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Situation of Water Use Efficiency in Egyptian Agriculture during the Period 2012-2016

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THE CURRENT research aims to enrich efforts exerted to increase crop production efficiency, which requires improving water use efficiency without posing negative impacts on the quantity or quality of water at the level of inlets. The most important results of the study were that the amount of losses in irrigation water reached its highest value between the field and the dam by about 7.815 billion m^3, while the amount of water lost between the dam and heads of irrigation canals reached about 5.525 billion m^3, but between the heads of the canals and the field it reached about 2.288 billion m^3. The productivity efficiency of the irrigation water unit, the net return of the irrigation water unit, the return of the invested pound, and the ratio of irrigation costs to total costs reached its maximum value in winter crops compared to summer crops at the level of the Republic. Finally, the research recommended that the government perform periodic maintenance of irrigation water canals along various stages, especially in Upper Egypt.

Keywords: Economic and technical efficiency, Egyptian agriculture, Irrigation water, Productivity.

Introduction

Water is a key determinant for agricultural and economic development in Egypt. It is not possible to achieve a comprehensive and sustainable development in the country without providing sufficient quantities of water, and using them efficiently in the same time (Elagrody & Solieman, 2005). In agriculture, Egypt mainly relies on Nile water as the major source for irrigation, in addition to groundwater, recycled agricultural drainage water, treated sewage water and some rainwater (Elagrody & Solieman, 2008). It is worth mentioning that 70% of fresh water consumption at the world level goes for the agricultural sector (Al-Sawalhy et al., 2010). However, water use efficiency in many countries does not exceed 50%. The Food and Agriculture Organization of the United Nations (FAO) expects that, by 2050, global needs for irrigation water is expected to rise by 50% to meet the growing demand for food associated with the growing increase in population in most countries (www.F.A.O.org). It is worth mentioning that world countries have been facing increased scarcity in freshwater resources due to improper management, inefficient use and climate changes (Elagrody et al., 2010). Water scarcity and quality problems represent a serious future challenge to food security and environmental sustainability in many parts of the world (Solieman et al., 2012). No doubt, addressing such issues requires improving land and water management, especially in water-scarce countries (Elagrody & Solieman, 2008). And since water resources represent a key determinant for developing Egypt's agricultural sector, one of the priority goals during the period of economic reform is to achieve comprehensive sustainable development in this sector, which comes on top of the important sectors targeted by the Country's Sustainable Agricultural Development Strategy in 2030 (Ministry of Agriculture and Land Reclamation, 2009).

In the light of the limited quantity of water in Egypt, estimated at 55.5 billion m^3, annual per

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capita share of water currently amounts to 650 m^3, which is considered low. The agricultural sector consumes around 70% of this total, while 20% goes for the industrial sector, and only 10% goes for domestic consumption (Solieman & Al-Sawalhy, 2014). Such low per capita share is expected to further decline in the near future with the increase in population and lack of development in water resources management, which hampers the efforts exerted to achieve sustainable development in Egypt's agricultural sector.

The study aims to improve efficiency of irrigation water use without posing negative impacts on the quantity and quality of water at estuaries. However, achieving this goal requires studying losses in irrigation water, in addition to assessing the current of production, economic and technical efficiency of irrigation water use in order to bring about the targeted development goals as planned for in Egypt's economic reform plan 2030.

Methodology and Sources of Data

The research applied descriptive analysis, and estimated some production, economic and technical efficiency indicators to assess the current situation of irrigation water resources in Egypt in the study period (2012-2016).

In regards to data sources, the research relied on some electronic sites such as the Central Agency for Public Mobilization and Statistics, the Arab Organization for Agricultural Development, the Ministry of Agriculture and Land Reclamation, as well as some websites relevant to the research subject.

