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THE NATIONAL AND INTERNATIONAL WATER POLICIES WITH FOCUS ON THE DRAINAGE WATER REUSE PRACTICES AND THE MEGA WATER PROJECTS

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ABSTRACT

The overgrowing water scarcity in Egypt should be the motive to develop alternative water resources. The article focuses on a technical review of the state-of-the-art water policies for the reuse of agricultural drainage water in irrigation worldwide and in Egypt, due to the increasing pace of implementing mega water projects. Satisfying future water demands in Egypt depends on better utilization and efficient use of the available water resources. Optimal water management, particularly the nonconventional water resources, is an essential prerequisite for the sustainable development of Egypt. The hypotheses examined are that the available quantities of agricultural drainage water in Egypt shall decrease and the quality of that drainage water shall improve. In the meantime, it is expected that soil and water salinity rates shall rise as a result of the multiple reuses of the drainage water and also due to the expansion of modern irrigation practice not only in the newly reclaimed desert lands but also in some old heavy soil lands. In addition, a technical review of the impacts of those changes above on the phenomenon of seawater intrusion in the northern parts of the Nile Delta is presented. It is concluded that the impact of the national water-saving, irrigation improvement projects, and expansion in land reclamation in the desert are inversely proportional to the resulting amount of agricultural drainage water in Egypt. That reduction is interpreted as about 20%, which needs further extensive applied research to verify. That amount might be compensated with the safe reuse of treated wastewater, with the due health safeguards. Accordingly, as stated in the NWRP2037, caution should be taken while projecting the future available agricultural drainage water for reuse in each geographic zone in Egypt.

Keywords: Water Reuse, Water Resources Planning, State-of-the-Art Water Reuse Experience Worldwide, Trade-off Options, Environmental Sustainability

1. INTRODUCTION

In a world where demands for freshwater are continuously growing, and where limited water resources are increasingly stressed by over-abstraction, pollution, and climate change, neglecting the opportunities arising from improved the management of all types of water is nothing less than unthinkable in the context of a circular economy UNWWAP (2017). As stated by the High-Level Panel on Water, 36% of the world's population already live in water-scarce regions, and by 2050 more than half the world's population will be at risk of water stress HLPW (2018). Competing demands for water are adding pressure to the allocation of freshwater resources. Governments around the world face an array of water policy options for managing structural water scarcity, droughts, and floods; improving water quality; and protecting ecosystems and their services. Careful planning promotes long-term water security and resilience to climatic and non-climatic uncertainties WRDM (2018). Water, importantly, connects to wider policy goals of mitigating poverty and ensuring social equity, public health, and macroeconomic performance, among others Rodriguez et al. (2020).

It is evident that integrated river basin planning approaches yield more sustainable and resilient systems. By planning and analysing water quality and quantity at the basin level, integrated solutions that are more socially, economically, and environmentally sustainable are possible Larsen (2019). Countries need to develop the right water policy, institutional, regulatory frameworks to promote that paradigm shift Rodriguez et al. (2020).

A projected population for 2030 has been estimated for each governorate based on an annual growth rate of 2.2 %. The total population of Egypt in 2030 is expected to reach 112.3 million citizens. Water reuse is central to cope-up-with challenges in water scarcity and population pressured regions. The latest population census in Egypt shows that there are more people now living along the narrow strip of land by the Nile than ever before, about 102 million CAPMAS (2021). The country's rapidly growing population, its limited water resources, and its dependence on food imports all reinforce the importance of an integral water and agricultural policy. Water plays innumerable roles throughout the society, economy, and environment. The importance of water cannot be overstated since it is a pillar of development, provides essential services for human health and safety, and supports life on this planet. With the recent series of economic reforms in Egypt that saw changes in the Egyptian pound's equivalence to other currencies, the application of a value-added tax, and decreases in energy subsidies, Egypt has a unique opportunity to focus on sector-level policies, including those within water and agriculture Kassim et al. (2018). Water reuse is a key strategy for water security. Water reuse is necessary to meet the challenge of increasing water demands at a time. As such, the UNESCO (2020) stated that water reuse is also essential to achieve the Sustainable Development Goals (SDGs).

Decision-making for water reuse must take into account many variables. For instance, to understand water availability, it is not sufficient to only know the volume of water available. A case study in Brazil highlights the importance of integrating quantity, quality and purpose in decision making to assess water availability and on water reuse investments UNESCO (2020). Surface-water resources originating from a single external water source being the Nile River, which provides an average annual fixed flow of 55.5 BCM/year since 1959, are now fully exploited. Also, groundwater sources have been brought into full production. Egypt is facing increasing water needs, demanded by rapidly growing population, increased urbanization, and an agricultural policy which emphasizes expanded production in order to feed the growing population. The per capita water share is currently less than 585 m^3/year, much less that the international water scarcity limit of 1000 m^3/year. As population and water demands increases, more freshwater may need to be reallocated to domestic uses, especially at inland cities and villages, that are far from coastal areas, where desalination of seawater could be a resort. This situation puts the existing agriculture sector in a vulnerable situation that is not being able to satisfy its current and future water requirements.

Coupled by the challenges and timeliness associated with developing additional Nile waters from upstream reaches. This risks any future plans for agriculture expansion of not having the necessary sustainable water resource AbuZeid (2017a). As water supply to domestic uses will continue to grow due to the increase in population, more wastewaters will be generated at about 80% of domestic water supply. Treated wastewater could lead to useful reuse in agriculture. The advantage is not only conserving water but also avoiding the ecological harms associated with the discharge of untreated wastewater into rivers, drains and lakes. Improved planning and management procedures are key measures prescribed to the optimum use of available water UNWWAP (2017).

Innovations in dealing with the water-energy-food nexus (Figure 1) in arid zones like Egypt is increasing, especially when it comes to desalination, wastewater treatment technologies, and groundwater pumping Maftouh et al. (2022). Egypt has implemented a combined policy of improving surface irrigation in the old lands (within the Nile Valley and the Nile Delta), while reuse agriculture drainage generated from improved surface irrigation, as well as enforcing modern irrigation such as drip and sprinkler irrigation in the new desert reclamation lands. This demonstrates the WEF nexus perspective that, transforming surface irrigation to pressurized drip irrigation is not always the best solution. It is important to look at the overall water use efficiency than just focusing on the on-farm irrigation efficiency AbuZeid (2017b).

Figure 1

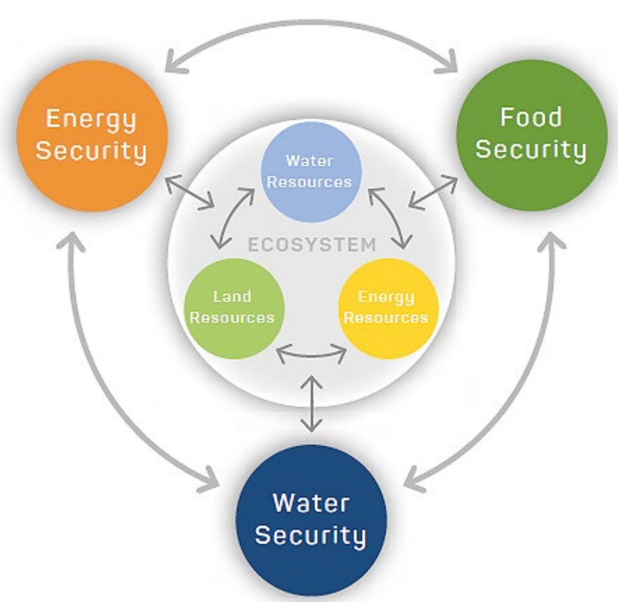

Figure 1 The Water-Energy-Food Nexus to Achieve Better Livelihood and Sustainable Development, AbuZeid (2017b)

In this review article; the international and national state-of-the-art water experiences on policies implementation regarding the reuse of agricultural drainage water for irrigation purposes, and how this is being affected by the mega water projects are reviewed and discussed, referring to the Egyptian National Water Resources Plan up to the year 2037, NWRP2037, . , in light of the increasing pace of implementing mega water projects such as the on-farm water management, installing modern irrigation systems, water saving, canal lining, and wastewater treatment projects. The motive is the envisaged uncertainty around whether Egypt shall have enough agricultural drainage water quantities -as a key nonconventional water resource- to contribute to narrowing the water supply-demand gap or not.

