Irrigation: Water Resources, Types and Common Problems in Egypt

Ahmed A. Abdelhafez, Sh. M. Metwalley and H. H. Abbas

1 Introduction

Water is the most important substance for human being and living organisms. Water scarcity is the lack of sufficient available water resources to meet the demands of water usage within a region. Water scarcity can occurr through two main mechanisms as follows: physical water scarcity, which occurs due to inadequate natural water resources to supply a region's demand and economic water scarcity, which occurs as a result of poor management of the available water resources. In Africa, there are several water resources, i.e., Congo, Nile, Zambezi and Niger rivers and Lake Victoria. Therefore, the scarcity of water in Africa is mainly economic due to the poor management of water resources. In Egypt, the development of water resources is very poor; on the other hand, there is an excessive growth of population. Furthermore, agricultural activities in Egypt consumes about 80% of The Nile water budget. Therefore, potential scarcity might occur in Egypt; especially, there is a critical argument due to the buildup of the Grand Ethiopian Renaissance Dam. Clearly, the construction of the Grand Ethiopian Renaissance Dam will negatively affect the recent situation of natural water resources in Egypt. It is worth mentioning that filling the Grand Ethiopian Renaissance Dam by 74 billion m^3 of Nile water may lead to change the demographic map of Egypt. In this chapter, we will address

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E.-S. E. Omran and A. M. Negm (eds.), *Technological and Modern Irrigation Environment in Egypt*, Springer Water,
https://doi.org/10.1007/978-3-030-30375-4_2

the water resources in Egypt. In addition, we will try to present the major problems of irrigation and the potential hazards that might occur due to the construction of the Grand Ethiopian Renaissance Dam.

2 Egyptian Water Resources Management History

In ancient times, the great Greek historian Herodotus said:

> Egypt is the Gift of The Nile.

He meant that The Nile is the one which gives life and existence to Egypt (Fig. 1). Nowadays, we can say:

> Just a River, it is Lifeblood for the Egyptians.

Management of irrigation water sources in Egypt is as old as the country itself. For thousands of years, agriculture in Egypt depended on the annual floodwaters of The Nile River to irrigate the arable lands. Historically, water level gauges or "Nilometers" were used to measure the height of The Nile floods and set taxes accordingly [1, 2]. The expected annual flood of The Nile River provided both fertile sediments and irrigation water for Egyptian agriculture. The Islamic conquests have developed these policies by introducing agricultural land levels, according to the ease by which irrigation from The Nile water is performed; in the calculation of taxes and revenues imposed on farmers [3].

Napoleon Bonaparte, commander of the French expedition to Egypt in 1798, was the first to consider the introduction of theory to The Nile water storage. Muhammad Ali Pasha, who ruled Egypt from 1805 to 1845, was a genius leader. He took Napoleon's idea and considered that the management of The Nile water is one of the pillars of the agricultural and economic renaissance in Egypt. He established the barrages and summer (*Seifi*) canals across The Nile River as a means of surface storage in The Nile and its branches during flooding periods, as well as allowing the recharge of groundwater reservoirs that are used when water is scarce. It started with the construction of the Esna Barrage with a total length of 900 m, and this barrage was rehabilitated by a new one. Esna Barrage was considered to be the main control unit for regulating Nile water and supplemented with a hydropower station [4]. Naga Hammadi Barrage was also established in the early 1900s with a total length of 330 m and reconstructed by the Egyptian governorate to maintain continued supply of water to the large irrigation areas downstream. Assiut Barrage was designed by the famous British engineer Sir William Willcocks in the year of 1898 with a total length of 1200 m. Thereafter, Delta Barrages were established in the year of 1939, followed by Zifta and Damietta reservoirs on the branch of Damietta and Edfina on Rosetta's branch (Fig. 2) [4]. A point to note, the main objectives of constructing barrages and dams in the past were to control The Nile water and to ensure continuous supply of The Nile water to agricultural areas.

