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CAN IRRIGATION WATER SAVING OPTIONS COPE WITH WATER SCARCITY IN EGYPT?

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Abstract

Egypt is faced by potential water scarcity due to increasing water demand. Hence, agriculture is under stress due to increasing competition for available water. Water-saving efforts should be made, especially in the old lands where irrigation pressing problems prevails, to increase water use efficiency in agriculture. This study attempts to answer two questions: What would happen if water-saving technologies and practices were scaled-up over the old lands during (2013-2017)? What is the impact of using such technologies and practices on water consumption and efficiency and food security in Egypt? Quantitative methods of analysis were used for published data to address both questions; water consumption, saving, efficiency, and self-sufficiency. The results show that laser levelling ranked first in terms of water saving for most crops, followed by the technology package promoted by the Integrated Irrigation Improvement and Management Project, dry planting, deficit irrigation, and alternate furrow irrigation. Laser levelling, the technology package, deficit irrigation, dry planting, raised bed planting, and alternate furrow irrigation were the best alternatives from water productivity standpoints whereas, laser levelling, the technology package, deficit irrigation, and raised bed planting gained the highest economic efficiency for most crops. Using most of these technologies and practices improved the self-sufficiency.

Key words: water; technologies; practices; efficiency; Egypt

Introduction

Egypt is facing growing water demands versus limited water resources. The agricultural sector receives the lion's share of Egypt's water resources (80%), as compared to about 11%, 3% and 2% consumed by municipalities, industries and aquaculture farms, respectively (MWRI, 2010). Given limited land and water resources, an increase in agricultural productivity is necessary to enhance food supply and improve food security that put more pressure on Egypt's water resources.

Based on (Satoh and Aboulroos, 2017), the Egyptian irrigation system comprises a vast network beginning at the Nile as the main feeder and including thousands of canals at different levels up to the tenth-branching level and with a total length exceeding 32,000 km. The system consists of feeder canals (*Rayahs*), main canals and branch (secondary) canals. The system ends with privately owned *mesqas* (tertiary channels). Depending on the Nile water, Egypt's agriculture is under pressure to justify its use of water resource, which is scarce. Hence, agriculture in Egypt is under stress due to increasing competition for available water.

In spite of water scarcity, irrigation water losses occur due to poor distribution and management of irrigation water. Conveyance and distribution networks (mainly as a result of evaporation from exposed water surfaces) and on-farm practices are major factors contributing to this situation. Based on (MALR, 2009), water conveyance efficiency is estimated at about 70%, and the overall efficiency of irrigation is estimated at about 50%.

Consequently, water-saving efforts should be made to increase water use efficiency in agriculture. In this context, improvements of water use efficiency in the Nile system will largely depend on the efficient use of water in agriculture. Irrigation modernization is a key element to improve the efficiency of water conveyance and distribution systems whereas, agricultural technologies and practices improve the efficiency of on-farm systems at the farm/plot level.

A close look at (MALR, 2020) reveals that the old lands located within the valley and Delta contribute to more than about 80% of the total cultivated area in Egypt.

On the other hand, (Mostafa and Fujimoto, 2015) mentioned that irrigation of old lands is currently confronted with pressing problems, including inequitable water distribution at *mesqas* (distributary canals) and *marwas* (field ditches), excessive water losses at marwa level of about 9-17%, and misuse of irrigation water, .. etc. Besides, many water-saving technologies and practices are solely suitable for the old lands, as well.

In this sense, the key research questions addressed for this study is: What would happen if water-saving technologies and practices were scaled-up over the old lands during the period (2013-2017)? Besides, what is the impact of using such technologies and practices on water consumption and efficiency and food security in Egypt?

Yet, the objective of this study was to estimate water saving, water efficiency and food security of the edible main crops "with" and "without" using water-saving technologies and practices in the old lands during the period (2013-2017). Finally, the study attempts to reach some recommendations for the dissemination of water-saving technologies and practices.