Results and Discussion

Losses during water transfer from Aswan to the fields over the period 2012-2016

Irrigation water is subject for losses while flowing from its main source until reaching the fields, either through evaporation, leakage into the ground, or absorption by weeds in water canals Hence (www.aoad.org), estimating the amount of losses at different stages is necessary to rationalize irrigation water (Fawaz, 2013) use. Table 1 shows that average quantity of water used at the field level amounts to 37.52 billion m^3, and ranges between a maximum of 43.6 billion m^3 in 2016 and a minimum of 32 billion m^3 in 2012, by 36.25%. In addition, average quantity of water used at the heads of irrigation canals amounts to 41.78 billion m^3, and ranges between a maximum of 44.5 billion m^3 in 2016 and a minimum of 36.9m^3 in 2012, by 20.6%. Finally, average quantity of water discharge at Aswan Dam amounts to 44.66 billion m^3, and ranges between a maximum of 46.7 billion m^3 in 2016 and a minimum of 40.1m^3 in 2012, by 16.46% over the study period (2012-2016).

TABLE 1. Quantity of water consumption and loss at different stages in Egypt over the period 2012-2016 (in billion m^3).

Year	Quantity of Water Consumed			Quantity of water loss		
	At the field	At the heads of irrigation canals	Discharged from Aswan Dam	From Aswan to the field	From Aswan to the heads of irrigation canals	From the heads of irrigation canals to the field
2012	32.0	36.9	40.1	8.1	3.2	4.9
2013	37.0	43.0	46.0	9.0	3.0	6.0
2014	38.0	43.5	46.5	8.5	3.0	5.5
2015	37.0	41.0	44.0	7.0	3.0	4.0
2016	43.6	44.5	46.7	3.1	2.2	0.9
Average	37.52	41.78	44.66	7.14	2.88	4.26

Source:The Central Agency for Public Mobilization and Statistics,Water Resources and Irrigation Bulletin, Various Issues 2012-2016.

Estimating losses in irrigation water along different stages indicates that the highest average loss, estimated at 7.14 billion m^3, occurs at the stage of water flow from Aswan to the field, as shown in Table 1. It is also clear that water loss ranges between a maximum of 9 billion m^3 in 2013 and a minimum of 3.1 billion m^3 in 2016, by 65.6%. On the other hand, loss in irrigation water flowing from Aswan until reaching the heads of irrigation canals amounts to 2.88m^3 on average, recording a minimum of 2.2 billion m^3 in 2016, down by 31.25% compared to 2012. Finally, loss in irrigation water flowing from the heads of irrigation canals to the fields amounts to 4.26 billion m^3 on average, recording a minimum of 0.9 billion m^3 in 2016, down by 85% compared to 2013, as shown in Table 1.

Measuring the technical efficiency of irrigation water used in Egyptian agriculture

Technical efficiency of irrigation water use can be estimated by assessing efficiency of water flowing from Aswan until reaching the fields, starting from Aswan until reaching the heads of irrigation canals, thereafter from the heads of irrigation canals to the fields at the country level, and at the levels of Lower, Middle and Upper Egypt, as follows:

Efficiency of water flowing from Aswan until reaching the fields

Assessing the efficiency of water flowing from Aswan until reaching the fields at the country level during 2016 revealed that it reached 92.76%. At the level of regions, Lower Egypt ranked first by recording an efficiency rate of 91.99%. Summer crops recorded the highest efficiency rate, estimated at 95.24%, while Nile crops recorded the lowest rate, estimated at 45.83%. Middle Egypt followed by recording an efficiency rate estimated at 76.14%. Summer crops recorded the highest efficiency rate, estimated at 85.71%, while Nile crops recoded the lowest level, estimated at 50.72%. Upper Egypt ranked last in terms of efficiency rate that reached 70.05%, with fruit crops recording the highest efficiency rate (79.71%) and winter crops recording the lowest efficiency rate (52.01%), as shown in Table 2.