Fig. 1 Nile River basin and its drainage network [5]

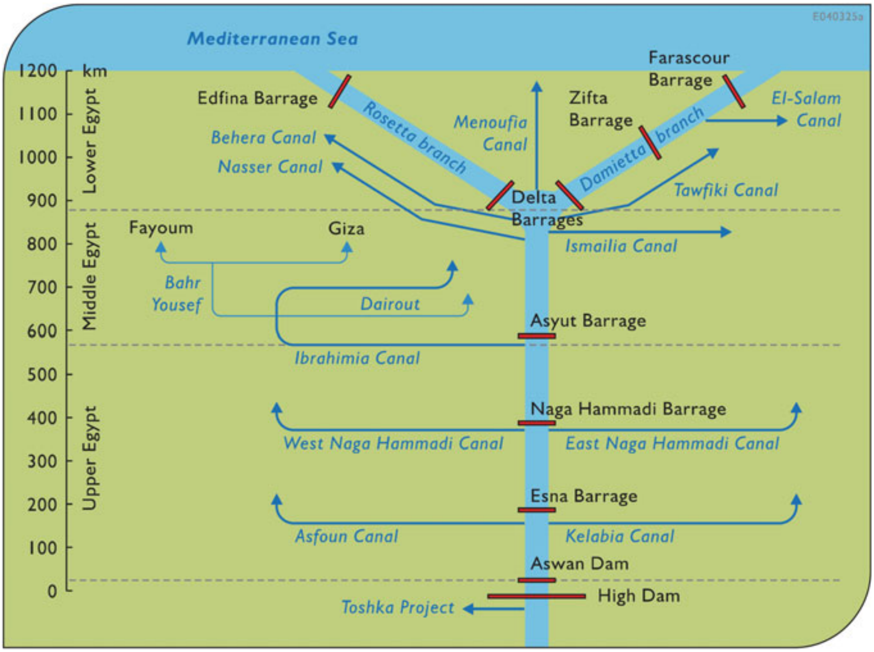

Fig. 2 Schematic diagram for barrages and dams constructed across The Nile River, which enabled Egypt to shift to perennial irrigation system which began in the early nineteenth century [5]

The establishment of Aswan reservoir during the period 1898–1902 was the first scientific attempt to store The Nile water in Egypt with a storage capacity of one billion m^3 $year^{-1}$, which was raised in 1912 to reach 2.5 billion m^3 $year^{-1}$ and then in 1932 reached 5 billion m^3 $year^{-1}$. The High Dam was built in the early 1960s, and Lake Nasser's storage capacity is about 160 billion m^3. It is often referred to Lake Nasser's reservoir as a "long-term storage" [5–7].

3 Water Scarcities and Low Irrigation Efficiency in Egypt

Based on the aridity index (AI) number (the ratio of annual potential evapotranspiration to annual precipitation), Egypt is among the arid countries ($0.05 < AI < 0.20$). Most of the agricultural soils in Egypt are classified as "Arid lands" category. Hence, irrigated agriculture accounts for the vast majority (>85%) of all the water used [7–10]. This unique situation can be expressed simply: Egypt depends entirely on irrigated agriculture.

Currently, Egypt suffers from freshwater scarcity and will face much tougher situations due to increasing the present and future water demands where the country has no enough alternative water resources. The Ministry of Water Resources and

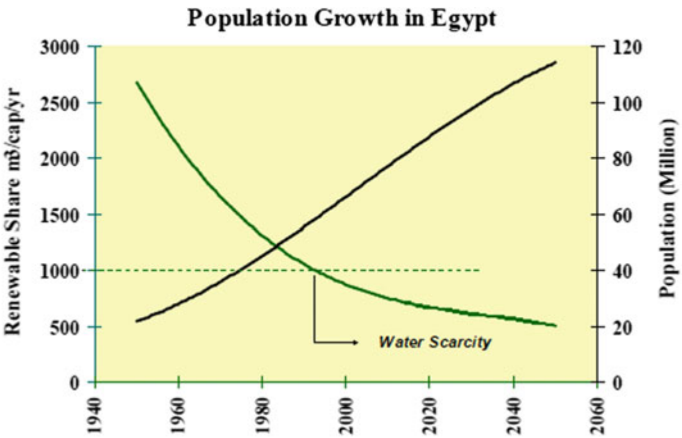

Fig. 3 Projected annual per capita share of renewable water resources in Egypt [12]

