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Economic Assessment of Resource Use Efficiency for Water Users Associations in Egypt

Enas Moh. Abbas SALEH
Senior researcher, Agricultural Economics Research Institute (AERI), Agricultural Research Centre (ARC)
enas_abbas_saleh@yahoo.com

Abstract

This article analyses resource use efficiency for Water Users Associations (WUAs) in Egypt. Data were collected from 200 farmers divided into two groups; Group I "without WUAs" and Group II "with WUAs". Data Envelopment Analysis was employed to measure, compare and assess the estimated efficiencies for both groups and determine the potential of input and cost savings. Separate analysis of both groups showed that the highest difference between optimum and present use of inputs for wheat were found in irrigation water and nitrogenous fertilizer respectively with 35.3%, and 22.7% for Group I and in machine work (35.3%) and fertilizers (27.4%) for Group II. These highest differences were mainly attributed to seeds, manure and labor for maize in Group I and for seeds and labor in Group II. Farmers of Group II were more efficient in using the inputs since they apply better input mix given input price, resulting in higher yields and profitability realized by Group II compared to Group I. This implied that there still exists a potential for increasing the profits of farms in Group I, if the inputs gap between the actual and the best-practice farms is narrowed. To conclude, Group II "with WUAs" ameliorates the efficiency of using resources, enhances the yield and improves livelihoods. The reliability of water supply improved for Group II, indicating positive impact to encourage farmers towards joining WUAs. Finally, joining WUAs is a good approach to increase agricultural productivity in a sustainable manner.

Key words: economic; WUAs; data envelopment analysis; efficiency; resource; Egypt

1. Introduction

Like other water-scarce countries, Egypt is facing fast growing demands versus limited water resources (Allam et al., 2004). Water resources in Egypt are becoming scarce as water has come below the water poverty threshold and surface-water resources originating from the Nile are currently fully exploited, while groundwater sources are being brought into full production (Moujabber et al., 2009). However, Egypt faces three major long-term challenges with respect to its water resources. One challenge is water scarcity due to fixed water supply and rocketing demand for water, fueled by rapid population growth, agricultural expansion, and industrial development. Another challenge is difficulties in the country's relationship with the Nile Basin states and independence of South Sudan. A third challenge is climate change, which puts further strain on scarce water resources. These challenges pose a number of questions related to the availability of water and the amount of supply that will be allocated for different consumptive and non-consumptive activities and development programs (Karajeh et al., 2011). 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.

Indeed, irrigation is a critical input for domestic agricultural production. Virtually all Egypt's agricultural lands are irrigated from the Nile River. 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 increasing stress due to increasing competition for available water. This is largely attributed to increased competition for water resources among other major water consuming sectors since 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). In spite of water scarcity, 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. Water conveyance efficiency is estimated at about 70%, and the overall efficiency of irrigation is estimated at about 50% (MALR, 2009).

Based on (Karajeh et al., 2011), irrigation modernization is a key element to improve the efficiency of water conveyance and distribution systems, as well as the efficiency of on-farm systems at the farm/plot level through using closed conduits to replace open channels, lining earth canals with stone or cement, tightening gates, and removing aquatic plants that consume large amounts of water. Besides, the efficient use of water at the farm level is a major issue.

In order to increase the irrigation efficiency and attain equitable share of water by improving irrigation water supply and increase agricultural productivity, Egypt introduced the Irrigation Improvement Projects (IIP) and the Integrated Irrigation Improvement and Management Project (IIIMP). The improvement process included two main components; physical changes and organization changes. The physical changes included; conversion from rotational to continuous flow in the secondary (branch) canals, improvement of tertiary level canals (*Mesqa*) by conversion of low level *Mesqas* to raised canals or pipelines, and replacement of individual pumps by collective pumping. The organization changes included establishment of Water Users Associations (WUAs) and creation of an Irrigation Advisory Service (IAS) (Allam, 2002).

The WUA is a non-governmental organization that incorporates representatives of farmers that benefit from the *Mesqa*. The WUA is responsible for *Mesqa* improvement (e.g. selection of *Mesqa* type, locating the new *Mesqa*, locating *Mesqa* turnouts), operation and maintenance (O&M) of the single point lift pump, scheduling turns among the members (irrigation scheduling), resolving disputes, and *Mesqa* maintenance (Allam, 2002). Moreover, the IAS is a governmental agency. The primary mission of the IAS is to facilitate and assist formation of WUAs and provides technical assistance to WUAs for *Mesqa* improvements, operation, maintenance, and irrigation scheduling among farmers (Allam, 2002).

According to (Ghazouani et al., 2012), Egypt recognized the importance of improving farmer's performance through encouraging farmers to participate in all decisions related to irrigation management and related water services at the *Mesqa*, with the additional objective to shift a part of costs of O&M onto farmers, in order to improve the O&M of irrigation and drainage systems, equity of irrigation supply and the resolution of conflicts among users by the establishment of WUAs. WUAs are responsible for O&M of the "improved *Mesqas*", that included single-point lift pumping stations, introduced by the Irrigation Improvement Projects (IIP) and the Integrated Irrigation Improvement and Management Project (IIIMP).

Till September 2014, there are more than nine thousand WUAs established in Egypt serving about 552 thousand feddans of which only about 73% were formally registered (MWRI, 2015). Based on Table A.1, about 29% of these WUAs were established in Behaira and Alexandria Governorates as compared to about 20% established in Assuit, Menia, Beni Seuf and Sohag Governorates (MWRI, 2015). Besides, more than 57% of the formally registered WUAs are located in these Governorates. Based on (CAPMAS, 2015), the total conveyance and distribution losses in the irrigation network between the main source in Aswan till the field respectively reached about 1.53 and 0.51 BCM in

Behaira and Assuit Governorates during the period (2010-2013). This represents about 28% and 32% of the total conveyance and distribution losses in Lower and Upper Egypt, respectively.

In this sense, the key research question addressed for this study is: Does WUAs improve resource use efficiency at farm level? Yet, the objective of this study was to determine the efficiency of resource utilization for WUAs via measuring the technical efficiency, allocative efficiency and economic efficiency of using different resources for producing the main crops at farm level, to compare and assess the estimated efficiencies for Group I “without WUAs” and Group II “with WUAs”, to determine the potential of input and cost savings in the production of the main crops in the study area, and to investigate farmers’ perceptions about WUAs (e.g. reliability of water supply, and participation), as well. Finally, the study attempts to reach some recommendations for decreasing such farm-level variations.

