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Economic study for the impact of establishing water users associations in the improved areas – case study: El-Atf canal – Egypt

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ABSTRACT

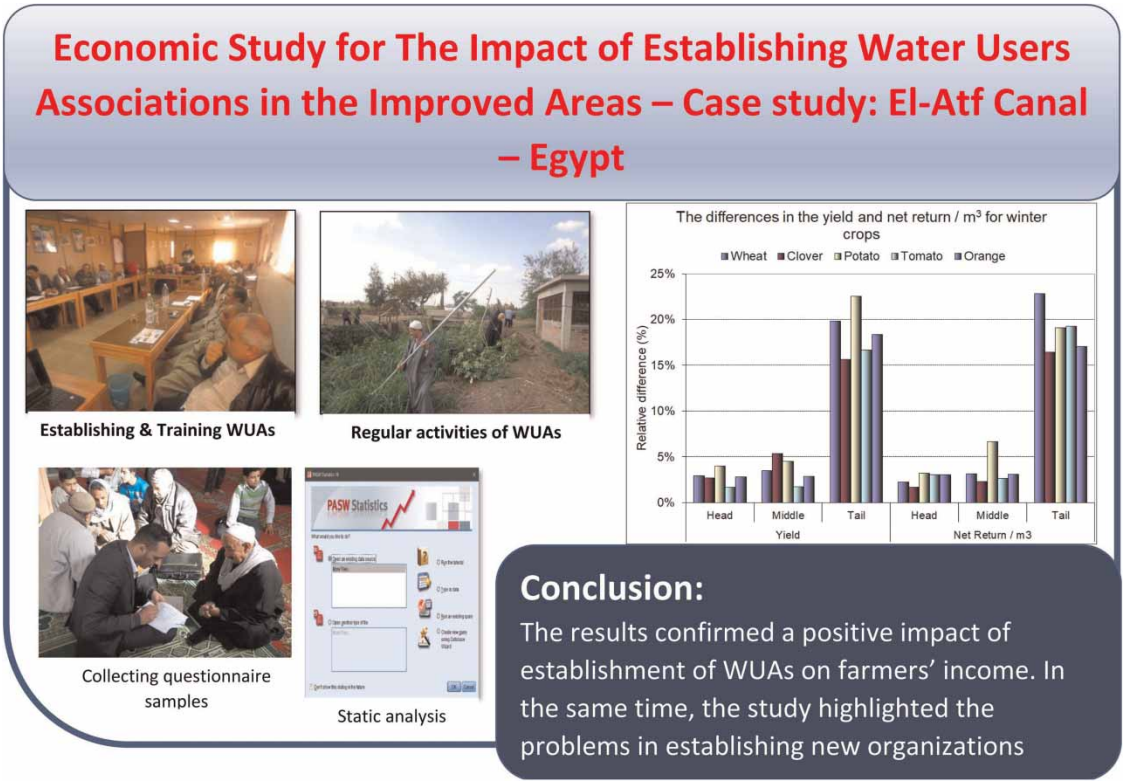
Water users associations (WUAs) were established in Egypt to help in rational distribution of irrigation water, in the operation and the maintenance of the improved Mesqas, and in solving the disputes between farmers. This study aimed to assess the economic impact of establishing water users' associations on improving farmers' income through increasing productivity and decreasing irrigation cost. The current study was conducted in an improved canal in El-Menoufia irrigation directorate (El-Atf canal), and it assessed the expected roles of WUAs boards in serving different members through identifying problems and giving suggestions to overcome them, the obstacles of establishing new associations and the impact of WUAs activities on improving the equity of water distribution. The economic impact of WUAs was assessed through comparing the net return per unit area and per unit of water, and water productivity in WUAs fields with traditional fields. The results referred to significant increase in crops yield with a decrease in total cost. As a result, there was an increase in the net return per unit of area and per unit of water. The differences were noticeable at tail end reaches due to the irrigation problems at these reaches before the establishment of WUAs.

Key words: equity of water distribution, improved area, irrigation cost, maintenance, productivity, water users associations

HIGHLIGHTS

- Assess the economic impact of establishing water users associations.
- Increasing the productivity of farms.
- Assessed the expected roles of WUAs' boards in serving different members through identifying problems and giving suggestions to overcome.
- An increase in the net return per unit of area and per unit of water.
- Decreasing the irrigation cost.

GRAPHICAL ABSTRACT



INTRODUCTION

The Irrigation Improvement Project (IIP) was a mega project that was implemented to improve water use efficiency and water productivity in the old lands in Egypt. The project has three main components. The first component is the constructing of single lifting points at the heads of different Mesqas connected with a system of pipelines and valves to replace open Mesqas and farmers' pumps. The second is the modification of the water distribution system in branch canals. It was planned to replace the rotation system with the continuous flow system and applying an internal rotation between improved Mesqas inside the branch canals. The third component is the establishment of water users associations (WUAs). The expected roles of these associations are related to the operation and the maintenance of the improved system. The roles also include scheduling the irrigation inside the improved Mesqas and solve the conflicts between farmers.