In order to reach this objective, the study is divided into three further sections. In the second section, the methodological framework is provided whereas, results and discussions are presented in the third section. The last section concludes with some remarks and recommendations on policy implications.

Materials and Methods

Data source and analysis

The study was conducted in the old lands using data published by (MALR, 2020) and (CAPMAS, 2020) during the period (2013-2017) and the results of some technical studies and projects published by some agencies.

Analytical methods

Quantitative methods of analysis were used in order to reach the objective of this study. Water consumption and saving for the area cultivated by the main crops in the old lands were calculated. Besides, water efficiency is calculated in terms of productivity and profitability, and Self-Sufficiency Ratio (SSR), as well. The forms of these indicators are represented using the following formulas:

- *Water consumption for the area cultivated by a crop (m^3/area) = Quantity of water consumed (m^3/feddan) x cultivated area (feddan).*
- *Water saving for the area cultivated by a crop "with" the use of water-saving technologies and practices (m^3/area) = Water consumption for the area cultivated by a crop "with" the use of the technologies and practices (m^3/area) - Water consumption for the area cultivated by a crop "without" the use of the technologies and practices (m^3/area).*
- *Water consumption for the area cultivated by a crop (m^3/area) = the quantity of water consumed by a crop (m^3/feddan) x area cultivated by a crop (feddan).*
- *Water productivity (Kg/m^3) = Yield of main product (ton/feddan) ÷ Quantity of water consumed (m^3)*
- *Water profitability (L.E./m^3) = Gross margin per feddan (L.E.) ÷ Quantity of water consumed (m^3)*
- *Self-Sufficiency Ratio (SSR) for a crop (%) = Crop production (ton) ÷ Crop consumption (ton) x 100.*

Results and Discussion

The impact of using water-saving technologies prevailing in old lands

The technology package promoted by the Integrated Irrigation Improvement and Management Project (IIIMP): Based on (FAO, 2005), the project's key physical interventions include the introduction of continuous flow in place of the traditional rotation system; provision of new control structures on secondary canals, typically equipped with automatic downstream control gates for cross regulators and modular discharge control gates at head regulators; and introduction of single-point lifting at the tertiary level with *mesqas* converted to high level systems comprising either low-pressure pipelines or raised lined channels, with gravity turnouts to individual *marwas*. Complementary on-farm improvements include piping of *marwas*, use of hoses, gated pipes, improved furrows, laser land leveling where needed, and water management assistance.

The findings of IIIMP suggested that improved irrigation increased availability of water and augmented the yields of irrigated crops by 12-15% on average, reduced irrigation time by 50%

on average, reduced pumping cost by 30% on average, and improved the equity of water distribution at the *mesqa* level, as well (FAO, 2005). Wheat, clover (long season), rice, maize, and cotton were the crops prevailed in the study area where IIIMP was conducted.

Table 1 represents the sequence of what would happen if the technology package promoted by the IIIMP was scaled-up over the old lands during the period (2013-2017). Assuming this package was disseminated in the old lands to wheat, clover (long season), rice, maize, and cotton (for example) during that period it turns out that water saving would respectively reach about 2.02, 1.42, 2.49, 1.93, and 0.26 billion cubic meters (BCM).

In turn, this result contributes to improving water efficiency in terms of productivity and profitability per cubic meter for the five crops. Water productivity increased respectively from about 1.40, 9.55, 0.73, 1.25, and 0.30 kg/m^3 for the five crops to about 2.47, 16.82, 1.26, 2.20, and 0.56 kg/m^3. Moreover, water profitability increased respectively from about 1.87, 3.87, 0.66, 0.93, and 1.43 L.E./m^3 for the five crops to about 3.79, 7.13, 1.33, 2.10, and 3.33 L.E./m^3, as shown in Table 1.

Besides, the dissemination of this package contributes to increasing the average total production for these five crops by about 838, 4028, 394, 717, and 31 thousand tons, respectively. Consequently, disseminating this package increased the Self-Sufficiency Ratio (SSR) of the edible crops from about 50.25%, 101.23%, and 55.45% for wheat, rice, and maize, respectively to about 52.66%, 101.25%, and 58.10% in that order (Table 1).

