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ICARDA International Center for Agricultural Research in the Dry Areas

Working Paper

Water and Agriculture in Egypt

Technical paper based on the Egypt-Australia-ICARDA Workshop on On-farm Water-use Efficiency

July 2011, Cairo-Egypt

Australian Government AusAID

Australian AID Australian Centre for International Agricultural Research

Water and Agriculture in Egypt

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Abbreviations

ACIAR	Australian Centre for International Agricultural Research
ARC	Agricultural Research Center
ARDC	Agricultural Research and Development Council
AusAID	Australian Government Overseas Aid Program
DTC	Drainage Training Center
EPADP	Egyptian Public Authority for Drainage Projects
EC	Electrical conductivity
EDASP	East Delta (new lands) Agriculture Services Project
ESP	Exchangeable sodium percentage
FAO	Food and Agriculture Organization of the United Nations
FIMP	Farm-level Irrigation Modernization Project
GDP	Gross domestic product
GIS	Geographic information systems
HRI	Hydraulics Research Institute
ICARDA	International Center for Agricultural Research in the Dry Areas
IFAD	International Fund for Agricultural Development
IIIMP	Integrated Irrigation Improvement and Management Project
IIP	Irrigation Improvement Project
IR	Infiltration rate
K	Hydraulic conductivity
LF	Leaching fraction
MALR	Ministry of Agriculture and Land Reclamation
MWRI	Ministry of Water Resources and Irrigation
NVSSARP	Nile Valley and sub-Saharan Africa Regional Program
NWRP	National Water Resources Plan
OFIDE	On-farm irrigation development in Egypt
OFIDO	On-farm irrigation development in the old lands
pH	Hydrogen ion concentration
RCTWS	Regional Center for Training and Water Studies
R&D	Research and development
RTC	Regional Training Center for Hydraulic Studies
SADS	Sustainable agricultural development strategy
SAR	Sodium adsorption ratio
SFA	Small Farmer Association
UNESCO	United Nations Educational, Scientific and Cultural Organization
WUA	Water Users Association

Executive summary

This document presents an overview of the water and agriculture situation in Egypt. It is a compilation of four background papers on farm-level water-management opportunities and challenges in the old lands, new lands, and reclaimed/salt-affected lands of Egypt. In addition it considers the technical, institutional, and policy aspects of the availability and allocation of water resources in Egypt. The papers were produced following the workshop, 'On-farm water-use efficiency and water management', held in Egypt 26-29 July 2011, which involved a high level delegation from the Australian Centre for International Agricultural Research (ACIAR), Egyptian scientists, research managers, and decision makers, and scientists from the International Center for Agricultural Research in the Dry Areas (ICARDA).

The purpose of this working paper is to support the Government of Egypt's Strategy for Sustainable Agricultural Development towards 2030 (SADS-2030). This strategy paper was published in 2009 and was concerned with the sustainable use of Egypt's natural and agricultural resources. Methods to increase land and water productivity, which would consequently raise food security, improve living standards, and reduce the poverty of rural inhabitants were also considered. It was also intended to assist in developing a better understanding of the research for development priorities of the main irrigated agricultural areas of Egypt and farm-level water management vis-à-vis SADS-2030.

This paper also provides a reference for the Egyptian-Australian-ICARDA collaborative research for development work in Egypt on irrigated agriculture over the coming few years. This work will be supported by the Government of Australia, through the Australian Government Overseas Aid Program (AusAID), under Australia's new Improvement of Irrigated Crop Production Trust Fund Initiative. The overarching objective is to improve on-farm water management, water-use efficiency, and the environmental sustainability of crop production in the Nile Delta. Broad areas of research for development have been identified under three general headings -

- Promotion of sustainable land-use production systems in the old lands of the Nile Delta
- Improvement of farmers' livelihoods through efficient, productive, and more equitable use of irrigation water in the new lands
- Improvement of the incomes of farmers through sustainable land and water management in salt-affected soils in the north-eastern part of the Delta.

This paper is also designed for use by researchers, practitioners, development agents, and managers who are interested in learning about Egypt's main agriculture production systems, the availability of water resources, and their use in agriculture.

A summary of the facts related to agriculture and water resources in Egypt is included in the paper. The constraints to and opportunities for the main Egyptian agro-ecologies are

presented. New, technically sound, attractive, and cost-effective physical and institutional interventions acceptable to farmers and communities are identified. Previously developed interventions are further tested, evaluated, and/or deployed.

The Egyptian population has grown from 38 million in 1977 to 91 million in 2012. Despite a decrease in the annual growth rate of the population in recent years to the current 1.8%, the population is expected to reach more than 92 million by 2017. About 55% of the population is dependent on the agriculture sector for its livelihood. Agriculture accounts for about 15% of the gross domestic product (GDP) and close to 32% of the total number employed in Egypt work within the sector.

Egypt has a total land area of approximately 1 million km^2, most of which is desert and only 5.5% is inhabited. Settlements are concentrated in and around the Nile Delta and the Nile Valley, which narrows considerably in Upper Egypt. The total cultivated land area is about 3.6 million ha (8.6 million feddan) – 3% of the total land area – and consists mostly of the old and newly reclaimed areas. The climate is arid with very scarce rainfall in a narrow strip along the north coast. The Nile River is the main and almost exclusive source of surface water in Egypt. Agriculture depends on the Nile waters and consumes about 80-85% of the annual water supply.

Geographically and agro-ecologically Egypt can be divided into five regions

- Upper Egypt
- Middle Egypt
- Middle Delta
- Eastern Delta
- Western Delta.

This paper contains relevant information on the agricultural land base that consists of the

- Old lands in the Nile Valley and Delta
- New lands reclaimed from the desert since 1952
- Rainfed areas
- Several oases where groundwater is used for irrigation.

The total irrigated areas amount to about 3.61 million ha (8.6 million feddan) and the rainfed areas cover about 84,000 ha (200,000 million feddan). Because of the accumulation of salts, mostly at the soil surface, 35% of the agricultural land is suffering from salinity.

This paper identifies the types of agricultural land in Egypt and the problems and constraints related to each. The old lands, found in the Nile Valley and Delta, are the largest irrigated area in Egypt. These lands, the area of which amounts to 2.25 million ha (5.36 million feddan), are irrigated by traditional surface irrigation systems with very low field water-application efficiency. Most of this land suffers from two important problems, continued

encroachment on the land diverting it from agricultural to non-agricultural uses and continued degradation of soil fertility in many agricultural areas.

The new lands include lands which have been reclaimed relatively recently – particularly since the construction of the Aswan High Dam – or are currently in the process of being reclaimed. Although the new lands are generally less fertile, over time and with good agricultural management practices, their productivity could improve.

In Egypt, nearly 2.8 million ha (6.7 million feddan) depend on rainwater. Almost 6% of this land area, which lies mostly along the north coast, is fit for traditional cultivation activities. The remaining areas are fit for pasturing activities and breeding small animals and camels. Although rain falls in winter only, the irregularity of the rainfall during the precipitation period from October to April makes it difficult to depend on the direct use of rain in the area. Thus, there is a need to resort to systems depending on the indirect use of rain – known as 'water harvesting systems'. Current work in this field is improving the indigenous systems and introducing modern systems of water harvesting based on accumulated knowledge and information, and employing methods for maximizing the use of rainwater using geographic information systems (GIS).

Given the accumulation of salts, mostly at the soil surface, as much as 35% of the irrigated agricultural land suffers from salinity. The majority of the salt-affected soils are located in the north central part of the Nile Delta and along its eastern and western sides. Increased attention is being given to the improvement of salt-affected soils since they are potentially productive and require less investment, effort, and time to restore their productivity than does the reclamation of new lands.

The technical paper specified the main Egyptian agro-ecologies and new technically sound, attractive, and cost-effective physical and institutional interventions, acceptable to farmers and communities. It also identified previously developed interventions for further testing, evaluation, and/or use. At the same time, there was an attempt, through this document, to support, directly and indirectly, the Government of Egypt's SADS-2030. This strategy focused on four main components:

- The sustainable use of natural and agricultural resources
- Increasing land and water productivity
- Raising food security
- Improving living standards and reducing poverty among rural inhabitants.

Moreover, modernization of the irrigation sector is seen as a key element in efforts to improve the efficiency of the water conveyance and distribution system, as well as the efficiency of on-farm systems at the farm/plot level.

Furthermore, there are several constraints that need to be addressed in order to achieve sustainable increases in land and water productivity and water-use efficiency at different scales in the Nile Delta. These include identifying and implementing appropriate and sustainable technical options for optimizing water use that are acceptable to Egyptian farmers with small- to medium-sized holdings, as well as enabling policies to ensure positive economic and environmental impacts. The appropriate technical options will help reduce the gap between food production and consumption and, in turn, improve the country's food security level. Because agriculture in Egypt depends on irrigation, water policies were implemented in Egypt as early as the beginning of the twentieth century. All policies were based on 'development', with water allocated first to domestic use and then to industrial requirements. The remainder went, by default, to agriculture. With all water resources exhausted, the last policy of 1997-2017 became an 'allocation' policy. This meant that no more agricultural expansion could be implemented after the total cultivated area covered between 4.20 and 4.62 million ha (between 10 and 11 million feddan).

Therefore, the key priorities in the research partnerships between Egypt and ICARDA are food security (specifically increasing wheat productivity) and water management (water-use efficiency and productivity). Efforts need to focus on improving the productivity of wheat-based systems, increasing on-farm water-use efficiency, and promoting conservation agriculture. Furthermore, it is necessary to develop and integrate the techniques and technologies for the acquisition and supply of water to agriculture with full community participation, and to achieve the efficient use of all sources of water in irrigated agricultural production.

The training provisions of the agreement will include individual degree training, individual non-degree training and internships, a visiting scientists program, and regional traveling workshops. These are essential in order to enhance the country's human capacity and to strengthen adaptive research. Such interventions are needed in the following areas of capacity development

- Crop water requirements
- Irrigation schedules
- Modern irrigation systems
- Water harvesting
- Supplemental irrigation
- Runoff-rainfall relations
- Watershed management
- Soil-water-plant relations
- Tillage
- Crop varieties testing
- Fertility
- Erosion prevention

- Agronomic practices
- Deficit irrigation and conservation agriculture
- Drought management
- Management of salt-affected soils.

Ultimately, irrigation is the main parameter in the agricultural sector and the entire national economy in Egypt. Almost all cultivated lands are under irrigation and, therefore, tremendous efforts should continue to be focused on maximizing the use of each drop of water.

1. Introduction

Agriculture is a dominant contributor to economic growth in Egypt, accounting for approximately 15% of the country's USD 232 billion GDP. Moreover, around 55% of the population is dependent on this sector for its livelihood and agriculture generates close to 36% of Egypt's total employment (MALR 2010) which reduced to 32% in 2012.

Some of the most productive land in the world lies in the Nile Delta, which is home to more than half of the country's population. Agricultural land in the Nile Delta and Valley amounts to approximately 2.73 million ha (6.5 million feddan[1]), representing 60% of the total cultivated land (FAO 2011) (Figure 1).

the

Agriculture in Egypt relies heavily on irrigation water. The land is dissected by a dense network of waterways, including 40,000 km of canals that branch from the Nile River and convey water to over 2 million farmers across several geographic areas. Alongside these conveyance canals are 18,000 km of drains, where water is partially reused by farmers or pumped back to higher level delivery canals bound for coastal lagoons and the Mediterranean Sea. The recycling of drainage water, coupled with a deficient drainage system and inappropriate in-field management of applied water, contribute to salt loading that has, and continues to have, significant negative implications for productivity. Understanding the causes of salt loading and developing management strategies to address the issue are imperative for the Government of Egypt (ACIAR/AusAID-ICARDA consultation with Egyptian counterparts, July 2011).

Of all sectors in Egypt, agriculture is the largest consumer of water, representing between 80 and 85% of the total water demand. However, because of recent population growth and climate change, the sector, and the country as a whole, are experiencing severe water scarcity. In 2006, the per capita share of water was 850 m^3/year. However, five years later in 2011 this figure had decreased to700 m^3/year and it is expected to drop to 500 m^3/year by 2030. This latter figure is widely considered to be below the water poverty level (Table 1).

[1] The feddan is an Egyptian unit of land area equal to about 0.42 ha or 1.038 acre.

Addressing this constraint will require a reduction in the diversion of water away from agriculture; this will necessitate significant increases in water efficiencies over a range of scales (i.e. basin to on-farm).

Table 1. Some indicators of the current status of water use in Egypt

Indicator	Estimated average
Agricultural water (billion m^3)	58
Per capita share of water (m^3), year 2011	700
Expected per capita share of water (m^3), year 2030	500
Irrigation water application efficiency (%)	50

With these natural constraint~~s~~, agricultural growth has been pursued in two directions (MWRI 2005). There has been *vertical expansion* through the intensification of existing cultivated lands; achieved by controlled irrigation management, improved water-use efficiency in horticulture, and obtaining a higher quantity and quality of production per unit of land and water. And there has been *horizontal expansion* into desert lands ('new lands'); involving better management techniques and water savings in the 'old lands', the irrigated agricultural lands which were claimed from the desert many generations ago and have been intensively cultivated ever since. This two-pronged policy approach is motivated by Egypt's population growth, concern about the country's growing dependency on food supply, and the need to compensate for the estimated 10,000 ha (22,000 feddan) of old lands that are annually lost through urbanization (MWRI 2005). Furthermore, Egypt is now fully utilizing its share of the Nile waters, and continued population and economic growth will exert further pressures on existing water resources (Hamza and Mason 2004). Challenging new development projects are being implemented by the government, such as the Al-Salam and Toshka agriculture projects. These projects will have a large impact on the distribution and use of water resources.

There are several constraints that need to be addressed in order to achieve sustainable increases in land and water productivity and water-use efficiency at different scales in the Nile Delta. These include identifying and implementing appropriate and sustainable technical options for optimizing water use that are acceptable to Egyptian farmers with small- to medium-sized holdings, together with appropriate enabling policies.

In light of the political changes that took place in February 2011 in Egypt, the Government of Australia, through AusAID, made a commitment to help support Egypt's irrigated agricultural research and development. This is being done through Australia's new Improvement of Irrigated Crop Production Trust Fund Initiative. This initiative is supported by AusAID with the overarching objective of improving on-farm water management, water-use efficiency, and environmental sustainability of crop production in the Nile Delta.

As a result of this initiative, the following actions have taken place:

- A high level Australian delegation mission to Egypt, 24–27 March 2011
- Egypt-Australia-ICARDA workshop, 'On-farm water-use efficiency and water management' (Project ID LWR/2011/018), 26–29 July 2011, Egypt
- A visit by senior Egyptian agriculture and water managers to review Australian approaches to water management in the Murray-Darling Basin, 4-15 October 2011
- An ACIAR delegation visit to Egypt, 14–17 November 2011.

One of the outcomes of the Egypt-Australia-ICARDA on-farm water-use efficiency and water management workshop was the development of four background white papers:

- Farm-level water management: opportunities and challenges in the old lands (Abdel-Hafez 2011; El-Gindy 2011; and El-Gindy et al., 2003)
- Farm-level water management: opportunities and challenges in the reclaimed/salt-affected lands (El-Kholy 2011)
- Farm-level water management: opportunities and challenges in the new lands
- Water resources in Egypt: availability and allocation (El-Quosy 2011).

After three days of deliberation, the workshop produced three concept notes for potential collaborative work in Egypt in the coming few years. The broad areas of research for development were identified under three general headings:

- Promotion of sustainable land-use production systems in the old lands of the Nile Delta
- Improving farmers' livelihoods through efficient, productive, and more equitable use of irrigation water in the new lands
- Improving the incomes of farmers through sustainable land and water management in salt-affected soils in the northeastern part of the Delta.

The focus of this document is to use these four white papers to develop a standalone and comprehensive technical paper containing a summary of the facts related to agriculture and water resources in Egypt. It will summarize the constraints and opportunities of the main Egyptian agro-ecologies and identify possible improvements and interventions, both physical and institutional, at the farm and meso-level. These improvements will not only be sound, attractive, and cost-effective at the scale at which they are adopted, but also consistent with other scales. They will not introduce effects that contradict other policy objectives or have unforeseen negative externalities which spread across the multi-level water system. It is worth mentioning that, over the years, scientists have developed a host of interventions for and learned many lessons about irrigated agricultural land in Egypt (El-Quosy et al. 1999). This implies that the process will not start from scratch and suggests that technically sound and economically viable interventions, acceptable to farmers and communities, can be further tested, evaluated, and/or used.

This technical paper is intended to support, directly and indirectly, the Government of Egypt's SADS-2030. This strategy has four main components:

- The sustainable use of natural and agricultural resources
- Increasing land and water productivity
- Raising food security
- Improving living standards and reducing poverty among rural inhabitants.

Moreover, the modernization of the irrigation sector is seen as a key element of the efforts to improve the efficiency of the water conveyance and distribution system, as well as the efficiency of on-farm systems at the farm/plot level. Thus, special attention – financially and otherwise – ought to be given a high priority by the government.

This document is designed to be used by researchers, practitioners, development agents, and managers who are interested in Egypt's main agricultural production systems and the availability and use of water resources in agriculture.

2. General facts on Egyptian agriculture and water resources

2.1 Demographic characterization of Egypt and Egyptian agriculture

Egypt has a total land area of approximately 1 million km^2, most of which is desert and only 5.5% is inhabited. Settlements are concentrated in and around the Nile Delta and its valley, which narrows considerably in Upper Egypt. The total cultivated land area is about 3.6 million ha (8.6 million feddan) – 3% of the total land area – and consists mostly of old and newly reclaimed areas. The climate is arid with very scarce rainfall in a narrow strip along the north coast. The Nile River is the main and almost exclusive source of surface water in Egypt. Agriculture depends on the Nile water and consumes between 80 and 85% of its annual water supply.