Based on Eefje Aarnoudse *et al.* (2018), introducing new water organizations as alternative to public institutions started from the late 1970s to ensure the effective performance of irrigation systems. They added that shifting from state to user management was often accompanied with high expectations. However, early assessments of the impact of WUA management on the performance of irrigation systems showed ambiguous results, partly because different kinds of indicators were used to assess WUA performance. Other assessments referred to the weak performance of WUAs. Bashier *et al.* (2014) studied the performance of WUAs in one of the command areas in Sudan, and he stated that WUAs are technically and financially poor. WUAs have low technical knowledge and insufficient equipment, and at the same time, there is not enough finance to take the full responsibilities of managing the system. Molle & Rap (2013) mentioned some weakness for WUAs in Egypt based on APP results (2007). These weaknesses included the extremely low participation of WUAs in water management, the poor understanding of the possibilities to take action, the low coordination between WUAs and Ministry of Water Resources and Irrigation (MWRI) field staff and the felt need of clear instructions from higher levels.

Other authors referred to successful stories in the improved areas operated by WUAs, Dutta (2013), studied water management in the improved areas in Egypt, and based on him, some farmers pointed out the impact of collective pumping on interpersonal relationships. Based on the same research, IIP has brought the farmers

together as everyone needs to cooperate for the rotation now. The study also referred to the impact of new water organizations in the equity of water distribution. Based on discussions with farmers, many farmers at the head of the Marwa used to take more water and the farmers at the end did not get enough water. After the implementation of the IIP, everyone gets the same amount of water as the duration is fixed for every farmer.

Regarding the reasons behind the success or the failure of WUAs, some authors connected the failure or success of WUAs with their type and size. Plusquellec (2002) distinguished between business-type organizations and social-type organizations. Business-type organizations almost replace the governmental agencies in their roles. Social type organizations are multi-tiered organizations that have introduced a possible solution for the management of large-scale irrigation schemes with a large number of small farmers. Plusquellec stated that business-type WUAs had successful stories in some countries, while social WUAs were found to be weak or paper associations. Another factor was the size of the irrigation system. Regarding the size, Hvidt (1998) mentioned that there was a big difference in the success of WUAs between small command areas (private or community-based systems) and large command areas and he stated that the success was very limited in some large command areas. Based on Zhang *et al.* (2013), WUAs with a relatively small number of member households, a large number of Water Users Groups, and a low pressure on the available water resources are more likely to achieve relatively high water use efficiencies.

Eefje Aarnoudse *et al.* (2018) divided the factors that influence WUA management to four categories with different items in each category. The first category is the socioeconomic and political setting, with different items such as economic development and government water policies. The second category is the water resource system, with items such as water availability, size of the irrigation system and irrigation infrastructure. The third category is governance, with items such as government organizations and property rights. The last category is the users, with items such as number of users, socioeconomic attributes and leadership.

Assessing the impact of irrigation reforms and the establishment of WUAs on farmers' economic conditions in the improved areas has provoked different and sometimes contradictory opinions in the literature due to different items that affect crop yields and in consequence, farmer' economic conditions. Dutta (2013) stated that the impact of the project on the crop yield could not be quantified. Garces-Restrepo *et al.* (2007) stated, 'It is not possible to identify distinctively the effects of the reforms in the irrigation sector in crop yields from the many other factors that may affect their seasonal value positively or negatively.' However, the authors mentioned that the majority of the farmers whom they met in the study reported an increase in crop yields. The authors also mentioned that there was no decrease or stagnation in crop yields in areas where water management had been taken up by farmers' organizations. Dawit Mekonnen *et al.* (2015) found that the presence of WUAs could increase the productivity by 10% at tail-end reaches and by 8% for those who were depending completely on groundwater.

RESEARCH PROBLEM

WUAs are facing different problems and obstacles that diminish their ability to fulfill their duties toward confronting the incorrect irrigation practices by different farmers. These problems and obstacles also affecting the ability of WUAs in solving the disputes between farmers, and guide them for optimal use of irrigation water, for maintaining the irrigation system and cooperating in its maintenance. Farmers are facing other problems in establishing their associations.

According to the above, the research problem can be stated as undefined obstacles of establishing WUAs. Such problems affect the performance of existing WUA and farmers' decisions in cultivating their fields as well as creating new WUAs. On the other hand, it is important to highlight the positive impact of WUAs on the farmers and specifically on increasing their income.

AIM

This study aimed to:

- Assess the economic impact of establishing WUAs on improving farmers' income through increasing the productivity and decreasing the irrigation cost.
- Identify the problems that make it harder for WUAs to fulfill their commitment, and the problems that are facing farmers in establishing new WUAs.
- Assess the performance of the established associations.

The assessment items include the ability of WUAs to improve the income level of different farmers, their performance in solving irrigation problems that are facing farmers, enhancing the equitable distribution of water between farmers, and participating in the operations and maintenance of irrigation system.

