Evaluation of irrigation improvement projects in the Nile Delta

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Water resources of Egypt are becoming scarce. Therefore the government is integrating activities toward optimizing benefits from the scarce water resources [1]. One of the most important efforts of Egyptian government in this regard is the Irrigation Improvement Project (IIP). The main objective of this study is to evaluate the performance of the IIP in the Nile Delta to determine the extent of achievements of project goals by assessing actual impacts and comparing them with expected impacts. Two command areas of IIP in the Nile Delta are chosen; El-Kahwagy and Daqalt command areas. Rapid Appraisal Process (RAP) is being used in this study to identify what can be done to improve project performance through applying a group of selected performance indicators. The results of this study showed efficient values of external indicators compared with the other projects evaluated by Burt and Styles [2] in other similar countries. It is noticed that the performance indicators are improved after applying IIP. Evaluation of IIP in the selected areas showed that the results of productivity indicators of IIP in Daqalt area is much better than El-Kahwagy area.

نظرا لمحدودية موارد المياه فى مصر وجهت وزارة الموارد المائية والرى جهودها للقيام بمشروعات بهدف تعظيم الاستفادة من مواردنا المائية. ومن أهم هذه المشاريع مشروع تطوير الرى فى الأراضي القديمة. ويهدف هذا البحث الى تقييم مشروعات تطوير الرى بمنطقة الدلتا ، حيث تم دراسة منطقتي القهوجى بمحافظة الغربية و دقلت بمحافظة كفر الشيخ وذلك عن طريق استخدام برنامج (RAP) والذي يوفر أسلوب منظم لتقييم مشروعات الرى عن طريق حساب مجموعة من مؤشرات الأداء الداخلية والخارجية ومقارنة هذه النتائج بمعايير ثابتة حددها تقرير منظمة الأغذية والزراعة (FAO) التابعة لهيئة الأمم المتحدة . كما تم عمل مقارنة بين نتائج مشروع التطوير فى مصر ومشاريع أخرى مشابهة فى ظروفها للظروف المصرية من حيث المناخ و نوعية المحاصيل المزروعة و نوعية التربة . كما تم عمل مقارنة بين قيم مؤشرات الأداء قبل وبعد تنفيذ مشرع التطوير بمنطقة القهوجى. كما تم أيضا عقد مقارنة بين قيم مؤشرات الأداء فى منطقة القهوجى ومنطقة دقلت بعد تطبيق مشروع التطوير بهم. وتبين من هذه الدراسة ان نتائج مؤشرات الأداء الخارجية لمشروعي تطوير الرى بمنطقتى القهوجى ودقلت ذات كفاءة عالية بصفة عامة مقارنة بالمشاريع الأخرى. كما أظهرت مقارنة نتائج مؤشرات الأداء قبل وبعد تطبيق مشروع التطوير بمنطقة القهوجى زيادة فى عائد الإنتاجية الزراعية بنسبة ١٥% بعد التطوير كما زاد مؤشر كفاءة الرى لمنطقة القهوجى بنسبة ٢٦% بعد التطوير.

Keywords: Evaluation, Irrigation, Improvement, RAP, Indicators.

1. Introduction

Irrigation Improvement Project (IIP) is considered a national project and it is to be seen as a first step in the direction of bringing the Egyptian irrigation system in line with the demand. IIP is enhancing irrigation efficiency through technical improvement such as: changing the operation of branch canals from rotation system to continuous flow system, grouping of individual pumps into one lifting point at the head of the mesqa (single-point lifting), low- level mesqas replaced by high level mesqa (J-section) or by low-pressure pipelines with alfa-alfa valves feeding marwas and land leveling by laser. In addition to institutional improvement such as exhorting and educating farmers through Irrigation Advisory Services (IAS) formed for the purpose of promoting the rational use of water for irrigation, forming Water Users Associations (WUAs) in new and old, improved and non-improved lands, for better water management and more efficient recovery of operation and maintenance costs. The objectives of IIP can be summarized as removing water supply constraints to the achievements for realizing optimum crop production and to improve the overall efficiency of water use [3]. According to Walker [4] the principal objective of evaluating surface irrigation systems is to identify management practices and system configurations that can be feasibly and effectively implemented to improve the irrigation efficiency.

