MWRI remains vulnerable to shocks, which could, for example, come from a series of dry years combined with reservoir development in the upstream part of the Nile Basin.

6.7 Can the Nile take its 'gift' back?

Herodotus' proverbial 'Gift of the Nile', Egypt is making use of all the water that flows into the HAD. As we have shown earlier, very little of it can be "saved." In official discourse and water balances, this inflow is unfailingly taken at 55.5 Bm^3—the "share of Egypt" as specified in a 1959 treaty between Sudan and Egypt. A long time "hegemon" in the Nile Basin (Warner et al. 2017), Egypt has seen its position weaken over the past five decades, both for internal reasons and as a result of the growth of upstream neighbors. The most notable of these, Ethiopia, is home to the headwaters of the Nile that contribute 85% of the runoff accruing to Sudan and Egypt, and is laying not unreasonable claim to the waters of the Nile. The on-going construction of the Grand Ethiopian Renaissance Dam (GERD) is a clear challenge to the current distribution of the river's resources, although the most crucial issue lies in how fast GERD—with its 74 Bm^3 of storage—will be filled (Wheeler et al. 2016). Once filled, the dam is expected to have a very limited impact in the short term on the inflow to the HAD, and its 169 Bm^3 of storage capacity, because it is a hydropower dam and diversion within Ethiopia for irrigation or otherwise will take time to materialize on a substantial scale. Irrigation expansion in Sudan probably dwarfs the potential of upstream countries, as vast swathes of flat land are available along the river course. International investors, including Egyptian companies, have spotted this bonanza and are currently developing large-scale irrigation facilities, tapping surface or groundwater. The expansion of irrigation in Sudan probably poses a much bigger risk to Egypt, and one which is already gradually materializing, though not as spectacularly as that of GERD (Yassin 2014; Hussein 2015).

Egypt's response to this challenge has wavered between confrontational and conciliatory tones, while remaining highly emotional. In a televised speech, the deposed President Morsi emphasized that, "The lives of the Egyptians are connected around [the Nile] as one great people. If it diminishes by one drop then our blood is the alternative" (BBC 2013); more recently, the minister of water resources and irrigation was reported as saying, "We won't accept cuts to our share of Nile waters, even a cup less" (Al-Masry Al-Youm 2017). While the country is publicly buttressing the defense of its "historical share of Nile waters," there are signs that it is already preparing for temporary reductions in supply, for example by building a mega seawater desalination plant (Tawfeek 2018) and working to reduce rice acreage.

Egypt's stance is further weakened by its policy contradictions. On the one hand, it claims it would collapse should one drop be withdrawn from its "share"; on the other, it periodically announces plans to expand irrigation by several Mfed, thereby undermining its own claim[11] to be facing a deficit of 30 Bm^3. Yet almost daily media coverage of the threats to Egypt's water resources also provide fertile ground for grand projects, such as the mega desalination plant, or flawed, multi-billion-dollar schemes to "improve efficiency." There has even been the occasional quixotic mega-project proposal, like the idea to distribute the HAD waters through huge pipes bordering the valley and avoid "losses," urged by scientists wanting Egypt to adopt a "third hydraulic revolution" to follow Mohamad Ali and Nasser (Al Ahram Hebdo 2013).

The supply/demand ratio is shifting, whether due to land expansion, new cropping patterns, or reduced water supply. We must note, however, that continued urban expansion over agricultural land works to decrease demand. As early as 1980, the annual loss in Egypt was estimated at 45,000 fed/year (Richards 1980), while the Ministry of Agriculture recently released a study showing that, between 1974 and 2007, 32,000 acres were lost each year on average, increasing to 41,000 fed between 2007 and 2010 (Al Ahram 2017; AhramOnline 2017). Since the revolution, several formal and informal sources report that this figure has multiplied by three.

[11] See, for example, a recent statement by the minister of water resources and irrigation (Egypt Today 2018).

7 Conclusion

Egypt's irrigation is a fascinating history of the gradual transformation of the Nile natural environment towards a cultivated area of around 3.78 million ha, a cropping intensity close to 2, and high land productivity. Water managers have learned to distribute around 60 Bm3 of water through a maze of 31,000 km of canals and operate hundreds of large-scale pump stations to lift water from canals and drains. Farmers have responded to various constraints on input factors by intensifying, diversifying, and mechanizing their production.