Table 1. The impact of technology package promoted by IIIMP in the old lands during the period (2013-2017).

Crop	Cultivated area in old lands (000 feddan)	Water consumption (BCM/area)		Water saving "With" (BCM/area)	Water productivity (Kg/m^3)		Water profitability (L.E./m^3)		Self-Sufficiency Ratio (SSR) %	
		Without	With		Without	With	Without	With	Without	With
Wheat	2663	5.446	3.431	2.015	1.400	2.466	1.870	3.790	50.25	52.66
Clover (long season)	1219	3.835	2.416	1.419	9.547	16.821	3.871	7.131	-	-
Rice	1239	6.725	4.237	2.488	0.732	1.255	0.658	1.334	101.23	101.25
Maize	1986	5.224	3.291	1.933	1.248	2.200	0.930	2.098	55.45	58.10
Cotton	223	0.692	0.436	0.256	0.304	0.556	1.432	3.326	-	-

Source: calculated from (MALR, 2020), (CAPMAS, 2020), and (FAO, 2005).

Laser land leveling (LLL): Field experiments proved that precise land leveling has positive impacts on reducing surface water run-off to a minimum, and increasing the yields of irrigated crops (e.g. wheat, clover (long season), rice, maize, cotton, and sugarcane) by 10-25% on average and reduced irrigation time by 25-50% on average (MALR, 2003). It also saves pumping cost by 20%. The yield increase per feddan is a result of the better water uniformity and better crop distribution in the field. Precise land levelling is assumed to be repeated only after 3 years or 6 cropping cycles.

Table 2 represents the sequence of what would happen if land laser levelling was scaled-up over the old lands during the period (2013-2017). Assuming this technology was disseminated in the old lands to wheat, clover (long season), rice, maize, cotton, and sugarcane (for example) during that period it turns out that water saving would respectively reach about 2.04, 1.44, 2.52, 1.96, 0.26 and 1.12 BCM.

In turn, this result contributes to improving water efficiency in terms of productivity and profitability per cubic meter for the six crops. Water productivity increased respectively from about 1.40, 9.55, 0.73, 1.25, 0.30, and 4.60 kg/m^3 for wheat, clover (long season), rice, maize, cotton, and sugarcane to about 2.63, 17.95, 1.38, 2.35, 0.57, and 8.65 kg/m^3, as shown in Table 2. This can be attributed to the fact that using this technology reduces irrigation time by 25-50%, and increases crop yield by 10-25%. Moreover, water profitability increased respectively from about 1.87, 3.87, 0.66, 0.93, 1.43, and 1.28 L.E./m^3 for the six crops to about 164%, 103%, 186%, 224%, 193%, and 132% L.E./m^3. This is due to the fact that using this technology reduces irrigation time by 25-50%, in turn reduces the average variable costs of these crops, and increases crop yield by 10-25%, in turn increases the average net profit per feddan of these crops.

Besides, the dissemination of this technology to increasing the average total production for theses six crops by about 1333, 6409, 862, 1141, 36, and

2405 thousand tons, respectively. Consequently, disseminating this technology increased the SSR of the edible crops about 50.25%, 101.23%, and 55.45% for wheat, rice, maize, and sugar produced from sugarcane respectively to about 53.85%, 101.14%, 59.24%, and 61.99% in that order (Table 2).

Table 2. The impact of land laser levelling in the old lands during the period (2013-2017).