The agricultural land base consists of old lands in the Nile Valley and Delta, new lands reclaimed from the desert since 1952, rainfed areas, and several oases where groundwater is used for irrigation. The total irrigated area amounts to about 3.61 million ha (8.6 million feddan), and the rainfed areas cover about 84,000 ha (200,000 feddan). Because of the accumulation of salts, mostly at the soil surface, as much as 35% of the agricultural land suffers from a relatively high level of salinity. The majority of the salt-affected soils are located in the north central part of the Nile Delta and on its eastern and western sides.

Geographically and agro-ecologically, Egypt can be divided into five regions

- Upper Egypt
- Middle Egypt
- Middle Delta
- Eastern Delta
- Western Delta.

Upper or southern Egypt is a narrow river valley, rarely more than 19 km wide, and more frequently only 1.5 or 3 km wide. Middle Egypt is the land between Upper Egypt and the Nile Delta. In the Delta region, which was previously called Lower or northern Egypt, the land is flat and fertile. The Delta is almost 480 km wide at the mouth of the Nile. These lands can also be divided into old lands and new lands.

Egypt's population grew from 38 million in 1977 to 85 million in 2011. Despite a decrease in the annual population growth rate in recent years – it is currently 1.8% – the population is expected to reach 92 million by 2017.

During the 1990s, the Egyptian economy experienced a period of sustained growth in response to economic reforms and liberalization; per capita annual income was reported at USD 1580 in 2007, placing Egypt in the lower middle-income country category. According to the World Bank and the Ministry of Economic Development's poverty assessment report (World Bank 2007), poverty is widespread in Egypt, affecting 40% of the population, and there are deep pockets of poverty. The 40% overall poverty rate in 2005 represents 28 million people, of which 13.6 million (19.6% of the population) are in absolute poverty and 14.5 million (21.0%), are near-poor. Furthermore, 2.6 million of the poor (3.8% of the population) are extremely poor. Poverty is more prevalent in rural areas; more than 70% of those who are poor or nearly poor live in rural areas.

2.2 Types of agricultural land in Egypt

2.2.1 Old lands

The old lands represent the largest irrigated area in Egypt and are found in the Nile Valley and Delta. These include lands which were claimed from the desert many generations ago and are intensively cultivated, mostly using water from the Nile. These lands, characterized by alluvial soils and spreading over 2.25 million ha (5.36 million feddan), are irrigated by traditional surface irrigation systems, which, compared to modern and improved irrigation systems, have a very low field water-application efficiency of around 50% (Figure 2). Most of this land suffers from two important problems, continued encroachment by non-agricultural uses at a rate of 8400 ha/year (20,000 feddan/year) and continued degradation of soil fertility.

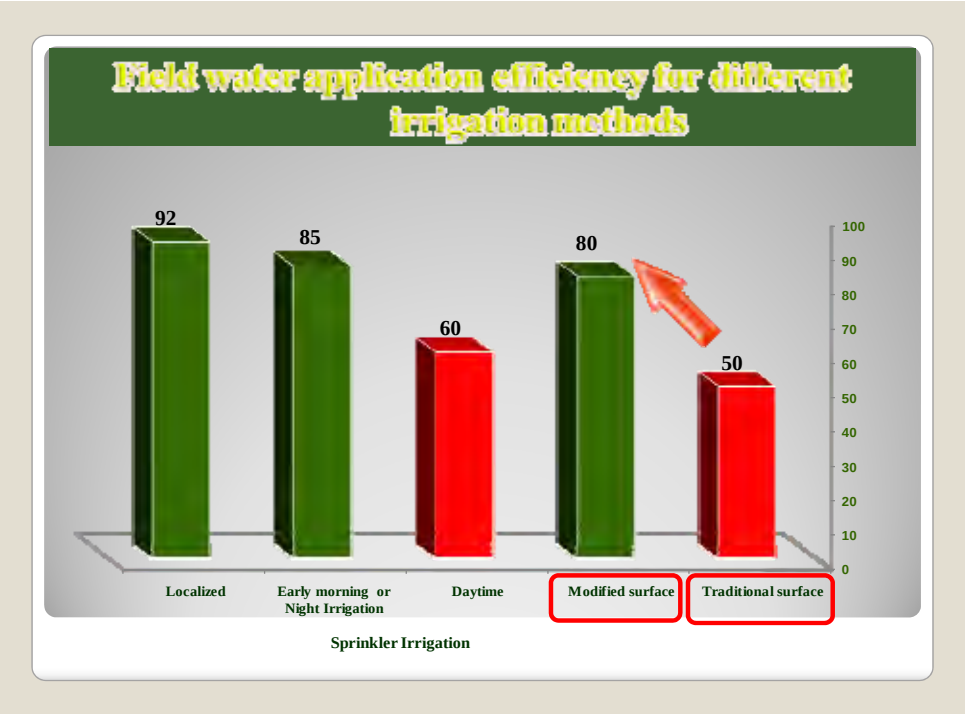

Figure 2. Field water-application efficiency for different irrigation methods (Egypt ARC 2011)

The results of a land classification based on productivity have shown that the area of first grade lands has declined by approximately one-third, from 1.26 million ha (3 million feddan) on average in 1996-2000 to around 410,000 ha (978,000 feddan) in 2001-2005. The area of second grade lands has increased from 33.6 to 41.8% during the same period. The area of third grade lands has also increased from around 0.5 million ha (1.25 million feddan) to approximately 0.9 million ha (2.12 million feddan), while the area of fourth grade lands has increased from 86,000 ha (205,000 feddan) to 340,000 ha (816,000 feddan). These data suggest that land-improvement programs and projects are a top priority.

Assessing the problem of the continued degradation of soil fertility would require undertaking periodic soil surveys as a basis for establishing fertilizer application rates. It would also require continued restoration and maintenance of agricultural drainage systems as well as installing ones where needed to help keep the soil healthy and productive.

In spite of agricultural expansion, land productivity has declined because agricultural rotation was not being followed before liberalization and the incompatibility of the fertilization regimes with the different crops.

The main water-related issues of interest in the old lands are to improve on-farm water management by lowering the rising water table, and to decrease salinity build-up by improving and developing irrigation and drainage system networks.

2.2.2 New lands

New lands (old-new lands and new-new lands) include lands that have been reclaimed relatively recently – particularly since the construction of the Aswan High Dam – or areas that are currently in the process of being reclaimed. They are located mainly on the east and west sides of the Delta and are scattered over various areas of the country. New lands cover 1.05 million ha (2.5 million feddan). The Nile is the main source of irrigation water, but in some desert areas underground water is used. Sprinkler and drip irrigation regimes are practiced.

Reclamation of these lands started in the early 1950s and is continuing. The government reclaimed approximately 806,400 ha (1.92 million feddan) of desert land between 1952 and 1987 and an additional 263,000 ha (627,000 feddan) between 1987 and 1991. During the fifth five-year plan (1993-1997), the reclamation of 240,500 ha (572,700 feddan) was proposed, of which about 197,400 ha (469,900 feddan) were actually reclaimed. During the sixth five-year plan (1998-2002), the targeted land reclamation plans were even more ambitious (Khalifa- Personal Communication).

Historically, land reclamation has been the government's greatest agricultural investment, second to irrigation, consuming between 30 and 35% of the agricultural budget. Of the lands reclaimed, significant areas are lost each year through degradation and urbanization. Current reclamation projects seek to cultivate 210,000 ha (500,000 feddan) of desert land through the Toshka project in the southwestern part of the country and 250,000 ha (595,000 feddan) in the eastern part of the Nile Delta and northwestern Sinai (the El-Salam Canal project).

Although new lands are generally less fertile, their productivity can be improved over time with sound agricultural management practices.

2.2.2.1 Key factors affecting newly reclaimed land development processes in Egypt

The major issues facing Egyptian agriculture are the shortage of water, climate change, and poor soil characteristics.

- Water shortage: The total amount of water used annually from various sources in Egypt is currently about 76.5 billion m^3. The Nile River directly supplies 73% of this demand and the majority of the rest mostly comes indirectly from the Nile – its groundwater aquifers, reuse of agricultural drainage water, and return flows from the river. By 2017, total water demand is projected to reach about 79.3 billion m^3/year, while the projected water supply will only reach 76.6 billion m^3/year. This represents a 2.7 billion m^3/year deficiency. The agriculture sector is, and will remain,

the largest user of water, and, therefore, faces the greatest challenge in its efforts to rationalize water use (Figure 3).

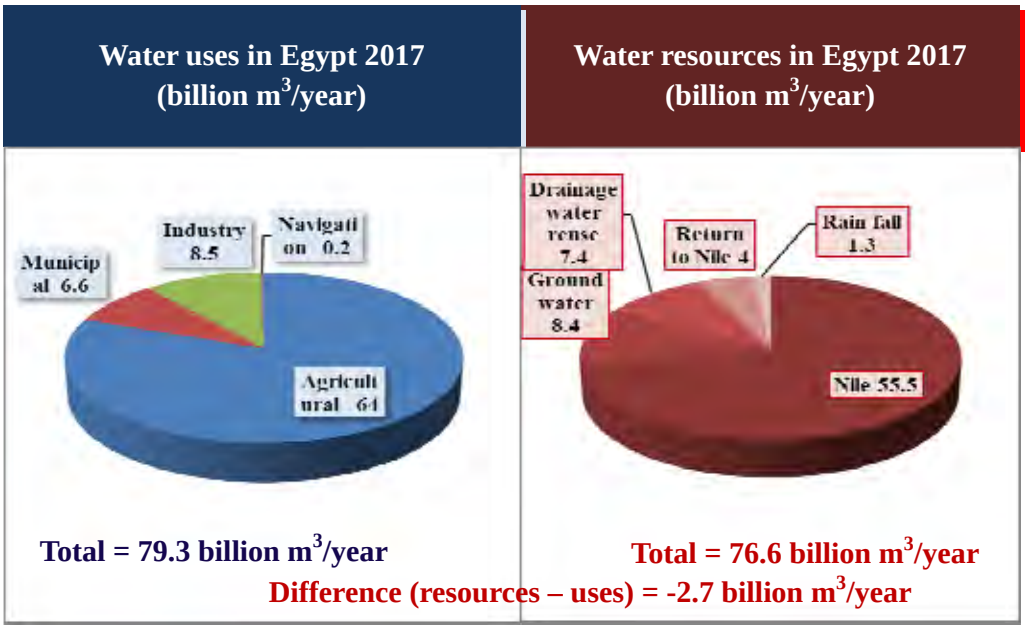

Figure 3. Projected water usage and available water resources in 2017

- Climate change: An array of serious threats related to the effect of climate change on agriculture is apparent. These threats include:
    - Possible effects of sea level rise on the densely populated Nile Delta and coastal areas
    - The likely reduction of the productivity of major crops and increases in their water requirements because of temperature rise
    - A probable general increase in irrigation demand
    - A high degree of uncertainty about the flow of the Nile.

Inefficient on-farm irrigation practices and the irrational use of water will reduce the capacity of Egypt to cope with climate change and potential fluctuations in the Nile's flow. Improved water-use efficiency measures, particularly in irrigation, are seen as an essential element of adaptation to climate change and water scarcity. Generally, the main variations in climatic conditions from the Sinai in the north to the Western Desert in the south are annual rainfall, temperature averages, and wind speed and direction. Any increase in aridity towards the southern border will, therefore, cause extreme variations in temperature and very high evapotranspiration.

In order to address climate change effects, Egypt has set up an inter-ministerial committee – the National Climate Change Committee, with representatives from a

wide range of government and non-government stakeholders – which is responsible for harmonizing action plans in response to climate change.

- Soil characteristics: In the desert areas, soil types and their properties are very much influenced by geomorphic and pedogenic factors. Generally, soils in the new lands are short of fertility nutrients (especially micro-nutrients), very low in organic matter, alkaline (high pH), and have inferior physical properties and moisture characteristics. In many areas, other adverse features include a high percentage of calcium carbonate ($CaCO_3$), a high salinity content, and, in some cases, gypsum. In the main, the physical constraints are hard pans, which are formed at varying depths in the soil profile under the influence of many cementing agents. The characteristics of these resources vary considerably from one location to another because of their mode of formation – mostly wind deposition of varied sediments, and the consequences of terrain attributes.

2.2.2.2 Challenges to improving new land development processes

The constraints undermining the attempts to improve the reclamation of new lands include inaccessibility, which impedes communication, prevents the development of infrastructure, and, ultimately, increases the costs of transporting inputs and commodities and limits marketing possibilities. Moreover, in areas relying solely on groundwater resources, there are further constraints – limited resources, projected duration of development projects, anticipated changes in the cost of water extraction, and the sustainability of the whole process. Other major requirements include the availability of human resources and certain skills and capabilities.

Technical issues that could cause difficulties in reclaiming new lands include:

- Lack of appropriate texture and composition
- Difficulty in leveling the surface layers
- Absence of organic matter
- Lack of macro- and micro-nutrients
- Shallowness of the soil
- Presence of soluble or less soluble salts, such as $CaCO_3$and gypsum
- Continual changes in the surface layer as a result of wind movement
- The presence of certain harmful elements, such as boron and selenium, resulting from rock fragmentation
- Inability to maintain humidity and preserve the nutritive elements (sandy soils) or bad drainage (clay soils)

2.2.3 Other types of reclaimed lands (mega projects)

A number of national mega projects for the reclamation of new lands are being implemented. These include:

- Developing the Sinai – a total area of 260,000 ha (619,000 feddan) is irrigated by a mixture of Nile and drainage water in a ratio of 1:1
- Developing the south of the valley:
- Qena and Aswan governorates –210,000 ha (500,000 feddan) irrigated by Nile water
- Sharq El-Oweinat, Darb El-Arbien, and Oasis projects –210,000 ha (500,000 feddan) irrigated by groundwater
- Toshka project – 227,000 ha (540,000 feddan) irrigated by lifting water from Lake Nasser.

2.2.4 Rainfed agriculture

The areas dependent on rainwater in Egypt cover nearly 2.8 million ha (6.7 million feddan). Most of these areas are located along the Egyptian north coast, between Al-Salloum in the west, near the Libyan border, and Rafah in the east, along the border with the Palestinian Territories.

There are numerous land units prevailing in these areas which can be divided into four main types:

- Sandy lands (deep alluvial sandy lands)
- Rocky and shallow lands
- Salt marshes and lands affected by salinity
- Lands consisting of sand dunes (northeastern coast).

Generally speaking, almost 6% of the land area – amounting to nearly 168,000 ha (400,000 feddan) – consists of deep or medium-deep lands and is fit for traditional cultivation activities (grains, legumes, protected cultivation, timber, and fruit). The remaining 94% consists of mainly shallow, rocky lands, and salty depressions, which are only fit for pasturing activities and breeding small animals and camels. Rocky areas are important for harvesting rainwater and for establishing subterranean reservoirs.

Annual rainfall varies in these areas, from 130 to 150 mm along the northwestern coast and from 80 mm (west of Al-Arish) to 280 mm (at Rafah), along the northeastern coast. This amount decreases with distance from the Mediterranean shore – 20 km south of the Mediterranean Basin the annual rainfall is less than 80 mm in the west and 60 mm in the east.

Although rain falls in winter only, the irregularity of the rainfall can make it difficult to depend on the direct use of rain, and, instead, farmers must use 'water harvesting systems'. These systems have been used for more than 2000 years on the northwestern coast – since the Roman era. Current work in this field seeks to improve indigenous systems and introduce modern systems of water harvesting based on accumulated knowledge and information, and methods of maximizing the use of rainwater employing GIS.

2.2.5 Saline lands

Soil salinity is caused by an excessive accumulation of salts and is typically pronounced at the soil surface. Salts can be transported to the soil surface by capillary action from a salt-laden water table, where they accumulate as a result of evaporation. They can also be concentrated in the soil as a result of human practices, such as the excessive and non-efficient use of agrochemicals, and by the addition of salts via the irrigation water. As soil salinity increases, the salt effects can result in a degradation of the soil's ability to support growth and, consequently, reduction in the amount of vegetation. As a result of mineral weathering, salts are also deposited via dust and precipitation. In dry regions, salts may accumulate and cause naturally saline soils. Proper irrigation management can avoid salt accumulation by providing adequate drainage to leach added salts from the affected soil root zone layers. Disrupting drainage patterns that provide leaching can also result in salt accumulation. An example of this occurred in Egypt in 1970 when the Aswan High Dam was built. The resulting change in the level of the groundwater resulted in soil erosion which led to high concentrations of salts in the water table. After the construction, the continuing high level of the water table led to the salinization of arable land.

Salinity can occur in drylands when the depth of the water table is between 2 and 3 m. The salts from the groundwater are raised by capillary action to the surface of the soil. It can also occur when groundwater is saline (a common condition) and land-use practices allow more water to enter the aquifer than it can accommodate. For example, the clearing of trees for agriculture can induce dryland salinity in some areas since the deep root systems of trees are replaced by the shallow root systems of annual crops, resulting in reduced water extraction and a rise in the saline water table.

Salinity is an important and growing source of land degradation all over the world. It can be reduced by leaching soluble salts out of the soil with excess irrigation water. Soil salinity control involves water table control and flushing in combination with tile drainage or another form of subsurface drainage. High levels of soil salinity can be tolerated if salt-tolerant plants are grown. Sensitive crops lose their vigor even in slightly saline soils. Most crops are negatively affected by (moderately) saline soils, and only a few food crops can thrive in, or even tolerate, severely saline soils. Rain or irrigation, in the absence of leaching, can bring salts to the surface by capillary action.

Salinity from irrigation can occur over time wherever irrigation occurs since almost all water (even natural rainfall) contains some dissolved salts. When crops consume water through evapotranspiration, salts are left behind in the soil and eventually begin to accumulate. Since soil salinity makes it more difficult for plants to absorb soil moisture, resulting in detrimental effects on plant growth and yield, these salts must be leached out of the plant root zone by applying additional water. This water in excess of plant needs is called the leaching fraction (LF). Additionally, salinization, as a consequence of using irrigation water, is greatly increased by poor drainage and the use of saline water for irrigating agricultural crops.