The table also shows that total loss in irrigation water during 2016 reached 7.815 billion m^3, to which Upper Egypt contributes by 3.105 billion m^3, Middle Egypt contributes by 2.45 billion m^3 and Lower Egypt contributes by 2.26 billion m^3, representing 39.73%, 31.35% and 28.92% of the total loss in irrigation water at the country level, respectively. It is worth noting that the high losses in Upper and Middle Egypt are due to high temperature degrees that lead to more evaporation, soil dryness thus the need to increase irrigation times compared to Lower Egypt, in addition to the poor quality of soil in the two regions compared to Lower Egypt.

As for the average efficiency rates of water flow and delivery for main agricultural crops grown at the country level and at the level of Lower, Middle and Upper Egypt, they reached 77.73%, 77.94%, 77.87%, and 77.37%, respectively. In addition, Middle Egypt ranked first in terms of efficiency of water used to grow winter crops (wheat, beans, sugar beet and long clover), followed by Lower Egypt, while Upper Egypt ranked last, as shown in Table 3.

Turning to the efficiency of water flow and delivery for main agricultural crops grown during the summer season, average efficiency rates reached 77.17%, 80.24%, 79.58% and 77.15% at the levels of the country, Lower Egypt, Middle Egypt and Upper Egypt, respectively. The estimated efficiencies revealed that Lower Egypt ranked first (for cotton, sugarcane, maize, sorghum and rice), followed by Middle and Upper Egypt, as shown in Table 3.

Efficiency of water flow and delivery from Aswan to the heads of canals

Average efficiency of water flow from Aswan until reaching the heads of irrigation canals at the country level reached 95.04% of the total amount of water discharged from Aswan in 2016. Lower Egypt recorded the highest efficiency rate, estimated at 93.38%, recording 95.92% for summer crops. Middle Egypt followed with efficiency estimated at 83.74%, recording 91.84% for summer crops. Upper Egypt ranked last with efficiency estimated at 79.41%, recording 86.96% for fruit crops, as shown in Table 2. Therefore, total loss in water at this stage reached 5.525 billion m^3, of which Lower Egypt accounts for 1.72 billion m^3, or 31.13% of the total amount of water loss at the country level.

TABLE 2. Efficiency of water transportation and delivery, and average water losses by season and region in 2012- 2016.

Region	Crop/Season	Amount of water used (billion m^3) at the:			Efficiency of Water Delivery from:			Loss (billion m^3)		
		Field	Heads of canals	Aswan	The field to the dam	The heads of canals to the dam	The field to heads of canals	The field to the dam	Heads of canals to the dam	Heads of canals to the field
Lower Egypt	Winter	7.100	7.300	7.900	89.87	92.41	97.26	0.800	0.600	0.200
	Summer	14.000	14.100	14.700	95.24	95.92	99.29	0.700	0.600	0.100
	Nile	0.220	0.260	0.480	45.83	54.17	84.62	0.260	0.220	0.040
	Fruit	2.400	2.600	2.900	82.76	89.66	92.31	0.500	0.300	0.200
Average		23.720	24.260	25.980	91.99	93.38	98.52	2.260	1.720	0.540
Middle Egypt	Winter	2.600	2.900	3.800	68.42	76.32	89.66	1.200	0.900	0.300
	Summer	4.200	4.500	4.900	85.71	91.84	93.33	0.700	0.400	0.300
	Nile	0.350	0.490	0.690	50.72	71.01	71.43	0.340	0.200	0.140
	Fruit	0.670	0.710	0.880	76.14	80.68	94.37	0.210	0.170	0.040
Average		7.820	8.600	10.270	76.14	83.74	90.93	2.450	1.670	0.780
Upper Egypt	Winter	1.550	1.960	2.980	52.01	65.77	79.08	1.430	1.020	0.410
	Summer	5.100	5.600	6.600	77.27	84.85	91.07	1.500	1.000	0.500
	Nile	0.064	0.074	0.099	64.65	74.75	86.49	0.035	0.025	0.010
	Fruit	0.550	0.600	0.690	79.71	86.96	91.67	0.140	0.090	0.050
Average		7.260	8.234	10.370	70.05	79.41	88.22	3.105	2.135	0.970
Republic	Winter	11.250	12.160	14.600	89.04	92.47	96.30	1.600	2.520	0.910
	Summer	23.300	24.200	26.200	98.36	99.81	98.55	0.430	2.000	0.900
	Nile	0.634	0.832	1.400	53.64	59.43	90.26	0.649	0.445	0.198
	Fruit	3.620	3.900	4.500	84.44	86.67	97.44	0.700	0.560	0.280
Country's Average		38.804	41.09	46.620	92.76	95.04	97.61	7.815	5.525	2.228