Crop	Cultivated area in old lands (000 feddan)	Water consumption (BCM/area)		Water saving "With" (BCM/area)	Water productivity (kg/m^3)		Water profitability (L.E./m^3)		Self-Sufficiency Ratio (SSR) %	
		Without	With		Without	With	Without	With	Without	With
Wheat	2663	5.446	3.404	2.042	1.400	2.631	1.870	4.946	50.25	53.85
Clover (long season)	1219	3.835	2.397	1.438	9.547	17.949	3.871	7.847	-	-
Rice	1239	6.725	4.203	2.522	0.732	1.376	0.658	1.885	101.23	101.14
Maize	1986	5.224	3.265	1.959	1.248	2.347	0.930	3.017	55.45	59.24
Cotton	223	0.692	0.433	0.260	0.304	0.572	1.432	4.199	-	-
Sugarcane	285	2.988	1.867	1.120	4.599	8.646	1.283	2.977	60.64*	61.99*

* for sugar.
Source: (MALR, 2020), (CAPMAS, 2020), and (MALR, 2003).

Cultivating short-duration varieties of rice*:* The Field Crops Research Institute (FCRI) developed some short-duration (early-maturing) rice varieties of 120-135 days, instead of 160 days for the traditional varieties. Such improved varieties include Giza 177, Giza 178, Sakha 101, Sakha 104, Sakha 106, Sakha 107, and Misr 1. Irrigation water consumption of these improved varieties reached about 4500-5200 m^3/feddan, compared to about 8000-8500 m^3/feddan for the traditional varieties.

According to (FCRI, 2019), cultivating short-duration rice varieties reduced irrigation water consumption by 30% on average.

Table 3 represents the sequence of what would happen if short-duration rice varieties were scaled-up over the old lands during the period (2013-2017). It turns out that water saving would respectively reach about 2.96, 2.62, 2.27, 2.62, 2.96, 3.78, and 2.62 BCM for Giza 177, Giza 178, Sakha 101, Sakha 104, Sakha 106, Sakha 107, and Misr 1.

In turn, this result contributes to improving water efficiency in terms of productivity and profitability per cubic meter for the seven varieties. Water productivity increased from about 0.73 kg/m^3 for the traditional rice varieties to about 0.74, 0.79, 0.74, 0.75, 0.79, 0.90, and 1.04 kg/m^3 for Giza 177, Giza 178, Sakha 101, Sakha 104, Sakha 106, Sakha 107, and Misr 1. Moreover, water profitability increased from about 0.66 L.E./m^3 for the traditional rice varieties to about 0.95, 1.12, 1.02, 1.02, 1.07, 1.22, and 1.73 L.E./m^3, respectively, as shown in Table 3.

Besides, the dissemination of this technology contributes to increasing the average total production for the seven rice varieties by about 219, 859, 719, 568, 568, 568, and 2602 thousand tons, respectively. Consequently, disseminating this technology increased the SSR of rice cultivated in the old lands during the period (2013-2017) from about 101.19%, 101.06%, 101.09%, 101.12%, 101.12%, 101.12%, and 100.83% for Giza 177, Giza 178, Sakha 101, Sakha 104, Sakha 106, Sakha 107, and Misr 1 in that order, as compared to about 101.23% for the traditional rice varieties (Table 3).

Table 3. The impact of cultivating short-duration varieties of rice in the old lands during the period (2013-2017).

Short-duration variety of rice	Water consumption (BCM/area)		Water saving "With" (BCM/area)	Water productivity (kg/m^3)		Water profitability (L.E./m^3)		Self-Sufficiency Ratio (SSR) %	
	Without	With		Without	With	Without	With	Without	With
Giza 177	9.588	6.625	2.964	0.732	0.737	0.658	0.946	101.23	101.19
Giza 178	9.588	6.973	2.615	0.732	0.792	0.658	1.121	101.23	101.06
Sakha 101	9.588	7.322	2.266	0.732	0.735	0.658	1.022	101.23	101.09
Sakha 104	9.588	6.973	2.615	0.732	0.750	0.658	1.020	101.23	101.12

Continuation of Table: 3									
Sakha 106	9.588	6.625	2.964	0.732	0.789	0.658	1.074	101.23	101.12
Sakha 107	9.588	5.811	3.777	0.732	0.900	0.658	1.224	101.23	101.12
Misr 1	9.588	6.973	2.615	0.732	1.042	0.658	1.729	101.23	100.83

Source: (MALR, 2020), (CAPMAS, 2020), and (FCRI, 2019).