2. OUTLINE

This review article is structured in five sections (Introduction, Review of methodological approaches on the reuse of drainage water policies for irrigation purposes, Discussion on the availability of agricultural drainage water for reuse in Egypt in the future, Conclusion and recommendations, and references). The main section shades the light on the state-of-the-art the methodological approaches used in the world that adopt the reuse of drainage water policies and its impacts. It overviews also how the nonconventional water resource is anticipated to be affected by the increasing pace of implementing the mega water projects in Egypt, such as the national irrigation improvement projects, including waster saving, modern irrigation, canal lining, and on-farm management, also the national sewerage network installation in villages, also the expansion in desert land reclamation, and finally the construction of mega wastewater treatment (WWT) plants that divert the treated wastewater to irrigate newly desert reclaimed lands. All those national projects contribute positively to the national food security but most likely reduce the quantity of the available agricultural drainage water in the Nile Delta.

3. REVIEW OF METHODOLOGICAL APPROACHES ON REUSE OF DRAINAGE WATER POLICIES

3.1. REVIEW OF THE INTERNATIONAL REUSE OF DRAINAGE WATER POLICIES

There are at least 60 countries around the world practicing various types of water reuse. It is difficult to compare the intensity of reuse in countries with different population and area size. With respect to total annual volume, China, Mexico, and the United States (mainly California, Texas, Arizona, and Florida) are the countries with the largest quantities of water reused. Pakistan, India, Brazil, Egypt, Jordan, and some Asian water basins come relatively next. In China and Mexico, reused water is mostly poorly treated wastewater. When considering the intensity of reuse per inhabitant, Qatar, Israel, and Kuwait are the countries first ranked, while if considering the percentage of reuse related to the total volume of fresh water used, Kuwait, Israel and Singapore become the first ones. When the technological achievements are considered California, Singapore and Japan are probably pioneers Angelakis and Gikas (2014).

UN Food and Agriculture Organization (FAO) unified the best practices worldwide and formulated the guidelines for reuse of drainage water. Adequacy and suitability of drainage systems and structures play a key role in increasing global agricultural production and improving global food security FAO (2018). Figure 2 illustrates a qualitative comparison among 13 famous countries with respect to its water reuse. Those countries are facing water supply challenges like Egypt. The red colour reflects lesser magnitude of the shown comparison aspect than the black colour. The following are some.

Figure 2

Comparison aspect / Countries	China	India	Pakistan	USA	Mexico	Brazil	Egypt	Jordan	Israel	Singapore	Qatar	Kuwait	Aral Sea basin
Large Q annual water reuse	√	√	√	√	√	√	√						
Mostly poor-treated wastewater	√				√								
Intensity of reuse per inhabitant							√		√	√	√	√	
Technological achievements WWT				√						√			
Increasing wastewater reuse							√						
Strong water reuse policies	√	√	√	√		√	√	√	√	√	√	√	
Soil salinity and water logging		√	√		√								√
Environmental degradation		√	√		√								√
Strong legislations and monitoring				√		√	√		√	√	√		

Figure 2 A Qualitative Comparison Among 13 Famous Countries in Water Reuse, Angelakis and Gikas (2014)

3.1.1. DRAINAGE WATER MANAGEMENT IN THE ARAL SEA BASIN

The Aral Sea Basin is mostly agricultural crops that depend mainly on surface irrigation. It is characterized by high evaporation and low precipitation. Water resources in the region consist of renewable surface water and groundwater as well as return flows in the form of agricultural drainage water and wastewater. Excessive irrigation water with low efficiencies had resulted in rising the groundwater levels and causing secondary soil salinization. Nearly half of the irrigated lands were affected by salinity. The shallow groundwater posed a major problem for agricultural production. To combat these problems, horizontal or vertical subsurface drains were developed. The disposal of drainage water caused considerable problems in terms of downstream water quality. Reasons for the waterlogging and salinity problems were the excessive irrigation. Drainage water use for irrigated agriculture was used for reducing the disposal problems in the Aral Sea Basin. Agricultural drainage water is currently reused for wetlands and biodiversity development, while the effluent drainage is disposed and left for evaporation in Desert depressions. The authorities put policies for regulating irrigation water and collecting drainage water but have not been viable enough to face the problem.

3.1.2. DRAINAGE WATER REUSE AND DISPOSAL IN INDIA:

The Northwest parts of India are characterized as water deficient region. The introduction of canal irrigation had reduced the gap between crops supply and potential demand to a certain extent. As irrigation development policy took place without the parallel development policy of drainage, water and salt accumulation has occurred in most canal command areas. Salinity has already affected large areas as remedial measures were not taken. In Punjab and Haryana, surface drains policy was constructed, and groundwater development and flood control were initiated in order to overcome waterlogging and salinity problems. Vertical drainage in the form of shallow groundwater wells was widespread throughout the region. Rise in the water table and subsequent salinization have continued in those areas. It will be necessary to maintain a fine balance between reuse and disposal of drainage water in order to establish a favourable salt regime in the region. The existing experience from small pilot projects is only indicative of the feasibility of reuse, shallow water table management and disposal requirements. The large-scale drainage disposal and reuse programs planned for Northwest India will make significant improvement toward a favourable salt regime at basin level.

3.1.3. DRAINAGE WATER REUSE AND DISPOSAL IN PAKISTAN

The water quality in the Indus River and its tributaries at their entry points into Pakistan is characterized by a low salt content. Apart from surface water, groundwater is an important source of supplemental irrigation supplies in the irrigation system of Pakistan. The salinity content of groundwater varied considerably. About one-third of the irrigated area had groundwater with a high salt content and a gradual rise in the water table. This had resulted in widespread waterlogging and salinity problems with serious adverse impacts on agricultural production. Then, vertical subsurface drains were installed in the affected lands. Water demand has continued to grow with the increasing population and land pressure. Government policies encourage the maximum use of groundwater pumped for drainage for irrigation in conjunction with the canal supplies. Where groundwater is saline, drainage effluent is allowed to be disposed into the canals for reuse after dilution or it can be conveyed to the rivers through drains at times of high river flows. A spinal drain has been constructed for areas located close to the sea. It was constructed to convey the highly saline subsurface drainage effluent and rainfall excess from the agricultural lands to the sea.

3.1.4. DRAINAGE WATER REUSE AND DISPOSAL IN THE UNITED STATES OF AMERICA

In western California, the United States of America, water delivery to the irrigated agriculture is based on water rights and water availability. That area was affected by waterlogging and salinity problems with water tables. The collected subsurface drainage water was used. The State of California promotes efficient water use through policies and legislation. Government policies exist for the reuse of reclaimed wastewater but not for the reuse of irrigation subsurface drainage water. However, there are constraints on the discharge of irrigation return flows to public water bodies. These constraints on drainage water discharges serve as an incentive for improved water management practices. New drainage water management practices have been identified with management options of reuse and disposal. Drainage water management options include source reduction, drainage water reuse, drainage water treatment, disposal in evaporation ponds, land retirement, groundwater management, river discharge, and salt utilization. For drainage water treatment, the flow-through wetland system appears to be the most promising option. Salt utilization has offered good long-term potential for meeting the salt balance challenge. The drainage water management practice used has still been inadequate to sustain irrigated agriculture in western California. However, a concerted effort is underway to sustain agriculture with other drainage water management options.

3.1.5. SEWAGE WATER TREATMENTS AND REUSE IN ISRAEL

Israel as a semiarid country, is characterized by long dry summers and short wet winters. Crop production in more than 50% of its agricultural lands relies mainly on modern irrigation. In recent decades, although the total cultivated lands have not been significantly changed, the area of irrigated land has been reduced, in accordance with the amount of available water for agriculture. Conventional sources of good quality fresh water became more limited. Therefore, in order to maintain sustainable agriculture to meet the increasing demands for food, and to combat desertification, reuse policy of unconventional water resources derived from treated sewage water (effluent) have been heavily applied and used for agriculture.