Since the 1960s, the relatively familiar picture of irrigated agriculture in the Old Lands has been paralleled by expansion into New Lands: the socio-technical landscape of the New Lands east and west of the Nile Delta, and further afield in the desert, have introduced new capital-intensive ways of farming. Although New Land development has come under criticism for various technical, economic, social, and political reasons, it has now established itself as a relatively high-performing sector, with a trend towards fruit tree cultivation. This expansion partly makes up for the dramatic loss to urbanization of arable land in the Delta and Valley, but it also signals a policy shift in favor of export-oriented, capital-intensive agriculture. "The idea that has dominated so much of the water policy in Egypt […] that any excess water available should be devoted to the extension of the irrigated area" (El Quosy 2006) has also served bureaucratic, financial, and political interests. It has been pushed to its limits, creating competition with Old Lands over Nile water, groundwater depletion, and economic inefficiencies (part of the equipped area is left idle for lack of water or soil salinization).

The Egyptian water administration has been repeatedly described as a centralized and vertical structure, with poor communication across internal branches/sectors. Reform programs devoted only to operational levels have a limited impact (Jacobs 2005), and those that are targeting institutional change—such as establishing Integrated Districts or BCWUAs—are eventually abandoned or put on the backburner once donor-funded programs come to an end. As Richards (1980) puts it, "The engineers of the bureaucracy naturally tended to think of the fundamentally social problems of Egyptian agriculture as essentially technical ones" and relatively little is known about what is really going on in the countryside, in terms of the labor and land markets, for example, and even water management itself. Research remains insufficient, if judged by the crucial importance of what is at stake.

The story of irrigation policy is intertwined with the wider political economy of the country. Accessing (irrigated) land has long been a privileged way to accumulate wealth and capital and also a means of relieving the pressure on the peasantry. Issues of food security, social stability, and geopolitics undergird the management of water resources. The increasing uncertainty generated by climate variability and water resource development in the upper Nile Basin, the overextension of the irrigation network, the high efficiency of water use at system level, and the institutional rigidities combine to foreshadow potential turbulence and herald the end of water abundance. In this, they echo the recent NWRP and its emphasis on the need to work within acknowledged limits.

8 References

Abdel-Dayem S, Abdel-Gawad S, Fahmy H (2007) Drainage in Egypt: a story of determination, continuity, and success. Irrigation and Drainage 56: S101–S111.

Abou-Korin AA (2002) Sustainability requirements of desert development in Egypt: The case of New Valley Region. Journal of Engineering Science.

Acloque Desmulier D (2018) Personal Communication by email.

Acloque Desmulier D (2017) Recomposition des acteurs et des espaces agricoles Egyptiens: enjeux politiques, socio-économiques et alimentaires. *Revue d'Économie Régionale & Urbaine*, 3: 457-482.

Adriansen HK (2009) Land reclamation in Egypt: a study of life in the new lands. Geoforum 440 (4), 664–674.

AhramOnline (2017) Urban encroachment, lost development, and Egypt's next president. Sunday, 15 January

Al Ahram (2017) Experts: Ministry of Irrigation deceived "people and the government". http://agri.ahram.org.eg/News/55542.aspx

Al Ahram Hebdo (2013) Irrigation: Nouveau débat sur les eaux du Nil. 13-19 février 2013 - Numéro 961.

Al Ahram weekly (2015) Reclaiming land. June 25, 2015

Al-Ahram Weekly (2000) Toshka in the crossfire, 27 Jan. - 2 Feb. 2000, Issue No. 466.

Alary V et al. (2017) Desert land reclamation programs and family land dynamics in the Western Desert of the Nile Delta (Egypt), 1960–2010. World Development 104 (2018) 140–153

Allan JA (2003) Virtual Water - the Water, Food, and Trade Nexus. Useful Concept or Misleading Metaphor? *Water International* 28:1, 106-113.

Al-Masry Al-Youm (2017) We won't accept cuts to our share of Nile waters, even a cup less, Egypt, December 2, 2017.

APP (Advisory Panel Project on Water Management) (2001) Workshop on Privatization / Sector Reform within MWRI (Roundtable discussion). 31st May 2001, Cairo, Egypt.