Source: the central agency for public mobilization and statistics, water resources and irrigation bulletin , various issues 2012-2016.

Results indicate the highest amount of water loss associated with winter and summer crops is estimated at 1.2 billion m^3, or 21.72% of the total amount of water loss in Lower Egypt. Total water loss in Middle Egypt reached 1.67 billion m^3, or 30.23% of the total amount of water loss at the country level. The highest amount of water loss associated with winter crops is estimated at 0.9 billion m^3, or 16.29% of the total amount of water loss in Middle Egypt. Moreover, the total amount of irrigation water loss in Upper Egypt reached 2.135 billion m^3, or 38.64% of the total amount of loss in irrigation water at the country level. The highest amount of water loss associated with winter crops reached 1.02 billion m^3, or 18.46% of the total amount of water loss in Upper Egypt during 2016, as shown in Table 2.

Efficiency of water flow from the heads of irrigation canals to the field

Efficiency rate of water flow from the heads of irrigation canals until delivered to the fields reached 97.61% during 2016. Lower Egypt recorded the highest efficiency rate in terms of water flow and delivery, estimated at 98.52%, with summer crops recording the highest efficiency rate, estimated at 99.29%, and Nile crops recording the lowest efficiency rate, estimated at 84.62%. Middle Egypt followed with efficiency rate estimated at 90.93%, with fruit crops recording the highest efficiency rate, estimated at 94.37%, and Nile crops recording the lowest efficiency rate, estimated at 71.43%. Upper Egypt ranked last by recording an efficiency rate estimated at 88.22%, with fruits crops recording the highest efficiency rate, estimated at 91.67%, and Nile crops recording the lowest efficiency rate, estimated at 86.49%, as shown in Table 2.

As a result, total loss in irrigation water at this stage reached 2.288 billion m^3. Total loss in Lower Egypt reached 0.54 billion m^3, or 23.6% of the total amount of water loss at the country level, with winter and fruit crops recording the highest amount of loss, estimated at 0.4 billion m^3, or 74.07% of the total amount of water loss in Lower Egypt. In Middle Egypt, total loss reached 0.78 billion m^3, or 34.09% of the total amount of loss at the country level, with winter and summer crops recording the highest amount of loss, estimated at 0.6 billion m^3, or 76.92% of the total amount of loss at the level of Middle Egypt. In Upper Egypt, loss in irrigation water reached 0.97 billion m^3, or 42.4% of the total amount of loss in irrigation water at the country level. Winter and summer crops recording the highest amount of water loss, estimated at 0.91 billion m^3, or 93.81% of the total amount of water loss at the level of Upper Egypt during 2016, as shown in Table 2.

Measuring the production and economic efficiency of irrigation water used in Egyptian agriculture

Production efficiency refers to the ability of managing irrigation water in such a way that contributes to raising the efficiency of irrigation water use. This can be achieved by realizing higher production quantity from the same amount of irrigation water, or obtaining the same production quantity using less amounts of irrigation water (Keshar, 2015). Economic efficiency, on the other hand, refers to obtaining the same quantity of production at lower cost of irrigation water, or obtaining more production quantity at the same cost of irrigation water. Generally speaking, production and economic efficiencies of irrigation water can be measured using a set of indicators, including productivity per cubic meter of irrigation water, net return per unit of irrigation water, return per pound invested in irrigation cost, and the ratio of irrigation costs to total costs (Shata et al., 2016).