3.1.6. SEWAGE WATER TREATMENTS AND REUSE IN SINGAPORE

Singapore is a small country with limited water resources and law population. It has exploited all its inland water sources then imported drinking water through a pipeline from its neighbour Malaysia. In the year 2000 and to explore the possibility of reusing wastewater for industrial and potable uses, the government of Singapore applied a new policy for reuse of marginal water. It launched a pilot wastewater recycling demonstration project. Thus, a portion of the treated effluent was diverted to a water purification plant, which included microfiltration, reverse osmosis, and ultraviolet radiation disinfection units. The final product is called "NEWater". The quality of that produced water was assessed and found health-impact free. The production of NEWater has considerably expanded. NEWater is primarily used in industrial applications and in cooling towers, however, a small amount is injected to the potable water reservoirs. Despite the technological progress, public opinion tends to view potable uses of reused water with scepticism. Few years after, water reuse project in Singapore has been well accepted by the public as a result of a systematic governmental promotion program.

3.2. EXISTING AND FUTURE WATER POLICIES IN EGYPT

The population of Egyptians living in Egypt continues to increase with an average growth rate of about 2.2% CAPMAS (2021). In addition, the increasing competition over the Nile River waters among the upstream riparian countries, in the absence of a commonly agreed river basin management vision, threatens the sustainability of Egypt's Nile water. The water scarcity challenge is exacerbated, requiring additional water resources especially for the municipal and agriculture sectors.

Abdel-Shafy and Mansour (2013) mentions two predominant types of drainage water reuse: 1) official reuse: water from any main drain, blended with freshwater from any main canals to be used downstream for irrigation purposes and for the municipal water supply; and 2) unofficial reuse: where farmers at the tail-ends of irrigation canals use their private mobile pumps on agriculture drains to irrigate their fields in the absence of adequate freshwater, also takes place. It is estimated that unofficial reuse accounts for up to 50% of the total reuse of drainage water MWRI (2018). The Nile River is currently the main drain for the Upper Egypt area, whereas the Mediterranean Sea is the main drain for the Nile Delta regions. Gravity reuse has been realized in the 1930s that all drains should be given the same attention given to canals. In the 1980s, agricultural drainage reuse became an official policy to augment irrigation water supplies. Afterwards, a huge agricultural reuse expansion plans were implemented in desert areas. Upper Egypt's agriculture drainage, in often cases still, finds its way to the Nile system and may be reused again downstream after mixing with fresh Nile water.

Egypt Vision 2030 was developed in 2016 as a Sustainable Development Strategy for Egypt up to the year 2030 MPED (2016). The Vision possesses a competitive, balanced, and diversified economy. This depends on innovation and knowledge, based on justice, social integrity, and participation. It is also characterized by a balanced and diversified ecological collaboration system, investing the ingenuity of place and humans to achieve sustainable development and to improve Egyptians' life quality. Based on that, the National Water Resources Plan in Egypt up to 2037 (NWRP2037) was developed in 2018 in line with the Egypt Vision 2030 (Figure 1). It addresses the challenges facing Egypt's dependency on the transboundary water resource of the Nile and on the nonconventional water resources (drainage water and wastewater) reuse in agriculture. The role of virtual water imports in achieving Egypt's food security is important. It reflects on existing water policies and provides actions for water policies that would achieve quick wins in the future. So far, Egypt imports virtual water (strategic crops and meats) in the amount of 34 billion m^3 every year MWRI (2018). Table 1 shows water supply-demand balance in Egypt as of 2017, extracted from the NWRP2037 MWRI (2018).

Table 1

Table 1 The 2017 Estimated Water Balance for Egypt (Billion m^3/year)

Water Resources	BCM/year	Water Demand Per Sector	BCM/year
1) Primary Water Resources:			
- Nile River	55.5	Domestic	10.8
- Non-renewable groundwater	2.1	Industry	5.4
- Rainfall	1.3	Agriculture	61.6
- Saline water desalination	0.4	Evaporation	2.5
Sub-total (1)	**58.2**		
2) Reuse From Secondary Water Resources:			
- Nile Valley & Delta groundwater	7.5		
- Agricultural drainage reuse	9.3		
- Treated wastewater reuse	4.2		
Sub-total (2)	**21**		
Total (1) + (2) = water availability	**80.3**	**Total water uses**	**80.3**

Extracted from the National Water Resources Plan in Egypt up to 2037 MWRI (2018)

Figure 3 shows the agricultural lands in Egypt with the main water control and distributions structures (High Aswan dam and main barrages on the Nile). The impacts of climate change on the water sector in Egypt need assessment not only at the national level but also at the transboundary level where 97% of the renewable water resources of Egypt originate upstream in the Nile River basin. From the institutional perspective, the water sector in Egypt is currently divided among two main Ministries: The MWRI, in charge of water resources planning and management, irrigation, and agriculture drainage, and the Ministry of Housing, Utilities and Urban Communities, in charge of domestic water supply and sanitation.

3.3. IMPACTS OF IRRIGATION IMPROVEMENT PROJECTS AND EXPANSION IN LAND RECLAMATION

Due to the aridity and limited freshwater resources; the total cultivated area of Egypt is about 3.45 % of the total area of the country. The Nile water system and its network of irrigation canals and agriculture drains in Egypt is considered one of the world's most efficient systems, with an overall water use efficiency, reaching over 75% in terms of water quantity. However, there is still room for improvement to increase the efficiency further at the local and farm levels, and to improve the quality of water delivered, which is another aspect of water use efficiency.

Figure 3

Figure 3 The Agricultural Lands in Egypt with the Main Water Control and Distributions Structures **source** www.sis.gov.eg

Based on literature review, irrigation improvement may save an additional 10–20% of freshwater availability. It will also provide better distribution and more equity in allocating water quantity and quality among irrigation water users AbuZeid (2011). So far, this has been contributing to the incremental increase in the supply of municipal water needed for urban expansion and the increasing population needs. On the other hand, state-of-the-art technology and innovations in irrigation are used in the desert reclamation projects for agriculture expansion.

Modern irrigation schemes such as automated smart sprinkler and drip irrigation technologies are adopted. Old agriculture lands in the Nile Valley and the Delta are being modernized. Farm irrigation in more than 1.0 million feddans have been modernized. Smart irrigation technologies are being practiced at few old lands in Egypt AbuZeid (2019).

Reallocating the water saving that result from water efficiency projects may not necessarily be reallocated to the same sector. With the ever-increasing demand in municipal water, a sector that has the highest priority in water allocation, it may be needed to reallocate Nile freshwater savings from the agriculture sector to the municipal water sector and allocate the treated wastewater resulting from municipal water uses to agriculture expansion projects AbuZeid (2019).

Under NWRP2037 - the business-as-usual (BaU) strategy in Egypt, the amount of water available for agriculture will fall to 59.6 BCM as gains in the overall availability of freshwater are less than the increased supplies to domestic and industrial usage. The area irrigated will remain quite similar to that of 2017; the water balance studies estimated that agriculture lands was 9.13 million feddan in 2017; while in 2037 it could be 9.6 million feddan. Although additional lands will have been reclaimed, existing lands will also be lost due to urbanization. As a consequence, farm households or agricultural enterprises will have to operate with about 8% reduction in the amount of water available to their crops. This is a more challenge as climate change will, due to the expected rise in temperature, resulting in higher potential crop evapotranspiration MWRI (2018).

The ambition of the NSDMWR (2019) is to save 10 billion m^3/year by 2030 – both through rational use of existing resources and development of new resources – through measures to be implemented between 2017 and 2037. The NWRP2037 has incorporated those measures and reflected their impact and cost. The impact of reducing the amount of irrigation water is directly proportional to the resulting amount of drainage water, however the percentage of that reduction in drainage water is the question which is difficult to answer. In this context, it is interpreted that the national project for canal lining shall prevent more irrigation water to infiltrate into the soil and reach the nearby drainage system. It is interpreted that the reduction in drainage water due to canal lining could reach (2-4) % of the irrigation water, which is equivalent to about 2.5 billion m^3/year (4% out of the 61.6 billion m^3/year total irrigation water in Egypt). This assumption is based on unpublished research and the personal interpretation.

General ratio of reducing the amount of drainage water to the amount of irrigation water have been mentioned in another research works about (20-25) %. This could be equivalent to 4.2 billion m^3/year (25% out of 16.8 billion m^3/year total reuse of agricultural drainage and shallow groundwater in the Nile Delta and Valley). The worst scenario is adopted just to show the extent of impact that might happened. Accordingly, it is assumed that expansion in land reclamation in the Delta's fringes and desert as well as irrigation improvement projects could cause reduction in agricultural drainage amount by about 4.2 billion m^3/year.