APP (Advisory Panel project on water Management) (2007) Proceedings of the workshop on Water Boards: From Policy to Strategy, 13-14 January 2007, Cairo, Egypt.

APP (Egyptian-Dutch Advisory Panel on Water Management) (2005) Workshop on intermediate reuse of drainage water. Cairo, Egypt, June, 23 - 2005.

APP. 2009. Governance in the Water Sector. The 43rd Panel Meeting Workshop. April 4th 2009, Cairo, Egypt.

ARDC (Agricultural Research and Development Council) (2009) Sustainable agricultural development strategy towards 2030. Cairo: Ministry of Agriculture and Land Reclamation, Egypt.

Ashur H, Abdelaziz S (1999) The President: Toshka is not only an agricultural and industrial project; it's the building of a new society. Al Ahram, February 16, 3.

Ayeb H (2008) Crise alimentaire en Égypte : compétition sur les ressources, souveraineté alimentaire et rôle de l'État. Hérodote 131(4):58-72.

Ayeb H (2010) La crise de la société rurale en Egypte. La fin du Fellah ? Paris: Karthala.

Barakat E (2009) IWRM I branch canal water user association assessment. Report No. 5. EPIQ. July 2009

Barnes J (2012) Pumping possibility: agricultural expansion through desert reclamation in Egypt. Social Studies of Science 42 (4), 517–538.

Barois J (1911) Les irrigations en Egypte. 2ème édition. Paris.

Bazaraa AS (2002) Reuse of agricultural drainage water: revision of the reuse mixing policy. Cairo: Advisory Panel Project on Water Management.

BBC (2013) Egyptian warning over Ethiopia Nile dam. 10/06/2013. www.bbc.com/news/world-africa-22850124

Bush R (2010) Food riots: poverty, power and protest. *Journal of Agrarian Change* 10(1):119–129.

Bush R (2007) Politics, power and poverty: twenty years of agricultural reform and market liberalisation in Egypt. Third World Quarterly, Vol. 28, No. 8, pp. 1599-1615.

CAPMAS (2018) http://www.capmas.gov.eg/

Corey GL (1978) Trip report. To assist Mission Team with defining scope of New Lands Development Project and in a site selection for the project. USAID.

Cuno KM (1992) The pasha's peasants. Land, society, and economy in Lower Egypt, 1740-1858. Cambridge Press.

Daily News Egypt (2016) Cabinet curbs water-consuming plants' cultivation to avert water shortage. 02 - 08 – 2016.

de Sainte Marie, C (1989) État et paysans dans les systèmes hydrauliques de la vallée du Nil (Egypte). *Études Rurales* 115-116: 59-91.

Deputy E (2011) Mubarak & Toshka: Let's do it for the Kids (2011). APSA 2011 Annual Meeting Paper. https://ssrn.com/abstract=1901986

Desert Development Center (DDC) (1997) Desert irrigation efficiency. Final Report to International Development Research Center of Canada (IDRC).

Dixon M (2013) The making of the agri-food corporate system in Egypt. PhD thesis, Cornell University.

DRI (2015) Yearbook 2013/2014. Cairo, Ministry of water and irrigation.

Egypt Independent (2014) On Toshka New Valley's mega-failure. Thursday 6 November 2014.

Egypt Today (2018) Egypt plans to face water scarcity, allots LE 900B, Egypt Today, Feb. 25, 2018.

El Assiouty I (1984) Pricing of irrigation water in Egypt. Supreme Council of Universities.

El Atfy HI, Viala E, Fredericks J, Svendsen M (2007) Improving the performance of irrigation and drainage systems in Egypt through decentralization and participation. Paper presented at the ICID Conference, October 2007, Sacramento, CA.

El Quosy DD (2006) A Study on Matching Irrigation Supply and Demand (MISD). Report prepared for Eco ConServ-Environmental Solutions. Cairo – July 2006.

El-Agha DE, Closas A, Molle F (2017) Under the radar: Dynamics of groundwater use in the Nile delta. Hydrogeology Journal 25:1621-1631.

El-Fellaly SH and Saleh EMA (2004) Egypt’s experience with regard to water demand management in agriculture. Eighth International Water Technology Conference, IWTC8 2004, Alexandria, Egypt

El-Sayed A (2011) Drainage water management in Egypt. Powerpoint presentation.