The impact of using water-saving practices prevailing in old lands

Deficit irrigation*:* The results of on-farm trials by (Karrou et al., 2011) suggested that deficit irrigation saves a relatively high proportion of the water applied with no significant losses in the yields of wheat, clover (long season), maize, and cotton. These results confirm that we can produce nearly the same yield of wheat while saving up to 30% of the water traditionally used by the farmers. As for clover (long season), maize, and cotton, deficit irrigation reduced the seasonal water applied by the farmer respectively by about 44%, 30%, and 25% with a reduction in the yields not exceeding 12%, 8%, and 10% in that order.

Table 4 represents the sequence of what would happen if this practice was scaled-up over the old lands during the period (2013-2017). Assuming this practice was disseminated in the old lands to wheat, clover (long season), maize, and cotton (for example) during that period it turns out that water saving would respectively reach about 1.63, 1.69, 1.57, and 0.17 BCM.

In turn, this result contributes to improving water efficiency in terms of productivity and profitability per cubic meter for the four crops. Water productivity increased respectively from about 1.40, 9.55, 1.25, and 0.30 kg/m^3 for the four crops to about 1.97, 15.00, 1.64, and 0.37 kg/m^3. Moreover, water profitability increased respectively from about 1.87, 3.87, 0.93, and 1.43 L.E./m^3 for the four crops to about 2.83, 5.88, 1.18, and 1.58 L.E./m^3, as shown in Table 4.

Besides, the dissemination of this practice decreased the average total production of these four crops by about 107, 4395, 522, and 20 thousand tons, respectively. Consequently, disseminating this practice decreased the SSR of edible crops cultivated in the old lands during the period (2013-2017) from about 50.25%, and 54.45% for wheat, and maize, respectively to about 50.22%, and 54.35% in that order (Table 4).

Table 4. The impact of deficit irrigation in the old lands during the period (2013-2017).

Crop	Cultivated area in old lands (000 feddan)	Water consumption (BCM/area)		Water saving "With" (BCM/area)	Water productivity (kg/m^3)		Water profitability (L.E./m^3)		Self-Sufficiency Ratio (SSR) %	
		Without	With		Without	With	Without	With	Without	With
Wheat	2663	5.446	3.812	1.634	1.400	1.971	1.870	2.825	50.25	50.22
Clover (long season)	1219	3.835	2.148	1.687	9.547	15.003	3.871	5.880	-	-
Maize	1986	5.224	3.657	1.567	1.248	1.641	0.930	1.178	55.45	54.35
Cotton	223	0.692	0.519	0.173	0.304	0.365	1.432	1.575	-	-

Source: (MALR, 2020), (CAPMAS, 2020), and (Karrou et al., 2011).

Alternate furrow irrigation*:* Based on (Abdelhafez, 2010), field trials on alternate furrow irrigation technique increased the yields of irrigated crops by 10.6% on average, and reduced irrigation time by 15% on average, as well.

Table 5 represents the sequence of what would happen if this practice was scaled-up over the old lands during the period (2013-2017). Assuming this practice was disseminated in the old lands to wheat, sugar beet, maize, cotton, and sugarcane (for example) during that period it turns out that water saving would respectively reach about 0.82, 0.14, 0.78, 0.10, 0.45 BCM.

In turn, this result contributes to improving water efficiency in terms of productivity and profitability per cubic meter for the five crops. Water productivity increased respectively from about 1.40, 9.14, 1.25, 0.30, and 4.60 kg/m^3 for the five crops to about 1.82, 11.89, 1.62, 0.40, and 5.98 kg/m^3. Moreover, water profitability increased respectively from about 1.87, 0.97, 0.93, 1.43, and 1.28 L.E./m^3 for the five crops to about 2.79, 1.66, 1.54, 2.25, and 1.84 L.E./m^3, as shown in Table 5.

