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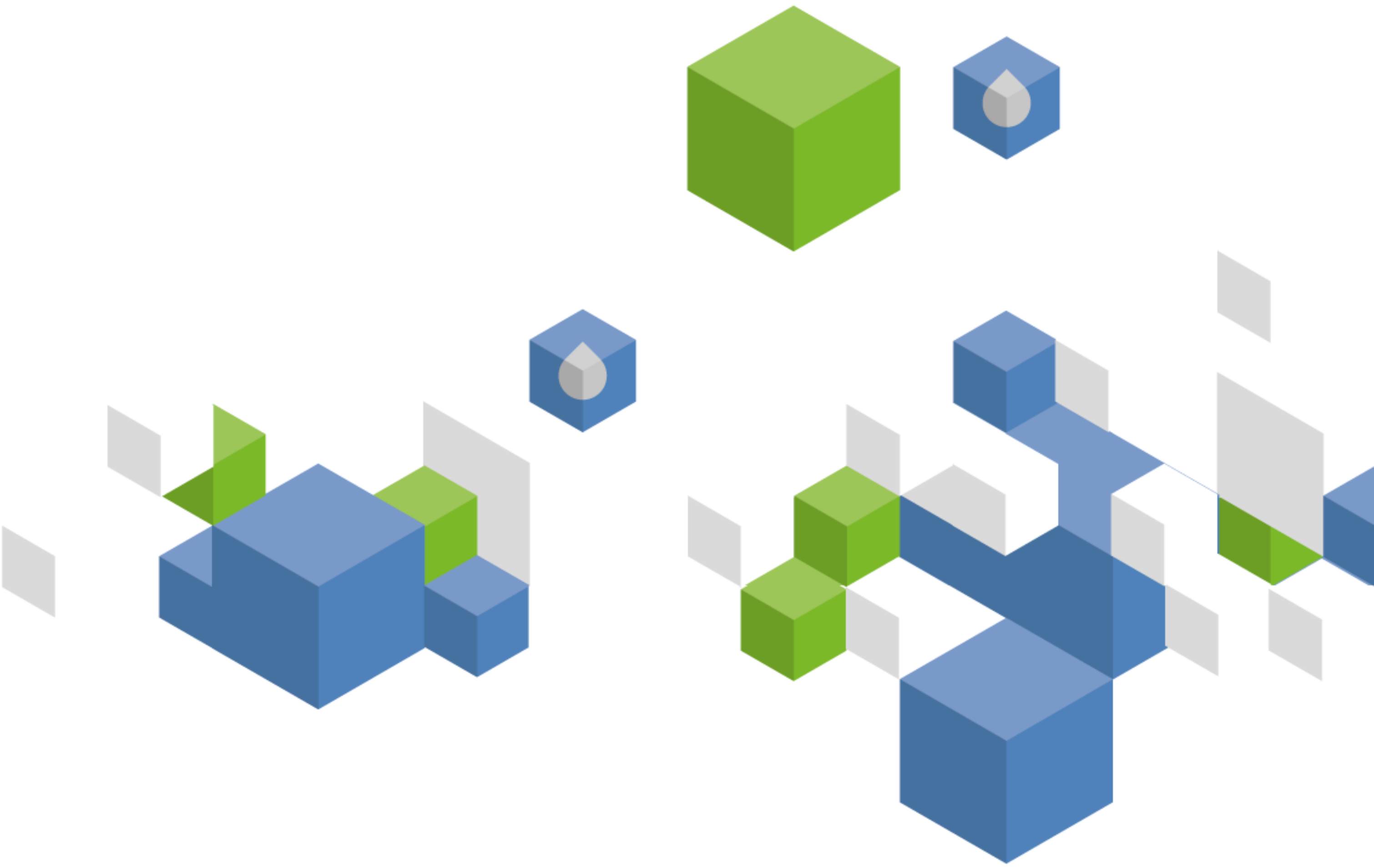

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Egypt

GEOGRAPHY, CLIMATE AND POPULATION

Geography

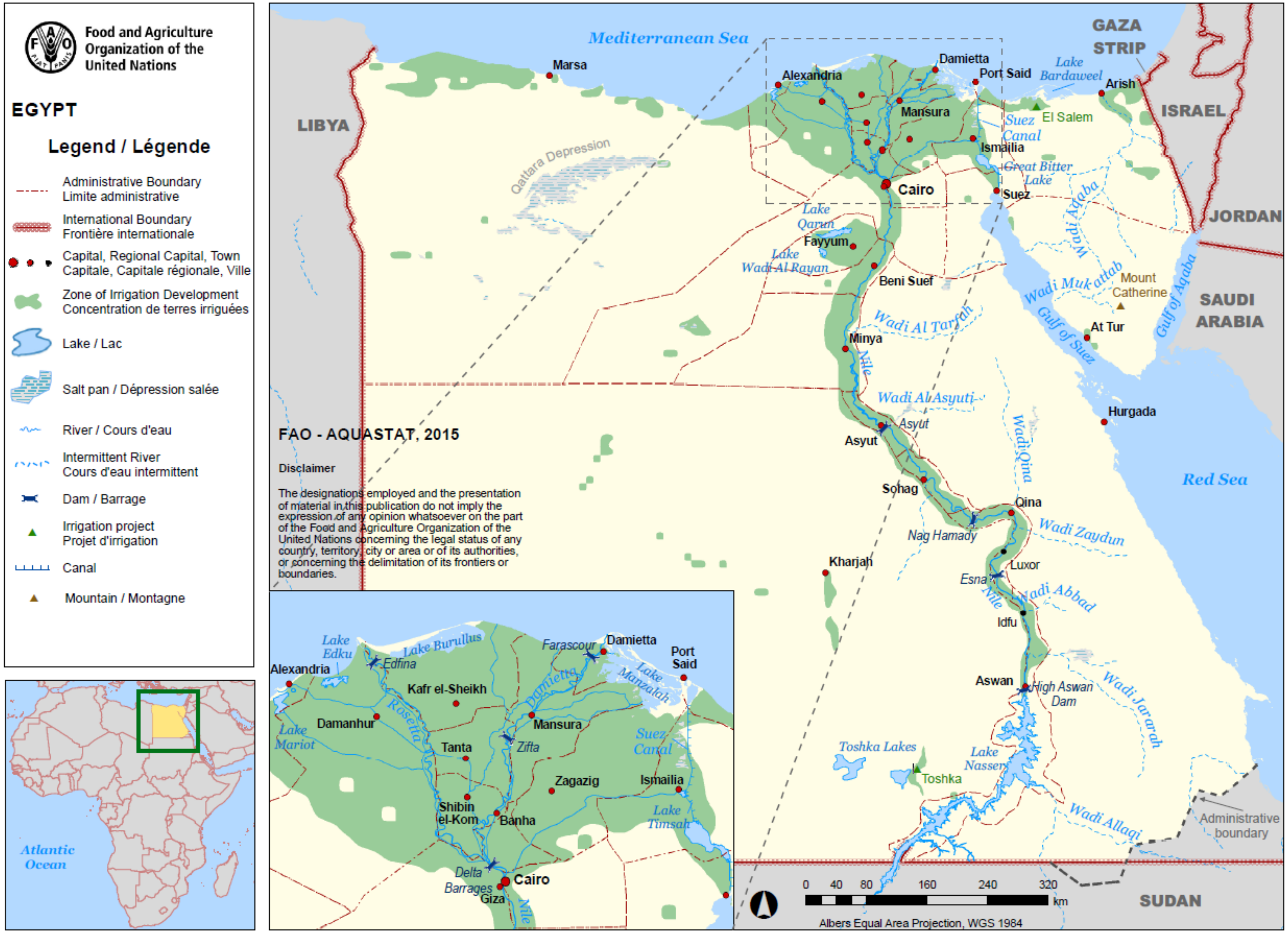
Egypt lies in the northeastern corner of the African continent and has a total area of about 1 million km2. It is bordered in the north by the Mediterranean Sea, in the east by the Gaza Strip, Israel and the Red Sea, in the south by Sudan and in the west by Libya. Its north-south extent is about 1 080 km, and its maximum east-west extent about 1 100 km. The Egyptian terrain consists of a vast desert plateau interrupted by the Nile Valley and Delta, which occupy about 4 percent of the total country area. The land surface rises on both sides of the Valley reaching about 1 000 m above sea level in the east and about 800 m above sea level in the west. The highest point of the country, at Mount Catherine in Sinai, is 2 629 m above sea level and the lowest point, at the Qattara Depression in the northwest, is 133 m below mean sea level.