In order to reach these objectives, 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.

2. Methodological Framework

2.1. Data source and analysis

2.1.1. Region of the study: According to (WB, 2010), Egypt is comprised of two parts: Upper and Lower Egypt. Upper and Lower Egypt can be divided into “Old Lands” and “New Lands”. Old Lands are found in the Nile Valley and Delta. They include land that was claimed from the desert many generations ago and has been intensively cultivated since. The Old Lands are typically deep, flat and extremely fertile through millennia of Nile silt deposits. The study was conducted in the old lands located at west Nile Delta of Lower Egypt in Behaira Governorate and at the Nile Valley of Upper Egypt in Assuit Governorate.

2.1.2. Surveying procedure and data collection: Data were collected from a formal survey conducted in 2014/2015. A multi-stage stratified random sampling design was used in this study to make representative sample. In the first stage the country was classified into two clusters based on the geographic location; Lower and Upper Egypt. The distribution of farms in the sample across these two clusters was determined based on the weight proportional importance of the total number of established and formally registered WUAs in each cluster and the total conveyance and distribution losses in the irrigation network, as well. In the third stage, Behaira and Assuit Governorates were selected to conduct the study since Behaira Governorate ranked at the top of the list of established and formally registered WUAs in Lower Egypt whereas, a small number of WUAs were established and formally registered in Assuit Governorate (MWRI, 2015) and since both Governorates contributed to about one third of the total conveyance and distribution losses in Lower and Upper Egypt, as well (CAPMAS, 2015). Then, each Governorate was classified into clusters based on its Districts. Within each Governorate, Districts were classified based on the number of WUAs. Therefore, Abou Hommos and Manflot Districts were selected to conduct the study respectively in the selected Governorates. Then in each District, villages were classified based on the total cultivated area. Balaqtar and Beni Adi El Bahariya Villages were selected to conduct the study in these Governorates, respectively. 100 farmers from each Governorate were randomly selected and were divided into two halves; without WUAs so called "Group I" and with WUAs so called "Group II" for comparison.

2.2. Analytical methods

Based on (Cooper, W.W., Seiford, 2007), a unit can be made efficient either by reducing the input levels and getting the same output (input orientation) or by increasing the output level with the same input level (output orientation). Data Envelopment Analysis (DEA) is a non-parametric method used for estimating the technical efficiency of using different resources for producing the main crops in the study area. The DEA approach isolates the efficient decision-making units (DMUs) then, the practices followed by the efficient DMUs form a benchmark as the best operating practices for the inefficient farmers. The input-oriented DEA approach for efficiency estimation is used for our analysis, which means that the output variables are held constant while DEA tries to maximize the possible proportional reduction in input usage (Coelli, Tim and Rao, 2003). Therefore, input-oriented Charnes-Cooper-Rhodes model (CCR-I) and input-oriented Banker-Charnes-Cooper model (BCC-I) are used in the present study. The Technical efficiency score of a farmer that is less than one indicates that, at present, this farmer is using more input than required from the different sources (Chauhan et al., 2006). Hence, it is desired to suggest realistic levels of input to be used from each source for every inefficient farmer in order to avert wastage of input without reducing the output level. The DEAP V2.1 computer program was employed with the assumption of constant return to scale (CRS) and then with the assumption of variable return to scale (VRS). Per feddan use of seeds (in Kg), nitrogenous and phosphates fertilizer (in Kg), manure (in m^3), labor (in days), machine work (in hours), and irrigation water (in m^3) were considered as inputs whereas, the yield of grains (in ardab) was considered as an output for estimation of farm level technical efficiency.

Moreover, farmers' perceptions were also recorded on the reliability about canal water access, and participation in the activities of WUAs. The reliability of canal irrigation was assessed by reliability scores for both groups in the study sample. Reliability scores were calculated by taking the average of farmers' opinion (1 for poor, 2 for satisfactory and 3 for good) on important aspects of irrigation management. Accessibility of irrigation water to the whole farm area, adequate availability of irrigation water, control on irrigation water, and resolving conflict water problems were considered to assess the reliability of canal irrigation. Farmer's participation in WUAs in given activities is expressed by the Participation Index (PI) calculated based on the number of activities they participate in by giving a score of 1 to each activity a farmer participates in (and 0 otherwise) and then taking the sum. The index value will thus range from 0 (participates in none of the activities) to 6 (participates in all activities). Based on PI, the farmers were categorized into two groups, active and inactive participation farmers. The higher the index score, the better the indication of farmer's participation in WUAs.

3. Results and Discussion

3.1. Characteristics of selected sample

3.1.1. Farmer's characteristics: Table 1 revealed that old farmers were dominated in the study sample since about 71% of them were older than 45 years. The study farmers had poor education as only a quarter of them had secondary whereas, only 13.5% had university education. However, the selected farmers in Assuit Governorate were lower-educated, as compared to the study farmers in Behaira Governorate. A good proportion of the study farmers gained good farming experience as about 75% of them spent more than 20 years in farming activities. Yet, farmers of Group II “with WUAs” were relatively younger and higher-educated than farmers of Group I “without WUAs” whereas, Group I gained more farming experience (Table 1).

3.1.2. Main crops: Wheat was dominant in the study farms in winter. In the summer season, rice was solely dominant in Behaira Governorate whereas, sorghum was solely dominant in Assuit Governorate, followed by maize in both governorates. Hence for the whole sample farms, wheat and maize were dominant in winter and summer seasons, respectively.

3.1.3. Water sources: The River Nile is the main source of irrigation, providing the study farms with more than 97% of water. Nile water is delivered to the study area respectively through Abies El Qadima and Beni Adi canals in Behaira and Assuit Governorates. Groundwater and mixed water are reliable sources used to cover water shortage occurring during summer months.

3.1.4. Irrigation system and type of canal improvement: All farms used surface (flood) irrigation and the tertiary canals (*Mesqas*) for Group I were unimproved open earthen and low-level ditch with non-organized water withdrawals through multiple pumping/lifting points along their length. Along the improved *Mesqas* where farmers are organized in WUAs (Group II), there were two types of improvement prevailing in the study sample; namely a) open lined and elevated *Mesqas* and b) buried low-pressure P.V.C. pipelines. Such types of improved *Mesqas* reduce the seepage of water to the minimum. Our findings were supported by (Saleh Enas, A. Abdel Mohsen, 2015).