3.4. IMPACTS OF EXPANSION IN INSTALLING SANITATION AND SEWERAGE NETWORKS

In case of water shortage, domestic water demand takes priority in satisfying demand over other sectors. The high dependency of Egypt on the one Nile River as the main source for renewable water resources forces the construction of long lengths of pipes to transfer domestic water to urban centers of population and remote suburbs AbuZeid and Wagdy (2019). The water supply coverage in Egypt has reached 100% in 2008, yet it dropped back to 99% in 2011 due to continued population growth and dropped again some more due to occurring cuts in investments in several years after 2011 HCWW (2014). The annual production of water supply reached 6.6 billion m^3 in 2011, with groundwater plants providing an additional 1.4 billion m^3 annually, reaching 12.25 billion m^3/year in 2022. Figure 4 shows the projected water supply in Egypt up to 2030, AbuZeid and Elrawady (2014). Although close to 100% of the households are connected to the national potable water networks, only about 56% of them are connected to the national sewage networks CAPMAS (2017). More specifically, it is 91% in urban areas and about 14% in rural areas, according to the Law 48/1982 AbuZeid and Wagdy (2019).

Figure 4

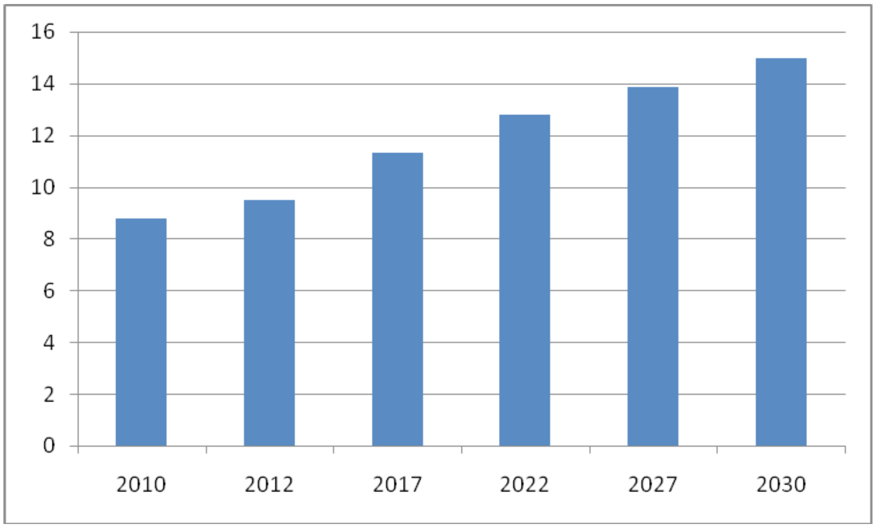

Figure 4 Projected Water Supply Capacity (billion m3), (modified from HCWW (2014)

The Government of Egypt launched the National Rural Sanitation Program (NRSP) in 2015, which aims to provide access to sanitation in villages and rural areas through the provision of local wastewater treatment plants, sewage networks and pump stations. Although amount of drainage water could be less due to the expansion in sanitation connections services instead of disposing it raw to the nearby open drains, the drainage water that was prohibited due to the high pollution rates can be reused safely EBRD (2021). A study by the World Bank in 2021 concluded that the expansion in small and medium sewage collection and treatment units, that dispose its treated water into the open drainage system in Egypt, leads to lowering the biological contamination and accordingly lowering the pollution loads that used to be mixed with the agricultural drainage water.

3.5. IMPACTS OF CONSTRUCTING THE MEGA WASTEWATER TREATMENT PLANTS

Using treated wastewater for non-potable uses saves potable water for drinking, since less potable water will be used for non-potable uses. Due to the technology involved, the cost of wastewater reuse exceeds that of potable water in many regions of the world, especially where a fresh water supply is conveniently available. However, treated wastewater is usually sold to citizens at a cheaper rate to encourage its use. Different countries tend to setup codes for using treated wastewater in irrigation; these codes usually link the type of crop to the degree of treatment. Skinless fruits and raw-edible vegetables require the highest degree of treatment. With the increasing population in Egypt, as more water will eventually need to be supplied to meet the basic human needs of domestic water demand, and with the water-saving programs that lead to less agricultural drainage water, the growing amounts of wastewater will make treated wastewater on top of the list of Egypt's alternative water resources. However, treated wastewater reuse in Egypt encounters several limitations that must be properly safeguarded.

Egypt produces about 7.0 billion m^3/year of wastewater in 2011. About 3.7 billion m^3/year of which were untreated, 2.4 billion m^3/year were secondary treated, 0.9 billion m^3/year were primary treated, and only about 0.1 billion m^3/year were tertiary treated. Out of that total (about 3.4 billion m^3/year) treated wastewater, only about 0.3 billion m^3/year were reused directly for agriculture, while the remaining amount was disposed to the national drainage network where they were indirectly reused HCWW (2014). About 96% of the collected wastewater was safely treated AbuZeid (2017b).

It is worth mentioning that the World Health Organization (WHO) and the UN Food and Agriculture Organization (FAO) set guidelines for wastewater reuse in agriculture WHO (2006), FAO (2000). In order to effectively implement wastewater management programs, suitable institutional structures must be aligned with the policy and regulatory frameworks to create the right incentives for reuse and resource recovery. Several institutional barriers, however, hinder the development of those activities. Among the major and key institutional challenges is the lack of coordination between different levels (inter-sectoral) of government Rodriguez et al. (2020). Utilizing treated wastewater for agricultural irrigation has been regulated and practiced in many countries such as the USA, Germany, India, Kuwait, Saudi Arabia, Oman, Jordan, and Tunisia. That practice first was adopted in Egypt at El-Gabal el-Asfar farm, which consists of an area of 3,000 feddans of wood trees, irrigated by that treated wastewater. Figure 5 shows the projected collected wastewater capacity till 2030, according to the 2030 Strategic Vision for Treated Wastewater AbuZeid and Elrawady (2014).

With this overview, an Egyptian wastewater treatment reuse code was developed by the Ministry of Housing, Utilities and Urban Communities (MHUUC) and adopted in 2015 (ECP 501/2015), MHUUC (2015). The ECP 501/2015 is more flexible than the old laws, yet the health safeguards of the humans and environment remain strictly met Khairy and Abdel Ghany (2021). It classifies the treated wastewater into three grades according to the level of treatment as shown in Table 2 and assigns agricultural groups that can be irrigated by treated wastewater as shown in Table 3.

Figure 5

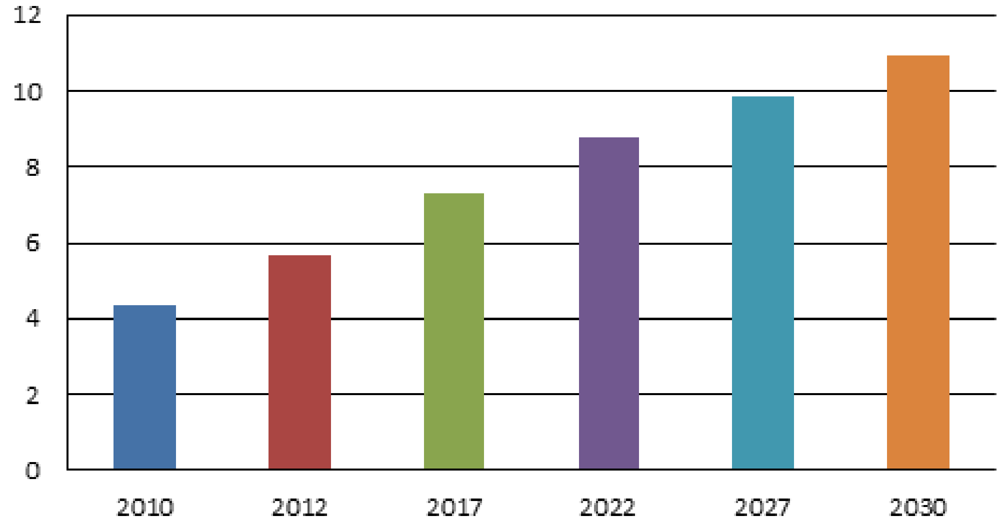

Figure 5 Projected Wastewater Collection Capacity (billion m3/year), (modified after HCWW (2014)