The majority of the country area is desert land. Most of the cultivated land is located close to the banks of the Nile river, its main branches and canals, and in the Nile Delta. Rangeland is restricted to a narrow strip, only a few kilometres wide, along the Mediterranean coast and its bearing capacity is quite low. There is no forest land. The total cultivated area (arable land plus permanent crops) is 3.8 million ha in 2013, or about 4 percent of the total area of the country. Arable land is about 2.7 million ha, or 73 percent of the total cultivated area, and permanent crops occupy the remaining 1 million ha (Table 1).

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	2013	100 145 000	ha
Agricultural land (permanent meadows and pasture + cultivated land)	2013	-	ha
• As % of the total area of the country	2013	-	%
• Permanent meadows and pasture		-	ha
• Cultivated area (arable land + area under permanent crops)	2013	3 761 000	ha
- As % of the total area of the country	2013	4	%
- Arable land (temp. crops + temp. fallow + temp. meadows)	2013	2 738 000	ha
- Area under permanent crops	2013	1 023 000	ha
Population:			
Total population	2014	83 387 000	inhabitants
- Of which rural	2014	56	%
Population density	2014	83	inhabitants/km^2
Economy and development:			
Gross Domestic Product (GDP) (current US$)	2014	287 000	million US$/year
• Value added in agriculture (% of GDP)	2014	14	%
• GDP per capita	2014	3 442	US$/year
Human Development Index (highest = 1)	2014	0.690	-
Gender Inequality Index (equality = 0, inequality = 1)	2014	0.573	-
Access to improved drinking water sources:			
Total population	2015	99.4	%
Urban population	2015	100	%
Rural population	2015	99	%

FIGURE 1
Map of Egypt



Climate

Hot dry summers from May to October and mild winters from November to April characterize Egypt's climate. Rainfall is very low, irregular and unpredictable. Annual rainfall ranges between a maximum of about 200 mm in the northern coastal region to a minimum of nearly zero in the south, with an annual average of 51 mm. Sinai receives somewhat more rainfall than the other desert areas (about 120 mm annually in the north) so the region is dotted with numerous wells and oases (MWRI, 2005). Summer temperatures are high, reaching 38°C to 43°C with extremes of 49°C in the southern and western deserts. The northern areas on the Mediterranean coast are cooler, with 32°C as a maximum.

Population

Population is estimated at 83.4 million in 2014 with an average annual growth rate of 1.7 percent over the period 2004-2014. The rural population is 56 percent of the total population. Overall population density is 83 inhabitants/km^2; however, with about 95 percent of all people living in the Nile Valley and Delta (MWRI, 2005), population density reaches more than 1 165 inhabitants/km^2 in these areas, while in the desert it drops to only 1.2 inhabitants/km^2.

In 2014, with 1 meaning being ranked best, the Human Development Index ranks Egypt 108 among 188 countries, while the Gender Inequality Index ranks Egypt only 131 among 155 countries. Life expectancy in Egypt is 71 years in 2013 and the under-five mortality is 24 per 1000 births in 2015, both progressing from 67 years and 60 per 1000 in the 1990s. Around 95 percent of the children in 2011 are enrolled in primary education, and 85 percent for secondary education with no distinction between boys and girls (WB, 2015). Adult literacy is 75 percent in 2013, with a gap between female literacy (67 percent) and male literacy (83 percent). Poverty concerns one quarter of the population in 2010 and is mainly a rural phenomenon (32 and 15 percent respectively in rural and urban areas). In 2015, 100 percent of the urban and 99 percent of the rural population were using improved drinking water sources, which is equal to 99.4 percent of the total population. The same year, 94.7 percent of the population were using improved sanitation facilities (96.8 and 93.1 percent respectively in urban and rural areas) (JMP, 2015).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2014, Egypt's gross domestic product (GDP) was estimated at US$ 287 000 million of which the agricultural sector accounted for 14.5 percent. Oil rents amounted up to 15 percent of GDP in the 1990s but are down to 7 percent in 2013. Food and raw agricultural products represent around 19 percent of exports in 2014 (WB, 2015). Egypt imports 44 percent of its cereals during the 2009-2011 period but exports cotton and citrus. Food represents 37 percent of Egypt's imports during the same period (FAO, 2015a). The country is one of the largest food importers. Prevalence of undernourishment remains below (or close to) 5 percent since 1990 in Egypt (FAO, 2015b).

Agriculture, even though contributing only 14.5 percent to GDP compared to 30 percent in the 1960s, is still a major economic activity in Egypt, as it plays an important role for many people as sustenance farming. Nearly all agriculture depends on irrigation water (MWRI, 2005). In 2010, the total irrigated area covers 98 percent of the cultivated area. Even the small, more humid area along the Mediterranean coast requires water harvesting or supplementary irrigation to produce reasonable yields. Since 1992, farmers can select the crops they grow; previously the government selected the cropping patterns (Gersfelt, 2007). Smallholdings characterize Egyptian agriculture, with about 50 percent of holdings having an area less than 0.42 ha (1 *feddan*). Urbanization represents a serious threat to agriculture in Egypt. It is prohibited by law to construct any buildings on farmland without a licence from the Ministry of Agriculture and Land Reclamation, and violators are prosecuted and face serious penalties.

WATER RESOURCES

The Egyptian territory comprises the following river basins:

- The Northern Interior Basin, covering 520 881 km^2 or 52 percent of the total area of the country in the east and southeast of the country. A sub-basin of the Northern Interior Basin is the Qattara Depression.
- The Nile Basin, covering 326 751 km^2 (33 percent) in the central part of the country in the form of a broad north-south strip.
- The Mediterranean Coast Basin, covering 65 568 km^2 (6 percent).
- The Northeast Coast Basin, a narrow strip of 88 250 km^2 along the coast of the Red Sea (8 percent).

The Nile river, with a total length of about 6 650 km, is the world's longest river with the Amazon in Southern America being the second longest with a total length of 6 400 km. However, debates over the true sources of both rivers and thus their entire length are ongoing and some studies consider the Amazon to be the longest river with a length of 6 990 km and the Nile the second longest with 6 850 km. The Nile supplies nearly all water in Egypt and the river is in the country almost fully controlled by the High Aswan Dam. The water entering Lake Nasser originates for about 85 percent from the Ethiopian highlands through the Blue Nile, Sobat river and Atbara river (MWRI, 2005). Control over the river started even before the Aswan Dam, with the remodelling (widening and deepening) of the six Nile branches in the Delta in the 1800s, as well as two major regulators on the two main branches: Rosetta and Damietta, built in the 1830s (El Qausy et al., 2011).

Under the Nile Waters Agreement of 1959 between Egypt and Sudan, 55 500 million m3/year flows annually from the Nile into Egypt. Internal renewable surface water resources are estimated at 500 million m3/year. This brings total renewable surface water resources to 56 000 million m3/year. Internal renewable groundwater resources are estimated at 1 300 million m3/year. The overlap between surface water and groundwater being considered negligible, the total renewable water resources of the country are thus 58 300 million m3/yr (Table 2), including 1 000 million m3/year of external groundwater entering the country from Sudan through the Nubian Sandstone aquifer. This aquifer located under the Western Desert is considered an important groundwater source, but this is fossil groundwater. The main source of internal recharge is percolation from irrigation water in the Valley and the Delta, considered to be secondary freshwater (i.e. water previously withdrawn and then returned to the system). Egypt's dependency ratio is one of the world's highest with 96.9 percent of the total renewable water resources flowing into the country from neighbouring countries. The total renewable water resources per capita stands at 700 m3/year/capita in 2014, but considering population growth is expected to drop below the 500 m3 threshold of absolute water scarcity by 2030.