Table 1. Characteristics of Group I “without WUAs” and Group II “with WUAs” in the study sample.

Farmer’s Characteristics	Behaira Governorate				Assuit Governorate				Total			
	Group I “without WUAs”	Group II “with WUAs”	Total	%	Group I “without WUAs”	Group II “with WUAs”	Total	%	Group I “without WUAs”	Group II “with WUAs”	Total	%
Age:	**50**	**50**	**100**	**100**	**50**	**50**	**100**	**100**	**100**	**100**	**200**	**100**
< 45 years	10	18	28	28	9	21	30	30	19	39	58	29
45 – 55 years	17	20	37	37	18	18	36	36	35	38	73	36.5
> 55 years	23	12	35	35	23	11	34	34	46	23	69	34.5
Education:	**50**	**50**	**100**	**100**	**50**	**50**	**100**	**100**	**96**	**104**	**200**	**100**
Illiterate	15	5	20	20	20	8	28	28	35	13	48	24
Can read and write	12	7	19	19	13	6	19	19	25	13	38	19
Primary	3	9	12	12	6	16	22	22	9	25	34	17
Secondary	12	19	31	31	8	14	22	22	20	33	53	26.5
University graduates	8	10	18	18	3	6	9	9	7	20	27	13.5
Farming experience:	**50**	**50**	**100**	**100**	**50**	**50**	**100**	**100**	**100**	**100**	**200**	**100**
< 20 years	9	16	25	25	6	19	25	25	15	35	50	25
20 – 30 years	14	25	39	39	20	14	34	34	34	39	73	36.5
> 30 years	27	9	36	36	24	17	41	41	51	26	77	38.5

Source: the results of the survey 2014/2015.

3.1.5. Irrigation pumps: Farmers in the study sample used irrigation pumps of different horsepower categories, ranging between 7-15 horsepower. However, irrigation pumps of 7 horsepower were widely spread in the study area. Selected farms in Behaira Governorate use irrigation pumps of higher horsepower than those farms located at Assuit Governorate. Diesel-driven pumps prevailed in Group I. Besides, diesel fuel constitutes the main energy source to operate the pumps that are installed at the head of *Mesqas* to divert water from branch canal to *Mesqas* in Group II whereas, electric pumps are also used sometimes in this group. However, electric pumps are more frequently used in Assuit Governorate.

3.1.6. Formation of Water Users Associations (WUAs): Farmers along the improved *Mesqas* are organized in WUAs to build, operate, and maintain their *Mesqas* on their own initiative. The board of a WUA consists of head, treasurer, gate operator, and other four members. The treasurer is responsible for collecting O&M fees from farmers and depositing the fees into a bank account made for WUAs to control the financial issues of the O&M of improved *Mesqas*. Besides, the gate operator is responsible for opening and closing the gates, and adjusting the water level according to the schedule provided by the district engineer.

3.1.7. Operation and maintenance (O&M) of the Mesqas and the lifting pumps: The activities of operation involve purchase of diesel and lubricants. A schedule of operation of the pump is decided by the WUAs council. Collection of fees is also the responsibility of the council. Collection of fees is determined on operating-hours basis or seasonal basis in the study sample. The latter is the most dominant alternative. The O&M fees are determined by the WUAs without any governmental interference. Maintenance of *Mesqas* such as regular cleaning is the responsibility of the WUAs. Some cleaning activities or repairs can be conducted by users themselves. In some cases, labor is hired to conduct some maintenance works for the WUAs.

3.2. Efficiency scores for the main crops in the study sample:

3.2.1. Efficiency scores for wheat farms: The results derived from Data Envelopment Analysis models are presented in Table 2. Respectively about 22% and 40% of wheat farms in Group I at Behaira Governorate were found as technically efficient farms with the assumption of CRS and VRS models, meaning they have technical efficiency scores of 1, as compared to about 26% and 44% for Group II in that order. However, the remaining (out of total 50 farms) were technically inefficient, i.e., their efficiency scores are below 1. In Assuit Governorate, the technically efficient wheat farms in Group I respectively constitutes about 38% and 76% of the sample farms under CRS and VRS models, whereas it reached about 34% and 92% for Group II, respectively. These findings indicated that the number of technically efficient wheat farms in Group II exceed those cultivated by Group I in the study sample. Moreover, the overall technical efficiency scores for wheat farms under the CRS and VRS models are presented in Table 2. Because the VRS DEA model is more flexible and envelops the data in a tighter way than the CRS DEA model, the VRS technical efficiency score is equal to or greater than the CRS or overall technical efficiency score (Cesaro, L.; Marongiu, S.; Arfini, F.; Donati, 2009).

According to (Coelli, 1996), the VRS model permits the calculation of technical efficiency devoid the effects of scale efficiencies. The results of this model presented in Table 2 showed that the overall technical efficiency of wheat farms in Group I at Behaira Governorate ranged from 0.81 to 1.00 with mean score of 0.94, compared to a range from 0.80 to 1.00 with mean efficiency score of 0.96 for Group II. In Assuit Governorate, the technical efficiency score ranged from 0.82 to 1.00 with mean score of 0.98 for wheat farms in Group I, compared to technical efficiency scores ranging from 0.92 to 1.00 with mean score 0.996 for Group II. This could be owing to the higher level of education for farmers of Group II that reflects better understanding of the input-output relationship measured by technical efficiency (Table 1).

Table 2. Technical efficiency (TE), allocative efficiency (AE), and economic efficiency (EE) scores for wheat and maize farms of Groups I and II based on CCR and BCC models in the study sample.