Generally, alternate furrow irrigation technique, besides saving considerable amounts of irrigation water, produced higher production rates and, thereby, increased the crop water productivity and profitability, as compared to the irrigation practices traditionally used by farmers. Besides, the dissemination of this practice contributes to increasing the average total production of these five crops by about 807, 911, 691, 22, and 1457 thousand tons, respectively. Consequently, disseminating this practice increased the SSR of edible crops cultivated in the old lands during the period (2013-2017) from about 50.25%, 98.26%, 55.45%, and 60.64% for wheat, sugar produced from sugar beet, maize, and sugar produced from sugarcane, respectively to about 52.59%, 98.29%, 58.03%, and 85.87% in that order (Table 5).

Table 5. The impact of alternate furrow irrigation in the old lands during the period (2013-2017).

Crop	Cultivated area in old lands (000 feddan)	Water consumption (BCM/area)		Water saving "With" (BCM/area)	Water productivity (kg/m^3)		Water profitability ($L.E./m^3$)		Self-Sufficiency Ratio (SSR) %	
		Without	With		Without	With	Without	With	Without	With
Wheat	2663	5.446	4.629	0.817	1.400	1.821	1.870	2.787	50.25	52.59
Sugar beet	399	0.942	0.800	0.141	9.138	11.891	0.967	1.663	98.26*	98.29*
Maize	1986	5.224	4.44	0.784	1.248	1.624	0.930	1.539	55.45	58.03
Cotton	223	0.692	0.588	0.104	0.304	0.396	1.432	2.254	-	-
Sugarcane	285	2.988	2.54	0.448	4.599	5.984	1.283	1.836	60.64*	85.87*

* for sugar.
Source: (MALR, 2020), (CAPMAS, 2020), and (Abdelhafez, 2010).

Long furrow irrigation*:* The results of on-farm trials confirm the potential of alternate furrow irrigation technique for increasing the yields of irrigated crops by 7% on average and reduced irrigation time by 2.5% on average (Abdelhafez, 2010).

Table 6 represents the sequence of what would happen if this practice was scaled-up over the old lands during the period (2013-2017). Assuming this practice was disseminated in the old lands to wheat, sugar beet, maize, cotton, and sugarcane (for example) during that period it turns out that water saving would respectively reach about 0.14, 0.02, 0.13, 0.02, and 0.08 BCM.

In turn, this result contributes to improving water efficiency in terms of productivity and profitability per cubic meter for the five crops. Water productivity increased respectively from about 1.40, 9.14, 1.25, 0.30, and 4.60 kg/m^3 for the five crops to about 1.54, 10.03, 1.37, 0.33, and 5.05 kg/m^3. Moreover, water profitability increased respectively from about 1.87, 0.97, 0.93, 1.43, and 1.28 $L.E./m^3$ for the five crops to about 2.22, 1.27, 1.18, 1.77, and 1.49 $L.E./m^3$, as shown in Table 6.

Besides, the dissemination of this practice contributes to increasing the average total production of these five crops by about 533, 601, 456, 14, and 962 thousand tons, respectively. Consequently, disseminating this practice increased the SSR of edible crops cultivated in the old lands during the period (2013-2017) from about 50.25%, 98.26%, 55.45%, and 60.64% for wheat, sugar produced from sugar beet, maize, cotton, and sugar produced from sugarcane, respectively to about 51.90%, 98.57%, 57.36%, and 61.99% in that order (Table 6).

The impact of long furrow irrigation in the old lands during the period (2013-2017).

Crop	Cultivated area in old lands (000 feddan)	Water consumption (BCM/area)		Water saving "With" (BCM/area)	Water productivity (kg/m^3)		Water profitability ($L.E./m^3$)		Self-Sufficiency Ratio (SSR) %	
		Without	With		Without	With	Without	With	Without	With
Wheat	2663	5.446	5.310	0.136	1.400	1.536	1.870	2.223	50.25	51.90
Sugar beet	399	0.942	0.918	0.024	9.138	10.029	0.967	1.269	98.26*	98.57*
Maize	1986	5.224	5.093	0.131	1.248	1.370	0.930	1.182	55.45	57.36
Cotton	223	0.692	0.675	0.017	0.304	0.334	1.432	1.768	-	-
Sugarcane	285	2.988	2.913	0.075	4.599	5.047	1.283	1.486	60.64*	61.99*

* for sugar.
Source: (MALR, 2020), (CAPMAS, 2020), and (Abdelhafez, 2010).