TABLE 2
Water resources

Renewable freshwater resources:			
Precipitation (long-term average)	-	51	mm/yr
	-	51 070	million m^3/yr
Internal renewable water resources (Long-term average)	-	1 800	million m^3/yr
Total renewable water resources	-	58 300	million m^3/yr
Dependency ratio	-	97	%
Total renewable water resources per inhabitant	2014	699	m^3/yr
Total dam capacity	2015	168 200	million m^3

Although very limited in terms of quantity compared to the total water resources, groundwater is the sole source of water for people living in the desert areas. The major groundwater systems in Egypt are:

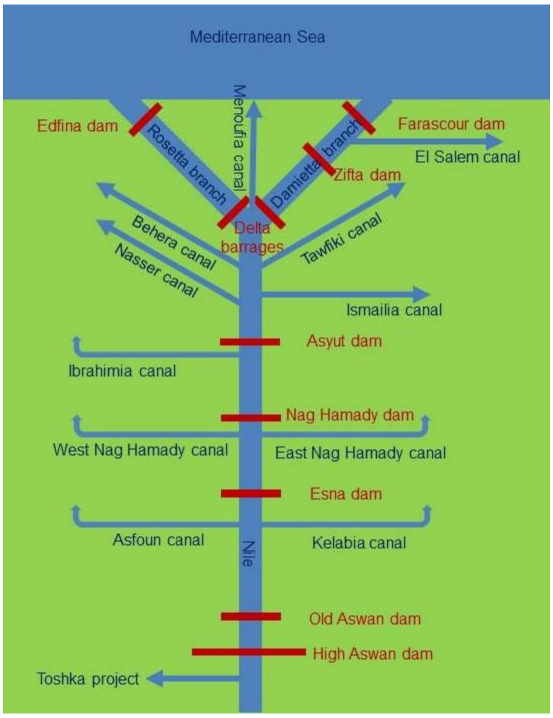
- Nile aquifer: mostly recharged by infiltration of excess irrigation water originally from the Nile river, so it is not an additional primary source of water but a secondary source of freshwater available for use. In term of abstractions, it provides about 85 percent of the total groundwater abstractions in the country (AfDB, 2015).

- Nubian sandstone aquifer: fossil groundwater in the south west part of the country shared with Libya, Chad and Sudan
- Fissured carbonate aquifer: widely spread over more than half of the country's area, on top of the Nubian aquifer
- Moghra aquifer: towards the Qattara depression, recharged both by rainfall and lateral inflow from the Nile, but containing also saline water in the north west
- Coastal aquifer: on northern and western coasts, recharged by rainfall, but presence of saline water underneath limits the abstracted quantities
- Hardrock aquifer: mostly in eastern deserts and southern Sinai.

The main Egyptian lake is the artificial Lake Nasser, created by the High Aswan Dam (called Lake Nubia on the Sudanese side). Lake Qarun in the Fayoum depression is entirely fed by drainage water, so with an increasing salinity. Its waters are more saline than sea since 1980. Storage of water in this depression was already reported in 4th century before the current era. Wadi Al Rayan lakes are also fed by excess drainage water transferred there since 1973, resulting in two interconnected lakes. From the Suez Gulf the Suez Canal joins the Red Sea through Lake Timsah and the Great Bitter Lake. Finally, on the coast, there are a few lagoons: lakes Mariot, Edku, Manzalah, Burullus and Bardaweel. These last two lakes, together with the Lakes Qarun and Wadi Al Rayan are the four Ramsar sites of the country, covering over 400 000 ha.

Apart from natural watercourses and water bodies, the country is dissected by a dense network of waterways, including 40 000 km of canals branching from the Nile river (ICARDA and AusAID, 2011) through hierarchically classified canals: principal (water directly from the Nile), main, branch and distributary canals. In addition, there are also *mesqas*, private ditches distributing water to the field (Gersfelt, 2007). Figure 2 shows a graph of the main canals.

FIGURE 2
Main canals and dams on the Nile river in Egypt



Full control of the Lower Nile is permitted downstream of the High Aswan dam, built in 1970, by the Old Aswan dam (1902), Esna (1908), Nag Hamady (1930) and Asyut (1902) dams. The Delta barrages are the Rosetta and Damietta dams, built in 1840, on their respective eponym Nile branches. The Zifta and Farascour dams are on the Damietta branch, while the Edfina dam is on the Rosetta one. In total, the dam capacity of the country reaches 168 200 million m^3.

All drainage water in Upper Egypt, south of Cairo, flows back into the Nile and the irrigation canals; this amount is estimated at 6 076 million m^3/year in 2013 (Capmas, 2014). Drainage water in the Nile Delta is estimated at 16 000 million m^3/year (ICARDA and AusAID 2011), of which 6 334 million m^3/year are reused in agriculture in 2013 (Capmas, 2014). A number of reuse projects in the southern part of the Delta and Fayyum governorate uses about 4 000 million m^3/year. In addition, unofficial direct pumping in drain by farmers uses large volume of drainage water and is difficult to measure (ICARDA and AusAID, 2011) but it is estimated to be about 2 700 million m^3 in 2010 (MWRI, 2011). Unofficial reuse is practiced along Bahr Baqar, Bahr Hadus, Gharbia, Edko and Umoum drains. There are 89 agricultural drains which directly flow into the river Nile. Most of them collect volumes of wastewater either municipal or industrial (MWRI and HCWW, 2011).

Produced municipal wastewater was estimated at 7 078 million m^3 in 2012, up from 3 760 million m^3 in 2001. Around 92 percent of this amount is collected and 57 percent, or 4 013 million m^3, is treated. Finally, 1 300 million m^3 of treated municipal wastewater is directly used in 2010 (MEA, 2012). The drainage system receiving the excess irrigation water also receives municipal wastewater, especially in the Upper Egypt, which discharges itself into the Nile or into the Northern Lakes and the sea (MWRI, 2005).

Sea water desalination is concentrated in the coastal areas along the Mediterranean and Red Sea, where there is no other source of water, and for tourism resorts. In 2010, desalination plants produced around 200 million m^3/year (ICARDA and AusAID, 2011).

INTERNATIONAL WATER ISSUES

The Nile river, the primary source of Egypt's water, is shared between 11 countries. The first Nile Waters Agreement between Egypt and (pre-2011) Sudan was signed in 1929. It allocated to Egypt the right to use 48 000 million m^3/year, while it gave Sudan the right to tap only about 4 000 million m^3/year. The remaining was allowed to flow unused to the Mediterranean Sea. The agreement does not allocate to Ethiopia any rights to use the Nile waters and also still binds Uganda, the United Republic of Tanzania and Kenya and bars them from using the Lake Victoria waters. Extraction of the Nile waters had to stop in these latter countries and even in Sudan during the cotton peak demand (May-July) to secure water for this traditional Egyptian crop (El Qausy *et al.*, 2011). In 1959, the Nile Waters Agreement between Egypt and Sudan assigned to Egypt 55 500 million m^3/year, measured at Aswan at the border with Sudan. The agreement was based on the average flow of the Nile during the 1900-1959 period, 84 000 million m^3/year, minus de evaporation from the artificial Lake Nasser. Average annual evaporation and other losses from the Aswan High Dam and reservoir (Lake Nasser) were estimated at 10 000 million m^3/year, leaving thus a net usable flow of 74 000 million m^3/year, of which 18 500 million m^3/year was allocated to Sudan and 55 500 million m^3/year to Egypt. The other riparian countries are still not included in this agreement.

In 1998, recognizing that cooperative development was the best way to bring mutual benefits to the region, all riparian countries joined in a dialogue to create a regional partnership to facilitate the common pursuit of sustainable development and management of Nile waters. The transitional mechanism, the Nile Basin Initiative (NBI), was officially launched in February 1999, and soon created and prepared a Strategic Action Programme, which consists of two sub-programmes: the Shared Vision Programme (SVP) and the Subsidiary Action Programme (SAP). The SVP is to help create an enabling environment for action on the ground through building trust and skill, while the SAP is aimed at the delivery of actual development projects involving two or more countries. Projects are selected by individual riparian countries for implementation and submitted to the Council of Ministers of the NBI for approval. Pre-2011 Sudan, Ethiopia and Egypt also adopted a strategy of cooperation in which all projects to be launched on the river should seek the common benefit of all member states and this should be included in accompanying feasibility studies.