		Behaira Governorate						Assuit Governorate					
		CRS			VRS			CRS			VRS		
		TE_i^{CRS}	AE	EE	TE_i^{VRS}	AE	EE	TE_i^{CRS}	AE	EE	TE_i^{VRS}	AE	EE
Wheat	**Group I "without WUAs":**												
	Mean	0.848	0.729	0.618	0.943	0.685	0.646	0.912	0.848	0.772	0.982	0.895	0.879
	Minimum	0.551	0.483	0.302	0.809	0.346	0.396	0.569	0.667	0.426	0.815	0.760	0.760
	Maximum	1	1	1	1	1	1	1	1	1	1	1	1
	Number of efficient farms	11	1	1	20	5	5	19	1	1	38	1	1
	Group II "with WUAs":												
	Mean	0.867	0.718	0.623	0.960	0.707	0.679	0.906	0.913	0.826	0.996	0.902	0.898
	Minimum	0.606	0.469	0.307	0.795	0.373	0.407	0.623	0.708	0.443	0.915	0.761	0.761
	Maximum	1	1	1	1	1	1	1	1	1	1	1	1
	Number of efficient farms	13	1	1	22	4	4	17	2	1	46	2	2
Maize	**Group I "without WUAs":**												
	Mean	0.966	0.715	0.691	0.986	0.580	0.572	0.848	0.729	0.621	0.976	0.704	0.687
	Minimum	0.805	0.579	0.520	0.921	0.340	0.328	0.551	0.483	0.302	0.845	0.537	0.913
	Maximum	1	1	1	1	1	1	1	1	1	1	1	1
	Number of efficient farms	25	1	1	35	3	3	11	1	1	34	3	3
	Group II "with WUAs":												
	Mean	0.961	0.735	0.706	0.987	0.609	0.601	0.867	0.718	0.627	0.983	0.747	0.734
	Minimum	0.803	0.625	0.558	0.921	0.351	0.913	0.606	0.469	0.307	0.852	0.584	0.584
	Maximum	1	1	1	1	1	1	1	1	1	1	1	1
	Number of efficient farms	18	1	1	35	3	3	13	1	1	38	4	4

EE= TE*AE
Source: The results of the survey 2014/2015.

Based on the results of the VRS model, the mean technical efficiency scores respectively reached 0.94 and 0.96 for wheat farms of Groups I and II in Behaira Governorate, implying on average that technical inefficiency respectively reached 5.7% and 4.0%, revealing that these wheat farms could potentially reduce their input levels on average respectively by about 5.7% and 4.0% and still achieve the same output levels. Moreover, the technical efficiency among wheat farms in Assuit Governorate can be increased respectively by 1.8% and 0.4% for Groups I and II and still produce the same levels of outputs. The allocative efficiency scores respectively reached about 0.69 and 0.71 for wheat farms of Groups I and II in Behaira Governorate, compared to about 0.895 and 0.902 for Groups I and II in Assuit Governorate in that order. It is evident that re-allocating the inputs of production for wheat farms in Group I saves about 31.5% and 10.5% of these inputs in Behaira and Assuit Governorates in that order, compared to about 29.3% and 9.8% for Group II in these Governorates, respectively.

Moreover, the mean economic efficiency of wheat farms of Groups I and II in Behaira Governorate respectively reached about 64.6% and 67.9%, referring to cost savings of 35.4% and 32.1% that could be achieved while maintaining the same output levels for these groups, respectively. The minimum economic efficiency for wheat farms in Groups I and II in Behaira Governorate are 39.6% and 40.7%, respectively. In Assuit Governorate, the minimum overall economic efficiency of wheat farms in Group I reached about 7.60% with a mean of 87.9%, compared to about 76.1% with mean efficiency of 89.8% for Group II. Consequently, the potential cost savings respectively reached about 12.1% and 10.2% that could be achieved while maintaining the same output levels for Groups I and II in Assuit Governorate.

These findings implied that wheat farms of Group II were more technically and economically efficient with respect to input and costs of input usage in wheat production as compared to other wheat farms in Group I and that wheat farms of Group II generally apply better input mix (the cost minimizing level) given input price, compared to wheat farms of Group I, as well.

<u>3.2.2. Efficiency scores for maize farms:</u> A close look at Table 2 reveals that out of the sample, respectively about 50% and 70% of maize farms in Group I at Behaira Governorate fall under the technical efficiency group with the assumptions of CRS and VRS models, whereas technically efficient maize farms reached about 36% and 70% for Group II in that order. In Assuit Governorate, the technically efficient maize farms in Group I respectively constitute about 22% and 68% of the sample farms under CRS and VRS models, compared to about 26% and 76% for Group II, respectively. These results showed better situation for maize farms of Group II in Assuit Governorate in terms of technical efficiency with respect to input usage in maize production, as compared to other maize farms in Group I.

It can be observed from Table 2 the technical efficiency scores of maize farms in Group I at Behaira Governorate under the VRS model fall within the range of 0.92 and 1.00 with mean score of 0.986, as compared to the technical efficiency scores obtained by Group II ranging between 0.92 and 1.00 with mean efficiency score of 0.987. The mean values of technical efficiency for the inefficient farms indicate that there is ample scope for improving their operating practices to enhance their input use efficiency. Considering Assuit Governorate, the results derived from the VRS model revealed Group I got technical efficiency scores between 0.85 and 1.00 with a mean of 0.976 whereas, the mean technical efficiency score obtained by Group II is 0.983, with a low level of 0.85 and a high level of 1.00. Based on these findings, farms with best farming practices are more efficient and waste less source of inputs. Thus, it is evident that adopting best farm practices of efficient farms can increase the technical efficiency respectively by 1.4% and 1.3% for Groups I and II in Behaira Governorate and maintain the same levels of outputs while, the technical efficiency in Assuit Governorate can be increased respectively by 2.4% and 1.7% for Groups I and II and still produce the same levels of outputs.

Besides, it is evident from the results of the VRS model presented in Table 2 that the overall mean economic efficiency of maize farms of Groups I and II in Behaira Governorate respectively reached 57.2% and 60.1%, referring to cost savings of 42.8% and 39.9% that could be achieved while still producing the same levels of outputs for Groups I and II in that order. Furthermore, the minimum economic efficiency scores obtained by maize farms in Groups I and II in Behaira Governorate are 32.8% and 91.3%, respectively. In Assuit Governorate, the results revealed that the minimum overall economic efficiency of maize farms in Group I reached 91.3% with a mean of 68.7%, as compared to a minimum overall economic efficiency of 58.4% with mean efficiency of 73.4% for Group II, indicating potential cost savings respectively reaching 31.3% and 26.6% that could be achieved while maintaining the same output levels for Groups I and II in Assuit Governorate.