2.2.5.1 Classification of salt-affected soils

Two main groups of salt-affected soils, related to plant nature, characteristics, and growth relationships, can be distinguished:

- Saline soils: These are soils containing sufficient neutral, soluble salts to adversely affect the growth of most crop plants. The soluble salts are mainly sodium chloride and sodium sulfate, but saline soils also contain appreciable quantities of the chlorides and sulfates of calcium and magnesium
- Sodic soils: Soils containing sodium salts capable of alkaline hydrolysis, mainly sodium carbonate (Na_2CO_3), have also been termed 'alkali' in older literature.

These two main groups of salt-affected soils differ in their chemical characteristics, their geographic and geochemical distribution, and their physical and biological properties. The two categories also require different approaches for their reclamation and agricultural use. In nature, the various sodium salts do not occur absolutely separate, but in most cases either the neutral salts or the ones capable of alkaline hydrolysis exercise a dominant role on the soil-forming processes and, therefore, in determining soil properties.

2.2.5.2 Extent and causes of salt-affected soils in Egypt

Poor soil and water management, the intrusion of seawater, the use of slightly saline water (drainage or mixed water) for irrigation without proper management and agronomic practices, or the use of saline groundwater as the only source for irrigation are, currently, the main causes of salinization in Egypt. Salinity of irrigation water can cause a build-up of salts in the root zone, particularly if the internal drainage of the soils (or leaching by rainfall or applied irrigation) is inadequate.

The current status of salt-affected soils is presented in Table 2.

Table 2. Present status of soil salinity levels in Egypt

Salinity level	Affected area (%)
Non-saline	55
Moderately saline	5
Highly saline	7
Very highly saline	5
Towns	~0.3
Water bodies	26
Swamps	~0.1

The majority of salt-affected soils in Egypt are located in the northern central part of the Nile Delta and along its eastern and western sides. Other affected areas include Wadi El-Natroun, Tal El-Kebeer, the oases, many parts of the Nile Delta and Valley, and Fayoum province. Approximately 0.9 million ha (2.1 million feddan) suffer from salinization problems in the cultivated irrigated areas. Furthermore, 60% of the cultivated lands in the northern Delta, 20% of the southern Delta and Middle Egypt, and 25% of the Upper Egypt regions are all salt-affected.

In some coastal areas, the extraction of groundwater has proceeded to the point where the intrusion of seawater into the aquifers has degraded the quality of these resources. Continued irrigation with such low-quality groundwater has contributed to the expansion of land salinization. The distribution of saline soils is closely related to environmental factors, such as climatic, geological, geochemical, and hydrological conditions.

Inundation of the soil by saline water over a long period of time is the major cause of salinization in the above-mentioned soils, as well as the tidal effect of seawater, such as in the case of Shalma and El-Hamoul, south of Burullus Lake. In the Mariut and Tal El-Kebeer areas, the main factor responsible for the deterioration of the soils is seepage from irrigation canals.

2.2.5.3 Anthropogenic causes

Humans, through poor soil and water management, and inappropriate agronomic practices, encourage soil degradation by salinization and sodification. Among these practices, the following are worth mentioning:

- Excessive applications of irrigation water
- Spreading scarce water resources on large areas so that neither the crop water requirements nor the salt leaching requirements are met
- Irrigation with poor quality water
- Poor land leveling

- Summer fallow practices in the presence of a shallow water table
- Misuse of heavy machinery that leads to soil compaction and poor drainage
- Excessive leaching during faulty reclamation techniques
- Adherence to improper cropping patterns and rotations.

2.2.5.4 Modes of formation of saline soils

- Saline seeps are the result of excessive leaching caused by reduced evapotranspiration after a change in land use from natural forest vegetation to cereal grain crop farms. Alternatively, it may also occur after a shift in the cropping pattern, such as the introduction of a fallow season in a grain farming system
- Salinity problems are also caused by the ingress of seawater through tidal waves, underground aquifers, or through the wind transport of salt spray (salt drift)
- Salinity problems are most extensive in the irrigated arid and semi-arid regions. In every river basin prior to the introduction of irrigation there existed a water balance between rainfall on the one hand and stream flow, groundwater level, and evaporation and transpiration on the other. This balance is disturbed when large additional quantities are artificially spread on the land for agriculture. Moreover, evaporation of groundwater through the soil surface will raise the salinity of the soil surface and root zone. Such salinization problems can be more severe when the salinity of the groundwater is high, as is usually the case in arid regions. Once the water table is within 1 to 2 m of the soil surface, saline groundwater can contribute significantly to evaporation from the soil surface and, thereby, to root zone salinization
- Localized redistribution of salts can often cause salinity problems of a significant magnitude. Soluble salts move from areas of higher to lower elevations, from relatively wet to dry areas, and from irrigated fields to adjacent non-irrigated fields, etc.

2.2.5.5 Modes of formation of sodic soils

Factors contributing to the formation of sodic soils are:

- A groundwater rich in sodium bicarbonate and Na_2CO_3, as in the eastern part of the Delta
- Desalination in the absence of enough divalent cations in the soil, as is the case in some parts of the Nile Delta and Valley
- Denitrification and sulfate reduction under anaerobic condition, as in the case of Wadi El-Natroun and the land along the Cairo-Alexandria desert road
- Weathering of sodium-alumino silicates, with Na_2CO_3 and sodium silicates remaining in solution, and colloidal silica and alumina in the soil micropores
- Highly sodic soils can be developed in a closed basin with an excess of evaporation over precipitation, if the inflowing water has a positive residual sodicity. Similarly,

groundwater containing residual sodicity could result in the formation of sodic soils when the groundwater table is near the surface and contributes substantially to evaporation.

2.2.5.6 Consequences of salinity

The consequences of salinity are:

- Detrimental effects on plant growth and yield
- Damage to infrastructure (roads and bricks and corrosion of pipes and cables)
- Reduction of the water quality for users
- Sedimentation problems
- Soil degradation, even to the point of abandonment, because soils are no longer suitable for crop production

2.2.5.7 Salinity and plant growth

Excess soil salinity causes poor and spotty stands of crops, uneven and stunted growth, and poor yields. The extent of these effects depends on the degree of salinity. The primary effect of excess salinity is that it renders less water available to plants, even though there is still water present in the root zone. This is because the osmotic pressure of the soil solution increases as the salt concentration increases. Apart from the osmotic effect of salts in the soil solution, excessive concentration and absorption of individual ions may also prove toxic to the plants and/or may retard the absorption of other essential plant nutrients.

There is no critical salinity point beyond which plants cease to grow. As salinity increases, growth decreases, until the plants become chlorotic and die. But plants differ widely among, and even within, species in their ability to tolerate salts in the soil. Salt tolerance ratings of plants are based on the yield reduction when grown in salt-affected soils, as compared to the yield in similar, but non-saline, soils.

2.2.5.8 Management of salt-affected soils

Since there is usually no single way to control salinity and sodicity, several practices should be combined into systems in order to function satisfactorily. This means that development of a technological package, which consists of individual practices, should be implemented as a package. This package should be field tested under farmers' conditions.

The management practices and human aspects related to the reclamation and sustainable use of salt-affected soils can be summarized as follows:

(i) Hydro-technical methods

Methods adopted to remove excess salts from the root zone include:

- Removing the accumulation of salt in the soil surface by mechanical means
- Flushing – washing away surface salts, especially in areas with a suitable hydrology, including an adequate slope; surface drainage accompanies the process in order to drain away the salty water
- Leaching by applying excess water and allowing it to leach the salts from the root zone

(ii) Leaching methods

- Continuous: maintain water at a depth of 10 cm by frequent additions of water to replace the amounts lost by evaporation and drainage
- Intermittent: water added in quantities sufficient to dissolve soluble salts.

In heavy clay soils with low hydraulic conductivity (K), using intermittent leaching after deep plowing and sub-soiling is recommended. Because of the association of clay swelling and waterlogged conditions, leaching at different intervals leads to a drying of the soil which considerably increases K values.

(iii) Drainage practices

The drainage network in Egypt, including open and subsurface drainage, is one of the largest in the world. Details on this topic are presented in Section 6 (Salinity and drainage, water use and reuse, and disposal).

(iv) Physical methods

Several mechanical methods have been used to improve infiltration and permeability in the surface and root zone, and thus control saline and sodic conditions.

- Land leveling makes possible a more uniform application of water for better subsequent leaching and salinity control. For coarse leveling, simple scrapers or levelers may be used, while for fine leveling the use of laser guidance has recently been adopted, which is more effective (precision 1 to 3 cm). Land leveling causes a significant amount of soil compaction and it is advisable to follow this operation with sub-soiling, chiseling, or plowing to break up the compact layers and restore or improve water infiltration
- Tillage is another mechanical operation that is usually carried out for seedbed preparation since it breaks up surface crusts and improves soil permeability. However, if this method is improperly executed it might form a plow layer or bring a saline layer closer to the surface. Heavy machinery traffic, and wet soil condition should be avoided

- Deep plowing is most beneficial on stratified soils with an impermeable layer. It loosens the soil, improves the physical condition of this layer, and increases the air space and K values. Deep plowing in sodic soils should be carried out after preliminary correction of the sodicity, otherwise the mechanical disturbance may cause collapse of the soil structure
- Sub-soiling opens channels for improving soil permeability. The shape of the sub-soiler's shanks, and the space between shanks, depend to a large extent on the depth, thickness, hardness, and continuity of the impervious layer. Sub-soiling leaves salts, grooves, or cracks in the compacted layers, which help air and water movement.

(v) Chemical methods

Soil amendments: Two types of amendments can be used for reclaiming sodium-affected soils. These are calcium-containing amendments and acid or acid-based amendments.

- Amendments that are used to provide soluble calcium include gypsum and calcium chloride. Gypsum is the most commonly used amendment in Egypt for reclaiming sodium-affected soil and reducing the harmful effects of high-sodium irrigation waters because of its solubility, low cost, and availability
- Amendments that produce calcium in calcareous soils by enhancing the conversion of soil $CaCO_3$ to gypsum include sulfuric acid (H_2SO_4) and sulfur. The acid reacts with the soil calcium carbonate to form gypsum (using H_2SO_4) or calcium chloride (using hydrochloric acid). Sulfur requires an initial phase of microbiological oxidation to produce H_2SO_4.

(vi) Biological management

Incorporating organic matter into the soil has two principle beneficial effects on saline and sodic soils. First it improves soil permeability and second, it releases carbon dioxide and certain organic acids during decomposition. These actions will help to lower the pH release of cations by making the $CaCO_3$ and other soil minerals soluble, thereby increasing electrical conductivity (EC) and replacing exchangeable sodium with calcium and magnesium, which lower the exchangeable sodium percentage (ESP).

Farm manure acts as a source of nutrients and improves soil structure and other properties. However, it does encourage the upward movement of salts.

2.2.5.9 Fertilizers for salt-affected soils

Salt accumulation in the soil may affect nutrient content and its availability for plants in one or more of the following ways:

- Changing the form in which nutrients are present in the soil
- Cation and anion interaction effects
- Effects of non-nutrient (complementary) ions on nutrient uptake
- Adverse interactions between salts already present and the added fertilizers, thereby decreasing the fertilizer-use efficiency.

The benefits expected from the reclamation of salt-affected soils will not be obtained unless adequate plant nutrients are supplied as fertilizer (but not in excess) or by other means. The type of fertilizer used in salt-affected soils should, preferably, be of acid reaction and contain calcium rather than sodium. It may also be necessary to take account of the complementary anions present.

2.2.5.10 Crop choice in salt-affected soils

The selection of crops for cultivation during the reclamation of salt-affected soils involves more than studying tolerance lists and choosing the most tolerant crop. Sometimes crops are chosen which are, from the viewpoint of reclamation, not ideal.

The selection should be based on tolerance to salt and waterlogged conditions and the economic value of the crop. In Egypt, it has been found that after six years of crop succession, complete desalinization of the root zone and normal use of the soil could be achieved, as demonstrated in Table 3.

Table 3. Cropping pattern as proposed during the leaching cropping stage

Crop rotation year	**Winter**	**Summer**
1st year	Leaching processes	Blowing/ Leaching
2nd year	Barley, rye grass, followed by berseem (clover)	Rice, sorghum
3rd year	Wheat followed by clover	Rice, cotton
4th year	Clover (catch crop) followed by wheat	Cotton, rice
5th year	Clover (catch) followed by beans	Cotton, corn, rice
6th year	Wheat followed by clover	Cotton, rice

Some important management practices should also be mentioned. While it is important to avoid over-irrigation, frequent irrigation is necessary to maintain moisture at 75% of field capacity.

2.2.5.11 Research and development opportunities for solving salt-affected soil problems under Egyptian conditions

While many of the tools and technologies for solving salt-affected soil problems are currently available, substantial research and development (R&D) is still required. The R&D opportunities fall into four categories:

a) Innovative techniques

Research activities, based on actual needs and demand, should address the technical and environmental problems encountered through development activities. Research is needed on the integration of various component technologies and the associated techniques. These include

- Appropriate precision agriculture
- Biogation technology
- Farming systems
- Cropping patterns
- Rational water resources use
- Agro-meteorological uses in irrigation
- Integrated land and water management
- Enhancement of the rate of agricultural development
- Detection of change based on remote sensing techniques
- Environmental issues and their impact on socioeconomic conditions.

Production and marketing concepts are among the major issues of interest.

b) Technical feasibility

Technical feasibility needs to be established at two levels, conceptual and practical. At the conceptual level, simulations and demonstration models can establish the optimum spatial scales for the range of crops and application systems. This will account for the spatial limitations of the application system, the constraints imposed by sensing needs and capabilities, and the ability of simulation tools to accurately predict the effects of small variations in applied depths on crop growth and yields. This stage must also determine if the diagnostic tools needed to determine the causes of particular crop responses are available and sufficiently accurate. At the practical level, needs assessments should be proven and demonstrated through in-field trials throughout the on-farm irrigation water-management sector.

c) Economic benefits

Current and past work has established that it is far from clear if the benefits outweigh the costs by a sufficient margin to warrant the adoption of new technologies for solving salt-affected soil problems. Work needs to be undertaken across a sufficient range of crops, soils, and irrigation application and management systems to determine where the maximum benefit can be obtained, and to direct the priorities for research investment. This will also establish the advantages of full versus staged or partial adoption. Specifically, quantifying the cost/benefit of integrated on-farm irrigation water management and the agronomic benefits of spatially varied applications for a range of crops appears to be of high priority. It also remains to be shown, through field trials rather than simulations, that adaptive systems can provide substantially greater benefits than traditional management scheduling.

d) Component technologies

Development of improved tools and technological packages needs to be continuous and sustainable. However, there are some clear immediate needs for particular sensing and simulation tools for integrated natural resource management packages and guideline systems currently under development. These are:

- Low cost, spatially-distributed, non-invasive sensing of soil moisture and crop response
- Improved crop models sensitive to small variations in irrigation management with a self learning capability
- Verification of the use of short-range radar for measurement of the spatial distribution of rainfall at the sub-field scale

3. Water resources/supply systems, water allocation, and water policies

Egypt is facing four major constraints with respect to its water resources:

- A fixed water supply and rocketing population growth
- Difficulties in the country's relationship with the Nile Basin states
- Independence of South Sudan declared in July 2011
- Climate change and its hidden future.

These four factors pose a number of questions related to the availability of water and the amount of supply that will be allocated for different consumptive and non-consumptive activities and development programs.

3.1 Water resources

3.1.1 Nile water

Water resources are the critical factor affecting production, services, and sustainable development in Egypt. The country is dependent on the Nile River as the major source of its water supply for all economic and service activities. The supply of Nile water is allocated by the Nile Water Agreement, signed with the Sudan in 1959 prior to the construction of the Aswan High Dam; Egypt's quota is fixed at 55.5 billion m^3/year. This quota constitutes about 90% of the country's water budget; the remaining 10% represents minor quantities of renewable and fossil groundwater, and a few showers of rainfall. Since completion of the dam in the early 1970s, Egypt has never released less than the allocated quantity, with the exception of 1988 when the water level in Lake Nasser fell to alarming levels.

The Nile Basin countries have always been very critical of the Nile Water Agreements and have, therefore, never admitted their validity. In May 2010, upstream countries called for the signing of a new framework agreement, to which Egypt and the Sudan strongly objected. The differences between the parties were threefold:

- Water security is defined by Egypt and Sudan, as acknowledged by agreements signed in 1929 and 1959. Upstream countries, however, reject these agreements on the basis of their old interpretations and history, which goes back to the era of colonialism when Britain signed on their behalf
- According to Egypt and Sudan, prior notification and their final approval are necessary before construction of any structure within the basin
- Consensus, and not a simple majority, is needed before any decision concerning Nile water is made, meaning that Egypt and Sudan, both individually and collectively, can veto any decision.

Upstream countries left the door open for Egypt and the Sudan to sign a new agreement until May 2011. Negotiations are still taking place, but no sign of agreement has yet materialized. In the meantime, there have been rapid developments in upstream sub-basins. These developments include construction of dams, establishment of huge irrigation schemes, and generation of vast amounts of hydropower. Obviously, these developments have occurred without the approval of Egypt and Sudan. However, Sudan has carried out some agricultural development projects and planned for the construction of new dams.

South Sudan became an independent country in July 2011 and this newly established state controls areas in the region where the Bahr el Ghazal sub-basin is located. This sub-basin receives one-third of the amount of rainfall which falls on the Nile Basin as a whole, although its contribution to the runoff reaching the main river is almost nil. The reason for

this is that water leaves the course of the Nile and spreads over vast areas of wetlands where it is lost by evaporation and evapotranspiration.

Upper Nile projects planned decades ago concentrated on capturing losses from the Bahr el Ghazal sub-basin. The Jonglie Canal project was one such project. It was intended to re-route a well-confined course of the river, dry out the surrounding areas, and establish an agricultural scheme capable of sustaining development in the region. Unfortunately, the excavation of the canal stopped in 1982 because of political unrest in southern Sudan. The Jonglie Canal was expected to save 8 billion m^3 of water from being lost to evaporation and evapotranspiration every year and this amount would have been divided equally between Egypt and Sudan. Other Upper Nile projects in Bahr el Zaraf, Bahr el Gabal, Mashar, and Baro Oboko are expected to save more than 40 billion m^3 of water/year. However, with South Sudan now being a sovereign state, this all depends on the policy adopted by the newly-formed government. There are fears upstream that, given the historical animosities with the North, South Sudan may divert water to neighboring African countries like Uganda and Kenya.