The NBI is intended to be a transitional institution until the Cooperative Framework Agreement (CFA) negotiations are finalized and a permanent institution created. This new Nile CFA was signed in 2010 by five countries–Ethiopia, Kenya, Uganda, Rwanda and United Republic of Tanzania–and in 2011 by Burundi. Egypt strongly opposed this agreement which gives deciding power over large-scale hydraulic projects to a commission representing all the signatories, hence cancelling Egypt's historical right of veto. Pre-2011 Sudan, a traditional ally of Egypt, initially also rejected the agreement, but the new Sudan is now considering its signature due to increasing awareness of the unequal sharing and also hoping for benefits, in particular from the Ethiopian Renaissance dam, expected to be completed in 2017. Due to its proximity to the Sudanese's border, the dam could provide water for vast areas of irrigable land in Sudan, as well as mitigate floods in the agricultural El-Gezira region and greater Khartoum. The Democratic Republic of the Congo is also still to decide upon the CFA signature, as well as South Sudan, moreover so since the water contribution of the latter is considerable. The CFA was ratified in 2013 by Ethiopia and Rwanda and in 2015 by the United Republic of Tanzania.

Upper Nile projects had always been considered in policies as a way to increase Egypt's share of the Nile water to up to 9 000 million m^3 additional, even though the projects were in upstream countries:

- The Jongeil Canal in Sudan, the first phase of which was completed at 80 percent when construction stopped in 1982, would have "saved" around 7 000 million m^3/year by by-passing the Sudd swamps. This volume would have been divided equally between Egypt and Sudan (El Qausy *et al.*, 2011).
- Two other projects in the upstream swamps, Mashar swamps and in the Bahr El Ghazal area, are expected to provide 5 500 million m^3/year to Egypt.

Some projects under construction, however, such as the Tekese dam on the border between Ethiopia and Eritrea and the Ethiopian Renaissance dam, will negatively affect the Egyptian share of the Nile waters.

The vast Nubian Sandstone aquifer, Egypt's main groundwater source, is also shared with Chad, Libya and Sudan (Table 3). Other transboundary aquifers are detailed in Table 3.

TABLE 3
Transboundary aquifers (Source: IGRAC, 2014)

Aquifer name	Total aquifer area (km^2)	Sharing countries
Nubian Sandstone Aquifer System (NSAS)	2 607 985	Chad, Egypt, Libya, Sudan
Western Aquifer Basin	15 250	Egypt, Israel, Palestinian Territory
Coastal Aquifer Basin	22 645	Egypt, Israel, Palestinian Territory

WATER USE

Total water withdrawal in 2000 was estimated at 68 300 million m^3, divided between agriculture, municipalities and industry at 86, 8 and 6 percent respectively. In addition, 4 000 million m^3 were used in-stream for navigation and hydropower. In 2010, total water withdrawal was estimated at 78 000 million m^3, including 67 000 million m^3 for agriculture (86 percent), 9 000 million m^3 for municipalities (11.5 percent) and 2 000 million m^3 for industries (2.5 percent) (Table 4 and Figures 3 and 4). Similarly to 2000, 4 000 million m^3 are also used in-stream for navigation and hydropower (ICARDA and AusAID, 2011).

TABLE 4
Water use

Water withdrawal:			
Total water withdrawal	2010	78 000	million m^3/year
- Agriculture	2010	67 000	million m^3/year
- Municipalities	2010	9 000	million m^3/year
- Industry	2010	2 000	million m^3/year
• Per inhabitant	2010	999	m^3/year
Surface water and groundwater withdrawal (primary and secondary)	2010	73 800	million m^3/year
• As % of total renewable water resources	2010	127	%
Non-conventional sources of water:			
Produced municipal wastewater	2012	7 078	million m^3/year
Treated municipal wastewater	2012	4 013	million m^3/year
Direct use of treated municipal wastewater	2010	1 300	million m^3/year
Direct use of agricultural drainage water	2010	2 700	million m^3/year
Desalinated water produced	2010	200	million m^3/year

FIGURE 3
Water withdrawal by sector
Total 78 000 million m^3 in 2010

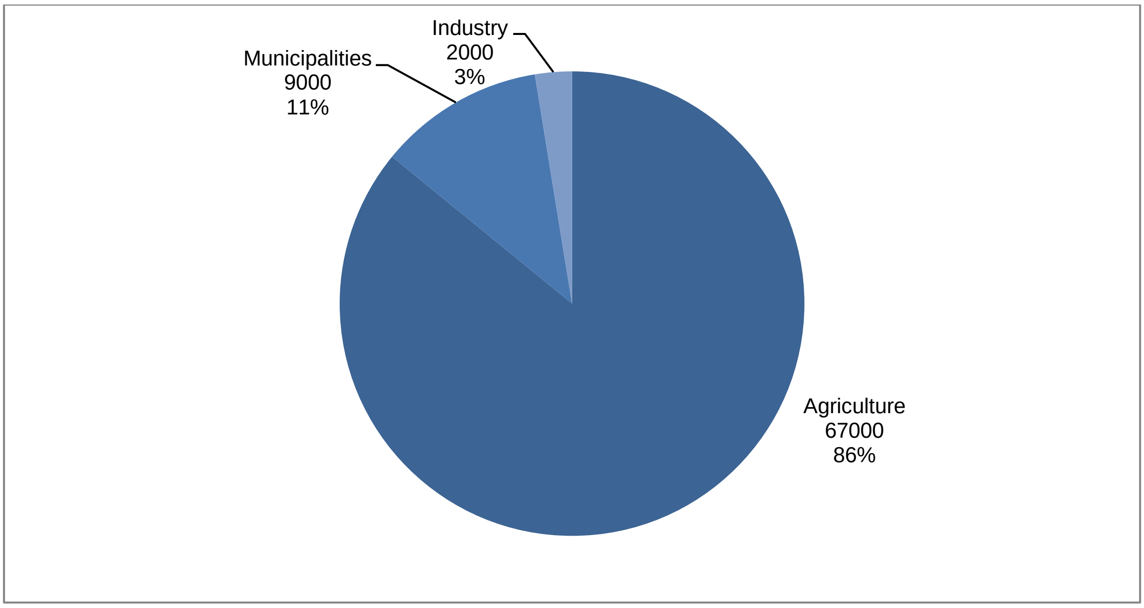
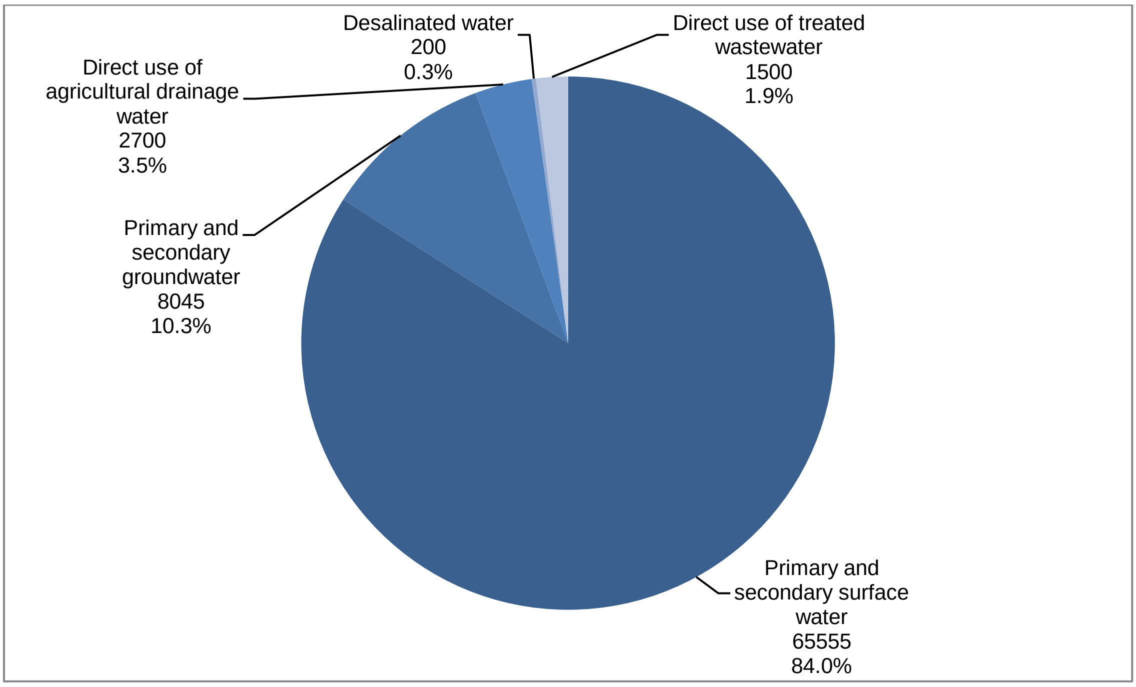


FIGURE 4
Water withdrawal by source
Total 78 000 million m³ in 2010



Groundwater extraction in 2010 was 8 045 million m³ comprising (ICARDA and AusAID, 2011):

- 6 200 million m³ from the Nile Basin (seepage waters or secondary freshwater),
- 1 700 million m³ from the eastern and western deserts, i.e. mainly the Nubian Sandstone aquifer,
- 145 million m³ from shallow wells in Sinai and on the northwestern coast.