Productivity per cubic meters of irrigation water

Data in Table 4 indicate that the highest value of production efficiency per unit of irrigation water for main agricultural crop grown at the country level is that associated with winter crops. Short and long clover ranked first with production efficiencies amounting to 12.21kg/m^3 and 10.5kg/m^3, followed by sugar beet, with production efficiency amounting to 8.4kg/m^3; onions, with production efficiency amounting to 6.8kg/m^3; wheat, with production efficiency amounting to 0.99kg/m^3; and finally broad beans, with production efficiency amounting to 0.55kg/m^3. Turning to summer crops, sugar cane ranked first with production efficiency per unit of irrigation water amounting to 3.99kg/m^3; followed by maize, which production efficiency amounts to 0.88 kg/m^3. Rice, sorghum, sunflower and cotton crops followed with production efficiencies amounting to 0.66kg/m^3, 0.88kg/m^3, 0.30kg/m^3 and 0.12kg/m^3, respectively, indicating that production efficiency per unit of irrigation water is higher for the winter season.

TABLE 3. Efficiency of Irrigation Water Flow and Distribution for Main Field Crops during 2012-2016 (billion m³).

Season	Crop	Efficiency of water flow and distribution from Aswan to the heads of irrigation canals (%)				Efficiency of water flow and distribution from the heads of irrigation canals to the fields (%)				Efficiency of water flow and distribution from Aswan to the fields (%)			
		Lower Egypt	Middle Egypt	Upper Egypt	Country level	Lower Egypt	Middle Egypt	Upper Egypt	Country level	Lower Egypt	Middle Egypt	Upper Egypt	Country level
Winter	Wheat	79.80	80.00	79.90	79.90	87.95	87.92	87.1	87.99	93.00	93.01	93.03	93.01
	Broad Bean	82.00	82.30	80.00	81.43	87.00	87.00	86.96	86.99	91.88	91.92	92.00	91.93
	Sugar beet	68.00	68.02	67.92	67.98	73.32	73.36	73.10	73.26	92.23	86.24	92.00	90.16
	Long cover	80.00	80.02	80.00	80.00	87.00	87.00	86.92	86.97	93.01	93.03	92.12	92.72
	Short clover	79.90	79.00	79.05	79.32	86.96	86.95	86.97	86.96	92.03	91.99	92.02	92.01
Average		77.94	77.87	77.37	77.73	84.45	84.45	84.21	84.43	92.43	91.24	92.23	91.97
Summer	Cotton	80.10	79.90	80.10	80.03	86.97	86.96	86.95	86.96	88.90	91.02	92.00	90.64
	Sugar can	79.60	78.20	69.50	65.77	87.97	87.94	87.95	87.95	93.00	93.05	93.00	93.02
	Maize	81.00	80.00	80.00	80.33	86.99	86.97	86.93	86.96	91.88	92.02	92.00	91.97
	Sorghum	80.50	80.00	79.00	79.83	87.94	87.95	87.96	87.95	92.00	91.66	92.00	91.89
	Rice	80.00	79.80	-	79.90	87.00	87.2	-	87.01	92.00	92.00	-	92.00
Average		80.24	79.58	77.15	77.17	87.37	87.40	87.45	87.37	91.56	91.95	92.25	91.90

Source: collected and calculated from Table 1.

TABLE 4. Productivity of irrigation water for main agricultural crops over the period 2012-2016 (in kg/m^3).