Hence, it is clear that maize farms of Group II were more technically and economically efficient with respect to input and costs of input usage in production, compared to farms of Group I.

3.3. Target use of inputs and cost savings for inefficient farms in the study sample

The results obtained from the DEA analysis can be used to determine how much a farm's technical efficiency (input use) can be improved by reducing the given input while maintaining output and it provides information about the potential resource savings that could be achieved while maintaining the same output level. In other words, the technical efficiency score of a farm that is less than one indicates that, at present, this farm is using more inputs than required from the different sources (Chauhan et al., 2006). DEA assigns weights to the inputs and outputs of the efficient farms e.g. that give the best possible efficiency to be selected by inefficient farms as best practice farms. Therefore, discrimination is desired to be made among the efficient farms while seeking the best operating practices to suggest realistic levels of inputs to be used for each inefficient farm in order to avert wastage of inputs without reducing the yield level.

In this context, Table 3 presents a comparison between present use (actual use) and projection or target use (cost minimizing use) of the used inputs. Therefore, in order to reach target cost minimizing use of inputs for wheat farms in Group I at Behaira Governorate, the actual use of seeds, manure, labor, machine work, and irrigation water can be reduced by about 8.33%, 1.96%, 23.08%, and 35.34%, respectively while maintaining the same levels of production. Besides, the actual use of nitrogenous and phosphates fertilizers, and labor can be increased respectively by 5.08%, 6.02%, and 10.53% and still produce the same levels of outputs. The results showed that the present use of seeds, phosphates fertilizer, manure, machine work, and irrigation water of Group II in Behaira Governorate can be reduced respectively by 0.85%, 5.38%, 6.25%, 17.39%, and 13.89% and still achieve the same output levels. Moreover, the present use of nitrogenous and phosphates fertilizers, and labor can be increased respectively by 5.08%, 6.02%, and 10.53% while producing the same levels of wheat. In Assuit Governorate, the results imply that if the wheat farms of Group I operated at full efficiency level it could reduce, on average, the actual use of seeds, manure, machine work, and irrigation water by 8.33%, 1.96%, 23.08%, and 35.34% and still produce the same level of outputs.

As for maize, it is clear that the per feddan input requirements of seeds, phosphates fertilizer, labor, machine work, and irrigation water in optimum condition for maize farms in Group I at Behaira Governorate respectively reached about 11 Kg, 138 Kg, 16 days, 30 hours, and 2521 m^3. Therefore, respectively about 15.38%, 13.21%, 5.88%, 9.09%, and 8.79% of these inputs can be reduced in for maize production process and still produce the same levels of output. As for Group II in Behaira Governorate, the results showed that the present use of seeds, phosphates fertilizer, labor, machine work, and irrigation water can be reduced respectively by about 16.67%, 12.60%, 13.33%, 7.41%, and 2.44% and still achieve the same outputs. Considering Assuit Governorate, respectively about 6.12%, 7.13%, 10.34%, 10.71%, 5.56%, and 2.09% of the actual use of seeds, nitrogenous fertilizer, manure, labor, machine work, and irrigation water for Group I can be saved in DEA approach pattern. In Group II of Assuit Governorate, labor and manure savings in the optimum condition (with 18.80% and 10.00%, respectively) had the highest percentages of input savings compared to present use; followed by seeds (7.41%), nitrogenous fertilizer (8.70%), machine work (4.04%) and water (1.70%).

Table 3. Actual & target input savings for inefficient farms of Groups I and II in the study sample if the farmers follow the target input package recommended by the DEA approach for wheat and maize.

Crop	Input	Behaira Governorate				Assuit Governorate			
		Present use (actual use)	Projection/ target use (cost minimizing)	Quantity saving per feddan	Contribution of input to quantity savings (%)	Present use (actual use)	Projection/target use (cost minimizing)	Quantity saving per feddan	Contribution of input to quantity savings (%)
Wheat	**Group I “without WUAs”:**								
	Seeds (Kg/feddan)	60.0	55.0	5.0	8.33	57.0	48.0	9	15.79
	Nitrogenous fertilizer (Kg/feddan)	177.0	186.0	(9.0)	(5.08)	176.0	136.0	40	22.73
	Phosphates fertilizer (Kg/feddan)	162.8	172.6	(9.8)	(6.02)	115.0	98.0	17	14.78
	Manure (m^3/feddan)	20.4	20.0	0.4	1.96	15.0	14.0	1	6.67
	Labor (days/feddan)	19.0	21.0	(2.0)	(10.53)	24.0	20.0	4	16.67
	Machine work (hours/feddan)	26.0	20.0	6.0	23.08	41.0	39.0	2	4.88
	Irrigation water (m^3/feddan)	1964.0	1270.0	694.0	35.34	3369.0	3157.0	212	6.29
	Group II “with WUAs”:								
	Seeds (Kg/feddan)	58.5	58.0	0.5	0.85	50.0	45.0	5	10.00
	Nitrogenous fertilizer (Kg/feddan)	141.5	173.0	(31.5)	(22.26)	146.0	125.0	21	14.38
	Phosphates fertilizer (Kg/feddan)	130.0	123.0	7.0	5.38	92.0	80.0	12	13.04
	Manure (m^3/feddan)	16.0	15.0	1.0	6.25	12.0	12.0	0	0.00
	Labor (days/feddan)	17.5	20.0	(2.5)	(14.29)	23.0	22.0	1	4.35
	Machine work (hours/feddan)	23.0	19.0	4.0	17.39	27.0	24.0	3	11.11
	Irrigation water (m^3/feddan)	1440.0	1240.0	200.0	13.89	2288.0	2150.0	138	6.03
Maize	**Group I “without WUAs”:**								
	Seeds (Kg/feddan)	13.0	11.0	2.0	15.38	9.8	9.2	1	6.12
	Nitrogenous fertilizer (Kg/feddan)	255.0	291.0	(36.0)	(14.12)	203.3	188.8	15	7.13
	Phosphates fertilizer (Kg/feddan)	159.0	138.0	21.0	13.21	92.7	104.6	(12)	(12.84)
	Manure (m^3/feddan)	5.0	5.0	0.0	0.00	8.7	7.8	1	10.34
	Labor (days/feddan)	17.0	16.0	1.0	5.88	22.4	20.0	2	10.71
	Machine work (hours/feddan)	33.0	30.0	3.0	9.09	36.0	34.0	2	5.56
	Irrigation water (m^3/feddan)	2764.0	2521.0	243.0	8.79	2613.5	2559.0	55	2.09
	Group II “with WUAs”:								
	Seeds (Kg/feddan)	12.0	10.0	2.0	16.67	10.8	10.0	1	7.41
	Nitrogenous fertilizer (Kg/feddan)	204.0	233.0	(29.0)	(14.22)	254.1	232.0	22	8.70
	Phosphates fertilizer (Kg/feddan)	127.0	111.0	16.0	12.60	116.0	128.0	(12)	(10.34)
	Manure (m^3/feddan)	5.0	5.0	0.0	0.00	10.0	9.0	1	10.00
	Labor (days/feddan)	15.0	13.0	2.0	13.33	23.4	19.0	4	18.80
	Machine work (hours/feddan)	27.0	25.0	2.0	7.41	39.6	38.0	2	4.04
	Irrigation water (m^3/feddan)	2050.0	2000.0	50.0	2.44	2523.0	2480.0	43	1.70