IRRIGATION AND DRAINAGE

Evolution of irrigation development

Irrigation started around 6 000 years before the current era (BCE) in Egypt using the Nile water flooding on the surrounding banks. Around 3 000 years BCE, the first irrigation infrastructures (embankments, dams and canals) were constructed by Egyptians, in some cases under forced labour, to divert the Nile waters into basins and expand the irrigated areas. Irrigation development included and still includes both increase in areas (horizontal expansion) and increase in in water use efficiency (vertical expansion), with for example the conversion of irrigation by flooding into perennial or full control irrigation at the end of the 19th century. Horizontal expansion results in the irrigated areas of Egypt being classified into:

- The Old Lands of the Nile Valley and Delta
- Oases
- The New Lands, reclaimed since the High Aswan Dam construction (1970), generally less fertile, on the Old Lands' fringes, as well as in new locations outside the Nile Valley and Delta such as the western desert.

Irrigation potential is estimated at 4 420 000 ha. The total area equipped for irrigation was 3 422 178 ha in 2002; 85 percent of this area was in the Nile Valley and Delta. In 2010, 3 610 000 ha are equipped for full control irrigation, including 2 730 000 ha in the Old Lands (76 percent) and 880 000 ha in the Oases and New Lands (Table 5).

TABLE 5
Irrigation and drainage

Irrigation potential	-	4 420 000	ha
Irrigation:			
1. Full control irrigation: equipped area	2010	3 610 000	ha
- Surface irrigation	2010	2 730 000	ha
- Sprinkler irrigation	2010	410 000	ha
- Localized irrigation	2010	470 000	ha
• Area equipped for full control irrigation actually irrigated		-	ha
- As % of area equipped for full control irrigation		-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		-	ha
3. Spate irrigation		-	ha
Total area equipped for irrigation (1+2+3)	**2010**	**3 610 000**	**ha**
• As % of cultivated area	2010	98.3	%
• % of area irrigated from surface water		-	%
• % of area irrigated from groundwater		-	%
• % of area irrigated from mixed surface water and groundwater		-	%
• % of area irrigated direct use from non-conventional sources of water		-	%
• Area equipped for irrigation actually irrigated		-	ha
- As % of total area equipped for irrigation		-	%
• Average increase per year	2002-2010	0.67	%
• Power irrigated area as % of total area equipped for irrigation		-	%
4. Non-equipped cultivated wetlands and inland valley bottoms		-	ha
5. Non-equipped flood recession cropping area		-	ha
Total water-managed area (1+2+3+4+5)	**2010**	**3 610 000**	**ha**
• As % of cultivated area	2010	98.3	%
Size of full control irrigation schemes:	**Criteria**:		
Small schemes	< - ha	-	ha
Medium schemes	> - ha and < - ha	-	ha
large schemes	> - ha	-	ha
Total number of households in irrigation		-	
Irrigated crops in full control irrigation schemes:			
Total irrigated grain production		-	metric tons
• As % of total grain production		-	%
Harvested crops:		-	
Total harvested irrigated cropped area	2010	6 333 000	ha
• Temporary crops: total	2010	5 535 000	ha
- Wheat	2010	1 261 000	
- Rice	2010	452 000	ha
- Maize	2010	927 000	ha
- Other cereals	2010	351 000	ha
- Vegetables	2010	776 000	ha
- Groundnut	2010	38 000	ha
- Sesame	2010	28 000	ha
- Other oil crops	2010	66 000	ha
- Potatoes and other tubers	2010	158 000	ha
- Pulses	2010	98 000	ha
- Sugarcane	2010	131 000	ha
- Sugar beets	2010	162 000	ha
- Cotton	2010	155 000	ha
- Temporary fodder	2010	932 000	ha

TABLE 5 (Continued)
Irrigation and drainage

Irrigated crops in full control irrigation schemes:			
Harvested crops:		-	
• Permanent crops: total	2010	798 000	ha
- Mangoes	2010	64 000	ha
- Citrus	2010	157 000	ha
- Grapes	2010	64 000	ha
- Figs	2010	32 000	ha
- Dates	2010	42 000	ha
- Other fruits	2010	389 000	ha
- Olives	2010	50 000	ha
Irrigated cropping intensity (on full control area actually irrigated)	2010	175	%
Drainage - Environment:			
Total cultivated area drained	2003	3 024 000	ha
• Non-irrigated cultivated area drained		-	ha
• Area equipped for irrigation drained	2003	3 024 000	ha
As % of total area equipped for irrigation	2003	88	%
Area salinized by irrigation	2010	900 000	ha
Area waterlogged by irrigation		-	ha

Surface irrigation is practiced in the Old Lands combined with water lifting systems, while pressurized irrigation–sprinkler and localized irrigation–is compulsory by law on the New Lands (Figure 5). The latter use a cascade of pumping stations from the main canals to the fields, with a total lift of up to 50 m. Located at the end of the systems, the New Lands that are at the fringes of the Old Lands, are more at risk of water shortage, and pressurized irrigation is more suitable for the mostly sandy soil of those areas. Crops therefore tend to be higher value crops such as tree crops and vegetables in these New Lands (MWRI, 2005).

Freshwater was the only source of irrigation up the 1920-30s, either surface water in the Old Lands and groundwater in the oases. Reuse of drainage water started after a dry period with a first pumping station constructed in 1928. Shallow groundwater was used outside the oases from the 1950s (El Qausy *et al.*, 2011) and increasingly since then. In 2005, 227 640 ha were irrigated by groundwater both in and outside the oases (ARE, 2009).

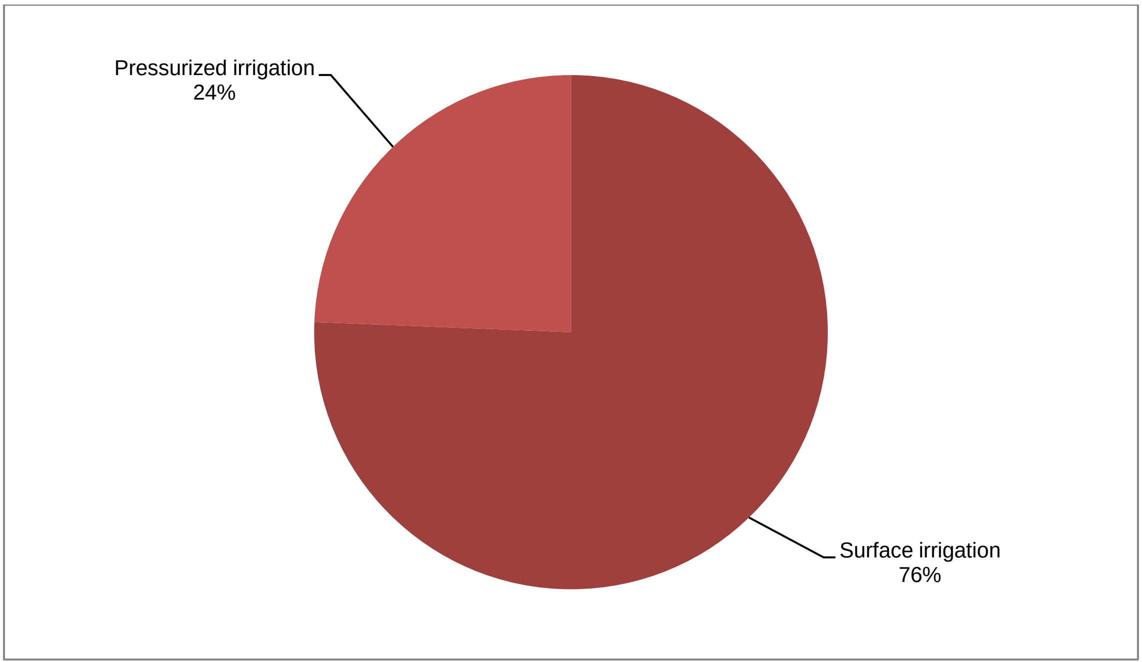
Rainwater harvesting is practiced on about 133 500 ha in Northwest coast and North Sinai, where the average rainfall is between 220 and 250 mm, and relies on the construction of cisterns and diversion dikes. Harvesting also occurs from flash floods in the Red Sea and Sinai Peninsula.