El-Zanaty & Associates (2001) Knowledge, attitudes and practices of Egyptian farmers towards water resources. National Survey 2001. EPIQ Water Policy Reform Program (Report No. 54). USAID.

Faggi P, Maury GR (1987) Étatisation de l'eau dans le projet «nouvelle vallée» en Égypte. In: L’homme et l’eau en Méditerranée et au Proche-Orient. IV. L’eau dans l’agriculture, pp. 103-110.

Fahmy H (1996) Comparative analysis of Egyptian water policies. *Water International,* 21:1, 35-45.

Gouda DM (2016) *Social Capital and local water management in Egypt*. AUC Press, Cairo.

Gumuchian H (1975) La République Arabe d'Egypte à la conquête de ses déserts. Revue de Géographie Alpine 63(2): 225-252.

Hanna F, Osman MAG (1995) Agricultural Land Resources and the Future of Land Reclamation and Development in Egypt. Options Méditerranéennes, Sér. B / n°9.

Hopkins N. et al. (1988) Participation and community In Egyptian New Lands: The case of South Tahrir, Cairo papers in social sciences. AUC, Cairo.

Hurst HE (1957) The Nile. A general account of the river and the utilization of its waters. Revised edition. London: Constable Publishers.

Hussein W (2015) Will Saudi agricultural investments in Sudan leave Egypt high and dry? Al Monitor – The pulse of the Middle-East.

Hvidt M (1995) Current efforts to improve irrigation performance in Egypt. Paper presented at The third Nordic conference on Middle Eastern Studies: Ethnic encounter and culture change, Joensuu, Finland, 19-22 June 1995.

Hvidt, M. 1998. Implementing new irrigation technology in upper Egypt: political and bureaucratic considerations. In Mollinga, P. (Ed), Water control in Egypt’s canal irrigation – A discussion of institutional issues at different levels, pp. 23-40.

ICG (International Consultants Egypt) (2009) Institutional framework and decision-making practices for water management in Egypt. INECO project report.

IFAD. 1980. Report and Recommendation of the President to the Executive Board on a Proposed loan to the Arab Republic of Egypt for The West Beheira Settlement Project.

IIMI (1995) An action plan for strengthening irrigation management in Egypt. USAID.

IIMI. 1995. Water Resources, lrrigation Operations and lnstitutional Issues: An Analysis of the Ministry of Public Works and Water Resources, Government of Egypt. IIMI-MPWR Study, 'Strengthening Irrigation Management in Egypt'. Report Number 2. Cairo.

IRG (1998b). *Water user association formation outside the Irrigation Improvement Program area* (APRP-Water Policy Activity, Report No. 9). Cairo: USAID.

IRG (International Resources Group), Winrock International and Nile Consultants. 2002a. Integrated water management district: MWRI plan for pilot implementation. APRP-Water Policy Activity, Report No. 62. Cairo, Egypt: USAID.

IRG (International Resources Group), Winrock International and Nile Consultants. 2002b. Assessment of the impacts of the water policy reform program. APRP-Water Policy Activity, Report No. 58. Cairo, Egypt: USAID.

IRG (International Resources Group); Winrock International; Nile Consultants (1998) National policy for drainage water reuse. Report No. 8. APRP - Water Policy Reform Program.

Ismail R. et al. 2001. Matching irrigation supply and demand. Solving water delivery problems in a liberalized agricultural economy. Policy Brief. MALR/USAID Agricultural Policy Reform Program (APRP).

IWMI and WMRI (2013) An exploratory survey of water management in the Meet Yazid Canal command area of the Nile Delta. Water and Salt Management in the Nile delta. Project Report No. 1. IWMI, WMRI: Cairo, 2013.

JACOBS (2005) Egypt: Water Sector Reform Programme, Identification Report. JACOBS Consultancy, London.

Karrou M, Oweis T, Benli B, Swelam A (eds) (2011) Improving water and land productivities in irrigated systems. Community-based optimization of the management of scarce water resources in agriculture in CWANA. Report no 10. ICARDA, Aleppo, Syria.