METHODS

The methodology depends on descriptive and quantitative statistical analysis of different economical elements to evaluate different indicators and different economical relationships as follows:

- The data was analyzed to investigate: the tasks performed by WUAs' boards to serve the members of their associations; the problems that hinder WUAs' boards from performing their expected roles; the suggestions to overcome these problems; and the economic impact of establishing WUAs in the improved areas. The items of these categories were assessed from the opinions of regular members and the boards of different WUAs and the results presented the relative importance of each item. The data also contained farmers' opinions about the obstacles they are facing while establishing new WUAs.
- Regarding the economic impacts, the study performed some economic efficiency standards for fields owned by farmers who are members of WUAs and fields owned by farmers who are not members of WUAs in 221 Mesqas spread on El-Atf canal using a 't' test for the difference between two means.
- Regarding data sources, the study depended on collecting samples of a questionnaire that was designed for this purpose. The samples were collected from El-Atf canal (El-Monofiya irrigation directorate) at the end of 2019 to represent the seasons of 2018–2019.
- The questionnaire contained different items related to costs, yield and income for different cultivated crops in the study area. Total collected samples numbered 240. The samples were distributed equally between WUA and non-WUA members, Therefore, 120 samples were collected from WUA members and 120 samples were collected from non-WUA members. In each reach (head, middle and tail-end), 40 samples were collected randomly along the reach.
- Two circular meetings were held with the boards of WUAs to discuss different problems that are facing WUAs and the suggested solutions for these problems, and to discuss the obstacles that are facing farmers while establishing new WUAs.
- In addition, the study depended on secondary data represented in the bulletins of the Economic Affairs Sector of the Ministry of Agriculture and Land Reclamation, and in the annual bulletins of Irrigation and Water Resources Statistics.

RESULTS AND DISCUSSION

Results

The role of WUAs in serving their members

Table 1 shows the relative importance of WUAs activities from the viewpoint of the WUAs members and boards.

The most important task was solving water distribution problems and resolving conflicts among farmers, with relative importance equaling 95%. Organizing periodic meetings for workflow came in second place with relative importance value equaling 93.3%. Determining the items of the association's budget and presenting financial matters to WUA members came in third place with a relative importance of 92.5%.

The activities that had importance order from fourth to eighth were participating in the maintenance of the irrigation canal, receiving improved Mesqas and canals, providing the required irrigation water for the different reaches of the canal, reducing the irrigation costs, and communicating with the administration to solve the irrigation problems. The relative importance of these activities was 90.8, 87.5, 85, 82.5 and 80%, respectively.

Preparing an annual maintenance plan and transferring the experiences from the engineers to the farmers had the same importance order, with a relative importance value equaling 77.5%. Training farmers on saving irrigation water came in tenth place, with a relative importance value equaling 72.5%.

The least two importance tasks were the coordination with other associations for distributing water between Mesqas and helping farmers sell their crops with relative importance values equaling 70.8 and 52.5% respectively.

Factors diminishing the influence of WUA

Table 2 shows factors that limit the influence of WUAs and preventing them from fulfilling their duties. The most serious factor was the absence of an explicit law that makes members pay for the expenses with a score of 100%.

Table 1 | Relative importance for different WUA activities

No	Item	Duplicates	Score (%)
1	Providing the required amount of the irrigation water for different farmers along the canal in the required time	102	85.0
2	Decreasing the irrigation cost	99	82.5
3	Solving irrigation disputes between farmers	114	95.0
4	Reporting irrigation problems to decision makers	96	80.0
5	Helping farmers in purchasing agricultural inputs and selling their crops	63	52.5
6	Participation in the maintenance of the irrigation canals	109	90.8
7	Receipting the improved Mesqas	105	87.5
8	Preparing the annual plan for operation and maintenance	93	77.5
9	Arranging regular meetings for workflow	112	93.3
10	Coordination with other WUAs for applying internal rotation inside the canals	85	70.8
11	Defining and presenting the WUA's budget elements	111	92.5
12	Receiving the required training from water steering engineers and transferring the gained experience to farmers	93	77.5
13	Guiding farmers to improve water use efficiency	87	72.5
Total number of samples		120	

Source: Compiled and calculated from the questionnaire.

Table 2 | Relative importance for different factors that limit the influence of WUAs

No	Item	Duplicates	Score (%)
1	Lack of obligatory law for paying expenses.	120	100.0
2	Lake of coordination between WUAs regarding applying the internal rotation inside the irrigation canals.	99	82.5
3	Lack of technical expertise.	87	72.5
4	Lack of training the members for technical works.	85	70.8
5	The lack of financial resources to carry out the required maintenance.	112	93.3
6	High maintenance cost.	96	80.0
7	Insufficient funds for WUAs.	114	95.0
8	Non-commitment of members to paying the maintenance expenses.	109	90.8
9	Weak coordination between different irrigation and agricultural agencies.	81	67.5
Total number of samples		120	

Source: Compiled and calculated from the questionnaire.