Table 2

Table 2 Grades of Treated Wastewater, MHUUC (2015)

	Grade A	Grade B	Grade C
BOD mg/l	<20	<60	<400
TSS mg/l	<20	<50	<250
Potential number of the colonic group in 100 cm^3	<1000	<5000	N/A
No. of eggs of nemetoda No./l	<1	<1	N/A

The total amount of produced wastewater in 2030 according to Egypt's 2030 Strategic Vision for WWT will be about 11.7 billion m^3. Assuming that all primary treatment plants will be upgraded to secondary treatment, the total expected amounts to be secondary treated at the national level in 2030 is 11.6 billion m^3 which is almost the whole produced amount, as the small remaining margin represents the current amount of 67.7 million m^3 that is subject to tertiary treatment and will be maintained through 2030. According to the 2030 Strategic Vision for WWT, 5.8 billion m^3 will be used directly in agricultural expansion areas, while 5.5 billion m^3 will be disposed into the agricultural drains in the delta AbuZeid and Elrawady (2014). According to the Ministry of Agriculture and Land Reclamation, 1.4 million feddans will be reclaimed for cultivation, according to the 2030 Sustainable Agricultural Development Strategy, with a total average annual water requirement of about 5.4 billion m^3. According to the 2030 Vision, these water requirements can be satisfied by the secondary treated wastewater produced in 2030. The Vision estimates an additional about 1.5 million feddans (not 1.4 million feddans) that could be reclaimed based on the remaining potential of secondary treated wastewater of 0.4 billion m^3 from desert front governorates and 5.5 billion m^3 from the delta governorates at an estimated water requirement of about 4100 m^3/feddan/year FAO (2021).

Table 3

Table 3 Agricultural Groups by Grade MHUUC (2015)

Grade	Agricultural Group	
A	G1-1: Plants and trees grown for greenery at tourist villages and hotels	Grass, Saint Augustine grass, cactaceous plants, ornamental palm trees, climbing plants, fencing bushes and trees, wood trees, and shade trees
	G1-2: Plants and trees grown for greenery inside residential areas at the new cities	Grass, Saint Augustine grass, cactaceous plants, ornamental palm trees, climbing plants, fencing bushes and trees, wood trees, and shade trees
B	G2-1: Fodder/ Feed Crops	Sorghum
	G2-2: Trees producing fruits with epicarp	On condition that they are produced for processing purposes such as lemon, mango, date palm, and almonds
	G2-3: Trees used for green belts around cities and afforestation of highways or roads	Casuarina, camphor, athel tamarix (salt tree). oleander, fruit-producing trees, date palm and olive trees
	G2-4: Nursery Plants	Nursery plants of wood trees, ornamental plants, and fruit trees
	G2-5. Roses and Cut Flowers	Local rose, eagle rose, onions (e. g. gladiolus)
	G2-6: Fiber Crops	Flax, jute, hibiscus, sisal
	G2-7: Mulberry for the production of Silk	Japanese mulberry
C	G3-1: Industrial Oil Crops	Jujoba, castor oil plant, and Jatrova
	G3-2: Wood Trees	Kaya, camphor, and other wood trees

The 2030 Strategic Vision for WWT provides options for reuse plans of each governorate in terms of recommended levels of wastewater treatment, projected amounts of produced wastewater, suggested mode of reuse, and whether it should be directly reused or conveyed by drains or canals for further reuse downstream AbuZeid and Elrawady (2014). The Egyptian Governorates were divided into two categories, with different strategies for each category, the first category consists of governorates without agricultural expansion plans which includes the six delta governorates (Menoufia, Dakahlia, Kafr El-Sheikh, Gharbia, Kalyoubia) in addition to Cairo, Alexandria, and Port Said. The other category consists of all governorates with a desert front and/or a future agricultural expansion plan. The secondary treated wastewater will be directed to the main drainage network allowing reuse downstream through agricultural drainage mixing pumping stations to be conveyed to Northern planned agricultural expansion areas such as North Sinai in the Northeast and Hammam area and others in the Northwest. Whereas, in case of the Desert front governorates and/or those with identified agricultural expansion plans, the secondary treated wastewater will be used directly for agriculture AbuZeid and Elrawady (2014). ReWater project by the International Water Management Institute (IWMI) in collaboration with CEDARE as well as several Egyptian governmental and non-governmental institutions; is developing a 2030 Shared Water Resources Strategy for Treated Wastewater Reuse. A first draft was prepared in late 2020, the final version still under preparation. The project helps to make a new policy based on actual data collection and a series of national consultations to assure stakeholders' involvement and demand satisfaction ReWater Project (2020).

After finalizing that strategy, a "National Plan for Wastewater Reuse" would also be needed on governorates level, so to be part of a national Integrated Water Resources Management (IWRM) Plan for Egypt and for other countries with similar water scarcity situation. To achieve that national plan, a national-dialogue function is needed among the different sectors and key stakeholders to discuss the challenges and opportunities.

Focusing on the allocation of treated wastewater for agriculture, it worth mentioning that several new agricultural projects in the desert areas are under construction with the aim to promote attractive communities' settlements in Sinai and western desert. Agriculture development projects in North Sinai depends on reuse of the treated agricultural drainage water of Bahr El-Baqar drain (mixed with huge amounts of wastewater from greater Cairo) providing about 5.6 million m^3/day of treated wastewater, which could be pumped from Bahr El-Baqar WWTP into the agricultural schemes in north Sinai (Egypt Today, 2019). Additionally, in middle Sinai, treated wastewater of El-Mahsama Drain could be pumped into Sinai adding about 1.0 million m^3/day to irrigate new agricultural schemes Khairy and Abdel Ghany (2021). In the near future, El-Hammam WWTP shall provide additional 7.5 million m^3/day to reclaim what is called the New Delta in the western desert of Egypt. Those three mega WWT projects shall provide about 5.1 billion m^3/year to irrigated new large agricultural schemes, as part of the national project to reclaim 1.5 million feddans MWRI (2022). The extraction of large amounts of agricultural drainage water mixed with raw wastewater, treating it in the mega mentioned above WWTPs, then diverting it to irrigate large, reclaimed lands out of the Nile Delta shall reduce the amounts of drainage water necessary for reuse in agriculture in those areas. This might be compensated with the safe reuse for treated wastewater through the new, local, and small WWTPs.

3.6. CHANGES IN WATER AND SOIL SALINITY IN THE OLD LANDS (THE NILE DELTA REGIONS)

Amer and Ridder (2016) informed that irrigation-induced salinity can arise as a result of the use of any irrigation water, irrigation method, irrigation of saline soils, rising levels of saline groundwater, and absence of drainage system in heavy soils combined with inadequate leaching. When surface water or groundwater containing mineral salts is used for irrigating crops, salts are carried out into the root zone. In the process of evapotranspiration, the salt is left behind in the soil, since the amount taken up by plants and removed at harvest is quite negligible. Table 4 shows the salinity classes' classification of the reused drainage water (quantities and qualities) in the Nile Delta in Egypt during (2020-2021). The more arid the region is, the larger is the quantity of irrigation water and, consequently, the salts applied, and the smaller is the quantity of rainfall that is available to leach away the accumulating salts. Excess salinity within the root zone reduces plant growth due to increasing energy that the plant must expend to acquire water from the soil Polyakov (2021).