Season	Crop	Lower Egypt	Middle Egypt	Upper Egypt	Country level
Winter	Wheat	1.54	1.06	0.84	0.99
	Broad Beans	0.91	0.49	0.44	0.55
	Sugar beet	9.01	7.22	7.57	8.4
	Long Clover	11.08	6.24	6.59	10.5
	Short Clover	13.78	9.17	11.23	12.21
	Onions	8.25	5.09	5.21	6.8
Summer	Cotton	0.22	0.18	0.21	0.12
	Sugar cane	-	4.10	3.96	3.99
	Sorghum	0.99	0.72	0.57	0.88
	Maize	-	0.44	0.46	0.43
	Rice	0.71	-	-	0.66
	Sun flower	0.35	0.31	0.21	0.30

Source: The Central Agency for Public Mobilization and Statistics, Water Resources and Irrigation Bulletin, 2012-2016.

It can also be noticed from the same table that production efficiencies per unit of irrigation water for winter and summer crops grown in Lower Egypt are higher compared to Middle Egypt and Upper Egypt. On the other hand, production efficiencies per unit of irrigation water for winter and summer crops grown in Middle Egypt, namely, wheat, broad beans, sugar cane, maize and sunflower, are higher Compared to Upper Egypt. Production efficiency per unit of irrigation water for sugar beet, short clover, onion, cotton and sorghum crops grown in Upper Egypt recorded higher rates compared to Middle Egypt, as shown in Table 4, indicating that production efficiency per unit of irrigation water is higher in Lower Egypt compared to Middle and Upper Egypt.

Net revenue per unit of irrigation water

Data in Table 5 indicate that net revenue per water unit for winter and summer crops grown at the country level reached LE 18.75 and LE 3.89, respectively, indicating that net revenue per unit of water used in cultivating winter crops is LE 14.86, i.e., 382% higher compared to summer crops. In addition, net revenue per water unit for winter crops grown in Lower Egypt reached LE 21.64, with onion recording the highest value, estimated at LE 6.11, and sugar beet recording the lowest value, estimated at LE 1.53. As for summer crops, net revenue per water unit reached LE 2.61, with maize crop recording the highest value, estimated at LE 0.91, and sunflower recording the lowest value, estimated at LE 0.49. In Middle Egypt, net revenue per water unit for winter crops reached LE 14.49, with short clover recording the highest value, estimated at LE 4.22, and broad beans recording the lowest value, estimated at LE 0.86. Net revenue per water unit for summer crops grown in Middle Egypt reached LE 2.82, with sugar cane recording the highest value, estimated at LE 0.88, and cotton recording the lowest value, estimated at LE 0.27.

Results also indicate that net revenue per water unit for winter crops grown in Upper Egypt reached LE 12.97, with onion crop recording the highest value, estimated at LE 3.94, and broad bean recording the lowest value, estimated at LE 0.75. For summer crops, net revenue per water unit reached LE 2.21, with sugar cane recording the highest value, estimated at LE 0.9, and cotton crop recording lowest value, estimated at LE 0.07, as shown in the Table 5.

Return on investment

Data in Table 6 indicate that the highest net return per pound invested in irrigation is that recorded during the winter season for onion crop, where it reached LE 37.51 in Lower Egypt, LE 21.22 in Middle Egypt and LE 25.06 in Upper Egypt. On the other hand, sugar beet grown in Lower Egypt and broad beans grown in Middle and Upper Egypt realized the lowest value of net return per pound invested in irrigation, estimated at LE 8.01, LE 4.46 and LE 3.95, respectively.

As for the summer season, the highest values of net return to irrigation costs are those realized from cotton crop grown in Lower Egypt (LE

7.04), sugar cane grow in Middle and Upper Egypt (LE 9.71 and LE 9.87, respectively); whereas the lowest values are those realized by rice crop grown in Lower Egypt (LE 4.81), cotton crop grown in Middle Egypt (LE 3.17) and sunflower crop grown in Upper Egypt (LE 2.22).