The second important factor was the lack of private funding with a score of 95%. The third important factor was the lack of financial resources for the maintenance with a score of 93.3%. The important tasks ranked from fourth to eighth were the lack of commitment from members to pay for maintenance costs, the lack of cooperation between different WUAs for water distribution, high maintenance cost, lack of technical expertise, and the difficulty in training members on technical works with rates equal 90.8, 82.5, 80, 72.5, 70.8%, respectively. The least important factor, from the viewpoint of farmers was the lack of coordination between different irrigation and agricultural agencies, with a score of 67.5%

Some suggestions for WUAs to overcome their weakness

Table 3 shows farmers' opinions to overcome the problems that hinder the WUAs from fulfilling the required role. The table has the relative importance of each suggestion based on the farmers who have this suggestion. The suggestion that ranked first was the necessity to provide the necessary funding and providing permanent

Table 3 | Relative importance for farmers' opinions to overcome difficulties that limit the influence of WUAs

No	Item	Duplicates	Score (%)
1	Activating the state's control over the associations of WUAs	60	50.0
2	Some authority being given to WUAs' boards to arrange the irrigation between farmers	96	80.0
3	Providing the necessary funds for WUAs	114	95.0
4	Increasing the opening days in the rotation system and making its information available for farmers	112	93.3
5	Imposing additional fees on each fertilizer sack for the benefit of WUAs	87	72.5
6	Providing a permanent headquarter for each WUA along the canal	114	95.0
7	Increasing the connection and continuous cooperation between irrigation and agricultural officials with WUAs to solve their problems	105	87.5
8	Continuous training for technical members and maintenance officials in WUAs	87	72.5
Total number of samples		120	

Source: Compiled and calculated from the questionnaire.

headquarters for each of the WUA along the canal. The scores of these suggestions were 95%. The suggestion that ranked second was the increase of 'on' days in the rotation and providing the associated information about these rotations to the farmers, with a score 93.3%. The cooperation between WUAs and irrigation and agricultural administrators was the third-most important suggestion with a score equaling 87.5%. The fourth important factor was providing the required authorities for WUAs to arrange the irrigation between farmers with a score equaling 80%. Imposition of additional fees on each fertilizer sack for the benefit of WUAs and the continuous training of technical members and maintenance officials came in the penultimate rank with a relative importance of about 72.5%. The activation of state control over WUAs ranked last with relative importance equaling 50%.

Obstacles face farmers in establishing new associations

Table 4 presents the obstacles that farmers face in establishing new associations with the associated relative importance scores. The table has the following results:

- 85.8% of non-WUA members believed that the administrative obstacles represented in the legal rules and procedures were important obstacles.
- 90.8% believed that the organizational obstacles represented in organizing work among members, boards, and irrigation and agricultural administrators were important obstacles.
- 72.5% believed that the technical obstacles represented in the limited availability of trained and qualified technicians to maintain the system are important obstacles.
- 95% believed that funding obstacles represented in providing necessary funds for associations to carry out their duties are important obstacles.

Table 4 | Relative importance for obstacles that farmers face in establishing new associations

No	Item	Duplicates	Score (%)
1	Administrative obstacles	103	85.8
2	Organizational obstacles	109	90.8
3	The technical obstacles	87	72.5
4	Funding obstacles	114	95.0
Total number of samples		120	

Source: Compiled and calculated from the questionnaire.

The impact of WUAs activities of improving equity of water distribution

Table 5 presents the following results

Table 5 | Comparing the current situation after the establishment of WUAs with old situations

No	Item	Situations improved		No change	
		Duplicates	Score (%)	Duplicates	Score (%)
1	Equitable distribution of the irrigation water between members	114	95.0	6	5.0
2	Equitable distribution of the irrigation water between head and tail-end regions	114	95.0	6	5.0
3	Applying an internal rotation system between members	117	97.5	3	2.5
4	The maintenance of the irrigation canal	102	85.0	18	15.0
Total number of samples		120		120	

Source: Compiled and calculated from the questionnaire.

- About 95% of the members of the WUAs stated that the fair distribution of water among the members of the associations in general, as well as the fair distribution of water among the members whose lands are located at the end or the beginning of the canal, have been achieved after joining the WUAs, while about 5% reported that the situation has not changed.
- About 97.5% of the members of the WUA stated that the water distribution system among the association's members is better after joining the WUAs than the previous situation, compared to about 2.5% who reported that the situation has not changed.
- About 85% of the members of the water user associations stated that the irrigation canal maintenance is better after joining the water user associations than the previous situation, while about 15% said that the situation has not changed.

The economic impacts of establishing WUAs

Winter season. Table 6 presents the results regarding the economic impacts of WUAs during winter season. The results were collected for five winter crops (wheat, clover, potato, orange and tomato). Five indicators were used to calculate the economic impact, which are yield, total cost per feddan (0.42 ha), net return per feddan, water productivity, and return of a unit of water.

The cultivated areas with previous crops were 649, 509, 463, 12.0, and 46.0 feddans respectively at the head and middle reaches. At the tail-end reach, the cultivated areas with previous crops were 865, 679, 16.3, 61, and 618 feddans respectively.

As a general conclusion:

- For all indicators, the results referred to an obvious change between members and non-members of WUAs, and the differences were statistically significant.
- The highest differences were at the tail-end reach, which represents around 40% of the cultivated lands with the investigated crops. This makes sense as the improvement has a higher impact at the tail-end reach due to the accumulation of water crises in these reaches.

Table 6 presents the results for the five indicators at the head, middle and tail-end reaches of the Al-Atf canal. Figure 1 depicts the difference ratios for the yield and the net return for the unit volume of water for different reaches in the canal.