Table 4

Table 4 Classification of Reused Drainage Water in the Nile Delta (Quantities and Qualities) During (2020-2021), DRI (2022)

Salinity Class	Eastern Delta Billion m^3/y	Middle Delta Billion m^3/y	Western Delta Billion m^3/y	Total Delta Billion m^3/y
< 750	1.235	0.070	0.224	1.529
750 - 1000	0.066	0.344	0.649	1.059

1000-1500	0.559	2.022	0.191	2.772
1500-2000	0.000	0.142	0.000	0.142
2000-3000	0.000	0.000	0.000	0.000

On the other hand, Table 5 shows the distribution of disposed drainage water (quantities and qualities) to the Northern lakes and The Mediterranean Sea from the Nile Delta regions in (2020-2021). The salt loads amounts are increasing yearly, compared with its values in (2015-2016), DRI (2022). The total salt load increased accumulatively by about 5%, from 31.9 million tons in (2014-2015), DRI (2016) to 33.6 million tons in (2020-2021), DRI (2022). The overall average water salinity increased by about 1.1 % from 2211 g/m^3 in (2014-2015) to 2234 g/m^3 in (2020-2021); respectively. It can be inferred that salts amounts from the agricultural lands of the Nile Delta increases with time proportional to the implementation of the water-saving policies and with the multiple drainage water reuse. In this context, it is good to highlight that turning 800 thousand feddans of heavy clayey soil agricultural lands in the Nile Delta from improved surface irrigation into modern irrigation (sprinkler and drip systems) might cause significant soil salinization problem with time due to the insufficient leaching and accordingly salts continue to accommodate significantly in the root zone Maftouh et al. (2022).

Table 5

Table 5 Distribution of Disposed Drainage Water to the Northern Lakes and the Mediterranean Sea (quantities and qualities) in the Nile Delta in 2020-2021

Delta Region	Discharge Billion m^3/y	Average Salinity g/m^3	Salt load Million Tons
Eastern Delta	5.513	1750	9.647
Middle Delta	5.102	2130	10.867
Western Delta	4.451	2951	13.134
Total Delta	15.066	2234	33.648

India would require around 311 million tons of food grains (cereals and pulses) during 2030 to feed around 1.43 billion people, and the requirement expectedly would further increase to 350 million tons by 2050 when India's population would be around 1.8 billion. To achieve food security in India, restoring the degraded lands due to poor drainage and lower irrigation applications is a viable need. Sub-surface drainage of water-logged saline lands, salt tolerant crop varieties and improved agroforestry techniques are some of the well-adapted technologies to use. Around 6.7 million ha area in the country is salt affected (salinity/alkalinity/acidification). The Government of India has fixed a target of restoring 26 million ha of degraded lands, including salt-affected soils through reuse of agricultural drainage by the year 2030 to ensure food security for the people Kumar and Sharma (2020). Water authorities in any relevant country should keep examining the design criteria for the present and future planned drainage systems under a wide range of water-saving policies as well as climatic conditions, with focus on exploring the vulnerability of both structural and non-structural components of the systems for more future efficiency Leavesley et al. (1992), Shiklomanov (1994).

3.7. CHANGES IN SEAWATER INTRUSION IN THE NORTHERN DELTA LANDS

Saltwater intrusion in coastal areas is highly correlated to the abstraction rate of the shallow groundwater and irrigation management practice. Egypt is following strict policies to rationalize the amounts of irrigation water, improve the on-farm's surface irrigation efficiency, practicing of multiple reuses of agricultural drainage water as well as the shallow groundwater in irrigation, and expand in treating wastewater and drainage water at the Northern parts of the Nile Delta, as indicated under sections (3.3) till (3.6) above. Those policies and practices affect negatively on the fresh versus saline groundwater equilibrium in the Northern parts of the Nile Delta, causing increasing seawater intrusion phenomenon in the Northern parts of the Nile Delta and as a result increasing the soil salinity Engelen et al. (2019). This requires more water for salts leaching from the top soil layers, which might not be the case with the expansion in water saving and water management projects in Egypt Khairy et al. (2020).

4. DISCUSSION ON THE AVAILABILITY OF AGRICULTURAL DRAINAGE WATER FOR REUSE IN EGYPT IN THE FUTURE

An assessment study by Rachele (2019) investigated that water reuse is a viable cost-effective policy measure for agriculture and it has a key role in mitigating water scarcity and reducing freshwater abstraction in the European Union countries. Furthermore, it suggested that treated wastewater can help mitigate the effects of climate change.

The total amount of water reuse (drainage water and wastewater) in Egypt reaches about 21.0 billion m^3/year. That amount can be classified into three categories: 1) the amount of officially reused agricultural drainage is 9.3 billion m^3/year; 2) summation of the unofficial reuse of agricultural drainage (by farmers, natural flow to the River Nile in the Upper Egypt and Nile Valley, and the shallow groundwater abstraction in the Nile Delta regions) is about 7.5 billion m^3/year; and 3) the treated wastewater reuse in Egypt is the amount of 4.2 billion m^3/year.

According to NWRC (2008), there was about 13.5 billion m^3 of mixed agriculture drainage and raw wastewater disposed annually to the Mediterranean Sea, the latter amount consists of about 7.0 billion m^3 of agricultural drainage of poor quality due to multiple reuses, as well as 6.5 billion m^3 of municipal and industrial wastewater. By 2020, Egypt initiated a rigorous strategy to maximize the use of the treated agricultural drainage water that is mixed with wastewater instead of disposing that large amount to the sea. The two mega WWTPs that are already operational (El-Mahsama WWTP and Bahe El-Baqar WWTP) as well as the about-construction finalization El-Hammam WWTP. The maximum capacity projected is about 5.1 billion m^3/year of treated water out of that originally large amount of poor-quality drainage water flowing into the sea. It is evident that diverting of such large amount of drainage water out of the Northern parts of the Nile Delta system most likely shall cause two problems: increasing the inland saline water intrusion from the Mediterranean Sea and accumulation of salts in the root zone of the agricultural crops under cultivation in the heavy soils of the Nile Delta regions (due to the multiple reuses of the saline drainage water).

Based on the technical review presented on the national and international water policies of drainage water reuse with respect to the mega water projects, the following results are extracted:

- The 2050 National Strategy for Development and Management of Water Resources NSDMWR (2019) recognized WWT as a potential solution for contributing to filling the gap between water demand and supply in Egypt by 2050. Accordingly, expansion in wastewater reuse in all governorates should be conditioned on the involvement of the private sector. NWRP2037 on the other hand, identified the drip irrigation as the most suitable irrigation method using the reuses treated wastewater, and assumed its irrigation efficiency ~80% Zhao et al. (2021).
- The broader concept of IWRM involves integrating land and water, upstream and downstream, groundwater, surface water, and coastal resources. One of the main pillars of the IWRM is optimizing supply, which in turn, involves conducting assessments of surface and groundwater supplies, analysing water balances, adopting wastewater reuse, and evaluating the environmental impacts of water distribution and use options. Also, utilizing an inter-sectorial approach to decision-making, where authority for managing water resources is employed responsibly and stakeholders have a share in the process, is another important IWRM component GWP (2020).

Figure 6

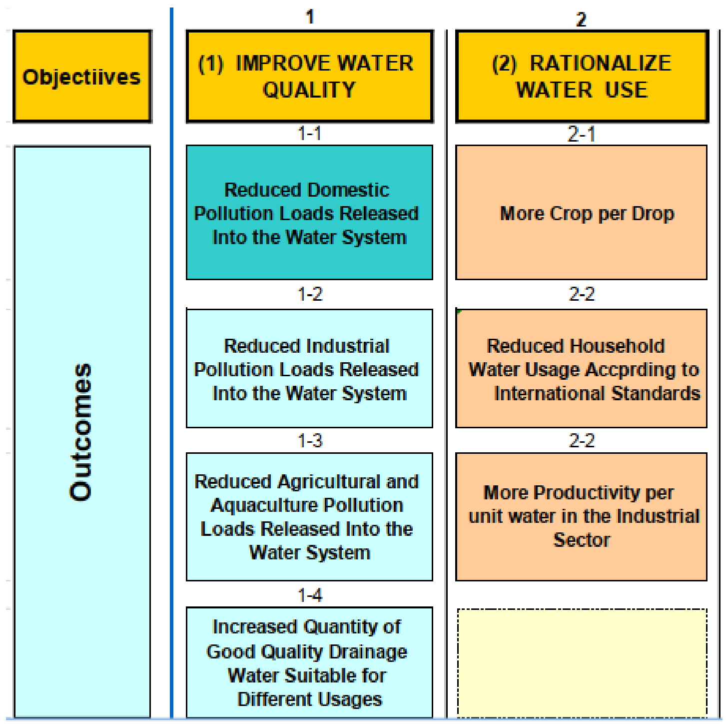

Figure 6 The First and Second Objectives of NWRP2037 Versus Its Outcomes - MWRI (2018)

- Based on the NWRP (2018), the illustration (Figure 6) explains that the first and second objectives of the NWRP2037 shall lead significantly to reducing the quantities of drainage water in the drainage system (surface system and sub-surface network), yet its qualities shall fairly improve due to the enforcement laws of banning the disposal of raw wastewater into the open drainage network. The operation of the mega WWTPs as well as the small & local WWT stations, implementation of the water saving and irrigation improvement projects, and availing enabling environment for IWRM most likely shall turn into less availability of drainage water for reuse. This situation put some risks as Egypt might not continue depending fully on drainage water reuse as a viable water policy practice.