In addition to the older developments in the oases of the New Valley, which pump water from the Nubian Sandstone aquifer, new large irrigation schemes are under development in the Toshka project; in 2003 about 4 200 ha were under cultivation and there are plans to extend the project to several times that area.

In the Fayoum Province, until the end of the last century gravity irrigation was practiced, without any water lifting system. By the year 2000, however, gravity irrigation was practised on only 1 900 ha, or less than 1.2 percent of the cultivated area in Fayoum.

Treated wastewater (after primary treatment) has been in use since 1911 in agriculture at the Gabal Al Asfar farm on 1 200 ha. Large scale pilot projects are in East Cairo, Abu Rawash, Sadat City, Luxor, and Ismailia. Most of the sewage water drained to the agricultural drains is actually reused indirectly (MWRI and HCWW, 2011). In 2010, 35 500 ha are directly using treated wastewater.

FIGURE 5
Techniques of irrigation
Total 3 610 000 ha equipped for full control irrigation in 2010



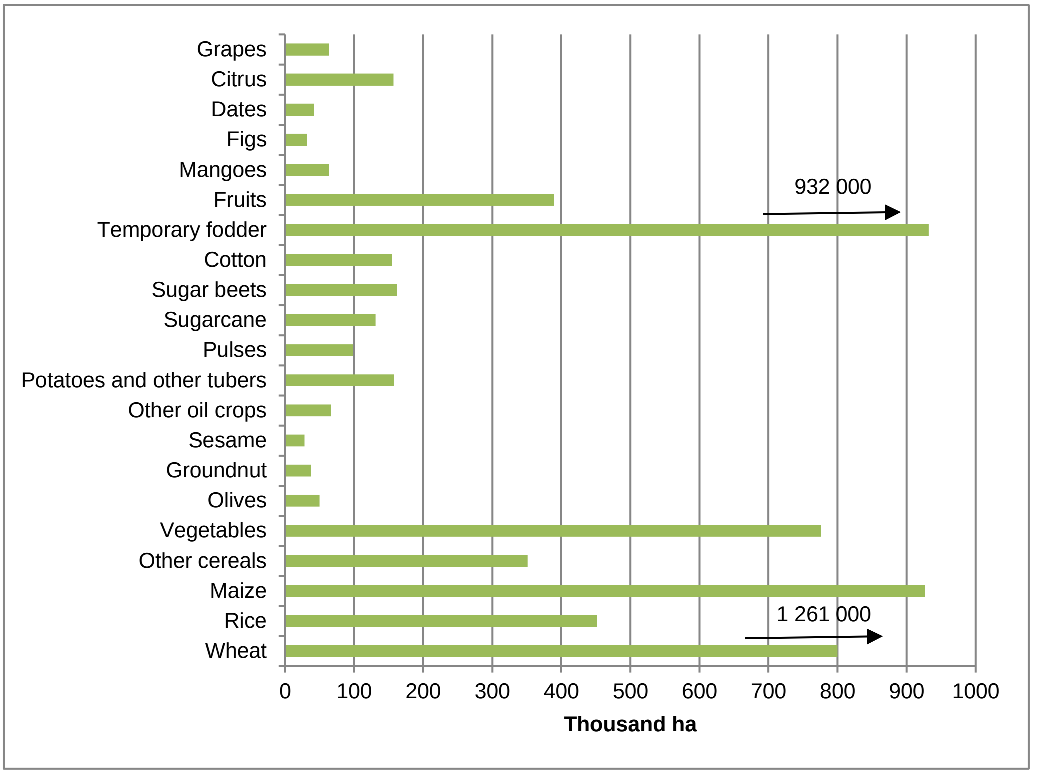
Role of irrigation in agricultural production, the economy and society

The cropped area was 6.333 million ha in 2010, with an average cropping intensity of 175 percent. There are three growing seasons in Egypt: winter - from November to May; summer - from April/May to October; and "*Nili*" - from July/August to October.

Most crops are grown both in the Delta and the Valley, with the exception of rice (Delta mainly) and sugarcane (Valley). The main winter crops are wheat and clover or berseem (*Trifolium alexandrinum*). Berseem is grown either over 3 months with 2 cuts as a soil improver (short berseem), usually preceding cotton, or over 6-7 months, either with 4-5 cuts as a fodder crop or grazed by tethered cattle (long berseem). Minor winter crops are, amongst others, pulses, barley and sugar beet. The main summer crops are maize, rice and cotton, the latter being the most important Egyptian export crop (Table 5 and Figure 6). Yields of most major crops have significantly increased within the 1980-2007 period: wheat yields have doubled from 3.24 tons/ha in 1980 to 6.48 tons/ ha in 2007, rice yields increased by almost 70 percent from 5.86 tons/ ha in 1980 to 9.79 tons/ ha in 2007 being among the highest in the world, sugarcane and sugar beets yields increased respectively by over 40 percent and 80 percent reaching 121 tons/ ha and 52 tons/ha in 2007. Only clover and cotton have not seen their productivity increased as much, with only 17 percent increase for clover reaching 71 tons/ha in 2007 while cotton yield remain stable at 2.6 tons/ha (ARE, 2009).

Irrigated crops in Egypt do not only contribute to food security but also to the GDP, in particular with cotton and some 5 percent of the horticultural production, and to the preservation of the environment. Indeed, rice production is critical to prevent salt-water intrusion and maintain soil quality in the Northern Delta. In addition, the cotton industry is also a huge employer for rural population with the sector employing over one million people during most of the year and the textile industry half a million (MWRI, 2005).

FIGURE 6
Harvested irrigated area
Total 6 333 000 ha harvested irrigated in 2010



Women and irrigation

Women's roles in agriculture and irrigation were investigated as part of a national survey on the attitudes of Egyptian farmers towards water resources in 1998 and 2001. Vast majority of women farmers–but 60 percent of men–never attended school. Most women farmers are widowed (70 percent) and have generally a smaller piece of land to cultivate (1.4 *feddan* against 3.5 for men). Women farmers mainly farm for household consumption. Almost no women visit their irrigation engineer, while 10 percent of men tend to go once per year. Seven out of 20 irrigations are practiced at night by women, while 10 are by men in the Nile Valley. In general, the interviewed women farmers tended to be less aware of ways to reduce water use (crop variety, land levelling, etc.). However, if they avoid night irrigations, it is also because they prefer not being out at night, either for fear that something happens to them or for fear of bad reputation. Women farmers were less keen to get a greater role in managing the *mesqa* and to join to a WUA, as half of them saw no benefit to join. Indeed, women are traditionally excluded from management systems: even when holding land, they are expected to send male representatives to meetings rather than attending themselves (USAID, 2001).

In addition to women farmers, farmers' wives were also interviewed. Of the 355 interviewed farmers' wives in 1998, 43 percent said that they helped in agriculture for an average of 22 hours per week, but with a significant disparity between Upper Egypt (9 percent) and the rest of the country (47 percent). Their main tasks consist in cultivation (almost all interviewed wives), livestock (over half) and irrigation (almost a third), but less than 10 percent of farmers seriously consider their wives' suggestion on those tasks. Because of men migration to the Arabian Gulf and internally to urban areas, rural women in those cases are largely responsible for farm work and irrigation. Hence, they are becoming important for water planning, since they also use water for domestic purposes. However, it is still challenging for them to claim a water right and be part of its management as it destabilize the status quo and interests of traditional decision makers (USAID, 2001).