Regarding the yield of the unit area at the tail end, the differences in yield between members' and non-members' farms for wheat, alfalfa, winter potato, winter tomato, and orange crops were 0.51, 5.0, 2.3, 1.65 and 2.5 tons/feddan respectively. At the middle reach, the differences in yield between members' and non-members' farms were 0.105, 1.9, 0.55, 0.3, and 0.3 tons/feddan for these crops respectively. At the head reach, the differences in yield between members' and non-members' farms were 0.09, 1.0, 0.5, 0.3, and 0.3 tons/feddan for these crops respectively.

Regarding total expenses, the differences in the expenses for wheat, alfalfa, winter potatoes, winter tomatoes, and oranges were 280, 240, 280, 300, and 240 L.E. (Egyptian pounds)/feddan respectively at the tail end. The differences were 151, 150, 130, 150, and 130 L.E./feddan at the middle reach and 131, 100, 90, 100, and 100 L.E./feddan at the head reach for the same crops. As there was a difference in the cultivated areas between winter crops, summer crops, and oranges (permanent crops), the weighted average abundance values were 186.2 L.E./feddan for winter crops, and 165.0 L.E./feddan for orange (Table 8).

Table 6 | Economic indicators for winter crops according to the farm site on the irrigation

		Productivity per feddan according to the farm site on the irrigation canal														
		Head					Middle					Tail				
Crops	Member or non-member	Production/ Feddan (ton)	Total cost/ Feddan (L.E.)	Net profit/ Feddan (L.E.)	Production of m^3 water (kg)	Return to m^3 Water (L.E.)	Production/ Feddan (ton)	Total cost/ Feddan (L.E.)	Net profit/ Feddan (L.E.)	Production of m^3 water (kg)	Return to m^3 Water (L.E.)	Production/ Feddan (ton)	Total cost/ Feddan (L.E.)	Net profit/ Feddan (L.E.)	Production of m^3 water (kg)	Return to m^3 Water (L.E.)
Wheat	Mem	3.18	11,249	10,458	1.35	9.23	3.12	11,349	9,382	1.33	8.81	3.08	11,420	8,955	1.31	8.66
	No	3.09	11,380	9,426	1.31	8.85	3.015	11,500	8,086	1.28	8.57	2.57	11,700	6,194	1.09	7.61
The difference		0.09**	−131**	1,032**	0.04**	0.38**	0.105**	−151**	1,296***	0.05**	0.24**	0.51**	−280**	2,761**	0.22**	1.05**
Clover	Mem	38	9,000	13,800	11.46	6.87	37.5	9,100	13,400	11.31	6.78	37	9,150	13,050	11.15	6.69
	No	37	9,100	13,100	11.15	6.69	35.6	9,250	12,110	10.73	6.44	32	9,390	9,810	9.65	5.79
The difference		1**	−100**	700**	0.31**	0.18**	1.9**	−150**	1,290**	0.58**	0.34**	5**	−240**	3,240**	1.5**	0.9**
Potato	Mem	13	24,500	12,550	6.42	18.3	12.75	24,550	11,788	6.3	17.94	12.5	24,600	11,025	6.17	17.59
	No	12.5	24,590	11,035	6.17	17.59	12.2	24,680	10,090	6.03	17.17	10.2	24,880	4,190	5.04	14.36
The difference		0.5**	−90*	1,515**	0.25**	0.71**	0.55**	−130**	1,698**	0.27**	0.77**	2.3**	−280**	6,835**	1.13**	3.23**
Orange	Mem	11	12,100	19,250	1.84	5.23	10.75	12,200	18,437	1.79	5.11	10.65	12,250	18,103	1.78	5.06
	No	10.7	12,200	18,295	1.78	5.09	10.45	12,330	17,453	1.74	4.97	9.0	12,490	13,160	1.5	4.28
The difference		0.3**	−100**	955**	0.06**	0.14**	0.3**	−130**	984**	0.05**	0.14**	1.65**	−240**	4,943**	0.28**	0.78**
Tomato	Mem	18	13,500	24,480	10.96	23.12	17.6	13,550	23,586	10.71	22.60	17.5	13,600	23,325	10.65	22.47
	No	17.7	13,600	23,747	10.77	22.73	17.3	13,700	22,753	10.53	22.22	15.0	13,900	17,750	9.13	19.26
The difference		0.3**	−100**	733**	0.19**	0.39**	0.3**	−150**	833**	0.18**	0.38**	2.5**	−300**	5,575**	1.52**	3.21**

For members and non-members in WUAs.

Source: Compiled and calculated from the questionnaire.

• Water requirement for crops involved were gained from Central Agency for Public Mobilization & Statistics (CAMPS 2019). Annual Bulletin of Irrigation and Water Resources Statistics, 2019. Issue December 2019, Egyppt.

*: Significant at 5%.