* Numbers between brackets represent negative values.
Source: The results of the survey 2014/2015.

On the other hand, Table 4 showed a comparison between actual and target costs and cost savings for inefficient farms. As for wheat farms, Table 4 showed that if Group I in Behaira Governorate used the target cost minimizing levels of inputs for production, this could result in cost savings estimated at about LE 374 per feddan and still produce the same level of outputs, as compared to about LE 63 per feddan for Group II. Such cost savings contribute to decreasing the actual variable costs by about 8.7%, as well as increasing the actual total revenue and actual gross margin respectively by about 5.7% and 16.8% for Group I. Besides, the cost savings in Group II contributes to decreasing the actual variable costs by 1.8% in addition to increasing the actual total revenue, and actual gross margin by about 0.9% and 1.7%, in that order.

If maize farms of Groups I and II used the target levels of inputs, this could save respectively about LE 321 and 332 of the actual variable costs per feddan while maintaining the same levels of output. Hence, saving about 7.2% and 7.9% of the actual variable costs for Groups I and II, along with increasing the actual total revenue respectively by about 5.9% and 6.1%. Besides, such cost savings could increase the actual gross margin by about 34.0% and 27.1% for maize farms of Groups I and II in Behaira Governorate, respectively.

Table 4. Consequence of cost savings for inefficient farms of Groups I and II in the study sample if the farmers follow the target input package recommended by the DEA approach for wheat and maize.

		Behaira Governorate		**Assuit Governorate**	
		Group I “without WUAs”	Group II “with WUAs”	Group I “without WUAs”	Group II “with WUAs”
Wheat	Cost savings (LE/feddan)	374	63	534	334
	Actual variable costs (LE/feddan)	4292	3501	5533	4205
	Target variable costs (LE/feddan)	3918	3438	4999	3871
	Contribution of cost savings to the actual variable costs (%)	**8.7**	**1.8**	**9.7**	**7.9**
	Average grain yield (Ardab/feddan)	16.00	17.92	18.12	19.6
	Average farm-gate price of grains (LE/Ardab)	407	407	411	411
	Actual total revenue (LE/feddan)	6512	7293	7447	8056
	Contribution of cost savings to the actual total revenue (%)	**5.7**	**0.9**	**7.2**	**4.1**
	Actual gross margin (LE/feddan)	2220	3792	1914	3851
	Target gross margin (LE/feddan)	2594	3855	2448	4185
	Contribution of cost savings to the actual gross margin (%)	**16.8**	**1.7**	**27.9**	**8.7**
Maize	Cost savings (LE/feddan)	321	332	360	433
	Actual variable costs (LE/feddan)	4472	4201	5923	5834
	Target variable costs (LE/feddan)	4151	3869	5564	5401
	Contribution of cost savings to the actual variable costs (%)	**7.2**	**7.9**	**6.1**	**7.4**
	Average grain yield (Ardab/feddan)	14.60	14.62	23.39	23.43
	Average farm-gate price of grains (LE/Ardab)	371	371	300	300
	Actual total revenue (LE/feddan)	5417	5424	7017	7029
	Contribution of cost savings to the actual total revenue (%)	**5.9**	**6.1**	**5.1**	**6.2**
	Actual gross margin (LE/feddan)	945	1223	1094	1195
	Target gross margin (LE/feddan)	1266	1555	1454	1628
	Contribution of cost savings to the actual gross margin (%)	**34.0**	**27.1**	**32.9**	**36.2**

Source: The results of the survey 2014/2015.

As for Assuit Governorate, if wheat farmers follow the target input package recommended by the DEA approach, respectively about 9.7% and 7.9% of the actual variable costs for Groups I and II could be saved and still produce the same level of outputs, compared to 6.1% and 7.4% for maize farmers. Likewise, such cost savings contribute to increasing the actual total revenue and actual gross margin respectively by 7.2% and 27.9% for wheat farms of Group I whereas, the cost savings contribute to increasing the actual total revenue, and actual gross margin by 4.1% and 8.7% in wheat farms of Group II, in that order (Table 4).

In the same way, if maize farms of Groups I and II in Assuit Governorate used the target levels of inputs this could save respectively about 6.1% and 7.4% of the actual variable costs for maize farms of Groups I and II, along with increasing the actual total revenue by 5.1% and 6.2%, respectively. Such cost savings increases the actual gross margin by 32.9% and 36.2% for maize farms of Groups I and II, respectively (Table 4).

These results implied that respectively about 8.7% and 7.2% of the actual variable costs for wheat and maize of Group I in Behaira Governorate could be saved if the farmers follow the input package recommended by the DEA analysis, as compared to about 1.8% and 7.9% respectively for wheat and maize farms of Group II. As for Assuit Governorate, the results showed that about 9.7% and 6.1% of the actual variable costs for wheat and maize produced in farms of Group I could be respectively saved, as compared to respectively about 7.9% and 7.4% for wheat and maize farms of Group II. Based on these consequences, it is evident that there is a narrow gap between the actual levels of inputs used in producing wheat in farms of Group II and the best-practice farms. By contrast, it is clear that the distance to the efficient frontier for maize farms of Group I is shorter than it is for Group II owing to using excess machine work and nitrogenous fertilizer by Group II in Behaira and Assuit Governorates, respectively.