Irrigation (MWRI) announced in May 2016 that Egypt's water resources produce 62 billion m^3 annually, while the consumption could reach 80 billion m^3 [5]. Thus, the annual per capita of water supply in Egypt is about 600 m^3 only, while the international average is 1000 m^3 [11]. In this context, MWRI [5] reported that average per capita share of about 800 m^3 cap^{-1} y^{-1} as of year 2004, while projections forecast a share of about 600 m^3 cap^{-1} y^{-1} by the year 2025 as depicted in Fig. 3. This indicates a sharp decline in water availability per capita more severe than predicted by the previous studies [2, 6, 9].

Consequently, water availability per capita rate has become already one of the lowest in the world. This is suggested for further declines due to the excessive increase in population on one hand and climate change and global warming on the other one. Accordingly, the gap between the limited water resources and the increasing demands for water is getting wider over time [13], and Egypt will soon face water scarcity.

3.1 Grand Ethiopian Renaissance Dam (GERD): View Point

The water shortage crisis is compounded owing to the fact that the main source of water, The Nile, originates from outside the borders of Egypt, making its discharge rates controlled by many other factors. Furthermore, in April 2011, Ethiopia has launched the construction of the Grand Ethiopian Renaissance Dam (GERD), with water storage capacity of 74 billion m^3. Egyptian experts predict a water reduction of about 20–34% owing to the construction of that Ethiopian dam. "This is estimated to be 11–19 billion m^3 on average over the Dam's filling period" [13, 14]; consequently, about one-third of the total agricultural lands might be subjected to drought. It is worth mentioning that the filling duration of GERD reservoir is of a major concern. According to the annual rate of precipitation in Ethiopia whose average is about

817 mm, GERD reservoir needs at least three years to be filled [15], which poses a potential threat of water reduction. Therefore, increasing the filling period of GERD reservoir is more favorable to eliminate the potential risk of the GERD. On the other hand, increasing the reservoir capacity will be associated with more risk and reduction of water to Egypt.

In the light of this severe shortage of freshwater, several policies and measures should be taken; the most important of which is to raise the efficiency of the Egyptian irrigation systems [16]. Enormous studies have shown that more than 70% of the cultivated area depends on low-efficiency surface irrigation systems, which cause high water losses, a decline in land productivity, waterlogging and salinity problems. Moreover, unsustainable agricultural practices and improper irrigation management affect the quality of the country's water resources. Reductions in irrigation water quality have, in their turn, harmful effects on irrigated soils and crops [2, 9, 10, 12].

> … one of the main components of the agricultural development strategy is to achieve a gradual improvement of the efficiency of irrigation systems to reach 80 per cent in an area of 3.36 million ha, and to reduce the areas planted with rice from 702.66 thousands ha (2007) to 546 thousands ha by 2030 in order to save an estimated 12 400 million cubic meters of water. [17]

However, attention should be paid regarding the reduction of rice agricultural soils due to the potential salinization of agriculture soils in the delta regions.

4 Water Resources of Egypt

Water resources in Egypt are confined to the withdrawal quota from The Nile water; the limited amount of rainfall; the shallow and renewable groundwater reservoirs in The Nile Valley, The Nile Delta and the coastal strip; and the deep groundwater in the Eastern desert, the Western desert and Sinai, which are almost nonrenewable. The nontraditional water resources include reuse of agricultural drainage water and treated wastewater, as well as the desalination of seawater and brackish groundwater [6, 7, 13, 18].