Raised bed planting: The findings of on-farm trials by (Karrou et al., 2011) on wheat, maize, and cotton suggested that raised bed planting increased the yields of these crops by 10% on average, reduced water applied by the farmers by about 25% on average, and reduced the variable costs by about 30% on average, as well.

Table 7 represents the sequence of what would happen if this practice was scaled-out over the old lands during the period (2013-2017). Assuming this practice was disseminated in the old lands to wheat, maize, and cotton (for example) during that period it turns out that considerable amounts of irrigation water would be saved of about 1.41, 1.18, and 0.16 BCM, respectively.

In turn, this result contributes to improving water efficiency in terms of productivity and profitability per cubic meter for these three crops. Water productivity increased respectively from about 1.40, 1.25, and 0.30 kg/m^3 for the three crops to about 2.08, 1.77, and 0.44 kg/m^3. Moreover, water profitability increased respectively from about 1.87, 0.93, and 1.43 L.E./m^3 for the three crops to about 3.82, 2.18, and 3.05 L.E./m^3, as shown in Table 7.

Besides, the dissemination of this practice contributes to increasing the average total production of these three crops by about 762, 652, and 20 thousand tons, respectively. Consequently, disseminating this practice increased the SSR of edible crops cultivated in the old lands during the period (2013-2017) from about 50.25%, and 55.45% for wheat, and maize, respectively to about 52.47% and 57.92% in that order (Table 7).

The impact of raised bed planting in the old lands during the period (2013-2017).

Crop	Cultivated area in old lands (000 feddan)	Water consumption (BCM/area)		Water saving "With" (BCM/area)	Water productivity (kg/m^3)		Water profitability (L.E./m^3)		Self-Sufficiency Ratio (SSR) %	
		Without	With		Without	With	Without	With	Without	With
Wheat	2663	5.446	4.036	1.411	1.400	2.078	1.870	3.818	50.25	52.47
Maize	1986	5.224	4.049	1.175	1.248	1.772	0.930	2.183	55.45	57.92
Cotton	223	0.692	0.532	0.160	0.304	0.436	1.432	3.053	-	-

Source: (MALR, 2020), (CAPMAS, 2020), and (Karrou et al., 2011).

Dry planting of clover (long season) and rice: According to (Abdelhafez, 2010), field trials on dry planting of clover (long season) save water consumption of both crops by about 420 and 1800-2000 m^3/feddan, respectively with yield loss in rice by about 9-15% (4 ton/feddan, in average), as well.

Table 8 represents the sequence of what would happen if this practice was scaled-out over the old lands during the period (2013-2017). Assuming this practice was disseminated in the old lands to clover (long season), and rice (for example) during that period it would help to save appreciable volumes of water reaching about 0.51, and 5.17 BCM, respectively and, above all, it would improve water efficiency in terms of productivity and profitability per cubic meter for both crops. Water productivity increased respectively from about 9.55, and 0.73 kg/m^3 for clover (long season), and rice to about 11.57, and 1.17 kg/m^3. Moreover, water profitability increased respectively from about 3.87, and 0.66 L.E./m^3 for clover (long season), and rice to about 4.79, and 1.56 L.E./m^3, as shown in Table 8

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Table 8. The impact of dry planting of clover (long season) and rice in the old lands during the period (2013-2017).