This discussion shows how fragile the Egyptian situation is with respect to the Nile waters and how future allocations depend on external factors.

3.1.2 Rainfall

Rainfall is limited to the coastal strip running parallel to the Mediterranean Sea. The amount is small – ranging between 80 to 280 mm/year – and provides an overall volume of 1.3 billion m^3/year. Rain is also erratic with respect to space and time. A number of water harvesting techniques are practiced in some regions. Conjunctive use of rain and groundwater enable some farmers to raise barley and wheat as well as peaches and cantaloupes in the east (the Sinai Peninsula) and olives and figs in the west. In addition, torrents and flashfloods occasionally occur on higher ground along the Red Sea coast. However, this water is not commonly used for agriculture because these weather patterns occur only once every 5 to 10 years and always take people by surprise. The establishment of high-cost infrastructure to dissipate the energy of this water and divert its direction for storage on both the surface and in groundwater aquifers is taking place, but not at a significant rate.

3.1.3 Groundwater

Although there is less groundwater than Nile water, the existence of aquifers in the desert, where no Nile water can be conveyed, makes this resource extremely precious. Desert aquifers are mostly deep and non-renewable, meaning that they are mined and the cost of exploitation is high. The average pumping rate from these aquifers at the present time is

about 1.5 to 1.85 billion m^3/year – although the actual potential is 3.5 billion m^3/year. However, there is strong resistance towards the use of fossil water for agricultural activities from environmentalists, and the government has been recommended to use this water for domestic purposes and bottling only.

The second source of groundwater is the Nile aquifer, which lies below cultivated land in the Valley and Delta. The reservoir is fed by surplus irrigation water and seepage from the Nile and its branches. Obviously, water in the reservoir is shallow and renewable and the quality is not as good as the deep groundwater in the desert. The average pumping rate from the Nile aquifer is about 3 billion m^3/year, although the potential is estimated to be between 5 and 6 billion m^3/year.

The third, smaller groundwater reservoir is the coastal aquifer, which is fed by rain falling on the coastal strip, forming lenses of freshwater, which sit above the saline groundwater and run parallel to the shoreline. Local inhabitants are aware that over-pumping of this groundwater would immediately cause water depression and, in turn, saltwater intrusion; therefore, they carefully pump it for domestic purposes only.

3.1.4 Non-conventional water sources

In countries where conventional (renewable) water resources are extremely scarce, non-conventional water sources provide highly valued supplies. This water is generally used for agriculture, landscaping, and industrial uses through specialized processes. These processes include

- The desalination of seawater and highly brackish water
- The harvesting of rainwater that is otherwise lost to the saline sink
- The collection, treatment, and use of wastewater
- The capture and reuse of agricultural drainage water
- The extraction of groundwater containing a variety of salts.

However, appropriate strategies are needed for managing soil, water, and crops when these resources are used for irrigation.

Given the continuous need to increase water resources and bridge the gap between supply and demand, Egypt has a long history of water reuse. The first pumping station, used to lift agricultural land drainage water to the Damietta branch of the Nile, was constructed near El-Serw city, Damietta governorate, in 1928. Since then the reuse of drainage water has been a fixed policy of successive Ministries of Irrigation. The reuse of treated sewage water was practiced even earlier than the reuse of land drainage water. Historical investigations reveal the use of treated domestic liquid waste in the irrigation of citrus farms in Al-Gabal Al-Asfar, east of Cairo. Recently, it was realized that the desalination of saline and brackish water is less expensive than transporting Nile water to tourist areas around the Sinai, Red

Sea, and northwestern coast. A number of desalination plants have, therefore, been established in these areas. The potential for desalination is growing at a fast rate, especially when renewable energy is used to replace conventional fossil fuel and brackish groundwater is targeted rather than extremely saline seawater.

3.2 Water allocation

Agriculture is the major consumer of water in Egypt, accounting for about 80 to 85% of the total net demand in the country. Because of Egypt's arid climate, nearly all agriculture depends on irrigation water. Any remaining water is used for municipal and industrial purposes, fish ponds, and other requirements. Since 1990, Egypt has been at the 'water poverty line' with respect to its per capita share of water; it fell to almost 1000 m^3/year. In 2011, however, this share decreased again to just about 700 m^3/capita/year, and is expected to fall to 500 m^3/capita/year before 2030 (Table 1).

Population growth, and the essential need for horizontal expansion of the cultivated land, which is vital to feed Egypt's growing population and ensure social and political stability, will increase demand for irrigation water. Improving the use of its limited water resources and saving considerable quantities of water to meet the needs of the horizontal extension of the cultivated area, is a major challenge for Egypt.

3.2.1 Agriculture

The total area of cultivated land at present is about 3.61 million ha (8.6 million feddan)– 2.73 million ha (6.5 million feddan) in the Nile Valley and Delta (old lands) and 0.88 million ha (2.1 million feddan) on the fringes of these regions in new lands reclaimed from the desert. Irrigated agriculture in Egypt is almost entirely dependent on Nile water – although there are minor contributions from groundwater. There is no significant rainfall except in a narrow strip along the north coast. At present, the average consumption of water for agriculture is about 58 billion m^3/year.

Agriculture has two major disadvantages over other activities, a large percentage of irrecoverable losses because of high rates of evaporation and evapotranspiration, and a financial return that is small compared to other activities, such as industry and tourism.

Expected increases in the consumption of water for domestic use, industry, and tourism will undoubtedly affect agriculture. In order to overcome this difficulty, agriculture has to come up with innovative ideas with respect to both cropping and irrigation systems. Although water is not treated as an economic commodity in Egypt, the country has to use water according to its value rather than its price. Crops are, therefore, cultivated according to their market value rather than local needs and consumption.

The large water losses, from both conveyance and distribution networks and farms, have to be reduced. Conveyance and distribution losses are mainly the result of evaporation from exposed water surfaces which can only be reduced if closed conduits are used to replace open channels. Losses can also be reduced by lining earth canals with stone or cement, tightening gates, and removing aquatic plants which consume large amounts of water. Furthermore, since the most significant conveyance losses are tail-end ones, these can be significantly reduced if night irrigation is practiced. Night irrigation not only reduces evaporation, but also reduces water flowing directly from freshwater canals to the drainage system. On-farm losses are as high as conveyance losses and both are estimated to be 30% of the total amount of water wasted.

It is well known that grain and fodder can never be profitable under irrigated conditions. However, Egypt has a relative advantage in the production of vegetables and fruit, cotton, and ornamental and medicinal plants. These products have to be supported by a strong marketing base.

3.2.2 Domestic water requirements

At present, water allocated for domestic use exceeds 25 million m^3/day, or between 9 and 10 billion m^3/year. This increases the per capita water consumption to more than 300 liter/capita/day, which is high compared to the world average. However, a large proportion of the water – estimated at between 30 and 50% – is lost in treatment plants, the pipeline network, and households. Eliminating these losses would decrease the net per capita consumption to a reasonable figure of between 150 and 200 liter/day.

The population of Egypt is currently around 85 million, and is expected to reach 106 million by 2030. By then, domestic water requirements will exceed 20 billion m^3/year, not only because of population growth, but also because of a rise in the standard of living.

3.2.3 Industry

The industrial base in Egypt is growing and major activities include the production of cement, ceramics, steel, textiles, sugar, and fertilizer. Factories – there are estimated to be in the neighborhood of 30,000 to 40,000 of them – are both private and public, and tend to vary in size. Present industrial water requirements stand at 7 billion m^3/year and this amount is expected to increase considerably during the coming decades – despite the fact that Egypt intends to promote only industries that consume less water and are more energy efficient. The major industry that is expected to dominate in coming years is cement, and given concerns about water shortages, techniques based on dry mix are preferred.

3.2.4 Tourism

The number of people visiting Egypt in 2010 reached a record high – more than 14 million tourists spent almost 150 million tourist nights in the country. Tourism is a water-consuming activity because of the need to irrigate golf courses; fill swimming pools, fountains, and artificial lakes; and maintain normal hotel practices. Given that the government hopes to attract 20 million tourists by 2020, the sector will have ever greater water needs. Furthermore, since the number of ferries commuting on the Nile, especially on the stretch between Luxor and Aswan, has risen to more than 250, these vessels require deeper water compatible with their drafts.

In view of the long distance between the Nile and the summer and winter resorts in the Sinai, Red Sea, and northwestern coast, the conveyance of Nile water has proved to be more expensive than local desalination of sea or brackish water. The amount of desalinated water according to the latest estimates is between 200 and 300 million m^3/year, and this type of activity is paid for by investors who charge the same rate to the tourist community.

3.3 Water policies

Water policies were implemented in Egypt as early as the beginning of the twentieth century. All policies were based on 'development', with water allocated first to domestic use, followed by industrial requirements. The remainder went by default to agriculture. With the exhaustion of all water resources, the last policy of 1997-2017 became an 'allocation' policy. This meant that no more agricultural expansion could be implemented after the total cultivated area reached between 4.20 and4.62 million ha (between 10 and11 million feddan).

Some of the water policies that are being considered in Egypt are listed below.

- Water pricing for agriculture is one of the major debates in Egypt. The main obstacle towards the application of pricing is land fragmentation, which requires the installation of millions of water meters and the employment of thousands of meter readers. However, since small farmers are barely able to survive because of costly inputs and the unfair practices of middlemen who under-value their commodities, cross-subsidies could be a potential solution. This intervention would charge big investors the costs of their irrigation water and increase the tariff for potable water for large consumers, hotels, and industries in favor of small farmers
- Water policies used to follow the 'pick the low hanging fruit first' rule with respect to quantity and quality. The use of fresh Nile water was the starting point; the use of shallow fresh groundwater followed; and the reuse of relatively moderate saline drainage and deep non-renewable groundwater came after that. The country is now

heading towards the desalination of considerable quantities of sea and brackish water

- Modification of cropping patterns and improvement of the irrigation systems (both delivery and on-farm) are now at the top of the country's priority list. Replacement of summer cultivation with wider winter cropping is one of the policy options since the consumption of water by summer crops is twice that of the winter ones
- Studying the cultivation of grain in other Nile Basin countries, where land and water availability appears to be better than in Egypt, especially in rainfed areas, is also under consideration
- The use of smaller sailing vessels, which have a shallow draft and, consequently, require less depth of water in the navigable channels of the Nile and its tributaries, will certainly reduce the requirements for water
- The introduction of short-age crop varieties, like rice, significantly reduces the number of irrigation days and seasonal crop water requirements
- Swapping crops between regions may reduce water requirements
- Supplementary irrigation and improvement of rain-harvesting techniques would enable the cultivation of vast areas in the Sinai Peninsula and the northwestern coast
- Industry has to survive on less water inputs by using closed cooling circles, less water consumption in the manufacturing process, and the re-circulation of treated effluent
- The relationship between Egypt and the other Nile Basin countries is vital for its survival. Implementation of methods for capturing water losses in South Sudan would provide a promising opportunity to reduce the river's runoff and divide any saved water between all Nile Basin states
- To deal with the effects of climate change, Egypt, with the help of international institutions, is in the process of developing a Regional Circulation Model capable of predicting river flows under different greenhouse gas emission scenarios.

4. Agriculture, food security and relevant policies

Food security has become an issue of prime political importance in Egypt, and potential agricultural expansion would increase pressure on the country's limited water resources. In order to meet increased food demand, two basic strategies are possible, importing food or growing more food with less water. Different agriculture projects have been established to enlarge the cultivated area and guarantee sufficient production of the country's main crops, issues that are considered top government priorities. Based on the concept of water reuse and increased efficiency, the use of scientific knowledge, international experience and cooperation, and advanced management tools should help in planning a sustainable future economy.

4.1 Agriculture and food security

Agriculture is a key sector in the Egyptian economy, providing livelihoods for 55% of the population and directly employing about one-third of the labor force. Although the contribution of the sector has fallen over time, it still accounts for about 14% of GDP and 20% of total exports and foreign exchange earnings. Industries related to agriculture, such as processing, marketing, and supplies, account for a further 20% of GDP.

The continuous increase in Egypt's population and the widening of the gap between food production and consumption are placing a heavy burden on the government's efforts to take prompt remedial actions and correct the economic deficiencies that result from this critical situation. Official policy promotes adopting modern techniques in the agricultural production system, and ensuring the modernization of Egyptian agriculture. The government plans to follow an integrated scientific approach, which has been verified experimentally, to ensure positive economic and environmental impacts. Since Egypt's cultivable land per capita (0.05 ha or 0.12 feddan) is one of the lowest in the world, the government is promoting two main policies – vertical expansion, which seeks to increase productivity in the Nile Valley and Delta, and horizontal expansion, which will add new productive land (Table 4).

Table 4. Cultivated and reclaimed agricultural land up to 2030

Type of land	**Area**	
	(million ha)	(million feddan)
Current total cultivated area	3.61	8.6
Cultivated old lands in the Nile Delta and Valley (surface irrigated lands)	2.73	6.5
Current total newly reclaimed lands (pressure irrigated lands – sprinkler and localized systems)	0.88	2.1
Production area (177% intensification)	6.39	15.2
Projected newly reclaimed areas till 2017	0.67	1.6
Projected newly reclaimed areas till 2030	1.26	3.0

Food security in Egypt, as in many other countries, is seen not only from a macroeconomic and trade perspective, but also through the lens of national health and security. The continuing dependence on food imports is, therefore, quite alarming for many policy makers. The main problem facing Egypt in this regard is that the annual growth rate of food production (2.6% between 1996 and 2006) is far below that of food consumption (3.6% over the same period). The projections of the Food and Agriculture Organization of the United Nations (FAO) indicate that current demand for major food crops, particularly wheat, mean that import requirements will remain very high (FAO 2003). In response, the Ministry of

Agriculture and Land Reclamation (MALR) is devoting substantial efforts to boosting wheat production.

Agricultural production can be divided into four complementary and interrelated systems, field crops, vegetables and fruits, forest trees, and medicinal, aromatic and ornamental plant crops.

Key priorities in the research partnerships between Egypt and ICARDA are food security (specifically increasing wheat productivity) and water management (water-use efficiency and productivity). Efforts need to focus on improving the productivity of wheat-based systems, increasing on-farm water-use efficiency, and promoting conservation agriculture.

4.2 Agricultural development policies

Agricultural development in Egypt is carried out in two different ways, through:

- Horizontal expansion, in which available water is first allocated to domestic and drinking purposes, followed by industry and, then, by default, to agriculture. In this way, the country has been able to establish a number of expansion projects that started in waterlogged areas parallel to the Mediterranean and then moved to desert spots along the fringes of the Nile Valley and Delta
- Vertical development, which is achieved by increasing production per unit area. Interventions include the improvement of seeds, the promotion of better varieties, the installation of field and open drainage, land leveling, night irrigation, the application of fertilizers and agrochemicals, the cleaning of irrigation canals, weed control, the application of post-harvest techniques, the conservation of irrigation water, increasing the cropping intensity, the introduction of short-age varieties, and changing cropping patterns

4.2.1 Strategies and polices towards the horizontal expansion of Egyptian agriculture

Extending agriculture to desert lands and maximizing water-use efficiency are the two main components of the national strategy to increase agricultural production in Egypt. Sustainable agricultural development in the new lands demands care and understanding of the fragile desert ecosystem. Present threats to the sustainability of production systems are recognized in vast reclaimed areas of the country. These threats, which are mostly responsible for Egypt's food gap, include a shortage of water, low irrigation water quality, and poor management practices.

Development projects in Egypt's deserts should be implemented alongside measures to protect the resource base and better manage dryland resources. Resource inventories of soil, topography, climate, biota, and socioeconomics should be made in order to develop

databases for good planning. According to these databases, management systems should be implemented that permit the sustained use of fragile lands which are being farmed and new lands which are being brought under cultivation for the first time. Furthermore, policies for reducing human and livestock pressures on deteriorating lands should be developed and implemented in order to prevent desertification.

Implementing sustainable land reclamation projects in Egyptian deserts should have been based on these concepts in order to expand agricultural activities in the western and eastern deserts on either side of the Nile Delta and Valley. Intensive irrigation projects required huge quantities of water from the Nile.

By using databases on soil and climate and effectively exploiting the experience and know-how developed during previous land reclamation projects, officials can implement the following components in sustainable horizontal expansion activities:

- Semi-arid agro-forestry of multi-value concepts, such as nitrogen fixing and fertility enhancement for rangeland and annual staple crops, including sorghum and groundnuts. This system produces biomass for both livestock and soil fertility conservation, protects against soil erosion, acts as wind breaks, and provides nitrogen fixing at the rate of between 30 and 40 kg/ha (between 13 and 17 kg/feddan) annually. It also provides enough space to produce corn, sorghum, groundnuts, and other cash crops for both human and animal consumption. Branches pruned from the trees can be used as firewood and thick stems can be used to make furniture. Shading provided by these trees would also help decrease evaporation and improve the micro-climates of the farms in the desert areas. Furthermore, a 15% increase in crop yield could be realized in protected fields
- Organic farming systems could also be considered a component of agricultural development projects, by producing clean food and fibers for both local and export markets. These activities would improve the economic and socioeconomic feasibility of the agricultural practices in planned projects.

4.2.2 Sustainable agricultural development strategy towards 2030 (SADS-2030)

The Egyptian Government's present strategy for agricultural development until the year 2030 (SADS-2030) argues that the following themes are essential for agricultural development:

- Promoting agricultural growth through the efficient and environmentally sustainable management of land and water
- Rationalizing the use of irrigation water and improving on-farm water management in the old lands
- Increasing new land reclamation, using water savings from the development of on-farm irrigation systems in the old lands

- Promoting private sector activities in new land reclamation
- Involving more rural women in development processes
- Improving technology transfer and capacity building activities at the farm-level base.