4.1 Conventional Water Resources

4.1.1 The Nile Water

Egypt reliese on The Nile water to provide nearly 97% of freshwater needs [7, 13]. This clearly shows that Egypt's national security depends on The Nile River. Currently, more than 90 million capita live around the valley and delta of The Nile. The Nile Valley is a narrow strip that expands from Aswan in the south to Cairo in the north while The Nile Delta starts from the south of Cairo and stretches up to the

Table 1 Egypt water resources in 2017 (unit: billion m^3 y^{-1}) [19]

Source	billion m^3 y^{-1}	Usage	billion m^3 y^{-1}
The share of the River Nile water	55.50	Drinking	10.70
Underground water (surface and deep wells)	9.60	Industries	5.40
Reuse of drainage waters	13.5	Agriculture	61.65
Rains and floods	1.30	Evaporation	2.50
Seawater desalinization	0.35		
Total	80.25		80.25

Mediterranean Sea in the form of a triangle. Both the valley and the delta depend entirely on The Nile River for drinking, farming, industry and the other economic activities. Therefore, any changes that might occur in the net water budget of The Nile River will affect the Egyptian demographic map.

The Nile water represents the main source of water in Egypt, amounted to be 55.5 billion m^3 annually according to the agreement of Egypt and Sudan in 1959. The Nile water source mainly serves irrigated soils in The Nile Valley and Nile Delta which together constitute 85% of total irrigated land in Egypt [7, 13] and consume about 77% of the total water resources in Egypt (Table 1).

The Nile River is the second longest river in the world, with a length of about 6700 km. The Nile basin stretches over 35 latitudes from latitude 4° south of the equator at its sources near Lake Tanganyika and reaches the line 31° north of the equator. The Nile basin extends its authority over more than nine longitudes, from the longitude of 29° at its roots in the tropical plateau to a longitude of ~38° at its springs in the Abyssinian plateau as shown in Fig. 1. The area of The Nile basin is about 2.9 million km^2, which includes parts of ten African countries, namely Ethiopia, Eritrea, Uganda, Burundi, Tanzania, Rwanda, Sudan, Congo, Kenya and Egypt.

The total area of these ten countries is about 8.7 million km^2. The Nile River passes through its long travel in different regions, languages and civilizations. It passes through several climatic regions, from the equatorial region with an average annual rainfall of about 800 mm at its source, and even the desert region that is very dry in northern Sudan and south Egypt.

The Nile River income, like most rivers, varies from a year to another while the lowest was 42 billion m^3 $year^{-1}$, and the highest was 150 billion m^3 $year^{-1}$ measured in Aswan. The average natural Nile River revenues during the twentieth century—estimated at Aswan—were about 84 billion m^3. The Nile collects water from three main basins, i.e., the Ethiopian plateau, tropical lakes' plateau and Bahr el Ghazal.

4.1.2 Underground Water

Renewable groundwater reservoirs are distributed between The Nile Valley (with a stock of 200 billion m^3) and the delta region (with a stock of approximately 400 billion m^3). This water is considered a part of The Nile water resources. The water withdrawn from these reservoirs is estimated by 6.5 billion m^3 year^{-1} since 2006. This is within the safe withdrawn level, which has a maximum limit of about 7.5 billion m^3 year^{-1} according to the Groundwater Research Institute. It is also characterized by a good quality where salinity range is about 0.47–1.25 dS m^{-1} in the south delta regions. The depletion of these reservoirs is allowed only when drought occurs for a long period. It is estimated that the drawdown of these reservoirs is around 9.6 billion m^3 in 2017 [2].

Nonrenewable aquifers are located under the Eastern and Western Desert and the Sinai Peninsula. The most important of these is the Nubian sandstone reservoir in the Western Desert, which is estimated by about 40 thousand billion m^3. It extends in the regions of northeast Africa and includes the lands of Egypt, Sudan, Libya and Chad. This reservoir is one of the most important sources of fresh groundwater; however, it is not readily available for use in Egypt due to its deep depths. It is therefore estimated that only about 0.6 billion m^3 of these waters are withdrawn annually that is enough to irrigate about 63,000 ha in Owainat area.