Generally speaking, there’s a potential room to save irrigation water and other resources if the farmers follow the target input package recommended by the DEA approach for production.

3.4. Farmers’ perceptions about Water Users Associations in the study area

3.4.1. Reliability scores of water supply: Based on (Arun et al., 2012), the reliability of irrigation influences the allocation of land and other resources to different crops and farm enterprises. Reliability scores were computed on different parameters of water supply. Table 5 revealed that all reliability parameters scored better for the interviewed members of WUAs. This confirms that availability of irrigation water and control have improved for Group II.

Table 5. Reliability scores of water supply for Groups I and II in the study sample.

	Behaira Governorate		**Assuit Governorate**	
Reliability scores of water supply	Group I “without WUAs”	Group II “with WUAs”	Group I “without WUAs”	Group II “with WUAs”
Accessibility of irrigation water to the whole farm area	1.54	2.64	1.68	2.58
Adequate availability of irrigation water	1.85	2.80	1.74	2.18
Control on irrigation water	1.87	2.56	1.42	2.05
Resolving conflict water problems	1.38	2.32	1.22	2.12

Source: The results of the survey 2014/2015.

3.4.2. Farmer's participation in WUAs: Table 6 showed that the overall value of participation index for the sample members of WUAs in Behaira and Assuit Governorates reached about 4.40 and 3.84, respectively. This inferred that Group II in Behaira Governorate had active participation in most of the activities of WUAs. However, Group II in Assuit Governorate were more involved in two activities namely; contribution of cash towards hiring labor to conduct further maintenance works for the WUAs and involvement in irrigation scheduling.

Table 6. Participation index of Group II in the study sample.

	Behaira Governorate	**Assuit Governorate**
Participation in the elections of the board of WUAs	0.82	0.30
Attending meetings on planning	0.92	0.76
Attending meetings for repairs and maintenance	0.58	0.46
Contribution of cash towards hiring labor to conduct further maintenance works for the WUAs	0.72	0.84
Involvement in irrigation scheduling	0.56	0.92
Motivating other farmers to join WUAs	0.80	0.56
Participation Index (PI)	**4.40**	**3.84**

Source: The results of the survey 2014/2015.

4. Concluding remarks, recommendations and policy implications

In order to reach more efficient utilization of its available water, Egypt is implementing programs for better water management in the agricultural sector. An important part of this is to introduce more efficient farmer participation in all decisions related to irrigation management at the *Mesqa*. Water Users Associations (WUAs) serve in this concern.

This study, therefore, employed Data Envelopment Analysis approach to data collected from 200 farmers divided into two groups; Group I "without WUAs" and Group II "with WUAs" to measure, compare and assess the estimated efficiencies for both groups and determine the potential of input and cost savings. Besides, this technique allows determining the potential of input and cost savings in the production of these crops.

The study concludes that farms of Group II were more technically efficient than those of Group I. Group I was not utilizing their production resources efficiently and they were not obtaining maximal output from the given level of inputs available to them, as well. Contrary to this, the results indicate that Group II was more efficient in using the inputs of wheat and maize production in the study area. Besides, farms of Group II generally apply better input mix (the cost minimizing level) given input price. Therefore, the agricultural extension body should direct farmers towards the best practices of cultivation and optimal use of different resources.

Separate analysis of both groups proved that since wheat and maize farms of Group II were found technically more efficient and waste less of inputs consequently, the gap between the actual levels of inputs used in these farms and the best-practice farms is narrowed whereas, the actual excess levels of inputs used in wheat and maize farms in Group I were far from the best operating practices. This result implied that there exists still a potential for increasing the profit of the farms in Group I, if the inputs gap between the actual and the best-practice farms is narrowed. This highlighted the importunate of that the utilization of different resources in production in terms of efficient, sustainable and economic use. It can be expected that all these measurements would be useful not only for decreasing production costs and providing higher efficiency, but also for reducing negative effects to environment, human health and maintaining sustainability. Based on these consequences, it is clear that joining the WUAs ameliorates the technical efficiency, allocative efficiency, and economic efficiency of using different resources in production. This can be a positive result towards encouraging farmers to join WUAs.

Based on our findings, the reduction in irrigation time and the reduced irrigation labor requirements contributed to decreasing the pumping and irrigation costs for Group II as a result of *Mesqa* improvement. This result was confirmed by (Ashour et al., 2010) showing that the costs of irrigation reduced after improvement owing to the single lifting point and better irrigation schedule that minimized waiting time until water is available at the head of the field.

Our results brought out the fact that the yields, total revenues and gross margins realized for wheat and maize produced in farms of Group II were higher than those obtained by Group I. Moreover, our results were supported by the results of (Molle et al., 2015) that reported saving water and improving the yields owing to *Mesqa* improvement.

Our results portray the positive impact of WUAs on increasing the efficiency of using different resources, enhancing agricultural productivity and improving livelihoods.

Furthermore, the reliability of water supply (including the availability of water and control) improved for Group II. This depicts the positive impact of joining WUAs. Hence, farmer's participation in WUAs contributes to improving farm water management and crop productivity. The overall participation index was found satisfactory. Besides, Group II in Behaira Governorate needs more active participation in irrigation scheduling whereas, the performance of Group II in Assuit Governorate on participation in the elections of the board of WUAs and motivating other farmers to join WUAs was found poor. This suggests a need to increase farmer's participation in WUAs that also expose them to water management training, taking into account the low level of education among farmers in Assuit Governorate. Therefore, the Irrigation Advisory Service (IAS) and the agricultural extension body need to be strengthened to provide continuing support to WUAs, develop farmer participation and forming WUAs.

Finally, the decentralization of irrigation management through joining WUAs is a good approach to increase agricultural productivity in a sustainable manner. Hence, efforts should be directed towards generating awareness among the farmers regarding the advantages of WUAs to induce effective and efficient participation of all stakeholders.

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Appendices:

Table A.1: Geographical distribution of WUAs in Egypt till September, 2014.