The strategy projects the provision of about 1.3 million ha (3.1 million feddan) of new lands by 2030 (see Table 2). The strategy's actual plans for improving new land development processes are dependent on saving water – approximately 13.5 billion m^3/year – from other agricultural activities in the old lands (see Table 5).

Table 5. On-farm irrigation water-management activities for improving water resources in Egypt based on SADS-2030[†]

Item	**Water savings (billion m^3/year)**
Stabilizing the rice cultivation area at 0.5 million ha (1.2 million feddan)	2.5
On-farm irrigation development in the old lands (OFIDO) of 2.1 million ha (5 million feddan)	10.0
Rehabilitation of the irrigation systems in the newly reclaimed lands	1.0
Total	**13.5**

[†] Only 60% of the saved water can be used efficiently.

5. Irrigation practices: methods, systems, strategies, efficiencies, and management

Egypt's irrigation system comprises three main components, the man-made water body created since the construction of the Aswan High Dam, delivery (conveyance and distribution) networks, and on-farm irrigation. While the first two components are the responsibility of the Ministry of Water Resources and Irrigation (MWRI), the last is the responsibility of MALR.

Egypt is expanding its irrigated areas, but water resources are not increasing. Sustainability is also being threatened by excessive pressure and changing land use. Marginal-quality water is often used. In addition, the country faces several challenges related to effective water resource management for irrigation. Policymakers need to

- Improve inefficient surface irrigation systems in the old lands
- Achieve annual reductions in water availability per capita given the population expansion and soil and water resource degradation
- Shift to cropping systems that rationalize the use of water
- Better manage distribution in the open canal system
- Effectively supervise water distribution in the old lands, keeping a close eye on environmental pressures.

The main problems and constraints facing on-farm irrigation management in Egypt are inefficient water use, high cost of irrigation systems, inadequate quality of irrigation equipment, and high salinity. Improved irrigation technology is urgently needed for the more efficient use of water, fertilizer, and chemicals. Better management is essential. There is also a need to improve soil conditions in terms of drainage and soil aeration in the root zone to maximize crop yields. Water management and irrigation technologies are, therefore, the main bases for the success of agricultural development projects in Egypt. In order to achieve the development project objectives, it is necessary to apply integrated water management and improve water use through new irrigation technologies. This will achieve water saving which in turn will enable horizontal agricultural expansion to be realized. It will also help to improve soil-water characteristics, decrease agricultural drainage requirements, increase crop production, and optimize water use.

The use of improved water-saving irrigation technologies needs to be pursued throughout the Nile Delta and Valley. These technologies have to be applied at the farm level to improve on-farm irrigation systems and the management and conservation of water and soil.

Recent irrigation improvement projects have introduced a number of interventions:

- A change from upstream to downstream control
- Replacement of traditional sluice gates by automatically controlled gates (Avis and Avio gates)
- Replacement of multi-point lifts with one-point lifts at the smaller tertiary canal (*mesqa*) level
- Use of elevated, lined *mesqas* and pipelines
- Introduction of Water Users' Associations (WUA) and irrigation advisory services.

Recently, MALR added downstream improvements and replaced open ditches at the farm level (*marwa*) with closed pipes, thereby complementing the above interventions, which are meant to be implemented on the upstream side of the *mesqa*.

5.1 Irrigation methods/systems

The Egyptian irrigation system is considered one of the most complicated systems in the world. Water in the Nile River is diverted to agricultural lands through a hierarchy of public canals that comprise carriers or principal canals, main canals, branch canals, and sub-branch canals. The branch canals deliver water into *mesqas*. Water is then conveyed from the *mesqas*, or in some cases directly from canals, to fields by farm ditches (*marwas*).

Water distribution and farm-level delivery are in accordance with a complex system of rotations. Canals deliver the water below the field elevation and farmers are obliged to lift the water into the *marwas* to their fields using diesel or electrically operated pumps. The drainage system consists of open drains that are run by gravity. Pumping stations are used along the course of the drains to raise the water from a low level, to lift the water at terminal points, or to mix it with irrigation water.

Flood (surface) irrigation is the dominant irrigation system in the old cultivated lands, which have a total surface area of 2.73 million ha (6.5 million feddan) (Table 4). Water consumption for this kind of irrigation represents 61% of the total water resources. Given its very low field water-application efficiency (Figure 2), improving this system can save considerable amounts of irrigation water, which can then be used for horizontal expansion (Table 5).

Pressure irrigation, including sprinkler and localized systems, are required by law for irrigating the newly reclaimed lands because of their higher field water-application efficiency (Figure 2)

Sprinkler irrigation is the application of water in the form of a spray, resembling a slight rainfall. Sprinkler irrigation systems, including center pivots and fixed or hand-moved systems, are used in irrigating traditional crops, such as wheat, maize, alfalfa, and vegetables.

Localized (micro-) irrigation is the frequent, slow application of water to the specific root zone area of the plant, by surface and subsurface drip, bubbler, spray, and pulse systems. Most fruit trees and vegetables respond well to localize irrigation systems.

The reuse of drainage water has been maintained in the Nile Delta as a fixed policy for water management in Egypt during the last five decades. However, this policy created severe environmental concerns, causing a number of mixing stations to be closed. The appropriate alternative is to lower dependence on the mixing of drainage water with freshwater by imposing tight freshwater management policies and, thus, generating less drainage water. This will also have a positive effect on producing high-standard commodities that could be exported to European and other international markets.

This introduction demonstrates the importance of water saving in Egyptian agriculture, particularly in the old lands where traditional flood irrigation is used. Water saving at the farm level will make considerable amounts of irrigation water available. Several experiments on irrigation improvement and irrigation efficiency, which have shown very promising results, have been carried out by the Agriculture Research Center of MALR, the Irrigation Research Center of MWRI, and universities. By applying a combined program of flood

irrigation improvement, which included farmer participation, an increase in yield was obtained and a reduced volume of irrigation water (of the order of 20%) was applied.

5.2 Water-use efficiency

Land in Egypt is generally highly productive, and, in combination with good climatic conditions (maximum sunlight and cool winters), is ideally suited for the intensive cultivation of a large variety of crops. However, there are several constraints and challenges that need to be addressed in order to achieve sustainable increases in water productivity (on-farm water-use efficiency) in Egypt. These include:

- Technical options for maximizing water-use efficiency, including water-management options, crops, cropping patterns and varieties, and agronomic management
- Water-management guidelines needed under conditions of water scarcity to produce more with less water
- Methods by which farmers can select cropping patterns and inputs to maximize income and water productivity and whether these could be developed into a general decision support tools
- Variation of land use as climate, markets, trade, etc. change and attention paid to how changes in land use can be predicted and/or managed to ensure sustainable agricultural production and livelihoods
- Ensuring the sustainability of production systems under an increasing risk of salinization and land degradation
- Methods for the more efficient management of water and policy options/incentives by farmers
- Policies needed to encourage efficient water use in irrigated areas
- Use of marginal-quality water for high productivity without degrading the land.

Through strategic national projects, the Government of Egypt is targeting about 2.73 million ha (6.5 million feddan) of surface irrigated land for on-farm water-management improvements. This is planned to be done by deploying improved on-farm irrigation systems (laser leveling and gated pipes) and modifying practices for better surface irrigation. These modifications would include

- Raised-bed planting
- The application of localized irrigation in fruit and vegetable fields
- The use of water according to crop requirements based on climatic conditions
- Improving irrigation management at the on-farm level:
    - An irrigation schedule based on soil-water relations
    - Deficit irrigation
    - Alternate furrow irrigation
    - Raised-bed irrigation
    - Surge irrigation, etc.

National research institutes have undertaken projects in Egypt and the results demonstrate the urgent need to develop approaches to improve on-farm water-use efficiency and the protection of ecosystems from the threat of increasing salinity and land degradation.

Problems related to the sustainability of water resources define a common research task – to develop and integrate techniques and technologies for the acquisition and supply of water to agriculture and for the efficient use of all sources of water in irrigated agricultural production with full community participation.

6. Salinity and drainage, water use and reuse, and disposal

6.1 Salinity and drainage

All drainage water in Upper Egypt south of Cairo flows back into the Nile and the irrigation canals. Estimates suggest that this water amounts to 4 billion m^3/year; while drainage water in the Nile Delta is estimated at 16 billion m^3/year. Furthermore, in 2010, treated municipal wastewater was estimated at 3.65 billion m^3/year. There are several desalination plants on the coasts of the Red Sea and the Mediterranean providing water for seaside resorts and hotels. Their total production in 2010 was estimated to be 200 million m^3. An estimate for the potential of non-renewable groundwater in the eastern and western deserts, mainly from the Nubian Sandstone Aquifer, is 3.75 billion m^3/year.

6.1.1 Drainage practices

Land degradation is a serious threat to the future of agriculture in Egypt. Great efforts and resources are required to bring back land productivity to pre-degradation levels. Currently, over 30% of irrigated agriculture in Egypt suffers from varying levels of salinity. In many dryland countries like Egypt, effective on- and off-farm drainage networks are a key element of sustainable and economically productive agriculture.

The use of drainage practices is an essential management option in irrigated agriculture. Management practices that result in less drainage water are attractive since they reduce the volume of drainage water to be disposed of. In conjunction with other drainage management options, such as source control, drainage water is a means of removing salt and trace elements from irrigated land.

In the absence of an effective open and tile drainage network at the farm level connected to a regional drainage canal for safe disposal, drainage water reuse could have several benefits. These include increasing water-use efficiency, optimizing the production and

environmental quality of irrigated farmland, improving the environmental quality of rivers and other water bodies, and enhancing the economic viability of farming.

6.1.1.1 Open drainage

Wherever circumstances cause the water table to rise to the soil surface during the sensitive plant development stage, open drainage should be considered as an option for reducing salinity levels and lowering the level of subsurface water. If the K values of the soil are low, making it impossible for excess water to seep through the soil profile to the subsurface drains, a surface drainage system, with furrows and small ditches of from 40 to 45 cm should be used, possibly combined with soil bedding. The bedding system, which is mostly made manually, can be used to grow vegetables or tree crops. In this system, water begins to accumulate at the surface when the irrigation rate exceeds the soil infiltration rate. This situation is common in most clay soils given their low K values and infiltration rates. The main types of surface drainage are bedding, furrow, and ditch systems. All these types have been evaluated in the Nile Delta and are being used in heavy soils.

Although only 2.5 million ha (6 million feddan) of agricultural land currently contain open drains, the government is planning to have complete open drain coverage in the future.

In sandy soil where permeability is high, natural drainage is reasonable and the groundwater table is deep. In that case, drainage is not a priority.

6.1.1.2 Subsurface drainage

Subsurface drainage is usually based upon a system of buried perforated pipes (tile drains) which control groundwater levels. The buried pipes have the advantage of not hindering mechanized farming. Furthermore, they require less maintenance than open ditches and do not lead to loss of land. When the soil profile allows the movement of water, the K value is more than 0.1 m/day and the soils are highly responsive to conventional tile drainage. The major problem associated with tile drainage of heavy clay soils with K values of less than 0.1 m/day is that the tiles usually need to be closer together to be effective, which may be uneconomical. In practice, the spacing is often determined using local experience and varies between 10 and 20 m in heavy clay soils of medium K values.

Another on-farm subsurface drainage system used in the Delta is called ‘mole drainage’. This system comprises unlined circular soil channels which function like tile drains. If a soil layer with a higher K value is at a great depth (more than 2 m) and the top layer is of very low K value, the drainage problem can be solved by vertical drainage.

The total area equipped with subsurface drains at the present time is almost 1.7 million ha (4 million feddan).

6.1.2 Developments to improve drainage conditions

Both MWRI and MALR consider subsurface drainage an important tool to improve soil conditions and sustain soil fertility. There is an ongoing program by the Egyptian Public Authority for Drainage Projects (EPADP) to implement subsurface drainage in the Nile Delta and Valley. The total area included in the program is about 2.69 million ha (6.4 million feddan), of which some 75% has already been completed. In addition, there is an ongoing drainage rehabilitation program in areas where existing drainage systems were not properly designed to cope with very specific soil conditions. These areas are mainly concentrated in the governorates of Menoufia, Gharbia, and Kalubia. Some smaller areas are located in Beheira, Sharkia, Beni Suef, Fayoum, Qena, and Sohag governorates. The total area already rehabilitated is about 0.17 million ha (0.4 million feddan), and the target area to be rehabilitated by 2012 is 0.5 million ha (1.2 million feddan).

Considering the present rates of development of new subsurface drainage systems and the rehabilitation of older systems, it is assumed that by the year 2017 the subsurface drainage systems in the old lands will be fully implemented and functioning properly. Other measures that will improve the field application efficiency are land leveling and controlled drainage. Laser land leveling in areas of the Irrigation Improvement Project (IIP), which is being carried out by MWRI in collaboration with MALR to improve irrigation efficiencies and water distribution among farmers in the old lands, showed promising results (with irrigation water savings of between 15 and 20%).

6.2 Water use and reuse

Water use

The total amount of water withdrawn in 2010 was estimated at 81 billion m^3. This included 67 billion m^3 for agriculture (82%), 9 billion m^3 for municipalities (11.1%), and 2 billion m^3 for industry (2.5%). In addition to these amounts, 4 billion m^3 were used for navigation and hydropower.

Groundwater extraction in 2010 was 8.045 billion m^3 and comprised:

- 6.2 billion m^3 from the Nile Basin (seepage water)
- 1.7 billion m^3 from the eastern and western deserts, i.e. mainly the Nubian Sandstone Aquifer
- 0.145 billion m^3 from shallow wells in the Sinai and along the northwestern coast.

Water reuse

Given the wide gap between supply and demand, there is a fixed policy in Egypt that reuses drainage water and mixes it with freshwater. However, being in a closed basin, the mixed water not only contains land drainage and freshwater, it also includes treated and untreated domestic sewage and industrial effluent.

Reused agricultural drainage water returned to irrigation canals amounted to 4.5 billion m^3/year in 2010. Of the 3.65 billion m^3/year of treated wastewater, 1.5 billion m^3/year is reused for irrigation, while the rest is pumped into large drains where it mixes with drainage water and is then used for irrigation. Treated wastewater is usually used for the landscape irrigation of trees in urban areas and along roads.

All drains in the upper part of the country, from Aswan to Cairo, discharge water into the main course of the river. This quantity is estimated at around 4 billion m^3/year. A number of reuse projects in the southern part of the Delta and Fayoum governorate consume about 4 billion m^3/year, while farmers unofficially use quantities which are not subject to official measurement.

6.3 Disposal[2]

Drainage water management is normally concerned with reducing drainage water and managing its disposal. However, these objectives are more complex than they appear. Drainage is practiced in order to maintain aeration in waterlogged root zones and/or to leach excess soil salinity to sustain agricultural production. The drainage water generated must then be managed through safe disposal or in well-structured drainage reuse systems.

To sustain irrigated agriculture, the maintenance of favorable salinity levels is the major concern when assessing minimum drainage disposal requirements. Furthermore, when seeking to maximize the reduction at source or reusing drainage water, minimum leaching is required to maintain favorable salt balances in the root zone. The minimum LF depends on the salinity of the irrigation water, the salinity of the soil, and the salt tolerance of the crops grown.

In the absence of a shallow groundwater table, soil salinity increases with depth in the root zone. However, if soil salinity is highest near the surface and is relatively constant or decreases with depth, traditional leaching procedures and calculations do not apply. In this

[2] Source of the material in this section: http://www.fao.org/DOCREP/005/Y4263E/y4263e0a.htm.

case, the upward movement of water driven by evapotranspiration will cause the leaching portion of the applied water to be zero, regardless of soil salinity level.

7. Capacity building of national staff and farmers in natural agricultural resource management

Almost all technical assistance projects implemented since the 1980s have had a training component. However, very fast developments require corresponding rapid developments in training and capacity building programs in order to match world standards.

Training is essential in order to strengthen adaptive research in the following areas:

- Crop water requirements
- Irrigation schedules
- Modern irrigation systems
- Water harvesting
- Supplemental irrigation
- Runoff-rainfall relations
- Watershed management
- Soil-water–plant relations
- Tillage
- Crop varieties testing
- Fertility
- Erosion control
- Agronomic practices
- Deficit irrigation and conservation agriculture
- Drought management
- Management of salt-affected soils.

Research is generally conducted at research stations or in farmers' fields to enhance the farmers' knowledge and facilitate adoption of the improved irrigation and associated land improvement and crop production technologies.

The successful adoption of improved crop cultivation practices and soil and water management require intensive farmer training programs. Initially, the staff of the relevant local government technical agencies and farmer technicians will be trained as trainers on natural agricultural resource management (including improving existing irrigation systems, developing new systems and crop technologies, and ensuring environmentally sustainable systems of production). These trainers will then be responsible for delivering training to farmers at the village level. Training will be provided on improved crop production technologies and practices, environmental awareness in relation to cultivation techniques, input usage, and waste disposal. Training will be held at the village and community level to

increase farmer awareness of the new technologies and issues relating to sustainability. Additionally, training for advanced farmers and farmer groups on natural agricultural resource management will also be conducted.

For years, ICARDA has focused on the human and institutional capacity development of national partners. Emphasis on capacity development and knowledge transfer and dissemination continues to be a major activity for ICARDA. Furthermore, ICARDA promotes degree and non-degree training in partnership with national programs, regional organizations, and advanced research institutes. Based on the annual capacity needs of national programs, several training courses are offered every year, on a priority basis, to help national programs improve the capacity of their practitioners in agriculture research and extension.

ICARDA uses different capacity development modalities to meet the needs of national programs. These modalities include individual degree training, individual non-degree training and internships, a visiting scientists program, and regional traveling workshops. Recently, ICARDA has developed a young agricultural scientists program wherein, each year, five or six non-degree scientists spend six months working alongside ICARDA scientists to acquire research competence in areas of interest to research programs or projects in their countries.