The annual withdrawal rate is expected to increase to about 2.5–3 billion m^3 year^{-1} as a safe and economic withdrawal. In general, the effects of the expected decline in the level of the groundwater reservoir should be avoided by shifting from the extensive plantation system to the specific plantation system of scattered areas (840–2100 ha) to conserve these aquifers for extended periods.

4.1.3 Rainfall and Floods Waters

Egypt is almost rainless except for the northern coast where rainfalls at an annual rate of 50–250 mm. On the northwestern coast, rainfall ranges from 50 to 150 mm year^{-1}. In the years of relatively heavy rain, the area cultivated with barley may exceed 42,000 ha. On the northeast coast, rainfall increases as we head eastward. The rate at El-Arish is 150 mm, while in Rafah, it is about 250 mm.

In the light of normal winter rainfall, the amount of rainwater falling over the northern parts of Egypt (about 200,000 km^2) is estimated at 5–10 billion m^3 year^{-1}. Of this amount, about 1.5–3 billion m^3 are flowing over the surface; much of it returns to atmosphere via evaporation and transpiration, and the rest leaks into the layers to be added to groundwater recharge. It is noted that the surface runoff water from the valley's ravine is lost into the sea or in the coastal saline ponds.

When winter rains are relatively high, a phenomenon that is repeated once every 4–5 years, the amount of surface runoff water may reach 2 billion m^3, and its impact extends to wider areas of Egyptian deserts. When the Egyptian lands are exposed to seasonal rains, a phenomenon that is repeated every 10 years, the amount of rain that flows above the surface may reach 5 billion m^3 and has significant impacts on the regions of Red Sea, South Sinai and The Nile River basin and often cause extensive environmental damage.

The amount of rains falling on the Sinai Peninsula and distributed over its various water basins as well as the amount of rains that flow on the surface and out of the water basins toward the sea are about 131.67 million m^3 annually and represent 5.25% of the total rainfalls.

It is worth mentioning that the average annual rainfall on the entire Egyptian territory is about 8 billion m^3 and that the flow is in the area of 1.3 billion m^3, and this helps to attract and harvest about 200–300 million m^3 $year^{-1}$ of these rains in Sinai and the northern coast and the eastern Red Sea.

4.2 Nonconventional Water Resources

4.2.1 Reuse of Agricultural Drainage Water

Agricultural drainage water includes the water used for leaching salts from soils (leaching requirements), the leakage from the irrigation and drainage systems, the unused canal endings and the sewage and industrial wastewaters that pour into agricultural drains. Therefore, this water is of low quality due to its high salinity and is mixed with water from drains that are often contaminated with chemicals used in the agriculture and industry. Salinity in this type of water ranges from 700 to more than 3000 mg L^{-1} [20], which are not suitable for irrigation for many crops.

Reuse of agricultural wastewater is a significant source of water resources development in the future. The improvement of the agricultural drainage water quality should be taken into consideration by directly treating the water of sub-drains or main drains before mixing them with freshwater and avoiding mixing them with sewage or industrial water to avoid the environmental risks of reusing such water without treatment. It is very important to discharge at least 50% of the total amount of agricultural drainage water to the sea to maintain the water and salt balance of The Nile Delta and to prevent the increased impact of deep-sea water interference with the North Delta aquifer [21].

4.2.2 Reuse of Municipal and Industrial Wastewater

Treated wastewater is one of the water resources that can be used for irrigation purposes if it meets the appropriate health conditions. The amount of treated water increased annually from 0.26 billion m^3 $year^{-1}$ in the early 1990s to about 0.6 billion m^3 $year^{-1}$ in 2000 and about 4 billion m^3 in 2017. Since the amount of collected wastewater exceeds 5 billion m^3 [22], the future policy is to increase the use of wastewater up to 4.5 billion m^3 [23]. It is used to irrigate nonfood crops for humans or animals and to plant forests in the desert for wood production. It is very crucial to focus on the treatments of municipal and industrial wastewater before use and their separation far away from agricultural drainage waters to avoid the risks of chemical waste on public health and the environment [22, 24].