Data also indicate that Lower Egypt realized the highest economic efficiency rates in growing wheat, broad beans, long clover, short clover, onion, cotton and maize compared to the Middle and Upper Egypt. Moreover, Middle Egypt realized the highest economic efficiency rate in growing sunflower crop compared to Lower and Upper Egypt. Finally, Upper Egypt realized the highest economic efficiency rate in growing sugar beet compared to Lower Egypt and Middle Egypt, and in growing sorghum crop compared to Middle Egypt, as shown in Table 6.

Rates of irrigation costs to total costs

It can be inferred from data in Table 7 that rates of irrigation costs to total costs has reached its maximum in the winter season, where it reached 21.58%, 19.07%, 14.64%, 9.73% and 9.49% for long clover, short clover, wheat, sugar beet and onions grown in Upper Egypt compared to Lower and Middle Egypt. (www.copmps.gove.eg)

TABLE 5. Net revenue per water unit for main crops over the period 2012 – 2016 (LE/m^3).

Season	Crop	Lower Egypt	Middle Egypt	Upper Egypt	Country level
Winter	Wheat	2.20	1.33	1.17	1.71
	Broad beans	1.73	0.86	0.75	1.49
	Sugar beet	1.53	1.40	1.59	1.49
	Long clover	4.29	3.03	2.39	3.60
	Short clover	5.78	4.22	3.13	5.22
	Onion	6.11	3.38	3.94	5.24
Summer	Cotton	0.60	0.27	0.07	0.53
	Sugar cane	-	0.88	0.90	0.90
	Maize	0.91	0.63	0.48	0.71
	Sorghum	-	0.47	0.57	0.58
	Rice	0.61	-	-	0.61
	Sunflower	0.49	0.57	0.19	0.56

Source: The Central Agency for Public Mobilization and Statistics, Water Resources and Irrigation Bulletin, 2012-2016.

TABLE 6. Return of the pound invested in irrigation for main agricultural crops over the period 2012-2016 (in LE).

Season	Crop	Lower Egypt	Middle Egypt	Upper Egypt
Winter	Wheat	8.24	5.37	4.92
	Broad beans	8.72	4.46	3.95
	Sugar beet	8.01	7.55	8.75
	Long clover	23.90	17.75	14.33
	Short clover	17.89	13.48	10.14
	Onion	37.51	21.22	25.06
Summer	Cotton	7.04	3.17	-
	Sugar cane	-	9.71	9.87
	Maize	6.48	4.63	3.53
	Sorghum	-	4.84	6.03
	Rice	4.81	-	-
	Sunflower	5.53	6.52	2.22

Source: Central Agency for Public Mobilization and Statistics, Water Resources and Irrigation Bulletin, 2012-2016.

TABLE 7. Rates of irrigation costs to total costs for main agricultural crops grown over period 2012-2016.

Season	Crop	Lower Egypt	Middle Egypt	Upper Egypt
Winter	Wheat	9.06	10.81	14.64
	Broad beans	5.82	8.37	9.73
	Sugar beet	8.41	12.14	12.39
	Long clover	14.46	18.47	21.58
	Short clover	12.84	18.08	19.07
	Onion	7.14	9.32	9.49
Summer	Cotton	3.93	4.74	-
	Sugar cane	-	9.45	10.35
	Maize	7.67	9.15	10.34
	Sorghum	-	8.20	8.81
	Rice	10.29	-	-
	Sunflower	6.49	7.75	8.73

Source: Central Agency for Public Mobilization and Statistics, Water Resources and Irrigation Bulletin (2012-2016).

As for the summer season, cotton crop grown in Middle Egypt recorded the highest economic efficiency rate (4.74%) compared to Lower Egypt; while sugar cane and sorghum crops grown in Upper Egypt recorded the highest rates (10.35% and 8.81%) compared to Middle Egypt. Maize and sunflower crops grown in Upper Egypt recorded the highest rates (10.34% and 8.73%) compared to Lower and Middle Egypt. Such results indicate that economic Upper Egypt realized the highest efficiency rate compared to Lower and Middle Egypt, as shown in table 7.