7.1 Implementation of training and human resource development in water and soil resources and on-farm irrigation management

The training of engineers and technicians within MWRI is an essential part of upgrading the system. The ministry established a training center in the early 1980s and promoted technical staff who successfully passed training courses relevant to their promotion. Eventually, the training center became regional when Egypt was assigned by the Nile Basin Initiative[3] to take over the training activities of the initiative. In order to make farmers aware of progress in the on-farm and delivery sides, the ministry introduced the concepts of WUAs and irrigation advisory services. Farmers are continuously invited to workshops, seminars, field days, and classroom lectures, not only to inform them about changes taking place, but also to hear their suggestions and opinions about further developments and improvements.

Technical capacity building in natural resource management, particularly of the national staff involved in activities concerning irrigation development (i.e. improvement of existing schemes and construction of new schemes), is a key element for the sustainable development of agricultural water resources. The training should be based on assessing the

[3] The Nile Basin Initiative is an inter-governmental organization dedicated to equitable and sustainable management and development of the shared water resources of the Nile Basin. More information on the Nile Basin Initiative can be found at http://www.nilebasin.org/newsite/.

technical capacity building requirements of the relevant staff in national institutions to prepare them for the important role they will play in the agricultural water resources development component of national agricultural projects. It should also be directed towards extension sector specialists on natural agricultural resource management programs. Furthermore, it should establish and develop both WUAs and farmer organizations for large and small scale water delivery lines, and specialists in on-farm irrigation advisory services.

Objectives of the training

- Enhance technical knowledge to improve the water-use efficiency of irrigation methods
- Improve the ability to distill and deliver technical information and provide high-quality irrigation services to target groups
- Develop a plan for the implementation of on-farm irrigation systems
- Perform these tasks reliably and sustainably
- Help farmers analyze problems
- Help farmers obtain information
- Help farmers adapt innovations to be suitable for their needs
- Help farmers to document and communicate the results of their experiments.

Outputs of the training

- Participants with greater understanding of irrigation and extension methods relevant to sustainable natural resource management practices
- Extension materials developed by participants
- Delivery programs in the form of action plans developed by participants for implementation upon their return to their work
- Strengthening of international training cooperation
- Trainers trained
- Description of human resources development modules and programs
- Recommended follow-up and periodic assessment of effectiveness and impacts
- Support MWRI and MALR in joint training programs conducted by the two ministries.

Activities

- Demonstrating improved on-farm irrigation systems and associated land-improvement measures and agronomic practices, including those appropriate for different crops
- Training the trainer and target groups
- Improving farmer awareness and knowledge through
    - Farmer exchange visits
    - Information publication
    - Mass media broadcasting and improvement

- Increased outreach through the MALR's interactive web-based extension information networks, the Rural and Agricultural Development Communication Network, and the Virtual Extension and Research Communication Network
- Improved extension delivery, including field allowances, transportation, minor equipment, and facility improvement.

Target groups

- Young researchers on degree and non-degree training
- Civil engineers, agricultural engineers, technicians, and private sector employees
- Extension staff
- Leaders of farmers' associations
- Public sector service providers as well as administrative and cooperative staff to be trained in workshops on the installation and repair of irrigation infrastructure and project implementation.

Areas of training

- System planning and improvement of joint planning approaches for water quantity (matching supply and demand)
- Water conservation measures
- Water resource management (quantity and quality)
- Developing alternative water resources
- Further developing surface water resources
- Protecting water resources
- Designing, implementing, operating, and maintaining integrated irrigation systems
- Analyzing and solving maintenance problems
- Acting flexibly and problem solving according to the field situation/farmers' requirements
- Setting standards and specifications of material and equipment
- Improving irrigation water-use efficiency
- Developing appropriate cropping patterns
- Irrigation methods and systems (spate, sprinkler and localized irrigation – drip, mini-sprinkler, bubbler, etc.)
- Supplemental irrigation
- Soil and water conservation
- Erosion reduction
- Water harvesting and optimizing the use of rainfall
- Groundwater recharge and enrichment and strengthening of groundwater management
- Setting standards to regulate the use of irrigation water
- Drought management

- Soil-water-plant relations
- Management of salt-affected soils
- Water-management planning and the operation and maintenance of hydraulic structures.

7.2 Capacity building for the empowerment of women

To promote the effectiveness and sustainability of any natural agricultural resource management project it is necessary to ensure that its benefits accrue equally to both men and women. The project has to ensure that women have equal access to technical advice and training, information, markets and employment, and representation in project management. They also need to be ensured equal access to funds for project activities. In order to promote gender awareness, gender-specific training will be provided for the boards of directors of Small Farmer Associations (SFAs), financial and technical service providers, the leaders of local government authorities, and village committees.

To enhance employment opportunities and access to project funds and other financial resources, women who, actually or potentially, use and manage income-generating activities within their families will be trained on how to apply for funds or loans, and how to better manage financial resources. It is estimated that at least 25% of the employment opportunities generated by the project will be provided for women, since poverty and lack of income-earning opportunities have led men to migrate to urban areas and the Gulf States in search of work. To achieve the target, activities suitable for women will be emphasized to encourage their participation. Increasing gender awareness will:

- Enhance the participation of women on the boards of directors of SFAs
- Improve the ability of women to apply for funds or loans and manage financial resources
- Ensure the effective representation of women in natural agricultural resources management projects
- Enhance the role of women in business and marketing activities.

7.3 National and regional training centers

There are several existing national and regional training centers that need support. Some examples of the major centers are provided below.

7.3.1 Drainage Training Center

The Drainage Training Center (DTC) was established in 1991 under the auspices of the EPADP. This training center provides various theoretical and practical training courses on all issues related to drainage in Egypt. The objective of the DTC is to promote the quality of

drainage works and improve their efficiencies through staff training. The center has well-equipped lecture rooms, computer laboratories, technical laboratories, and accommodation facilities.

7.3.2 International Center for Training at Al-Amria (Alexandria)

The International Center for Training and Development in the New Lands, Al-Amria, was established in 1976 under the Land Reclamation Sector of MALR. This training center, which is the major agricultural training facility in Egypt, has been working under the sponsorship of the UNDP and FAO. The center is located at Km 34 on the Alexandria-Cairo desert road. The center provides training courses nationally for different agricultural institutions and fresh graduates, regionally for Nile Basin and African countries, and internationally for the Middle East and West Asia countries. The core training of the center focuses on new lands agriculture and protected agriculture.

The center is well equipped with excellent training facilities, including five conference, workshops, and meeting rooms of different capacities. It has also an accommodation facility with 400 rooms and a restaurant with capacity for 400 persons. The center has accommodation facilities for trainers and important visitors. In addition, the center has demonstration and experimental sites for different training modules. In addition to its training services, the center is a trusted resource for extension activities to farmers in Nubaria new lands area.

7.3.3 Regional Center for Training and Water Studies

The Regional Center for Training and Water Studies (RCTWS) was established in 1992 under the Training Sector for Water Resources and Irrigation of MWRI in Giza, Egypt. The RCTWS is a well-known training center that has been working under the auspices of the United Nations Educational, Scientific and Cultural Organization (UNESCO) since 2002. It has coordinated and executed a number of regional training courses for the Nile Basin, African, Arab, and Mediterranean countries, as well as two major regional conferences and a number of workshops and seminars. It has well-equipped lecture rooms that can accommodate between 20 and 40 participants, computer laboratories, technical laboratories, a number of meetings rooms that can accommodate from 60 to 80 participants, and a conference hall that can accommodate up to 400 participants. The RCTWS offers full-board accommodation at its three star hotel. Sports facilities and a swimming pool are available for recreation.

Modules introduced by RCTWS

The regional governing board and advisory technical committee of RCTWS consist of national and regional experts from government and non-government institutions, in addition to several water ministers from member states and other concerned stakeholders. Based on regional training needs, nine modules are proposed every two years:

- Integrated water resources management (five weeks)
- Water resources assessment and hydro-informatics (six weeks)
- On-farm water management (six weeks)
- Groundwater management in the framework of integrated water resources management (two weeks)
- Non-conventional water resources in arid and semi-arid regions (two weeks)
- Environmental management of water resources (four weeks)
- Project management (two weeks)
- Cultural and scientific responses to water crises (two weeks)
- Protecting water quality for sustainable livelihoods and poverty alleviation (two weeks).

7.3.4 Regional Training Center for Hydraulic Studies

The Regional Training Center for Hydraulic Studies (RTC) was established in 1995 to provide hydraulic and river engineering training. The initiative to establish the center was taken by the Egyptian Government – represented by the Hydraulics Research Institute (HRI[4]) – and the Netherlands Government – represented by UNESCO-IHE Institute for Water Education, Delft, Netherlands. Ongoing support is provided by the Egyptian Government. The main objective of RTC is to transfer HRI's scientific and technical expertise in hydraulic engineering and related subjects to African and Arab countries.

The center provides an annual three month diploma course on 'Hydraulic engineering in river basins' which was first organized in 1996. The main objective of this course is to enhance the understanding of natural river processes and the consequences of human interventions. The center also provides tailor-made short courses related to hydraulic engineering in river basins and environmental hydrology.

The center has a four star hotel for full-board accommodation and well-equipped facilities for training and conferences.

[4] HRI is one of 12 research institutes within the National Water Research Center of MWRI. Additional information on HRI can be found at http://www.hri-egypt.org/.

8. Institutions responsible for water and agriculture in Egypt

Several ministries are involved in water resources management in Egypt. The MWRI plays a key role; it is in charge of the development and management of water resources, and the operation and maintenance of dams, weirs, irrigation canals, and drainage canals. It also monitors water quality. The MALR is involved in improving agricultural activities and land reclamation, including water management at the on-farm level. The Ministry of Housing, Utilities and New Communities provides water supply and sanitation services. The Ministry of Health and Population, the Ministry of State for Environmental Affairs, the Egyptian Environmental Affairs Agency, and the Ministry of Local Development also have specific roles in the sector.

To ensure coordination among the ministries involved in water resources, there are several committees, including the Supreme Committee of the Nile – headed by the Minister of Water Resources and Irrigation – the Committee for Land Reclamation, and the Inter-Ministerial Committee on Water Planning.

8.1 Institutions responsible for water management, policies, and legislation related to water use in agriculture (MWRI and related institutions)[5]

The MWRI is in charge of water resources research, development, and distribution and undertakes the construction, operation, and maintenance of irrigation and drainage networks. Specifications and permits for groundwater drilling are also the responsibility of MWRI. The MWRI represents Egypt in meetings of the Nile Basin countries on Nile water issues. There are several joint projects between these countries for the development of the Nile waters. These projects, if completed, would increase the water shares of member countries significantly. Egypt would gain an additional 9 billion m^3 of Nile water per year. Within MWRI, the following sectors and departments are important:

- Planning Sector – responsible at the central level for data collection, processing, and analysis for planning and monitoring investment projects
- Public Works and Water Resources Sector – coordinates water resources development work
- Nile Water Sector – in charge of cooperation with Sudan and other Nile Basin countries
- Irrigation Department –provides technical guidance and monitoring of irrigation development, including dams

[5] Source: AQUASTAT – FAO's Information System on Water and Agriculture (http://www.fao.org/nr/water/aquastat/countries/egypt/index.stm).

- Mechanical and Electrical Department – in charge of the construction and maintenance of pumping stations for irrigation and drainage.

In addition to the above institutions, other public authorities directly related to MWRI include:

- Egyptian Public Authority for the High Dam and Aswan Reservoir –responsible for operation of the Aswan High Dam
- EPADP –responsible for the construction and maintenance of tile and open drains
- Egyptian Public Authority for Shore Protection, also called the Shore Protection Authority –responsible for the planning of shore protection activities
- National Water Research Center –comprises 12 institutes and is the scientific body of MWRI for all aspects related to water resources management
- General Survey Authority
- Regional Center for Irrigation and Water Management
- Irrigation Improvement Sector
- Nile Protection Sector
- Groundwater Sector
- Water quality Sector
- RTC

8.2 Institutions responsible for water management, policies, and legislation related to water use in agriculture (MALR and related institutions)

The MALR is in charge of agricultural research and extension, land reclamation, and agriculture, fisheries, and animal wealth development. The Agricultural Research Center (ARC) comprises 16 institutes and 11 central laboratories and is the scientific body of MALR for all aspects related to agricultural development. The Land Development Authority is in charge of contracting and monitoring land development projects and manages land allocations to investors and individuals. The Agricultural Development and Credit Bank provides credit to farmers to finance various production requirements.

8.3 Other national institutions

Other participating institutions are:

- Ministry of Finance, Ministry of Electricity and Energy, Ministry of Housing, Utilities and New Communities, Ministry of Investment, and Ministry of Information
- Egyptian universities in different regions, private sector bodies, the Public Authority for Geological Survey, Advisory and Consultancy entities, the National Investment Bank, and other national and foreign banks
- Egyptian syndicates
- Academy of Science and Technology
- National Research Center.

8.4 Regional and international organizations

External cooperation plays an important role in shaping Egypt's modern water resources management through both investment financing and technical assistance. Regional and international organizations involved in water and agriculture in Egypt include

- ICARDA
- Center for Environment and Development for the Arab Region
- Arab Center for the Study of Arid Zones and Dry Lands
- Arab Center for Agricultural Development
- Arab Organization for Agricultural Development
- UNDP
- FAO.

9. National projects on water and agriculture

Ancient Egyptians cultivated the flood plain of the Nile River. Successive generations expanded cultivation on both sides of the flood plain from north to south. This continuous expansion enabled the area of arable land to increase from 1 million ha (2.5 million feddan) in the early 1800s to almost 3.6 million ha (8.6 million feddan) at the present time. According to recent estimates, this area is expected to have increased to between 4.2 and 4.6 million ha (between 10 and 11 million feddan) by 2011.

In order to continue the expansion of arable land, a number of research, pilot, and full-scale projects have been implemented to maximize the total amount of water available for agriculture. These projects use scarce water resources more efficiently by reducing losses from irrigation and reusing drainage water that would otherwise be wasted. Some of these projects are listed below.

9.1 Water resources and on-farm irrigation management

9.1.1 Irrigation improvement project

The IIP is an ambitious program that is being carried out by MWRI in collaboration with MALR to improve irrigation efficiencies and water distribution among farmers in the old lands. The major components of IIP are:

- Renovation and improvement of branch canals, including modular discharge regulators at the head of branch canals, cross regulators, and downstream water control structures
- Conversion from rotational to continuous flow
- *Mesqa* improvement by conversion of low-level *mesqas* to raised canals or pipelines
- Establishment of WUAs

- Improvement of on-farm water management (integrated soil and water-management practices).

The total area planned for improvement under IIP by the year 2017 is about 1.47 million ha (3.5 million feddan), of which some 70% is located in the Delta. In order to achieve the maximum benefits from these measures, the IIP developments are supported through irrigation advisory services. The irrigation advisory services will also support WUAs that will be established outside areas considered for IIP improvements.

9.1.2 Integrated irrigation improvement and management project

The IIP, MALR, EPADP, and several institutional programs on water management are expected to further develop and coalesce into the integrated irrigation improvement and management project (IIIMP).

This project is designed to achieve integrated planning, management, and execution of all interventions needed at the command level (WMRI 2010). The objectives of the IIIMP are to:

- Develop the framework for an integrated water-management plan and program in selected command areas and combine water quantity and quality management through interagency and stakeholder consensus
- Improve the institutional, financial, and environmental sustainability of water services through the decentralization of water management, intensive user and private sector participation in the investment, operation, and maintenance at the district/branch canal level and below, and improved water-quality management practices
- Establish and expand the WUAs and water boards in line with the government policy of integrated irrigation and drainage water management. This would include support for WUAs at the tertiary level, their extension to branch canal level, and their incorporation into water boards at the district level.

The project started in 2004 and initially covered 210,000 ha (500,000 feddan) in the Delta (Mahmoudia/Beheira – 82,320 ha or 196,000 feddan, Meet Yazid/Gharbia and Kafr El-Sheikh – 52,080 ha or 124,000 feddan, and Bahr Tanah/East Dakahlia – 36,500 ha or 87,000 feddan), Middle Egypt (Serry/Minia – 31,920 ha or 76,000 feddan), and Upper Egypt (Tomas and Afia/Qena – 7140 ha or 17,000 feddan).

9.1.3 The MALR Sustainable Agricultural Developing Strategy towards 2030

The overall goal of this program is to improve on-farm irrigation systems in the old lands in order to save significant amounts of water which can then be used to reclaim targeted areas in the 2030 horizontal expansion plan. The objectives of the project are to:

- Improve agricultural productivity in order to increase the value of crop production per unit of land and water
- Improve the livelihoods of the rural poor (small farmers, the landless, rural women, and unemployed youth) in the project area through targeted interventions to enhance farmers' production potentials and raise household income.

This would be achieved through:

- Improvements in the irrigation network
- Improvements in the agricultural productivity of small holdings through an appropriate integrated research and extension system
- Support to marketing for small holders and the landless
- Support for income-generating micro- and small enterprises for the rural poor through capacity building and access to financial services.

The project strategy will include the following components:

- An integrated approach to irrigation development will be followed in which the status of secondary irrigation systems, *mesqas* and *marwas,* and on-farm improvements will be assessed simultaneously to ensure overall efficiency of the on-farm irrigation system. Interventions will be planned and implemented accordingly
- Smallholder irrigation improvements will be complemented by a series of interventions to ensure maximum returns on investment; these will include support to appropriate extension/research systems and rural financial services to address the needs of youth, women, and the landless
- Institutional capacity building, including capacity building of WUAs, will form an essential element of these interventions in order to assist the rural poor. In particular, *mesqa*-level WUAs will be promoted well ahead of scheme rehabilitation
- The effective participation of target groups in all activities will be carefully planned. In particular, the design of irrigation improvements, their implementation and operation, and their maintenance will be discussed and agreed upon with concerned farmers. The principle of cost recovery through farmers' financial contributions to irrigation improvement will be systemically followed and its modality agreed upon with farmers upfront
- For off-farm development, priority will be given to the poorest and landless on a systematic basis, ensuring that conditions are accessible to poor young men and women as well as older women heading households. Facilitating their access to these services will also be done through training and empowerment measures

- Gender mainstreaming and women's empowerment will be incorporated as an integral part of all project initiatives
- Monitoring and evaluation mechanisms, which provide accountability and allow adequate feedback, will be established to facilitate rational adjustments.