4.2.3 Desalination of Sea Water

Owing to the length of Egypt's coastline both on the Mediterranean Sea and on the Red Sea, and the effective government action during the last two decades and the present to maximize tourism and industrial development of coastal areas, the provision of water resources for this development is a guarantee of its existence and sustainability.

One of the most important sources of water available in coastal areas is desalination, whether for seawater or brackish water. The challenge for adopting desalination technique has been and is still in the development of commercially viable methods. The extensive experience gained over the past 40 years and the improvements in desalination technology have made desalination very technically acceptable and provide high-quality water to arid areas that have been deprived of water sources for sustainable economic and social development. In the mid-1960s, the idea of desalinization was illusory, and most of the activity in that field was experimental, and many of the first projects failed to meet the expectations on which they were adopted. At present, it is a highly reliable technology, and many countries rely on it for financial capacity such as the Gulf countries, but costs remain relatively high compared to other water resources. The Middle East and North African countries contribute to 41.3% of the world's desalinated water [25].

For Egypt, desalinization of seawater can be used as an untraditional water source for the development of desert and coastal communities. Solar, wind and nuclear energies can be used in the desalination process instead of transferring electricity or oil to these regions to raise the economies of exploitation of this source [25].

A previous study indicated that the cost of desalting 1 m^3 of seawater ranged between 5.40 and 18.88 LE depending on the capacity of the desalination plant, which makes the use of this water for agricultural purposes economically inefficient at present [26]. Nowadays, some studies are conducted aiming at desalination of brackish water in the groundwater reservoir near the northern coast of the Mediterranean Sea and North Sinai, which are relatively less saline than seawater, thus reducing the cost of desalination technique [25, 26].

5 Irrigation Systems and Their Common Problems

Methods of irrigation in ancient Egypt are thought to be the basis of many agricultural technologies followed worldwide [27]. According to de Feo et al. [28], the ancient Egyptians used various hydraulic technologies to lift water from the near river banks to water their crops, i.e., Shadouf, Tanbur and Saqiya. The Shadouf device consists of a bucket attached from one side to a wooden arm and from the other side to a counterbalance [29]. It can lift water from the near river banks up to 1–6 m [30]. In case of Tanbur (or Archimedes' screw), it consists of a watertight cylinder enclosing a chamber called off by spiral divisions running from end to end [31], and the water is lifted in the turn of cylinder around its axis from the immersed bottom of the spiral chamber in the water [32, 33]. Saqiya (or waterwheel) consists of a row of pots attached to the rim of a revolving wheel so that turning wheels by oxen allow the pots to be filled with water when dipped into an irrigation canal and then lifted on the wheel to a height of 3–6 m [31].

Recently, increasing global population has placed major stresses on the available water resources especially with declining groundwater availability and decreasing water quality [34] to supply fruits, vegetables and cereal foods consumed by humans [35]. Thus, irrigated agriculture is thought to play major roles for satisfying the basic needs and improve life standards [36]. Increasing water use efficiency is the key to overcome water shortage problems and, on the other hand, reduce the environmental problems [37] through optimizing source to sink balance and avoid excessive vigor [38]. This might take place through adopting low-volume irrigation technologies, especially in arid soils [39]. The techniques of water distribution within the field differ according to the quantity of water available for irrigation, other natural resources, system cost and irrigation efficiency in addition to a number of institutional, financial and production inputs [36]. Generally, there are many types of irrigation systems, e.g., surface irrigation, sprinkler irrigation and drip irrigation.