**: Significant at 1%.

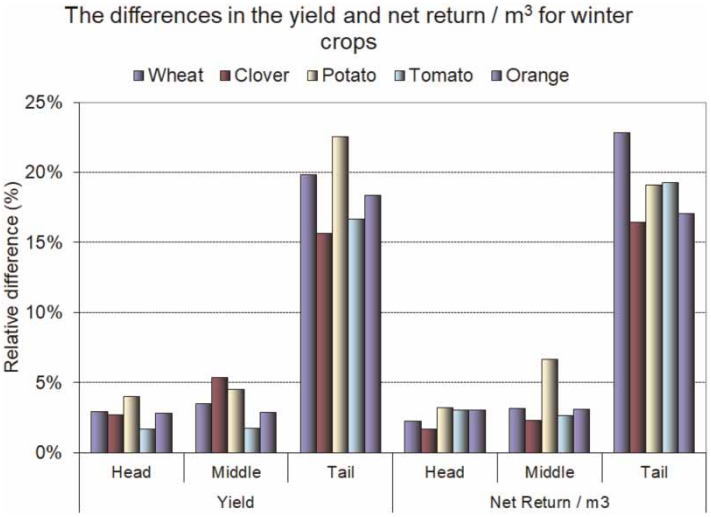


Figure 1 | Difference ratios between WUA members' fields and other fields during winter season.

The differences in the net return/feddan for wheat, alfalfa, winter potatoes, winter tomatoes, and oranges were 2,761, 3,240, 6,835, 5,575, and 4,943 L.E./feddan respectively at the tail end. The corresponding values were 1,296, 1,290, 1,698, 833, and 984 L.E./feddan at the middle reach and 1,032, 700, 1,515, 733, and 955 L.E./feddan at the head reach. The weighted average abundance values were 1,893.1 L.E./feddan for winter crops, and 2,558.9 L.E./feddan for orange (Table 8).

Regarding water productivity, the differences for previously mentioned investigated crops were 0.22, 1.5, 1.13, 1.52, and 0.28 kg/m^3 respectively at the tail end. The differences decreased to 0.05, 0.58, 0.27, 0.18, and 0.05 kg/m^3 at the middle reach, while they were 0.04, 0.31, 0.25, 0.19, and 0.06 kg/m^3 at the head reach.

Regarding the net return for the unit of water, the differences for same investigated crops were 1.05, 0.9, 3.23, 3.21, and 0.78 L.E/m^3 respectively at the tail end. The differences between net return/m^3 for WUA members' fields and non-members' fields for the same investigated crops were 0.24, 0.34, 0.77, 0.38, and 0.14 L.E./m^3 at the middle reach, while they were 0.38, 0.18, 0.71, 0.39, and 0.14 L.E./m^3 at the head reach. The weighted average abundance values were 0.62 L.E./m^3 for winter crops, and 0.40 L.E./m^3 for oranges (Table 8).

Summer season. Another five summer crops were investigated for the economic impact of the establishment of WUAs as well. Table 7 summarized the results. The crops were maize, tomato, potato, cucumber, and zucchini, and the same indicators were used for summer season. Figure 2 depicts the difference ratios for the yield and the net return for the unit volume of water for different reaches in the canal.

The cultivated areas for previously mentioned crops were 1,151.2, 18.3, 13.4, 15.0, and 18.0 feddan respectively at the head and middle reaches. At tail end reach, the cultivated areas with previous crops were 1,535, 24, 18, 20, and 24 feddan respectively.

The same general achievement during the winter season was found during the summer season. The results referred to a significant change between WUA members and non-members, and the highest differences were found at the tail-end reach.

Regarding the yield, the differences between the yields of previously mentioned investigated crops in fields of WUA members and non-members were 0.62, 2.5, 2.0, 1.55, and 1.2 tons/feddan respectively at tail end reach. At the middle reach, the corresponding differences were 0.1, 0.4, 0.8, 0.25, and 0.25, tons/feddan. At the head reach, the differences were 0.07, 0.3, 0.4, 0.25, and 0.25 tons/feddan for the investigated crops respectively.

Regarding total expenses, the differences in the expanses for maize, summer tomato, summer potato, summer cucumber, and summer zucchini at the tail end were 140, 250, 350, 150, and 150 L.E./feddan respectively. The differences between WUA members' fields and non-members' fields for the same crops were 110, 100, 150, 50, and 50 L.E./feddan at the middle reach, while they were 90, 130, 50, 50, and 50 L.E./feddan at the head reach. The weighted average abundance values were 0.62 L.E/ m^3 for winter crops, and 0.40 L.E./m^3 for oranges (Table 8).

Table 7 | Economic indicators for summer crops according to the farm site on the irrigation