This program includes five national projects:

- On-farm irrigation development in Egypt (OFIDE)
- Improving the efficiency of agricultural land resources
- Addressing the adverse effects of climate change through an agricultural weather network
- Land reclamation and increasing the cultivated area
- Integrated development of rainfed areas.

These projects are included in the first action plan 2010-2017, SADS-2030.

9.1.4 National project for on-farm irrigation development in Egypt

The main objectives of the OFIDE project are:

- Raising the efficiency of field irrigation systems from around 50 to 75% on 2.1 million ha (5 million feddan) by the year 2021, and on 0.88 million ha (2.1 million feddan) in the newly reclaimed lands during the first action plan
- Saving the greatest possible quantities of water to be used in reclaiming and developing new areas (Table 8)
- Increasing agricultural production and improving its quality
- Maximizing the use of land and water units and raising the efficiency of water use
- Contributing to solving the problems associated with the deterioration of soil properties and fertility
- Expanding the use of agricultural mechanization and increasing investment opportunities in the local manufacture of agricultural equipment and the supply of raw materials for field irrigation systems
- Increasing the income of farmers and creating new jobs
- Encouraging the establishment of WUAs as a department (or sector) in the Agricultural Cooperative Association and facilitating their participation in the development, management, operation, and maintenance of improved irrigation canals (*mesqas* and *marwas*) in the Nile Valley and Delta
- Improving pressure irrigation systems in the newly reclaimed areas
- Implementing public health objectives. Improved irrigation methods and conveying irrigation water to farmers' fields by irrigation pipes or concrete-lined canals will prevent weed growth and the propagation of bilharzia snails and mosquitoes. Direct

contact between farmers and water will be avoided, thereby preventing disease infection.

Table 8. Selected results from applied research and studies of on-farm irrigation management in the old lands

Crop	Area (1,000 ha/ [1,000 feddan])	Water savings (m^3/ha/[m^3/feddan])		Total water savings (million m^3)	
		Localized irrigation system	Modified irrigation system	Localized irrigation system	Modified irrigation system
Sugarcane	126/[300]	9,524/[4,000]	8,095/[3,400]	1,200	1,020
Maize	714/[1,700]	3,119/[1,310]	2262/[950]	2,227	1,615
Faba bean	126/[300]	2,193/[921]	674/[283]	276	85
Wheat	1,260/[3,000]		833/[350]		1,050
Fruit trees	273/[650]	4,048/[1,700]	1,190/[500]	1,105	325
Total	**2,499/[5,950]**			**4,808**	**4,095**

Source**:** Suttles et al. 1999)

The project has two sub-projects:

- On-farm irrigation development in the old lands
- Rehabilitating and improving the management of on-farm irrigation in newly reclaimed lands.

9.1.5 On-farm irrigation development in the old lands sub-project, 2.1 million ha (5 million feddan)

The reasons for establishing the sub-project in the Nile Delta and Valley include:

- The low efficiency of traditional surface irrigation systems in the old lands (Figure 2)
- The continuous reduction in water share per capita because of population expansion
- The degradation of soil and water resources resulting from excessive irrigation
- The need for crop patterns that rationalize the use of water
- The mismanagement and inappropriate distribution of the older, presently used open canal system
- The multi-supervisions of water distribution through 'old lands' user and beneficiary associations
- Future environmental pressures in terms of natural resources and global warming
- The energy used by both irrigation and drainage

the primary proposed techniques for improvement encompass:

- Renovating *mesqas* and *marwas* by converting them to pipes and using control valves at water entry points in fields (Figure 4)

- Using improved on-farm irrigation systems (laser leveling and gated pipes) and modifying practices for better surface irrigation
- Applying localized irrigation in fruit and vegetable fields
- Applying crop water requirements based on climatic conditions
- Improving irrigation management and scheduling at the farm level (schedule based on soil-water relations, deficit irrigation, and alternate and surge irrigation)
- Preparing an agro-ecological zoning map based on GIS to identify best land-use patterns.

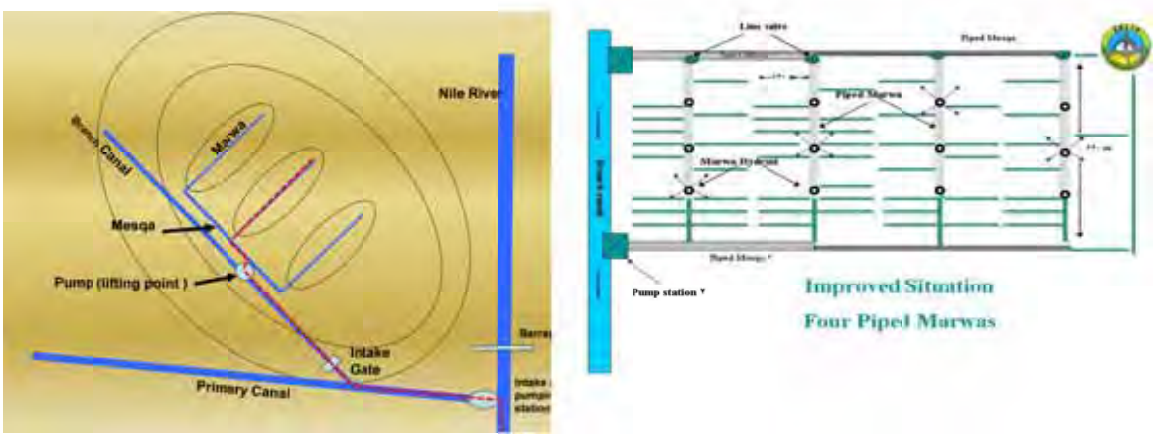

Figure 4. Renovation of *mesqas* and *marwas*

Among the expected outputs of the sub-project are:

- Improved irrigation of 0.2 million ha (0.5 million feddan) per year (1.5 million ha (3.5 million feddan) during the first action plan 2010-2017)
- Maximized water savings so more water can be used to reclaim and develop new areas
- Reclamation of land that is currently occupied by *marwas*, *misqas*, ditches, and canals and the cultivated area increased by approximately 150,000 ha (350,000 feddan)
- Improvements in soil properties and productivity of between 20 and 30%
- Improved and modernized irrigation management at the national level by better estimates of the proper requirements for irrigation water and fertilizer for different crops using agro-meteorological data.

The potential sub-project impacts at the national level include:

- Improving the population distribution map in Egypt, including the settlement of significant numbers of people in new agriculture areas outside the Nile Delta and Valley. This would increase the inhabited areas in these regions, reduce population pressures and social problems, and prevent further urban incursions on agricultural land

- Providing one million additional jobs that would employ between 4 and 5 million people on an additional approximately 420,000 ha (1 million feddan). This would contribute significantly to reducing unemployment
- Saving and reducing energy used in agriculture, which in turn would save substantial amounts of the subsidized petroleum products used for pumping water in the current system
- Improving soil properties, increasing soil productivity, and reducing water losses in agricultural drainage systems. This will reduce the burden on the drainage network and increase the rate of agricultural intensification and modernization in the Nile Delta and Valley
- Increasing the agricultural mechanization rate, which would intensify agriculture by 200%
- Increasing opportunities for the manufacture of equipment and materials for on-farm irrigation systems, increasing farmers' incomes, and creating new jobs. The sub-project would provide significant opportunities for investment in many areas of production and agricultural support services as a consequence of land reclamation and agricultural development projects. Such support services include agricultural mechanization services, laser land leveling, marketing services and agricultural products processing and export to most agricultural provinces
- Creating a driving force to activate the business market and increase investment in Egypt by supporting existing companies and newly established firms in both the private and public business sector. This would provide opportunities in various aspects associated with the development of irrigation systems, land reclamation, and infrastructure enhancement in the newly reclaimed areas
- Supporting and strengthening the export capacity of agricultural products and helping to increase the rates of product processing, especially in the context of integrated projects.

The potential sub-project impact at the farm level would be

- Achieving an equitable distribution of irrigation water at different farm levels (large- and smallholdings), thereby eliminating water scarcity among end-users
- Increasing productivity of the agricultural land unit at a rate of about 20% in developed areas
- Increasing the average income of smallholder farmers (defined as owning less than 1.3 ha (3 feddan) and representing about 85% of farmers in the targeted areas) by between 15 and 20% and, in addition, increasing the capital value of the agricultural land itself as a result of improving on-farm irrigation systems, equipment, and supplies
- Improving the public health of farmers and reducing the threats of endemic diseases as a result of improved irrigation systems. Interventions will include replacing open irrigation canals with buried ones, which will significantly reduce direct contact with

water. These measures would provide better and healthier environmental conditions for the rural population and reduce the costs of preventing and treating disease.

Implementation areas of the sub-project

- Upper Egypt Region: Assiut, Sohag, Qena, Luxor, and Aswan governorates
- Middle Egypt Region: Giza, Beni Suef, Fayoum, and Minia governorates
- Middle Delta Region: Kalubia, Menoufia, Gharbia, Dakahlia, Kafr El-Sheikh, and Damietta governorates
- Eastern Delta Region: Sharkia governorate
- Western Delta Region: Beheira governorate

Implementation phases of OFIDO

Phase 1

- Establishment of pilot farms (completed and funded by ICARDA) that will provide an applicable information and technology package for improving on-farm irrigation systems in the old lands at two sites in Kalubia governorate and Sakha in Kafr El-Sheikh governorate
- Establishment of an on-farm irrigation extension center to strengthen the agricultural extension sector in the field of on-farm irrigation. The University of California at Davis is providing short-term training courses for Egyptian extension workers (75 persons) on field irrigation

Phase 2

The objective of this phase is to evaluate the information and technology package established at the farm level in Phase 1.

9.1.6 International Fund for Agricultural Development project

This IFAD project started February 2011, and five pilot locations have been proposed in five governorates.

Middle Delta: Kafr El-sheikh and Beheira governorates (13,000 ha [30,000 feddan])
Upper Egypt: Assiut, Sohag, and Qena governorates (6000 ha [15,000 feddan])
t-

Budget:	IFAD covered the cost of implementing the project, providing a soft loan of up to approximately USD 47 million
Area:	19,000 ha (45,000 feddan)

9.1.7 World Bank project: farm-level irrigation modernization project (FIMP)

The proposed project will be financed, in part, by a loan of up to approximately USD 100 million, which will be disbursed over five years and will cover 84,000 ha (200,000 feddan). It started September 2011.

The project has two components:

- *Marwa* and farm-level irrigation improvements
- Farm-level technology development and dissemination

9.1.8 African Development Bank project

This proposed project is still under discussion and will be financed, in part, by a loan of up to USD 250 million, which will be disbursed over five years and cover 105,000 ha (250,000 feddan). The project is estimated to begin in 2012.

9.1.9 Project for rehabilitating and improving the management of on-farm irrigation in the newly reclaimed lands, 0.88 million ha (2.1 million feddan)

The technical and economic studies include:

- Redesigning the pressure irrigation networks according to the local conditions of each province, region, and location, and the technical specifications of the equipment
- Improving monitoring and evaluating through the preparation of progressive reports and assessments within the planned schedule.

The expected outputs of the project will include:

- Improving irrigation of 0.126 million ha (0.3 million feddan) per year – 0.88 million ha (2.1 million feddan) during the first action plan
- Saving the largest possible quantities of water to be used for reclaiming land, horizontal agricultural expansion, and improving soil properties and productivity by between 20 and 30%
- Improving and modernizing irrigation management at the national level by estimating the proper requirements for irrigation water and fertilizers for different crops using agro-meteorological data.

The project impact at the national level should embrace:

- Saving on and reducing the amount energy used in agricultural activities, which will also save on the amount of petroleum products used for pumping water in the current systems

- Improving soil properties, increasing land productivity, and reducing water losses in agricultural drainage systems. This will reduce the burden on the drainage networks and increase the rate of agricultural intensification and modernization in the Nile Delta and Valley
- Increasing the investment opportunities for manufacturing irrigation tools, equipment, and other accessories at the local level. This will result in a consequent increase in the agricultural services which will be created during the development of on-farm irrigation systems. These agricultural services include processing, marketing, and the export of agricultural commodities. In addition, other new service industries related to rehabilitation and development will be established
- Providing working power and energy for existing companies as well as for new private and public ones dealing with activities related to irrigation system development
- Supporting and enhancing capabilities for exporting agricultural commodities, and an increased rate of processing and manufacturing of such products, particularly through integrated agricultural management in newly reclaimed lands.

The project impact at the farm level will be to:

- Increase the average income of farmers by between 15 and 20%
- Increase the capital value of agricultural land as a result of improving on-farm irrigation systems, equipment, and supplies
- Achieve an equitable and fair distribution of irrigation water at different levels of farm (large- and smallholdings), thereby eliminating water shortage problems among end-users.

The sub-project will be implemented in:

- Upper Egypt: Qena, Aswan, and New Valley governorates
- Middle Egypt: Fayoum and Minia governorates
- Eastern Delta: Sharkia, Port Said, Ismailia, Suez, and North and South Sinai governorates
- Western Delta: Beheira, Alexandria (Nubaria), and Matrouh governorates.

9.1.10 Other projects

- Egypt water use and management project, 1977-1984
- Integrated soil and water improvement project, 1987-1994
- Rehabilitation and replacement of major barrages on the Nile River and its branches
- Shore protection projects
- Irrigation and drainage pumping stations
- Drainage projects

9.2 Major national projects based on the use of marginal-quality water in agricultural development

9.2.1 Al-Salam Canal project

The Sinai Peninsula represents Egypt's eastern strategic extension and the historical link to its Arab neighbors. In the framework of a comprehensive development plan, the construction of the Al-Salam Canal diverted the flow of Nile water to the Sinai, connecting this important part of Egypt to the Nile Valley (Figure 5). The estimated water requirements needed for reclaiming and cultivating 260,400 ha (620,000 feddan) – 92,400 ha (220,000 feddan) to the west of the Suez Canal and 168,000 ha (400,000 feddan) to the east of it – are approximately 4.45 billion m^3 of fresh Nile water mixed with agricultural drainage water in a 1:1 ratio. This would ensure that the salinity ratio would not exceed 1000 parts per million; this will necessitate selecting the proper crop combinations.

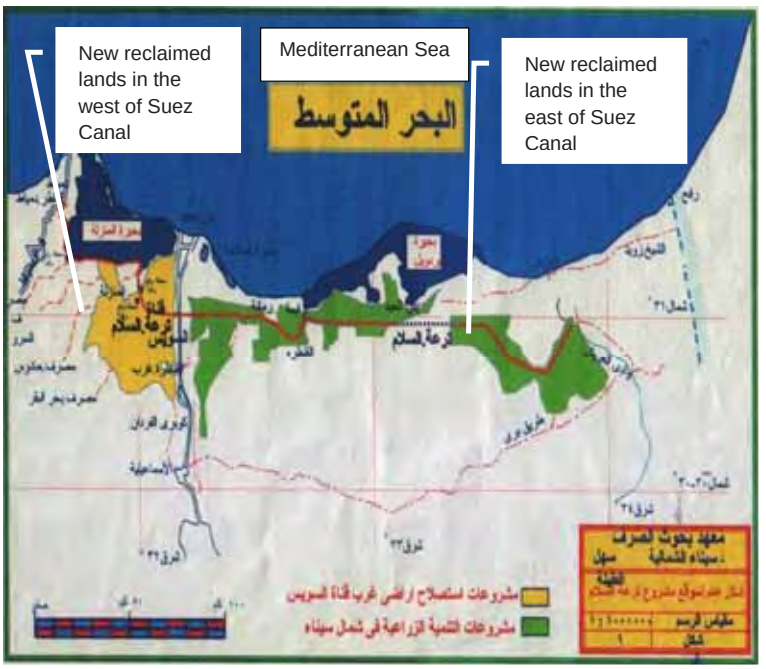

Figure 5. Map showing Al-Salam Canal project area east and west of the Suez Canal

The project consisted of two phases.

Phase 1: Constructing Damietta Dam at km 222 on the Damietta branch

The Damietta Dam was constructed on the Damietta branch in the Nile Delta to raise the upstream water level of the dam to 1.7 m and provide Al-Salam Canal with the required discharge. The canal was constructed in front of the Damietta Lock and Dam, west of the

Suez Canal, with the purpose of reclaiming 92,000 ha (220,000 feddan) west of the Suez Canal along its 89.75 km length. Infrastructure works have been completed. An area of approximately 75,600 ha (180,000 feddan) is currently being cultivated (through the East Delta project) (Figure 6).

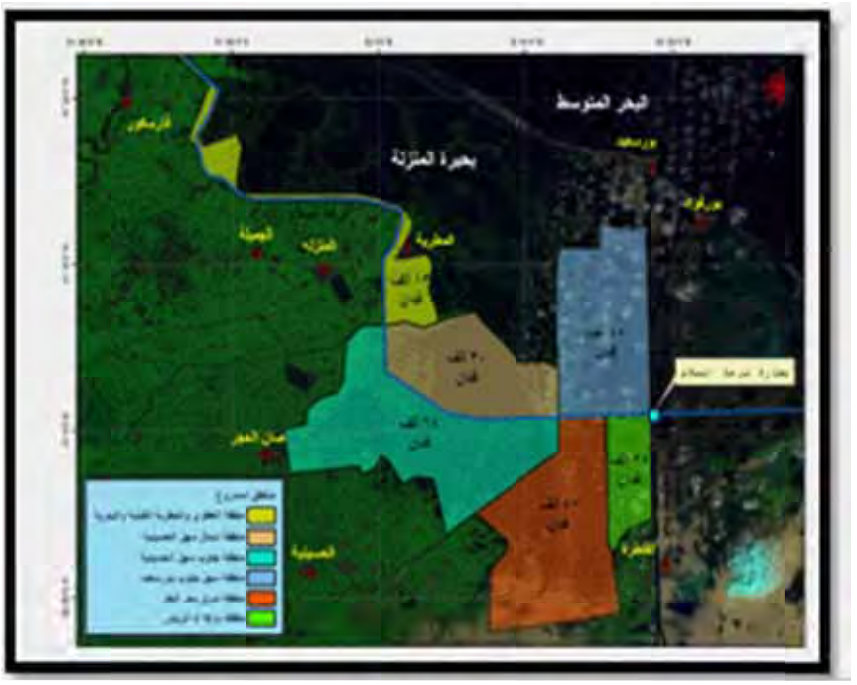

Figure 6. Phase 1 reclamation areas of the Al-Salam Canal project

The project command area of Phase 1, which amounts to 92,400 ha (220,000 feddan), is distributed as follows:

- Al-Atawy, Al-Mataria Al-Baharia, and Al-Mataria Al-Keblia, with a command area of 5500 ha (13,000 feddan), in Dakahlia governorate
- Sahl Al-Husainia north, with a command area of 12,600 ha (30,000 feddan), in Sharkia governorate
- Sahl Al-Husainia south area, with a command area of 26,900 ha (64,000 feddan), in Sharkia governorate
- Bahr Al-Bakar east, with a command of 19,700 ha (47,000 feddan), in the governorates of Ismailia and Port Said
- Berket Om Al-Reesh, with a command area of 8800 ha (21,000 feddan), in Port Said governorate
- Sahl Ganoub south of Port Said area, with a command area of 22,700 ha (45,000 feddan), located in Port Said governorate.