5.1 Surface Irrigation

It is often called *flood irrigation* in which water moves by gravity surface flow [40] either across the entire field (basin irrigation) or the water is fed into small channels (furrows) or strips of land (borders) [41]. Surface irrigation was and is still the common irrigation system in many regions. This method is applied on lower lands of heavy textured soils in the presence of suitable drainage system that may lead to over logging conditions [42]. On the other hand, several problems might be associated with this system first of which, the high water lose due to evaporation and seepage, in addition, the phenomenon of water shortage at canal tail end (CT); that commonly occurs due to several reasons, i.e., widening and cleaning of the canal pathway that may lead to decrease the velocity of water, loses of water through seepage along the canal path and the inadequate amount of water at the beginning of irrigation way [43, 44]. Surface irrigation consisted of several types as follows:

5.1.1 Basin Irrigation

Water is supplied in small level field ground leveled to zero slope in both directions [45] enclosed by a dyke to prevent runoff [42] to form small bounded units [46]. In case of large areas, uneven distribution of irrigation water might occur [47]. The first artificial basin irrigation was established by deliberating flooding and draining using sluice gates and water contained by longitudinal and transverse dikes [31]. Although this type of surface irrigation is the least expensive to operate and manage, it is considered to be the most expensive to develop and maintain [48]. Basin irrigation is suitable for many crops, especially paddy rice. However, soil type and surface morphology are important factors controlling the use of basin irrigation. The size of basin should be small if the soil is sand and had steep slope [41]. Shortage of water occurs in some places in basin irrigation system where the water was stood for a short time affecting the growing plants due to the lack of moisture. As a result, farmers used to build up dicks and dams to maintain water on a soil surface for a constant time [49].

5.1.2 Furrow Irrigation

Furrow irrigation is directed by small parallel channels conveying water down or along the slope of the field under the influence of gravity [50]. Water infiltrates through the soil and spreads along the primary directions of the field vertically and horizontally [42]. Crops are grown on ridges between furrows [41]. However, there might exist higher erosion and pollution risks with the concentrated water flow in the furrows [51, 52]. In this concern, applying water-soluble polyacrylamide to the irrigation water can minimize water runoff and consequently soil erosion [53]. It is worthy to mention that the water use efficiency under furrow irrigation might be low. Wide-spaced furrow irrigation or skipped crop rows can lessen water evaporation from the soil surface, as is the case for drip irrigation [54]. Moreover, alternate irrigation of one of the two neighboring furrows probably saves in arid areas [54]. The furrow irrigation is more favorable for many crops, especially crops that would be damaged if water covered their stem or crown [41]. A point to note that flat soil is more suitable for furrow irrigation, and slope should not exceed 0.5% [41, 55].

Since the furrow irrigation system wets as little as 20% of the field surface, extra time might be needed to ensure the complete wetting of fine particle soils [56].

5.1.3 Border Irrigation

It is the extension of basin irrigation to suit larger mechanized farms in which land is divided into wide, level rectangular strips [57] "with a minimum slope of 0.05% to provide adequate drainage and a maximum slope of 2% to limit problems of soil erosion" [41] and its drain exists at the lower end [42]. Length and width of the strips and basins depend on field slope, soil texture and the amount of water received in each strip. In case of sandy and silty loam soils, shorter strips are required while the clayey soils require longer strips [57]. The border irrigation system is suitable for many crops, except those that require prolonged ponding [58].

5.2 Irrigation Using Sprinkler Systems

It is the method of irrigation through which water is sprayed in the air in the form of small water droplets similar to natural rainfall [41] to optimize water application on sloping fields [59], also to overcome the waterlogging problems [60]. However, "most of the water losses take place from the water that leaves the nozzle until it reaches soil rhizosphere" [61] probably through wind drift and evaporation and transpiration losses [62]. Farmers should carefully select the right wind conditions for irrigation [63]. Also, they can avoid further evaporation and transpiration losses by nighttime irrigations which might bring such losses to almost negligible levels [64]. Furthermore, matching the sprinkler rate can guarantee more uniform entry of irrigation water into the root zone [65]. The area wetted is circular, and sprinklers should be operated close to each other to attain an overlap of at least 65% of the wetted diameter [41]. Some sprinklers are designed to optimize the use of various inputs for improving or enhancing economic crop production using precision agriculture (PA) technologies [60]. Others are supplied by remote sensors to simultaneously monitor water status in the field for improving the efficiency of water use [66].