Crops	Members or not members	Productivity per Fadden, According to the farm site on the irrigation canal														
		Head					Middle					Tail				
		Production/ Feddan (ton)	Total cost/ Feddan (L.E.)	Net profit/ Feddan (L.E.)	Production of m^3 water (kg)	Return to m^3 Water (L.E.)	Production/ Feddan (ton)	Total cost/ Feddan (L.E.)	Net profit/ Feddan (L.E.)	Production of m^3 water (kg)	Return to m^3 Water (L.E.)	Production/ Feddan (ton)	Total cost/ Feddan (L.E.)	Net profit/ Feddan (L.E.)	Production of m^3 water (kg)	Return to m^3 Water (L.E.)
Tomato	Mem	18.2	13,500	24,720	8.46	17.76	17.9	13,600	239,900	8.32	17.47	17.7	13,680	23,490	8.22	17.27
	No	17.9	13,630	23,960	8.32	17.47	17.5	13,750	230,000	8.13	17.08	15.2	13,930	17,990	7.06	14.83
The difference		0.3**	−130**	760**	0.14**	0.29**	0.4**	−100**	990**	0.19**	0.39**	2.5**	−250**	6,280**	1.16**	2.44**
Maize	Mem	3.36	9,180	3,860	0.94	3.65	3.32	9,280	3,564	0.93	3.60	3.28	9,380	3,308	0.92	3.55
	No	3.29	9,270	3,467	0.92	3.57	3.22	9,390	3,067	0.90	3.49	2.66	9,520	798	0.74	2.89
The difference		0.07**	−90**	393**	0.02**	0.08**	0.10**	−110**	497**	0.03**	0.11**	0.62**	−140**	2,510**	0.18**	0.66**
Potato	Mem	13	24,500	12,030	6.42	18.04	12.8	24,600	11,368	6.32	17.76	12.5	24,650	10,475	6.22	17.35
	No	12.6	24,550	10,856	6.22	17.48	12.0	24,750	8,970	5.93	16.65	10.5	25,000	4,505	5.19	14.57
The difference		0.4**	−50*	1,174**	0.20**	0.56**	0.8**	−150**	2,398**	0.39**	1.11**	2**	−350**	5,970**	1.03**	2.78**
Cucumber	Mem	10	10,700	120,000	4.94	11.20	9.75	10,800	11,333	4.81	10.93	9.65	10,850	11,056	4.77	10.83
	No	9.75	10,750	11,269	4.79	10.87	9.50	10,850	10,715	4.69	10.65	8.10	11,000	7,387	4.00	9.08
The difference		0.25**	−50*	731**	0.15**	0.33**	0.25**	−50*	618**	0.12**	0.28**	1.55**	−150**	3,669**	0.77**	1.75**
Zucchini	Mem	8.50	10,700	15,650	4.20	13.01	8.35	110,800	15,085	4.12	12.78	8.2	10,850	14,570	4.05	12.55
	No	8.25	10,750	14,825	4.07	12.63	8.10	10,850	14,260	4.00	12.40	7.0	11,000	10,700	3.46	10.72
The difference		0.25**	−50*	825**	0.13**	0.38**	0.25**	−50*	825**	0.12**	0.38**	1.2**	−150**	3,870**	0.59**	1.83**

For members and non-members in WUA.

Source: Compiled and calculated from the questionnaire.

• Water requirement for crops involved were gained from Central Agency for Public Mobilization & Statistics (CAMPS 2019). Annual Bulletin of Irrigation and Water Resources Statistics, 2019. Issue December 2019, Egyppt.

*: Significant at 5%.

**: Significant at 1%.

Table 8 | The increase in the average net return per feddan, the return per unit of water and the decrease in the total costs per feddan for members of the WUAs in the study sample in Menoufia Governorate season 2018–2019

Crops	Cultivated area (feddand)	Total cost (L.E./feddan)	Net revenue (L.E./feddan)	Return to water (L.E./m^3)
Summer field crops	4,052.7	−117.2	1,376.0	0.38
Winter field crops	4,052.7	−186.2	1,893.1	0.62
Total field crops	4,052.7	−303.4	3,269.1	1.0
Oranges	1,543.8	−165.0	2,558.9	0.4
The weighted average		−265.2	3,073.2	0.834
Total cultivated area*	5,596.5	−1,484,376	17,199,111	4,670.2

The weighted average was used for field crops and oranges due to the change in the areas cultivated by different crops.
*Figures for this row are for the total cultivated area, not per feddan
Source: Compiled and calculated from the study sample data.

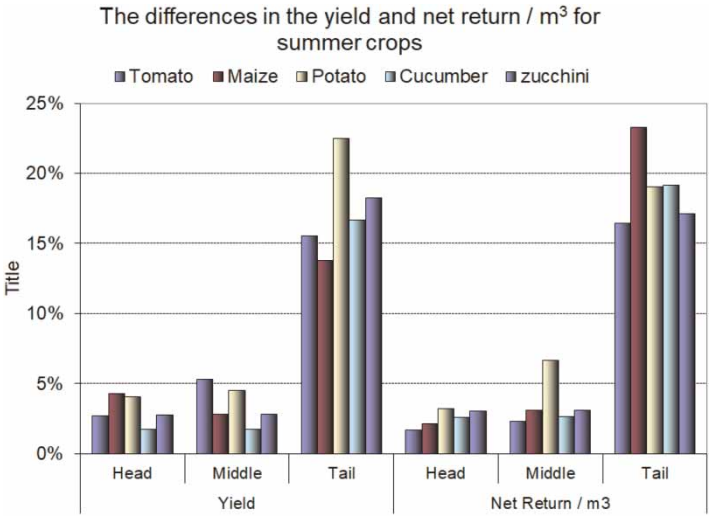


Figure 2 | Difference ratios between WUA members' fields and other fields during the summer season.