Governorate	**No. of established WUAs**	**%**	**Area Served (000 feddans)**	**%**	**No. of formally registered WUAs**	**%**
Behaira and Alexandria	2650	29.26	170	30.75	2011	30.52
Gharbia, Kafr El Sheikh and Menufia	3346	36.94	197	35.69	2062	31.29
Sharkia and Dakahlia	932	10.29	65	11.79	573	8.70
Menia, Beni Seuf, Assuit and Sohag	1840	20.32	93	16.84	1807	27.42
Aswan and Qena	167	1.84	16	2.88	61	0.93
Others	122	1.35	11	2.04	75	1.14
Total	**9057**	**100.00**	**552**	**100.00**	**6589**	**100.00**

Source: Unpublished data collected from MWRI, 2015.

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التحليل الاقتصادي لكفاءة استخدام الموارد في روابط مستخدمي مياه الري بجمهورية مصر العربية

إيناس محمد عباس صالح*

*** باحث أول - معهد بحوث الاقتصاد الزراعي - مركز البحوث الزراعية**

يعتبر نهر النيل المصدر الأساسي لمياه الري في جمهورية مصر العربية ، ومع النمو المضطرد للسكان وتعاظم الاحتياجات الغذائية لهم ، فلا مناص عن تعظيم الاستفادة بكل قطرة من المياه ، وذلك من خلال تنفيذ خطة لتطوير الري وتكوين روابط مستخدمي المياه. وتحاول الدراسة الراهنة الإجابة عن تساؤل حول: هل الانضمام إلى روابط مستخدمي مياه الري يحسن من كفاءة استخدام الموارد على مستوى المزرعة؟ ومن ثم فإن الدراسة الراهنة تستهدف تقدير ومقارنة الكفاءة الفنية والاقتصادية لاستخدام الموارد في الإنتاج ، وتحديد ذلك القدر من الموارد التي يتم الإسراف في استخدامها ، وكذا الموارد (والتكاليف) التي يمكن توفيرها ، فضلاً عن التعرف على مدى ثقة واعتمادية أعضاء الروابط في الحصول على مياه الري من خلال الرابطة ، وقياس مدى مشاركة أعضاء الروابط في أنشطتها المختلفة.

وقد اعتمدت الدراسة على نتائج استبيان تم بالموسم الزراعي ٢٠١٥/٢٠١٤ لعينة تضم 200 مزارعاً تم اختيارهم من محافظتي البحيرة وأسيوط وتم تقسيمهم إلى مجموعتين: تضم الأولى "الزراع غير المنضمين للروابط" ، وتضم الثانية "الزراع المنضمين للروابط". ولتحقيق هذا الهدف ، فقد استخدمت أسلوب المنحنى مغلف البيانات لأهم المحاصيل بمنطقة الدراسة (القمح والذرة الشامية) ، كما تم استخدام بعض المقاييس للتعرف على مدى ثقة أعضاء الروابط في الحصول على مياه الري من خلالها ومدى مشاركة الأعضاء في أنشطة الروابط.

وأوضحت نتائج الدراسة أن متوسط الكفاءة الفنية لزراع القمح بعينة الدراسة من المجموعتين الأولى والثانية بمحافظة البحيرة قد بلغ نحو ٠,٩٤ و٠,٩٦ على الترتيب ، وهو ما يشير إلى إمكانية توفير الموارد المستخدمة في الإنتاج بنحو ٥,٧% و٤,٠% للمجموعتين على الترتيب مع تحقيق نفس المستوى من الإنتاج ، وقد بلغ متوسط الكفاءة الفنية للمجموعتين الأولى والثانية بمحافظة أسيوط نحو ٠,٩٨ و٠,٩٩٦ بالترتيب. وقد حقق زراع القمح بعينة الدراسة بمحافظة البحيرة كفاءة اقتصادية بلغت نحو ٦٤,٦% و٦٧,٩% للمجموعتين بالترتيب ، مما يعني إمكانية توفير نحو ٣٥,٤% و٣٢,١% من تكاليف الإنتاج للمجموعتين على الترتيب مع تحقيق نفس المستوى من الإنتاج ، في حين بلغت الكفاءة الاقتصادية للمجموعتين الأولى والثانية بمحافظة أسيوط نحو ٨٧,٩% و٨٩,٨% بالترتيب. وبالنظر إلى متوسط الكفاءة الفنية لزراع الذرة الشامية بعينة الدراسة من المجموعتين الأولى والثانية بمحافظة البحيرة ، فقد تبين أنه قد بلغ نحو ٠,٩٧٦ و٠,٩٨٣ على الترتيب ، في حين بلغ متوسط الكفاءة الفنية للمجموعتين الأولى والثانية بمحافظة أسيوط نحو ٠,٩٨ و٠,٩٩٦ بالترتيب. وقد حقق زراع الذرة الشامية بعينة الدراسة بمحافظة البحيرة كفاءة اقتصادية بلغت نحو ٥٧,٢% و٦٠,١% للمجموعتين بالترتيب ، بينما بلغت الكفاءة الاقتصادية للمجموعتين الأولى والثانية بمحافظة أسيوط نحو ٦٨,٧% و٧٣,٤% على الترتيب.

وتشير نتائج الدراسة إلى أنه باتباع النموذج الذي اقترحه أسلوب المنحنى مغلف البيانات ، فإنه يمكن تخفيض التكاليف المتغيرة الفعلية لإنتاج القمح والذرة الشامية بنحو ٨,٧% و٧,٢% بعينة الدراسة للزراع من المجموعة الأولى بمحافظة البحيرة ، وذلك بالمقارنة بنحو ١,٨% و٧,٩% للمجموعة الثانية. وفي محافظة أسيوط ، تبين أن اتباع النموذج المقترح يخفض التكاليف المتغيرة الفعلية لإنتاج القمح والذرة الشامية بنحو ٩,٧% و٦,١% بعينة الدراسة للزراع من المجموعة الأولى بمحافظة أسيوط ، وذلك بالمقارنة بنحو ٧,٩% و٧,٤% للمجموعة الثانية.

نظراً لأن نتائج الدراسة أوضحت تفوق الكفاءة الفنية والكفاءة الاقتصادية لزراع القمح والذرة الشامية المنضمين لروابط مستخدمي المياه بعينة الدراسة في محافظتي البحيرة وأسيوط ، فإن الدراسة توصي بتفعيل دور هذه الروابط وتوعية الزراع بأهمية الانضمام إليها بهدف رفع كفاءة استخدام الموارد (وأهمها مياه الري) مع تحقيق لا مركزية في إدارة مياه الري.