The most important results

Main findings indicate that amount of water lost while flowing from the dam to the field ranked first, where it reached 7.815m^3. Moreover, winter crops grown at the country level recorded the highest production efficiency per unit of irrigation water compared to summer crops. Onions and clover crops realized the highest net revenue per unit of water used in cultivating winter crops, while sugar cane and maize recorded the highest net revenue per unit of water used in cultivating summer crops in at the country level.

The highest return on investment at the level of winter crops grown in Lower, Middle and Upper Egypt was that realized from short clover, while cotton crop realized the highest return on investment at the level of summer crops grown in Lower Egypt, and sugar cane realized the highest return on investment at the level of Middle and Upper Egypt.

Findings regarding the rate of irrigation cost to total cost revealed that short clover realized the highest rate at the level of winter crops grown in Lower Egypt, while long clover realized the highest rate in Middle and Upper Egypt. As for the summer season, rice crop grown in Lower Egypt realized the highest rate, while sugar cane realized the highest rate at the level of Middle and Upper Egypt.

Conclusion

In 2016, water loss declined by 61.73%, 31.25% and 81.63%, compared to 2012.

- Lower Egypt ranked first in terms of water transfer and delivery efficiency, followed by Middle Egypt and Upper Egypt. Amount of water lost while flowing from the dam to the field ranked first, where it reached 7.815 billion m^3 , while the amount of water lost between the dam and heads of irrigation canals reached about 5.525 billion m^3, But between the heads of the canals and the field it reached about 2.288 billion m^3. also the results indicate that the long distance between Aswan dam and different irrigation stages leads to reduced efficiency of water transfer and delivery, in addition to increase water losses.

- Winter crops grown at the country level recorded the highest production efficiency per unit of irrigation water compared to summer crops, mainly due to higher temperature degree that lead to increased evaporation rate and the need to increase the number of irrigation times. Production efficiency per unit of irrigation water used to grow winter

and summer crops in Lower Egypt surpassed that recorded for Middle and Upper Egypt due to the higher temperature degree compared to Lower Egypt, in addition to the better soil fertility in Lower Egypt.

- Onions and clover crops realized the highest net revenue per unit of water used in cultivating winter crops, while sugar cane and maize recorded the highest net revenue per unit of water used in cultivating summer crops in at the country level. In addition, onions realized the highest net revenue per unit of water used in cultivating winter crops at the level of Lower and Upper Egypt, while short clover realized the highest net revenue per unit of water at the level of Middle Egypt. In addition, maize realized the highest net revenue per unit of water used in cultivating summer crops at the level of Lower Egypt, while sugar cane realized the highest net revenue per unit of water at the level of Middle and Upper Egypt.

- Short clover realized the highest return on investment at the level of winter crops grown in Lower, Middle and Upper Egypt, while cotton crop realized the highest return on investment at the level of summer crops grown in Lower Egypt, and sugar cane realized the highest return on investment at the level of Middle and Upper Egypt.

- Short clover realized the highest rate of irrigation cost to total cost at the level of winter crops grown in Lower Egypt, while long clover realized the highest rate in Middle and Upper Egypt. As for the summer season, rice crop grown in Lower Egypt realized the highest rate, while sugar cane realized the highest rate at the level of Middle and Upper Egypt.

Recommendation

- The government must perform periodic maintenance of irrigation water canals along various stages, especially in Upper Egypt.

- Increase the efficiency of irrigation water using through both the development of irrigation water systems.

- Reducing the cultivated area with crops that consume a lot of water, and imposition of fines for violators.

- Use the results of scientific research in generalizing the varieties which less water-consumption, besides using some ways to contribution to the reduction of the rates of water consumption, such as ground laser leveling.

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