Crop	Cultivated area in old lands (000 feddan)	Water consumption (BCM/area)		Water saving "With" (BCM/area)	Water productivity (kg/m^3)		Water profitability (L.E./m^3)		Self-Sufficiency Ratio (SSR) %	
		Without	With		Without	With	Without	With	Without	With
Clover (long season)	1219	3.835	3.323	0.512	9.547	11.568	3.871	4.788	-	-
Rice	1239	9.588	4.416	5.172	0.732	1.169	0.658	1.556	101.23	101.15

Source: (MALR, 2020), (CAPMAS, 2020), and (Abdelhafez, 2010).

Dry planting of clover (long season) with land laser levelling*:* The results of on-farm trials confirm the potential of dry planting of clover (long season) with land laser levelling for

increasing its yield by 12% on average and reduced irrigation time by 13% on average (Abdelhafez, 2010).
Table 9 represents the sequence of what would happen if this practice was scaled-out over the old lands during the period (2013-2017). Assuming this practice was disseminated in the old lands to clover (long season) during that period it turns out that water saving would reach about 0.51 BCM.
In turn, this result contributes to improving water efficiency in terms of productivity and profitability per cubic meter for this crop. Water productivity increased from about 9.55 kg/m^3 to about 12.34 kg/m^3. Moreover, water profitability increased from about 3.87 L.E./m^3 to about 5.38 L.E./m^3, as shown in Table 9.

Table 9. The impact of dry planting of clover (long season) with land laser levelling in the old lands during the period (2013-2017).

Crop	Cultivated area in old lands (000 feddan)	Water consumption (BCM/area)		Water saving “With” (BCM/area)	Water productivity (kg/m^3)		Water profitability (L.E./m^3)		Self-Sufficiency Ratio (SSR) %	
		Without	With		Without	With	Without	With	Without	With
Clover (long season)	1219	3.835	3.323	0.512	9.547	12.340	3.871	5.376	-	-

Source: (MALR, 2020), (CAPMAS, 2020), and (Abdelhafez, 2010).

Conclusion

The economic exploitation of agricultural resources, especially for water resources, is one of the main goals of the Egyptian Sustainable Agricultural Development Strategy towards 2030 (SADS) to achieve sustainable agricultural development. Despite the limited water resources, but the efficiency of water irrigation use is low due to the immense volume of water losses through surface irrigation system, as well as the low efficiency of surface irrigation system as a result of excessive use of irrigation water. This study has analyzed the impact of using water-saving technologies and practices in the old lands during the period (2013-2017).
Empirical findings showed that land laser levelling, the technology package promoted by IIIMP, deficit irrigation, dry planting, raised bed planting, and alternate furrow irrigation were the best alternatives from water productivity standpoints whereas, land laser levelling, the technology package promoted by IIIMP, deficit irrigation, and raised bed planting gained the highest economic efficiency for most crops.
Based on these results, farmers in the old lands are encouraged to adopt land laser levelling, the technology package promoted by IIIMP, deficit irrigation, dry planting, raised bed planting, and alternate furrow irrigation to get more income and maintain efficient use of water.
Moreover, the results from this study confirm that land laser levelling ranked first in terms of contributing to water savings for most crops, followed by the technology package promoted by IIIMP, dry planting, deficit irrigation, and alternate furrow irrigation. Moreover, empirical results indicate that using most of these water-saving technologies and practices improved the Self-Sufficiency Ratio (SSR) of the crops in the study area. Therefore, sufficient farmer’s access to knowledge and improving communication channels between farmers and agricultural extension and skilled extension personnel on management practices are of high importance to transfer such promising techniques to farmers.
Finally, these recommendations are supported not only by our findings but also by the objectives of the National Agricultural Sustainable Development Strategy 2030 targeting improving water-use efficiency in irrigated agriculture, rationalizing of water and land use through the introduction of new short-duration varieties of rice, and introduction of agricultural management technologies and practices in order to improve agricultural production systems (MALR, 2009). Moreover, these recommendations are in perfect concordance with the cornerstone for the Water Resources Strategy 2050 targeting the modernization of irrigation infrastructure through irrigation improvement package in old lands, and improve on-farm water management technologies e.g. land laser leveling, and short-age rice varieties (MWRI, 2010).

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