Phase 2: Establishment of the Al-Salam Canal siphon under the Suez Canal

The siphon consists of four tunnels; each 770 m long with an inner diameter of 5.10 m and outer diameter of 6.34 m. The siphon is designed to pass under the Suez Canal. It will discharge 160 m^3/second of Al-Salam Canal water west of the Suez Canal at 27.8 km (according to the Canal's numbering) south of Port Said into the Al-Sheikh Gaber Al-Sabah Canal east of the Suez Canal (Figure 7).

Figure 7. Phase 2 reclamation areas of the Al-Salam Canal project

Constructing Al-Sheikh Gaber Al-Sabah Canal east of the Suez Canal

The length of the canal is 175 km and, in Phase 2, it is intended to reclaim 168,000 ha (400,000 feddan) east of the Suez Canal. The reclaimed land is distributed as follows:

- Sahl Al-Teena area, with a command area of 21,000 ha (50,000 feddan), located within Port Said governorate
- Ganoub Al-Kantara Sharq, with a command area of 31,500 ha (75,000 feddan), in Ismailia governorate
- Rabaa area, with a command area of 29,400 ha (70,000 feddan), situated in North Sinai governorate
- Beer Al-Abd area, with a command area of 36,330 ha (86,500 feddan), located in North Sinai governorate

- Al-Sarw and Al-Qwareer area, with a command area of 35,700 ha (85,000 feddan), in North Sinai governorate
- Al-Mazar and Al-Meedan area, with a command area of 14,070 ha (33,500 feddan), located in North Sinai governorate.

9.3 East Delta (new lands) agriculture services project

The East Delta (new lands) agriculture services project (EDAS) provides services to facilitate settlement and increase agricultural production for about 29,000 low-income families settling on approximately 54,600 ha (130,000 feddan) of recently developed lands irrigated by Al-Salam Canal. This area is located west of the Suez Canal and includes new agricultural areas in four governorates, Port Said, Sharkia, Ismailia, and Dakahlia (Figure 8).

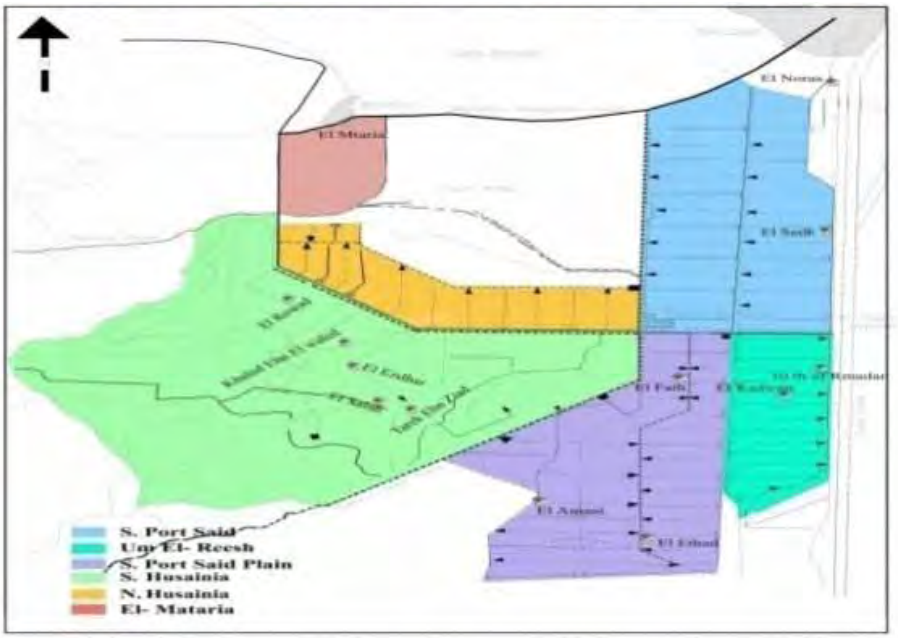

Figure 8. East Delta (new lands) agriculture services project areas

The main objectives of the project are to:

- Establish and rehabilitate drinking water stations
- Establish sanitation plants
- Reclaim 8400 ha (20,000 feddan)
- Provide effective civil extension organizations to help farmers
- Execute the environmental monitoring works which are included in the project agreement.

The activities of the environmental monitoring study cover the monitoring and/or reporting of issues relevant to the following in the project areas

- Soil
- Irrigation water
- Drainage water
- Groundwater
- Potable water
- Fodders
- Grains
- Vegetables
- Milk.

These activities have been carried out at 16 previously designated monitoring sites in the eastern part of the Delta.

The results of the monitoring study are summarized below.

Soil monitoring

Infiltration rate (IR) and permeability tests were conducted in the field. The IR ranged from 0.35 to 120 mm/hour and permeability from 4.8 to 80.4 cm/day. Therefore, the structure of the soils studied could be classified as very poor or moderate in quality and the permeability of the water through the soil could be classified as moderate.

The chemical properties of the collected soil samples were determined from extracts of saturated soil paste. Sodium ion was the major cation, while chloride and sulfate ions were the major anions. In terms of soil salinity – measured by the EC, ESP, and pH – 85% of the soils studied were saline or saline-sodic, while the rest were normal. The results of the soil gypsum content and gypsum requirement tests indicated that most of the soils investigated needed only an adequate drainage system or improvements to existing drainage facilities and the addition of the appropriate amounts of water to meet leaching requirements. The total amounts of iron, copper, cadmium, and lead were also determined in the soil samples; iron being the most prevalent element.

Pesticide residues in the soil samples were detected using the gas chromatography technique. Diazinon, chlorpyrifos, heptachlor, and aldrin pesticides were the most prevalent compounds.

Irrigation, drainage, and groundwater monitoring

Cations, anions, pH, EC, total dissolved solids, and total suspended solids, as well as the sodium adsorption ratio (SAR) and adjusted SAR were determined for the water samples.

Sodium ion was the major cation in the irrigation, drainage, and groundwater, whereas the chloride ion$^-$ was the major anion in both the drainage and groundwater, followed by the sulfate ion. Salinity, as measured by EC, in 82% of the irrigation water samples collected from the secondary and main irrigation canals was ≤ 3.0 dS/m (usual range). However, it was more than 3.0 dS/m (unusual range) in 88% of the drainage samples and 100% of the groundwater samples. The SAR values were less than 15 (usual range) in 98% of the irrigation samples, 56% of the drainage samples, and 13% of the groundwater samples. The EC, SAR, sodium, and chlorine were used to classify the water in terms of potential irrigation problems and the degree of restriction on water use.

Iron, copper, cadmium, and lead were detected in the irrigation, drainage, and groundwater samples using the atomic adsorption technique. Iron was the major element detected in both the irrigation and drainage water samples. All four heavy metals, especially iron and lead, were detected in the groundwater samples.

Pesticide residues were determined in the irrigation, drainage, and groundwater samples. Malathion, phorate, aldrin, endrin, heptachlor, lindane and, to some extent, permifos-Me and diazinon were the most common pesticide residues detected in all the irrigation, drainage, and groundwater samples.

The total coliform and total fecal coliform counts and the levels of Salmonella, Shigella, and other parasites present in the irrigation, drainage, and groundwater samples were also examined. The total coliform count in the irrigation water ranged from 40 to 9000 MPN/ml and the fecal coliform count ranged from 20 to 300 MPN/ml. In the drainage water and groundwater samples, both the total and fecal coliform counts ranged from 20 to 16,000 MPN/ml. Salmonella and Shigella were more often detected in the drainage and groundwater samples than in the irrigation ones. *Entamoeba histolytica* and *Giardia lamblia*, especially *Entamoeba*, were detected in most samples of the irrigation, drainage, and groundwater.

10. Past project findings, guidelines, and recommendation for improving water productivity in Egyptian agriculture

Through its national agricultural research system, and in coordination and collaboration with regional and international research institutions such as ICARDA, Egypt has undertaken work to develop and/or improve its agricultural system over the past two decades. These efforts include crop improvements, developing better and more efficient irrigation methods and systems, and improved soil, crop, and land management practices.

Based on its extensive experience in Egypt, ICARDA proposes new research that complements past and ongoing activities. This includes joint work with the Economic and

Social Committee for West Asia of the United Nations (ESCWA) on empirical estimates of on-farm water-use efficiency in Egypt. Testing and evaluation of on-farm level interventions showed that irrigation water consumption in farmers' fields fell by about 30% with correspondingly reduced pumping costs. Labor costs for land preparation, irrigation, and weed control also fell by 35%. Yields were the same or higher than the conventional system and farmers' net incomes increased by 15%. Crop water productivity increased by over 30% and the net return per unit of water was 20% higher than under conventional irrigation. The package was transferred to farmers by national counterparts through field visits, farmers' field schools, workshops, meetings with development technicians and policy makers, and publications. Most farmers in the benchmark communities and neighboring communities have already adopted the new package.

The fundamental scope of the work was to introduce and implement new water-saving technologies and promote farmers' participation and involvement in WUAs and other community and governmental organizations, particularly those concerned with the extension service of MALR.

On-farm trials were conducted at several locations representing old land sites in Menoufia governorate to generate the data required for modeling water productivity and the sustainable use and management of water resources. Trials could also help fill gaps in available information, which is necessary to improve the management of scarce water supplies and increase water savings. In addition, the benchmark project introduced new, simple, and accepted techniques, with the involvement and partnership of farmers, to increase crop water productivity, reduce water losses, and achieve better water savings.

The on-farm trials recommended wide furrow irrigation and deficit irrigation as simple tools to be implemented by the farmers. These resulted in increased crop production, improved crop water productivity, and, above all, helped to save appreciable volumes of water as compared with traditional techniques.

The raised-bed furrow technique showed very satisfactory results at the different research sites (old lands and marginal lands) for both the main winter crops (wheat, berseem clover) and summer crops (corn, cotton). Besides saving around 25% of the water applied by the farmers for most crops, this technique increased production of the main crops investigated by nearly 10%. Furthermore, the implementation of this simple technique resulted in average water savings of between 20 and 22%.

Generally, the wide furrows, besides saving considerable amounts of irrigation water, produced higher production rates and, thereby, increased the crop water productivity to values around 30% higher than the irrigation techniques currently practiced by farmers. The

deficit irrigation technique maximized the use of the water applied and achieved values close to those that emerged when farmers applied water in excess.

The findings of the trials at selected sites (old lands and marginal, salt-affected soils) showed that implementing wide furrows, where a relatively high proportion of the applied water is saved, did not result in any significant losses in the yield production of the major winter and summer crops. The whitepaper produced from this study includes guidelines for water-saving and water-conservation extension, defining the responsibilities of government agencies and identifying appropriate soil and water conservation technologies. It also includes guidelines on how to develop subsidies and incentives, how they should be used to increase crop water productivity, and in which form they should be provided to farmers. In addition, it suggests relevant support tools to improve Egyptian crop water productivity based on the main research findings, recommendations, and the workable packages of the Irrigation Benchmark Project outputs.

Other development projects in Egypt have adopted the package. These include the East Delta Rural Development Project, financed by IFAD and the World Bank, and the Crop Intensification Project of Middle Egypt, financed by IFAD, and IIP in Beheira and Kafr El-Sheikh governorates. Furthermore, the national extension system is transferring the package to six additional governorates in Egypt. Project interventions originally tested at a few pilot sites are, therefore, being rapidly scaled-up over a large area by a range of partners, leading to substantial impacts on water productivity and farm incomes.

11. Summary and issues to be considered

11.1 Summary of measures to improve overall water-use efficiency in agriculture

The final product of the National Water Resources Plan (NWRP) project is the National Water Resources Plan to 2017 (NWRP-2017) (MWRI 2005). The plan gives a description of water resources in the country, highlighting problems, issues, and proposed measures and activities to tackle water scarcity[6].

The NWRP strategy includes a large number of policies and measures that will be implemented over the next few years. Many stakeholders are involved in its implementation and careful planning and coordination are required. An implementation framework has been developed that assigns clear responsibilities for carrying out the activities involved. It also includes the budgetary implementation requirements, including investments and recurrent costs.

[6] Source: http://www.mwri.gov.eg/En/plan46.html.

The implementation of the NWRP will follow Egypt's five-year and annual planning system and forms an element of the overall planning and coordination structure of the water sector.

Measures to improve overall water-use efficiency in agriculture

According to NWRP-2017, and SADS-2030) the following actions for improving overall water-use efficiency in agriculture will be taken:

Horizontal expansion

- Carrying out further horizontal expansion, depending on the availability of additional water

Improvement of irrigation efficiencies

- Prioritizing efficiency measures in affected areas
- Continuing IIP- and IIIMP-related activities to rehabilitate the water distribution systems in prioritized areas, i.e. areas where drainage water would otherwise flow to sinks and where reuse of drainage water is not recommended because of adverse effects
- Providing irrigation advisory services that would include all new development areas
- Lining in stretches of canals which suffer from high leakage losses
- Using laser land leveling where possible and where needed to increase field application efficiencies
- Controlling drainage during the cultivation of rice
- Using modern irrigation techniques in all new development areas with light-textured soils
- Gradually introducing modern irrigation techniques to replace traditional irrigation methods in oases and gradually phasing out the cultivation of rice in these areas
- Controlling well discharge in desert areas
- Improving operations and maintenance activities through private participation (water boards and WUAs)
- Reducing the irrigation supply after rainfall, combined with extra storage upstream from barrages in the Delta.

Improvement of drainage conditions

- Continuing the subsurface drainage program of EPADP, with the intention of integrating activities within IIP into IIIMP

Reuse of drainage water

Review of the drainage water reuse policy in Egypt:

- Implementing intermediate reuse at appropriate locations
- Prioritizing drainage water reuse in areas where
    - Drainage water would otherwise flow to sinks
    - The least harm is done to other downstream users
    - Groundwater is least vulnerable to pollution
- Allowing higher permissible salinity of irrigation water after mixing with drainage water
- Promoting the use of crops that are less sensitive to salinity.

Constraints to improving water productivity

The fast rate of growth of Egypt's population is one of the major constraints to the country's development plans in all sectors, not just agriculture. However, in spite of the existing circumstances, there is still plenty of room for improvement. The major factors affecting this potential improvement are:

- Water allocation
- Water valuation
- Water pollution
- Water resources development
- Farmers' participation
- Institutional reform
- Private–public partnerships
- Public awareness.

Irrigation is the main parameter in the agricultural sector and the entire national economy in Egypt. Almost all cultivated lands are under irrigation and therefore, tremendous efforts should be made towards maximizing the use of each drop of water.

Research and development activities needed:

- Update data on natural resources (land, water, and climate) using GIS and satellite imagery data
- Study integrated agro-climate systems and develop the existing agricultural systems (irrigated agriculture, rainfed agriculture, and rangelands)
- Implement integrated main field crops management
- Implement integrated main horticulture crops management

Further elaborations are also needed for the following technical aspects:

- Water-use efficiency and water productivity
- Crop water requirements and irrigation scheduling based on remote sensing techniques
- Soil-plant-atmosphere relationships and crop growth modeling
- Saline and marginal-quality water irrigation practices and their management
- Climate variability and changes and their impacts on agriculture
- Land evaluation and agro-ecological characterization
- Performance assessment; operational analysis and rehabilitation
- Energy consumption in delivering water to where it is needed; irrigation water supply and pumping station regulation
- Water resources management: reservoir operation, and groundwater exploitation

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About ICARDA and the CGIAR

Established in 1977, the International Center for Agriculture Research in the Dry Areas (ICARDA) is one of 15 centers supported by the CGIAR. ICARDA's mission is to contribute to the improvement of livelihoods of the resource-poor in dry areas by enhancing food security and alleviating poverty through research and partnerships to achieve sustainable increases in agricultural productivity and income, while ensuring the efficient and more equitable use and conservation of natural resources.

ICARDA has a global mandate for the improvement of barley, lentil and faba bean, and serves the non-tropical dry areas for the improvement of on-farm water use efficiency, rangeland and small-ruminant production. In the Central Asia and West Asia and North Africa region, ICARDA contributes to the improvement of bread and durum wheats, kabuli chickpea, pasture and forage legumes, and associated farming system. It also works on improved land management, diversification of production systems, and value-added crop and livestock products.
Social, economic and policy research is an integral component of ICARDA's research to better target poverty and to enhance the uptake and maximize impact of research outputs.

CGIAR is a global research partnership that unites organizations engaged in research for sustainable development. CGIAR research is dedicated to reducing rural poverty, increasing food security, improving human health and nutrition, and ensuring more sustainable management of natural resources, It is carried out by the 15 centers who are members of the CGIAR Consortium in close collaboration with hundreds of partner organizations, including national and regional research institutes, civil society organizations, academia, and the private sector.
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