5.3 Drip Irrigation

Drip (or micro) irrigation, also known as trickle irrigation, is a system of irrigation through which water falls drop by drop at or near the root zone of plants [67]. It is then considered the most efficient method of water irrigation since evaporation and runoff are thought to be low [68]; also, this method can effectively minimize evapotranspiration rates from plants grown in tropical climate regions, with dry and hot summers [69]. Under proper management, the efficiency of drip irrigation is typically within the range of 80–90% [70]. This method is the ideal for wastewater reuse [71] and for irrigation with low-quality water [72] to protect the environment on one hand and to sustain economic vitality on the other hand [73]. Micro-irrigation with fertilization also provides an effective and cost-efficient way to supply water and nutrients to crops [74] in a process known by fertigation [75, 76]; however, using low water quality in fertigation can accumulate salts within the root zone to reach toxic levels [77]. Drip irrigation is also used as a method of partial wetting of the root zone (controlled alternate partial root-zone irrigation (CAPRI), also called partial root-zone drying (PRD) [78] through simultaneously exposed to both wet and dry zones [79]. Water quality plays an important role for sustainable performance of irrigation system, for example, in New Valley, Egypt; groundwater is the major source of different applications. The groundwater in New Valley contains high concentrations of salts and iron metal ions; consequently, when iron ions are oxidized they lead to corrupt the dripping units (Fig. 4). The wetted zone supplies water and nutrients to plants while, at the same time, the non-wetted zone reduces loss of water by evaporation from soil surface [80] probably because the plants that receive fully

Fig. 4 Precipitation of iron metal ions and salts on the soil surface in the New Valley, Egypt (Image was taken by the corresponding author from the Faculty of Agriculture farm, New Valley University in October, 2017)

irrigations usually have widely opened stomata; therefore, the partially dried part of the roots stimulates partial closure of the stomata to reduce water loss through transpiration) [78].

5.4 Subsurface Irrigation

It is used in areas of high water tables in which the water table is artificially raised to moisture below the plants' root zone, yet the moisture rises past the roots [81]. This type of irrigation can also be applied on the seepage of the nearby water sources (e.g., canals or rivers) [82]. Subsurface drip irrigation (SDI) can further substantially improve irrigation water use efficiency (IWUE) than did the surface drip irrigation through reducing evaporative loss while maximizing capture of in-season rainfall by the soil profile [69]. Furthermore, roots concentrate at a depth of the irrigation tubes [83]. However, SDI can eliminate soil air (including oxygen) within the rhizosphere during and following irrigation events [84]. Such reduced condition of root respiration hinders plant growth by decreasing transpiration while improving the unselective flow of ions and salt ingress into the plant to reach toxic levels [69]. Thus, injection of air into the drip lines improves the aeration of the root zone more generally and therefore affects crop growth [85]. Generally, the life of a SDI system should be at least 10–15 years for economic competitiveness [86].

6 Conclusions and Recommendations

It could be concluded clearly that Egypt may suffer from water shortage through the next few years due to increasing the present and future water demands beside of the expected shortage in Egypt share of The Nile water due to the building of the Grand Ethiopian Renaissance Dam (GERD). Egyptian experts predict a water reduction of about 11–19 billion m^3 owing to the construction of that Ethiopian dam. Consequently, about one-third of the total agricultural lands in Egypt might be subjected for drought. Therefore, attention should be paid to overcome these problems through development of irrigation systems, reuse of agricultural wastewater, desalination of seawater and managing the discharge and usage of groundwater. Furthermore, applications of advanced irrigation systems should be preceded by studying the major characteristics of water resource to ensure its safe use.

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