Linant de Bellefonds LA (1873) Mémoires sur les principaux travaux d'utilité publique, exécutés en Egypte depuis la plus haute antiquité jusqu'à nos jours.

Luzi S (2010) Driving forces and patterns of water policy making in Egypt. *Water Policy*, 12, 92-113.

Merrey DJ (1998) Governance and institutional arrangements for managing water resources in Egypt. In Mollinga, P. (Ed), Water control in Egypt's canal irrigation – A discussion of institutional issues at different levels (pp. 1-22). Wageningen: Wageningen University.

Meyer G (1998) Economic changes in the newly reclaimed land: From state farming to smallholding and private agricultural enterprises. In S. Hopkins and K. Westergaard, eds. Direction of Change in Rural Egypt, pp. 334-356. Cairo: American University of Cairo Press.

Meyer G (1996) The impact of liberalization and privatization on the agricultural sector in Egypt. In Hopfinger, H. (Ed.). Economic liberalization and privatization in socialist Arabic countries: Algeria, Egypt, Syria and Yemen as examples. Gotha: Perthes, pp.121-143.

Mikhai AM (2008) The Nature of Ottoman Egypt Irrigation, Environment, and Bureaucracy in the Long Eighteenth Century.

Ministry of Irrigation (Egypt), USAID (1986) Strategies for irrigation development in Egypt. Water Management Synthesis II, Project Agricultural and Irrigation Engineering.

Mitchell T (2002) Rule of Experts. Egypt, techno-politics, modernity. University of California Press.

Mohamed AI (2013) Irrigation water quality evaluation in El-Salam canal project. *International Journal of Engineering and Applied Sciences* 3(1):2305-8269.

Molle F, Rap E (2014) Brief Retrospective on Water User Organizations in Egypt. Water and Salt Management in the Nile delta. Project Report No. 3. IWMI, WMRI: Cairo, 2014.

Molle F, Rap E, Al-Agha DE, Ismail A, Abou El Hassan W, Freeg M (2015) Irrigation Improvement Projects in the Nile Delta: promises, challenges, surprises. Water and Salt Management in the Nile Delta Project Report No. 4. IWMI, WMRI: Cairo.

Molle F, Gafaar I, Ezzat Al-Agha D, Rap E (2018) The Nile delta's water and salt balances and implications for management. *Agricultural Water Management* 197(15): 110-121.

Mott MacDonald (2011) Matching water supply and demand. Technical Report 57. National Water Resources Plan Coordination Project (NWRP-CP)

MPWWR (Ministry of Public Works and Water Resources) (1990) The Nile and history of irrigation in Egypt. Cairo: MPWWR.

MPWWR (Ministry of Public Works and Water Resources). 1990. The Nile and history of irrigation in Egypt; Cairo, 444p.

MWRI (2002) Adopted measures to face major challenges in the Egyptian Water Sector. Cairo: MWRI.

MWRI (2005) Water for the future. National water resources plan for Egypt 2017. Planning sector of Ministry of Water Resources and Irrigation.

MWRI (2010) Strategy of Water Resources of Egypt till 2050, Ministry of Water Resources and Irrigation.

MWRI (2013) NWRP Measures. National Water Resources Plan, Coordination Project (NWRP-CP). Technical Report 44. Ministry of Water Resources and Irrigation.

MWRI, USAID (1986) Strategies for irrigation development in Egypt. Water Management Synthesis II, Project Agricultural and Irrigation Engineering.

NWRP (2017) The National water Resources Plan NWRP 2017-2030-2037 Egypt. The Ministry of Irrifation and Water Management, Cairo.

OOSKAnews (2013) Egypt Allows Private Investment in Irrigation. Weekly Water Report, Middle East and Africa. OOSKAnews. 05/21/2013.

Perry CJ (1996) Alternative approaches to cost sharing for water service to agriculture in Egypt. Research Report 2. Colombo, Sri Lanka: International Irrigation Management Institute (IIMI).

Richards A (1982) Egypt's Agricultural Development, 1800-1980: Technical and Social Change. Boulder.

Richards A (1980) The agricultural crisis in Egypt, The Journal of Development Studies, 16:3, 303-321.

Ritzema HP (2009) Drain for gain. Making water management worth its salt. PhD thesis. UNESCO-IHE Institute for Water Education.