Regarding net return per feddan, the highest difference was at the tail-end reach like other indicators, and the differences of net return/feddan for summer tomato, maize, summer potato, summer cucumber, and summer zucchini were 2,510, 6,280, 5,970, 3,669, and 3,870 L.E./feddan respectively.

The differences between net return/fedx for WUA members' fields and non-members' fields for the same crops were 497, 990, 2,398, 618, and 825 L.E/feddan at the middle reach, while they were 393, 760, 1,174, 731, and 825 L.E/feddan at the head reach. The weighted average abundance values were 1,376.0 L.E/ feddan for summer crops (Table 8).

Regarding water productivity, the results referred to a significant change between members and non-members of WUAs as was the case for other indicators, and the highest differences were at the tail-end reach (0.18, 1.16, 1.03, 0.77, and 0.59 kg/m^3 for investigated crops respectively). The differences between water productivity for WUA members' fields and non-members' fields for the same crops were 0.03, 0.19, 0.39, 0.12, and 0.12 kg/m^3 at the middle reach, while they were 0.02, 0.14, 0.20, 0.15, and 0.13 kg/m^3 at the head reach.

Regarding the net return for the unit of water, the differences between members and non-members increased at the tail end, and the values for summer tomato, maize, summer potato, summer cucumber, and summer zucchini were 0.66, 2.44, 2.78, 1.75, and 1.83 L.E./m^3 respectively. The differences were 0.11, 0.39, 1.11, 0.28, and 0.38 L.E/m^3 at the middle reach, while they were 0.08, 0.29, 0.56, 0.33, and 0.38 L.E/m^3 at the head reach. The weighted average abundance values were 0.38 L.E/m^3 for summer crops (Table 8).

Discussion

The previous section presented the results regarding the yield, the net return per unit area, the productivity and the net return per unit area for WUA members and non-members in the El-Atf canal, and the collected data was analyzed

statistically. Considering both seasons, the difference between the yield of WUA members' fields and non-members' fields at the head and middle reaches ranged between 1.7 and 5.3%. At the tail-end reach, the differences ranged between 13.8 and 22.5%. The differences between total cost per feddan at WUA members' fields and non-members fields, were between 0.2 and 1.6% at the head and middle reaches. At the tail-end reach, the differences were between 1.13 and 2.56%. Regarding net return per feddan, the differences ranged between 3.1% and 26.7% at the head and middle reaches. At the tail-end reach, the differences were between 30.6 and 314.5%. For water productivity, the differences ranged between 1.7 and 6.6% at the head and middle reaches. At the tail end reach, the differences were between 15.5 and 24.3%. The scores for the net return of water volume were very close to the scores of yield and water productivity.

The previous results referred to a significant improvement in different situations after the establishment of WUAs. This included the increase of crop yields and water productivity, and a decrease in the total cost. As a results, there was an increase in the net return per feddan and net return per unit of water. Due to the accumulation of the irrigation problems at the tail-end reach, the impact of irrigation improvement with the establishment of WUAs was more noticeable in this reach than other reaches, and therefore, the differences between WUA members' fields and non-members' fields increased.

CONCLUSION

Participatory water management became an essential element to improve water distribution through the irrigation network to face any possible decrease in water resources. This is highly important in arid countries, such as Egypt. In Egypt, WUAs were established with a hope to help in improving the equity of water distribution and in operating and maintaining the irrigation system in a suitable way. The responsibilities of these organizations include solving conflicts between farmers and coordinating with the engineers at irrigation districts. However, many problems are facing these associations and they are preventing them from performing their roles in the optimal way. In addition, many problems are facing farmers in establishing new associations.

The current study highlighted the problems that are facing the existing WUAs, and the problems in establishing new organizations based on the opinions of the farmers in these areas. In addition, the study highlighted the economic impacts of establishing water user associations.

Based on farmers' opinions, most of the problems that are facing the existing WUAs are connected to the absence of explicit law and the lack of sufficient funding for the suitable maintenance of the improved system. Providing sufficient funding is highly important for the sustainability of WUAs, and for the achievement of irrigation improvement projects.

Regarding the economic impact of the establishment of WUAs, the study confirmed the positive impact of farmers' income. This positive impact was observed in the productivity per feddan, the net return per feddan, the productivity of the water unit, the return per unit of water, and the decrease in the total costs. Based on the statistical analysis, the differences between WUA members' fields and non-members' fields were significant. The average increase in the net return per feddan in WUA members' fields was L.E. 3,073.2 and the average increase in the net return per unit of water in WUA members' fields was L.E. 0.834 EGP. In addition, the average decrease in the total cost per feddan in WUA members' fields was L.E. 265.2. The total increase in the net return for the total study area was about L.E. 17.2 million. The total cost savings in the study area were about L.E. 1.5 million.

It is recommended to help WUAs to fulfill their responsibilities through providing sufficient funding and required capacity building and through establishing an explicit law for the responsibilities of WUAs, which gives them the power to collect fees and arranging different agricultural and irrigation activities. The study also recommended continuous visits to and continuous cooperation with members of the WUAs to define and solve their problems.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details. The authors confirm that the data supporting the findings of this study are available within the article. Raw data that support the findings of the study are available from the corresponding author, upon request.

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