- The interpretation of the results from the NWRP2037, the amount of reused drainage water and wastewater shall increase from 26% to 28% by the year 2030; accordingly, the amounts of direct agricultural drainage water reuse shall increase from 13.5 billion m^3 to 16 billion m^3 by the year 2030. However, the amount of drainage water flowing into the Mediterranean Sea and Lake Qaroun in Fayoum was about 8.4 billion m^3 in the year 2020 and expected to decrease to 3.4 billion m^3 by the year 2030.
- The interpretation of the results of the 2030 Strategic Vision for Treated Wastewater is that the maximum amount of direct (official reuse) agricultural drainage water available for reuse was about 12.6 billion m^3 in the year 2020 and shall not exceed 11.2 billion m^3 in the year 2030, including the reuse for treated wastewater from the new small and local WWT stations spread in all governorates (was about 13.5 billion m^3/year in the year 2017). However, the expansion in safely using WWT through the mega WWTPs in Egypt (which increases incrementally to reach ~5.1 billion m^3/year by 2030) shall contribute to filling that deficit.

The decision makers in Egypt have been aware of the limiting factors on policies for agricultural drainage water reuse. Those factors should be inherited in the future water policy decisions of the agricultural drainage water reuse in the Nile Delta are:

- Due to the expansion in water management and water saving projects, the amount of irrigation water allocation to the old lands of the Nile Delta as well as the amount of the resulting agricultural drainage water shall continue to decrease. This is occurring as a result of diverting large amounts of treated wastewater out of its original system (Nile Delta and Valley) in Egypt.
- Excessive reuse as well as water saving practices might cause the accumulation of salts in the root zone, particularly in the clayey and loamy clay soils in the Nile Delta regions. Accordingly, salt balance in the Nile Delta shall be altered significantly if compared to the existing salt balance condition.
- The new water resources law must be enforced nationwide to assure neither the drainage water does not include heavy metals and toxic pollutants, in case the mixing with raw industrial water disposals could not be strictly stopped, nor the presence of agricultural chemicals in drainage water that could cause the deep percolated water to harm the groundwater reservoirs in some agricultural lands.

AbuZeid (2019) concluded that Egypt succeeded in implementing a group of water policies that encourage the conservation and use of nonconventional water resources, improve water allocation, and water accounting, and jointly develop new Nile water resources. It is crucial to plan to use the suitable type of water for the appropriate use at the proper geographic location. Applying the fit-for-use water concept is going to result in reduced costs and efficient overall water-use. Although there are some attempts to make use of agricultural drainage water after mixing with treated wastewater for safe agriculture in some areas, and use of high-value non-renewable groundwater for drinking water bottling, which contribute to the concept, yet; there is still no policy that is adopting the concept at the national level. Allocating the nonconventional water resources for agriculture in the coastal cities on the Mediterranean and the Red Sea should be the first, then to consider desalination for fulfilling drinking water needs and start planning for it, if new water resources are to be sought. In the near future when Egypt will need to expand in desalination, proximity of seawater and brackish groundwater should play a role in reducing the cost of providing desalinated water.

It will be prohibitively expensive to convey desalinated water inland for long distances. Inland governorates will therefore have to continue depending on the Nile water, groundwater, and treated wastewater as the main sources for sustainable development in the future. This may require a new water policy that prohibit Nile water allocation to the coastal governorates, and instead to keep it for the inland governorates. With the existing limited share of Egypt from the Nile waters, no more internal Nile waters should be reallocated to coastal cities, as desalination would be the most appropriate resource for those coastal cities AbuZeid (2019). Desalination may appear to be the easy solution for providing new water resources; however, in some cases there are other priority options that are more cost-effective for making more water resources available, especially agricultural water-services pricing, water conservation, and reuse of locally treated wastewater options AbuZeid (2017c).

The mega projects in the water sector create a room for reducing agriculture water losses by about 10%. A "swap approach" in the type of water provided for agriculture represents another option of reallocation, whereby agriculture drainage water, or treated wastewater rich in nutrients, may replace fresh Nile water for agriculture to free fresh Nile waters for drinking and domestic uses Stefan et al. (2020). This requires more attention to be given to the quality of agriculture drainage water for satisfying future water demand AbuZeid (2017c).

It is proposed that more solid actions in terms of a trade-offs (swap) approach to be considered as shown in Table 6. It explains the proposed water resources trade-offs scenarios. That approach depends on swapping water resources among the competing sectors based on the geographical location, nature of use, water accounting and monitoring systems. Yet it needs further examination and technical investigations by the researchers and scientists before it is discussed at the policy level in Egypt.

The major outcome that accrues to Egypt in case new water trade-offs approach is adopted is alleviating the pressure on the Nile water since the inhabitants of the coastal cities and remote communities shall be water self-sufficient. They shall use desalinated water for drinking purposes; as well as maximize the use of treated wastewater (which is uniquely considered an increasing renewable water resource) in agriculture -in addition to the seasonal rain-. That should be attained with strict human-use and environmental safeguards under the Egyptian Code for treated wastewater reuse of the year 2015 (ECP 501/2015).

Table 6

Table 6 Adoption of a New Water Trade-Offs/Swap Approach1 Between the Competing Sectors in Egypt

	Water Resources to be used	**Comments**
	Municipal and Domestic Sector:	
Sector/sub-sector	River Nile system, as usual	Continues to drink from the river Nile water after purification
New communities and cities outside the Nile Delta and Nile Valley	Desalinated water with sufficient human-use safeguards	Using the existing and new desalination stations (the sources could be brackish groundwater as

		an economic solution, if compared with desalination of the seawater)
Agriculture Sector:		
Canal command areas in the Nile Delta and Nile Valley	- Fresh Nile water augmented by agricultural drainage water reuse - Treated wastewater could be used wherever it exists according to the Egyptian ECP Code No. 501/2015	- Sources are drainage networks (surface and sub-surface), as well as shallow groundwater - The treated wastewater could be used directly of after mixing with drainage water with caution, so that no harm occurs to the humans or environment.
Newly reclaimed agricultural lands in the Nile Delta fringes and Saini	- Treated wastewater directly from the mega WWTPs; and/or - Groundwater abstracted within the aquifers' safe yields	- According to the water grade and permitted crops as per the Egyptian ECP Code No. 501/2015 - GW with reasonable quality suitable for the crops
Wood and non-fruitful trees	- Treated wastewater from the mega WWTPs; and - Smaller & local WWT stations spread nationwide	Wood, fabric, and industrial crops
Industrial Sector:		
Industrial facilities	Treated wastewater with strict safeguards	Using smaller & local WWT stations spread nationwide
Electrical Power Sector:		
Cooling the thermal electrical stations nationwide	Treated wastewater with strict safeguards	Using smaller & local WWT stations spread nationwide
Inland Navigation Sector:		
Nile cruises and trade vessels	Nile water to be utilized (not used) as usual	With strict laws to prohibit disposal of all types of liquid and/or solid wastes in the river Nile system by all means.
Tourism Sector and Oil & Gas industry:		
Touristic facilities in the Nile Delta fringes (coasts of The Mediterranean Sea & Red Sea, Oasis, and Saini)	Desalinated water for drinking/domestic uses with sufficient human safeguards	Using new and existing desalination stations

[1]*Assumptions:*

1) Raw wastewater is collected separately apart from the drainage water system (surface and sub-surface networks), the treated wastewater could be mixed with the drainage water for agricultural reuse in the Nile Delta, and

2) Endorsing the "canal command areas" concept instead of the "directorate and/or governorate" concept in irrigation water distribution/allocation.