Status and evolution of drainage systems

Drainage issues–waterlogging and salt accumulation–started in Egypt with the conversion to full control irrigation and the construction of the Delta barrages, which led to a rise in the groundwater table and a resulting decline in cotton yields. A drainage programme was initiated before the construction of the High Aswan Dam but became a national programme only from 1970 onwards, aiming to drain all the cultivated area. The drainage system consists of sub-surface drains at farm level, open drains to collect the effluent and direct it into the Nile, its branches, canals or coastal lakes and pumping stations to maintain the level of water in the drains low enough for the water to flow out of the fields. The National Drainage Programme is essential for the government water resources' strategy in order to increase reuse of agriculture drainage water and thus water efficiency (AfDB, 2015).

In 2003, slightly over 3 million ha of the total irrigated area of about 3.4 million ha were drained, of which about 2.2 million ha with sub-surface drainage. The sub-surface drained area represents more than 65 percent of the total irrigated area. There are 99 pump stations devoted to the pumping of drainage effluent. The power-drained area was estimated at about 1.65 million ha in 2000. Drainage water from agricultural areas on both sides of the Nile Valley is returned to the Nile river or main irrigation canals in Upper Egypt and in the southern Delta. Drainage water in the Delta is either pumped back into irrigation canals for reuse or pumped into the northern lakes or the Mediterranean Sea.

Currently, over 25 percent of irrigated agriculture in Egypt suffers from varying levels of salinity (ICARDA and AusAID, 2011).

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

The first official institution in charge of irrigation, the Department of Publics Works, was established in 1836. Its name was then changed various times to Ministry of Public Works (1914), Ministry of Irrigation (1964), Ministry of Irrigation and Land Reclamation (1977), Ministry of Irrigation (1978), Ministry of Public Works and Water Resources (1987) and finally Ministry of Water Resources and Irrigation (MWRI) in 1999.

Currently, MWRI is in charge of water resources research, development and distribution, and undertakes the construction, operation and maintenance (O&M) of the irrigation and drainage networks. Specifications and permits for groundwater well drilling are also the responsibility of MWRI. Within MWRI, the following sectors and departments are of importance:

- The Nile Water Sector: in charge of cooperation with Sudan and other Nilotic countries.
- The Irrigation Department: provides technical guidance and monitoring of irrigation development, including dams and comprises 6 sections: irrigation; horizontal expansion and projects; grand barrages; groundwater; Nile protection; irrigation improvement.
- The Planning Sector: responsible at central level for data collection, processing and analysis for planning and monitoring investment projects.
- The Water Resources and Irrigation Sector in Lower/Upper Egypt
- The Water Resources, Irrigation and National Structure Sector in North Sinai
- The Mechanical and Electrical Department: in charge of the construction and maintenance of pumping stations for irrigation and drainage.

Further to the above institutions, other public authorities are directly related to MWRI:

- Egyptian Public Authority for High Dam and Aswan Dam is responsible for dam operation.
- Egyptian Public Authority for Drainage Projects (EPADP) is responsible for the construction and maintenance of tile and open drains.

- National Water Research Centre (NWRC) comprises 12 institutes and is the scientific body of MWRI for all aspects related to water resources management.
- Water Quality Management Unity
- Institutional Reform Unit

The Ministry of Agriculture and Land Reclamation (MALR) is in charge of agricultural research and extension, land reclamation and agricultural, fisheries and animal wealth development. The Agricultural Research Center comprises 16 institutes, 11 central laboratories, the Regional Center for Food and Feed, and the National Gene Bank. They are considered to be 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 allocation to investors and individuals. The Agricultural Development and Credit Bank provides credit to farmers to finance various production requirements.

The new Ministry of Water and Wastewater Utilities (MWWU), created in 2012, took over its functions from the Ministry of Housing, Utilities and Urban Communities that had previously been in charge of the sector. The Ministry covers the whole sector of drinking water and wastewater. The following institutions report to the MWWU:

- Egyptian Water and Wastewater Regulatory Agency (EWRA)
- Holding Company for Water and Wastewater (HCWW) and its 23 affiliated companies
- National Organization for Potable Water and Sanitary Drainage (NOPWASD)
- Construction Authority for Potable Water and Wastewater (CAPW) (EU, 2012)

The Ministry of State for Environmental Affairs (MSEA) and the Egyptian Environmental Affairs Agency (EEAA) under its jurisdiction mostly concentrate on the quality aspect of water.

The National Water Council (NWC) ensures inter-ministerial coordination by integrating policies and activities at national and local level, and it is assisted by a technical secretariat and Water & Environment units in the different Ministries and organisations. At governorate level, a Regional Management Committee (RMC) includes all stakeholders and is chaired by the local MWRI responsible (MWRI, 2005).

Water management

At regional level, the 22 Irrigation directorates and 22 Drainage directorates, each divided into 62 inspectorates and about 206 districts of 20 to 60 000 *feddan* (40 to 100 000 farmers) were replaced by "Integrated Water Management Districts" (IWMD) in 2009. Integration of irrigation, drainage and groundwater was tested with 4 pilots sites established in 2001 and 2003. Based on these, 8 General Directorates for Water Resources & Irrigation and 45 Integrated Water Management Districts (IWMD) were established and are fully operational (USAID, 2011).

Water Users Associations (WUAs) exist in parts of the country and operate at *mesqa* (tertiary) level where farmers on one *mesqa* select a representative to the association, which meets regularly with the district irrigation engineer to determine the major reports that need to be made. The association is also responsible for organization regular *mesqa* maintenance and resolving conflicts. Other organization units used in the management of irrigation follow the hierarchical canal classification (Table 6). Upscaling of the WUAs to higher level, in particular to the secondary level with the Branch canal through Branch Canal water Boards formed with *mesqa* representatives, is projected but still at pilot test scale (MWRI, 2005). Only 53 boards were established in 2002, in particular in the Fayyum and Nile Delta areas (USAID, 2011).

TABLE 6
Water management levels and units

	Number of WUAs	Area (feddans)	Number of farmers
Mesqas (tertiary)	100 000	10-100	150
Branch canals (secondary)	4 000-5 000	500-3 000	1 000-5 000
Main canals (or feeder canal)	400-600	15 000-25 000	10 000-20 000
Irrigation district	300	20 000-60 000	40 000-80 000
Governorates	26	200 000-500 000	1 000 000

Irrigation water distribution into the irrigation network is managed by the MWRI and its local representatives (Gersfelt, 2007). Water flow is continuous up to the branch canal (second level). At the *mesqa* or third level, distributaries receive water according to a rotation schedule. Water is pumped from the distributaries to irrigate fields (lift: about 0.5-1.5 m).

Finances

Investment especially in land reclamation and irrigation improvement, O&M, as well as rehabilitation costs of irrigation and drainage infrastructures are traditionally financed by MWRI, only the pumping costs from the *mesqa* to the field are paid by farmers. However, in Toshka mega project (see prospect section for more details), proposed water charges combine area and volumetric based charges (MWRI, 2005).

Within the land reclamation programme, the government's investments target irrigation and drainage infrastructure, settlement construction, and provision of potable water, electricity and roads. Very little is invested in social services (education and health), and no investment is made in the provision of agricultural services (technology, water management and rural finance). Consequently, poor settlers face difficulties in settling and farming, and a considerable percentage move back to the old lands and abandon their new land farms.

Policies and legislation

The legal basis for irrigation and drainage is set in Law No. 12/1984 and distinguishes public property of the irrigation and drainage infrastructures from canals and private banks, defines water distribution and O&M costs, and protects irrigation infrastructures, navigation and beaches. The Law's implementation regulation adds details about groundwater, wastewater and water-lifting machines. Its supplementary Law No. 213/1994 designs farmer participation through WUAs and defines the benefits and costs of irrigation systems by the WUAs. Decrees of the MWRI and its ancestors No. 2/1989, No. 14867/1991, No. 72/1993, No. 14900/1995 and No. 402/1996 complete this legislation (MWRI, 2015).