Rivlin HAB (1961) The agricultural policy of Muhammad Ali in Egypt, Cambridge.

Roccu (2013) The Political Economy of the Egyptian Revolution Mubarak, Economic Reforms and Failed Hegemony.

Roest CWJ (1999) Regional water distribution in the Nile delta of Egypt.

Ruf T (1987) L'histoire de la maîtrise de l'eau en Egypte. In : Aménagements hydro-agricoles et systèmes de production. Montpellier : CIRAD.DSA, (6), 361-374.

Sadowski Y (1991) Political vegetables? Businessman and bureaucrat in the development of Egyptian agriculture. Brookings Institution, Washington DC.

Salem O (2011) Review of the Institutional Reform Strategy of the Ministry of Water Resources and Irrigation. Second Draft.

Seckler D (1996) The new era of water resources management. Research Report 1. Colombo, Sri Lanka: International Irrigation Management Institute (IIMI).

Sims D (2015) Egypt’s desert dreams: development or disaster? American University in Cairo Press, Cairo.

Sirry Bey H (1935) Irrigation policy. Government Press, Bulak, Cairo.

Sowers JL (2003) Allocation and accountability: state-business relations and environmental politics in Egypt. PhD thesis, Princeton University.

Springborg R (1979) Patrimonialism and policy making in Egypt: Nasser and Sadat and the tenure policy for reclaimed lands. Middle Eastern Studies 15(1): 49-69.

Tawfeek S (2018) Sisi vows to protect Egypt's share of Nile water. January 9, 2018. Egypt Independant. www.egyptindependent.com/sisi-vows-protect-egypts-share-nile-water/

Tellioglu I, Konandreas P (2017) Agricultural policies, trade and sustainable development in Egypt. Geneva: International Centre for Trade and Sustainable Development (ICTSD) and Rome: United Nations Food and Agriculture Organization (FAO).

van Achthoven T, Merabet Z, Shalaby KS, van Steenbergen F (2004) Balancing Productivity and Environmental Pressure in Egypt. Toward an Interdisciplinary and Integrated Approach to Agricultural Drainage. Agriculture & Rural Development Working Paper 13, World Bank.

Verhoeven H (2015) The nexus as a political commodity: agricultural development, water policy and elite rivalry in Egypt. International Journal of Water Resources Development 31(3): 360-374.

Voll SP (1980) Egyptian Land Reclamation since the Revolution. Middle East Journal, Vol. 34, No. 2 (Spring, 1980), pp. 127-148.

Wahish N (1998) Toshka turns millennial green. Al-Ahram Weekly On-line, 27 Aug. - 2 Sep. 1998, Issue No.392.

Warner J (2013) The Toshka mirage in the Egyptian desert – River diversion as political diversion. Environmental Science and Policy 30 (2013): 102-112.

Warner J, Mirumachi N, Farnum RL, Grandi M, Menga F, Zeitoun M (2017) Transboundary 'hydro-hegemony': 10 years later. WIREs Water 2017, 4:e01242.

Waterbury J, Whittington D (1998) Playing chicken on the Nile? The implications of micro-dam development in the Ethiopian highlands and Egypt's New Valley Project. Natural Resources Forum 22 (3), 155–164.

Weber P (2011) Is Egypt facing a Water Crisis ? Egyptian-German Water Resources Management Reform Programme (Agricultural Components).

Wheeler KG et al. (2016) Cooperative filling approaches for the Grand Ethiopian Renaissance Dam, Water International 41(4): 611-634.

Willcocks J, Craig JI (1913) Egyptian irrigation. Third Edition. E&FN Spon: London.

World Bank (1980) Report and recommendation of the president of the international development association to the executive directors on a proposed credit to the Arab republic of Egypt for a new land development project (West Nubariya), November 25, 1980.

World Bank (1999) Second pumping stations rehabilitation project. Implementation completion report. Arab Republic of Egypt.

World Bank (2005) Project appraisal document on a proposed loan in the amount of US$120 million to the Arab Republic of Egypt for an Integrated Irrigation Improvement and Management Project (IIIMP).

World Bank (2007) Implementation completion and results report. IIP Project. World Bank.

Yassin N (2014) Why is Egypt's hydro-political concern more intense on Sudan? The Reporter - English Edition, May 31, 2014.