The limited freshwater resources in Egypt as well as expansion in treated wastewater use may put risks on the future of the existing investments in the agriculture sector and reduce significantly Egypt's competitiveness in the agriculture export markets, and in achieving national food security. Reallocation of a "different" type of water resource (such as cheap desalination for the irrigation purpose) may be needed to compensate for the depleted groundwater in the agriculture sector and to maintain the economic and social activities associated with the sector. On the other hand, reallocation of water away from the existing establishments in the agriculture sector is not recommended, due to the negative socio-economic impact that might have on the inhabitants. A paradigm shift is needed to take the tough and wise decisions, and to get into innovative solutions at the technological, institutional, financial, and legislative levels. Bridging the supply-demand gap and water demand management and keeping water conservation is a priority. Among the viable solutions are expansion in nonconventional water resources such as treated wastewater, cheap desalination, introducing models of public–private partnerships, and modifying the legislations that govern the way water is currently being managed to adapt to a more water-efficient and competitive Egypt by the year 2037.

The existing and recommended water policies in Egypt are prohibiting the disposal of inappropriately treated or untreated wastewater into agriculture drains. This requires actions to raise the level of wastewater collection and treatment. The agricultural water quality improvement and safe reuse of the treated domestic as well as industrial wastewater should be enforced to maintain the sustainable development efforts of Egypt. The modification of the Egyptian Code for treated wastewater reuse (ECP 501/2015) is necessary to allow the use of treated wastewater for irrigating appropriate agricultural crops according to the level of treatment and the type of crop need to be embraced and fully implemented. This will contribute not only to food production but also to the improvement of water quality and the environment. Water security measures on medium- to long-term should include serious cooperation with the Nile basin countries to realize concrete win-win projects, such as those which provide more yield to the Nile waters (e.g., South Sudan), more hydropower (e.g., D.R. Congo), and more food for all (e.g., The Sudan), without affecting the existing water uses in the downstream countries, particularly Egypt.

There is a possibility that reuse of agricultural drainage water alone cannot fulfil the increasing demand for agriculture. In satisfying the growing water demands in agricultural and industrial sectors, treated wastewater reuse could provide the perfect and may be the only practical solution for filling the gap in the future water needs, yet; that still faces challenges to achieve food security in Egypt. The formulation and implementation of a sustainable water policy in Egypt in the future should consider that result in order to properly match the limited freshwater supply by the developed alternatives of the nonconventional water resources.

Currently, the strong monitoring, enforcement systems and raising the public awareness in the entire Egypt need strengthening to reduce water losses. Proper water accounting systems are also needed in all sectors. Water users' associations need to be legally recognized and given an official role and mandate. The private sector's role in the water sector needs to be clearly defined, motivated and legally accepted. Continuous capacity building programs and investment in human resources in the water sector are crucial. In addition, some sectoral policy actions are recommended as follows:

- Industrial facilities to be enforced to install their own treatment facilities, and the disposals into the waterways to be strictly monitored for abiding by the water quality standards.
- All primary WWTPs to be upgraded to secondary treatment level by 2030.
- Nile Delta and Valley governorates' WWT small and local plants/stations to dispose secondary treated wastewater into the agriculture drains and reuse downstream through agricultural drainage mixing pumping stations.

- Desert-front and agricultural-expansion governorates to allocate future treated wastewater directly to desert expansion land reclamation.
- Maintain existing wood forests' production without further expansion and direct future treated wastewater to agriculture expansion areas to satisfy the increasing agricultural water demands.
- Existing tertiary treatment levels to be maintained through 2030 without further expansion in tertiary treatment at government expense.
- Empowering the funder role of the private sector, as the beneficiary in the whole process of wastewater treatment and reuse.
- The Egyptian WWT reuse code (ECP 501/2015) is more flexible than the old laws, yet the health safeguards of the humans and environment remain strictly met. Yet, modifying the ECP 501/2015 is necessary to allow for expansion in permissible agriculture crops cultivation on treated wastewater according to international standards (e.g., new WHO guidelines).

5. CONCLUSION AND RECOMMENDATIONS

The international and national state-of-the-art water policies experiences concerning the reuse of agricultural drainage water for irrigation purposes, and how this is being affected by the mega water projects are reviewed and discussed. As stated in the Egyptian NWRP2037, there is an increasing rate of implementing the national water management and development projects such as on-farm water management, installing modern irrigation systems, water saving, canal lining, and wastewater treatment projects. In addition, the Egyptian Water Resources Law, and the Egyptian Code for Treated Wastewater Reuse, with its enforcement bylaws are being implemented through strict safeguards toward healthy and efficient implementation in Egypt. Those good practices aim at achieving the sustainable development and environmental quality.

The research question: whether Egypt shall have enough agricultural drainage water quantities -as a key nonconventional water resource- to contribute to narrowing the water supply-demand gap or not is examined. The impacts of the following were reviewed and discussed: i) implementing the national irrigation improvement projects on the agricultural drainage water rates; ii) providing sanitation utilities service as well as constructing sewerage networks in villages and rural areas on the water quantity and quality of the agricultural drainage systems; 3) constructing mega wastewater treatment plants on the availability of agricultural drainage water for reuse in the Nile Delta; iv) water and soil salinity in the Nile Delta regions; and v) seawater intrusion phenomenon in the Northern Delta lands.

It was interpreted that impact of the national water saving and irrigation improvement projects jointly with the expansion in desert land reclamation is inversely proportional to the resulting amount of agricultural drainage water in the old lands of Egypt. Based on the literature review accomplished, it is assumed that expansion in land reclamation in the Nile Delta fringes and desert as well as irrigation improvement projects could cause reduction in the available agricultural drainage amount by about 4.2 billion m^3/year. The actual percentage of that reduction in drainage water is the question which needs further applied research to answer. On the other hand, the extraction of large amount of agricultural drainage water mixed with raw wastewater for treatment purposes in the northern parts of the three Nile Delta regions (totalling about 5.1 billion m^3/year) shall reduce the available local drainage water for reuse in those mentioned areas. This might be compensated with the reuse of treated wastewater from the new small and local wastewater treatment plants spread in those areas.

Accordingly, caution should be taken while projecting the available agricultural drainage water for reuse in Egypt, as stated in the NWRP 2037. Most likely, the reuse of agricultural drainage water quantities in the Nile Delta regions included in the NWRP2037 need to be lowered due to the newly constructed (or under construction) mega water projects as well as the expansion in "Hayah Karima" national program. On the other hand, the quantities of treated wastewater all-over Egypt shall increase gradually compensating and may be exceeding the projected amounts of drainage water reuse as stated in the NWRP2037.

The efficient water management in Egypt can increase the quantity and improve the quality of available water for its people and for future economic growth. This can be achieved through the adoption and application of a group of water policies including on-farm water management, water saving, canal lining, expanding the safe use of nonconventional water resources especially treated wastewater for agriculture, and desalinated water for drinking purposes, implementing the fit-for-use water allocation approach and the swap (trade-offs) concept among the competing sectors and based on the geographic location, enforcing a strong water accounting and monitoring systems and joint development of new Nile water resources in cooperation with the Nile basin countries, especially South Sudan, D.R. Congo and The Sudan.

The following water policy considerations of a number of unresolved questions are recommended toward the realization of Egypt Vision 2030:

- Reviewing the water and salt balance of the old lands in the Nile Delta for estimating the future available drainage water state, for proper water reuse (drainage and treated wastewater) policies in agriculture in Egypt.
- Monitoring and analysing the operation of a number of pilot agriculture areas irrigated with reused water (containing teared wastewater) for determining the changes in crop productivity, soil salinity and water quality of the receiving systems, before setting new agricultural water reuse policies in Egypt.
- Developing an operational and institutional roadmap to allow for more flexibility in treated wastewater reuse covering the entire Egypt using the trade-offs (swap) approach among the competing sectors.
- Developing a realistic "National Strategy for Wastewater Reuse" and a "National Integrated Water Resources Management (IWRM) Plan" in Egypt.
- Modifying the Egyptian Code for Treated Wastewater Reuse (ECP 501/2015), to allow the usage of secondary and tertiary treated wastewater for irrigating edible crops, taking into consideration the due human health and environmental safeguards.

CONFLICT OF INTERESTS

None.

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