Regarding environmental protection, and in particular water contamination, Law No. 48/1982 intends to protect the Nile water from sewage pollution, together with the executive regulations No. 92/2013 of the MWRI. More generally, environmental Law No. 4/1994, as amended by Law No. 9/2009, and its executive regulation are the main legislation governing environmental protection in Egypt (AfDB, 2015).

Water policies, regularly introduced from 1928 onwards, were mostly water development policies. The 1928 water policy fixed the limit of horizontal expansion at 3 million ha, which was attained by 2000. The 1933 water policy corresponds to water storage expansion of the Nile river within and outside Egypt for the country's benefit, including: i) the 2nd increase in height of the Aswan Dam (up to a storage capacity of 2 500 million m^3), ii) the construction of the Jebel Aulia dam on the While Nile in Sudan, saving 2 000 million m^3 per year available for Egypt, iii) proposals for the Sennar Dam on the Blue Nile and the Junglei canal project in Sudan and for storage in Lake Tana in Ethiopia. The 1953 water policy pursued the same logic with the additional water made available by the increase in height of the Owen Dam in Uganda, partially financed by Egypt. The 1959 water policy is directly linked to the 1959 Nile Water Agreement between Sudan and Egypt to prepare for the construction of the High Aswan Dam and the new resources made available. Full control and exploitation of the Nile waters being permitted by the High Aswan Dam, the following policies concentrated on finding additional water resources, in particular groundwater and reuse of drainage water (El Qausy *et al.*, 2011). The 2000 water policy recommends establishment of full property rights on irrigated lands (MWRI, 2005). The latest water policy of 1997-2017 increases the horizontal expansion up to 4.62 million ha, to which almost all the water budget would be dedicated. The deficit involved in this water budget is only compensated by "savings" through structural and non-structural measures–improvement of irrigation techniques, rehabilitation, increased reuse of drainage water and treated wastewater, subsurface drainage expansion, change from supply to demand management, WUAs expansion at primary and upper levels, etc.–rather than concrete new water sources, leaving no emergency reserve (El Qausy *et al.*, 2011).

Agricultural policies also include some elements of water management. The 1980s Agricultural Development Strategy intended to fight salinization and improve irrigation in the newly reclaimed areas. The 1990s strategy aimed to improve water return and efficiency through improved irrigation techniques. The Sustainable Agricultural Development Strategy towards 2030 focuses on decentralization of water management through WUAs, irrigation O&M cost recovery, and decrease of rice and sugarcane areas, which are crops consuming a large amount of water per ha (ARE, 2009). Its objective is to achieve a comprehensive economic and social development based on a dynamic agricultural sector capable of sustained and rapid growth while paying a special attention to vulnerable social groups and reducing rural poverty.

ENVIRONMENT AND HEALTH

Irrigated lands, in particular the Old Lands, suffer from urban encroachment diverting it to non-agricultural uses, as well as deterioration of the soil fertility. The latter mostly results from accumulation at the soil surface of salt from the irrigation water on around 25 percent of the agricultural lands at various degrees, located in the northern part of the Delta. Costs of restoration of salt-affected soils being less expensive than reclamation of new lands, their recovery is prioritized (ICARDA and AusAID, 2011). This has led to a reduction in salinized areas from about 1.2 million ha in 1972 to 900 000 ha in 2010 thanks to installation of drainage systems.

Salinization has three different origins in Egypt:

- Lack of drainage system and inappropriate water management at field level.
- Large reuse of drainage water to complement freshwater especially in the lower reaches of the canals, where salt load is increasing. The salinity of agricultural drainage water is higher in winter, especially downstream because less water is used for irrigation. In the new Al Salam Canal, drainage water is mixed with Nile water at a ratio of 1:1 resulting in the salinity of the mixed water being within safe levels.
- Seawater intrusion in aquifer is caused by groundwater over-extraction in the Delta shallow aquifer leading to water salinization and advance of the salt water interface. About half of the Delta contains brackish to saline groundwater. Rice is cropped in the Delta in order to maintain low salinity level and stop seawater intrusion in the aquifer.

Over-extraction of groundwater is not limited to the Delta aquifer. Water levels are also dropping in the Moghra aquifer due to large withdrawals by reclamation projects, as well as industrial and municipal users at the fringe of the Nile Delta. In addition, depletion of fossil groundwater also occurs in Egypt. The Nubian aquifer, containing mostly fossil groundwater, faces a drop in groundwater level by 70-80 meters in some areas of western desert of Egypt, and the main water flow's direction was disrupted.

In addition to salt load, contamination from agricultural activities through nutrients, pesticides, and herbicides, and from high population density, increasing industrial and municipal effluents, is also degrading water quality (AfDB, 2015). Egypt's most vulnerable areas are the fringes of the Nile Valley and Delta where a protecting clay cap is absent and where the aquifer is directly exposed to pollution.

In the Delta, water quality deteriorates northward with decreasing flow and increasing discharge. The Rosetta branch receives Greater Cairo's wastewater, while fertilizer industries discharge in the Damietta branch (MWRI, 2005). Thus, sustainability of water resources in Egypt is not only challenged by quantity but also by quality.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The National Water Resources Plan 2017 estimates that the total cultivated areas would increase to 4 053 000 ha by the year 2017, and 4 830 000 ha by 2030. It also is anticipated that the cropped area would increase to about 8 064 000 ha at an intensification rate of 198 percent in 2017, and to about 9 660 000 ha at an intensification rate of 199 percent in 2030.

For this horizontal expansion, it was projected in 2007 that an additional 525 000 ha of new lands be reclaimed by 2017 and 1 302 000 ha by 2030 (ARE, 2009) in particular through mega projects, some of which are already partly functioning:

- The El Salem project east of the Delta (92 400 ha) and in North Sinai (168 000 ha) using water from the El Salem Canal diverting water from the Damietta branch, as well as agricultural water drainage derived from Bahr Hadous, Lower Serw drains.
- The Toshka or New Valley project (228 000 ha) near Lake Nasser using water from the Sheikh Zaid canal and groundwater pumping to expand oases into large private farms.

The long-term plan is to reclaim 630 000 ha in the above projects, as well as in the Nile Valley and in Matruh governorate, to create Bedouin villages, as well as industrial and commercial associations. As new lands, all new development areas have to use sprinkler or localized irrigation, surface irrigation is not permitted outside the Nile Valley. The El Salem and Toshka projects have been financed locally and with aid from Arab countries and international agencies. The water to irrigate all these new development is both primary freshwater (of which 90 percent groundwater), as well as indirect (secondary freshwater) and direct use of non-conventional sources of water (treated wastewater and agricultural drainage water), in particular from water savings through:

- Rehabilitation and improvement of on-farm irrigation techniques in existing equipped areas on 882 000 ha for the 2010-2017 period (MARL, 2011)
- Changes in cultivated crops:
    - Reduction of the rice cropping area from more than 700 000 ha in 2007 to 378 000 ha by 2030 and introduction of varieties with short crop cycle
    - Reduction of the sugarcane cropping area to less than 126 000 ha to be replaced by sugar beet.
    - Cultivation of wheat and maize on terraces for an area of 1 260 000 ha and 714 000 ha respectively, using short crop cycle varieties for maize in particular
    - Development of irrigated horticulture with modern irrigation techniques
    - Expansion of clover (leguminous) crop area on more than 1.26 million ha
- Improvement in irrigation efficiency to reach 80 percent in over 3.3 million ha, in order to save an estimated 12 400 million m^3 (ARE, 2009). This efficiency will be achieve with:
    - Improvement of irrigation networks: lining, gates and weeds
    - Laser land levelling
    - Night irrigation to reduce tail end losses and evaporation losses
    - Use of desalinated sea water as a strategic choice for municipalities and industries
    - Improved crop rotation
    - Reuse of drainage water

In addition, both agricultural policies, in particular cropping patterns modification, and water management policies, such as allocation rules and upscaling of WUAs, are expected to increase water efficiency, saving some water for the new developed areas. This would redirect the traditional water development in the country towards a more efficient water allocation policy. Development of irrigation outside the traditional Nile Valley and Delta will also populate some desert areas of Egypt and de-densify the highly densified traditional areas.

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