Molden and Gates [5] studied the performance measures for evaluation of irrigation-water delivery systems. They developed performance measures to facilitate analysis of irrigation water delivery systems in terms of adequacy, efficiency, dependability and equity of water delivery. The measures provided a quantitative assessment not only overall system performance, but also contributions to performance from structural and management components of the system. Gergis [6] used this assessment and evaluated the performance of improved and traditional water delivery system by measuring several indices such as; adequacy, efficiency, dependability and equity and she used a mathematical model for modernizing delivery system.

A few performance indicators have been included in irrigation field for many decades and many have developed indicators that they have found to be useful. Murray-Rust and Snellen [7] described the framework of using performance indicators and noted two approaches to the use of performance indicators in the field of irrigation. Firstly, attempts to develop indicators which allow the performance of one system to be compared to similar systems elsewhere. Secondly, the use of indicators to compare actual results with what was planted. Bos [8] lists about 40 multidisciplinary performance indicators. Molden et al. [9] worked on other indicators such as indicators for comparing performance of irrigated agricultural systems.

El-Kholy et al. [10] studied the improvement of the on-farm irrigation management and practices in Egypt. Several performance indices such as adequacy, reliability, equity and other parameters using actual field data have been studied on a case study on Herze and Numania area (El-Minia, Egypt). She stated that IIP solves the problems of this area, which has the most conflict and the least efficiency in the irrigation system and creates better communication between the supplier and users. She concluded that there is an increase in productivity in the range between 6% and 25%. Moreover, saving in operation and maintenance costs is reduced approximately by 50% and 90%, respectively.

Hevdit [11] collected survey data on three canal commands in middle Egypt. They are Herz-Numaniya and Beni Ibeid, which are located close to the city of Minia, and Qiman Arus, adjacent to the city of Beni Suef. In his study, he analyzed the IIP effort at three parameters, water control, land saving and farm income. He analyzed water control on three dimensions (adequacy, reliability and fairness). He concluded that farmers' water control is improved because of well functioning continuous flow in operation. The mesqa systems improved water control, in addition to saving land. 40% of saved lands are used for agriculture and 60% for roads. He observed sizable reduction in irrigation cost including pumping cost. He noticed the decrease of time used to irrigate and cost of canal maintenance. Farmer income is improved and an increase of 13% in yields following IIP improvement is gained.

El-Nashar [12] compared between the discharge and area served before and after applying IIP in Saidiya canal (Zgazig) and Mahmoudia canal (Damanhour). She suggested a system of improvement in Mashtoul command area according to IIP components. The economic evaluation of the improvement process is also included. She stated that after calculation of area served and discharge before and after development, it was found that a saving in water quantities equals to 14%. A saving in land areas equals 4% of the total served area can be obtained.

The main objective of this study is to evaluate the IIP in the Nile Delta (El-Kahwagy and Daqalt command areas) using RAP to identify what can be done to improve project performance thr-ough applying a group of selected and performance indicators. According to Burt [13], RAP is defined as a diagnostic tool that allows a qualified evaluator to systematically examine the irrigation project to be determined by computing several indicators (internal and external).

2. Cases studied

In order to carry out this evaluation, two command areas of IIP are chosen. They are El-Kahwagy in El-Gharbia governorate and Daqalt in Kafer El-Sheikh governorate. They are alike in their physical status, located in the Nile Delta and feeding from Meet Yazeed main canal in the middle of the Nile Delta as shown in fig. 1.

Daqalt area is served by Daqalt canal, which is a typical traditional distributary canal in the Nile Delta serves an area of about 5400 feddan. The Ministry of Water Resources and Irrigation improved the canal to be operated under continuous flow through three downstream control gates but it is still operating with rotation flow system. The area is served by about 82 improved mesqas. About 75% of improved mesqas are planed to be pipelines and the other mesqas are concrete J-section. El Kahwagy area is served by El-Kahwagy canal. El-Kahwagy canal is a distributary canal, which was improved in 1992 as a pilot area of the IIP. It is operated under continuous flow. The flow in the canal is controlled by Avis gates, which are downstream control devices. Manual gates are used to control discharges into branches. Branch canals are fed from El-Kahwagy canal. Single point lifting is introduced at each improved mesqa (concrete lined or low pressure pipe lines). Improved mesqas are operated and maintained by Water Users Associations.

3. Rapid appraisal process

The Rapid Appraisal Process (RAP) allows a qualified evaluator to systematically examine the irrigation project to be determined [14]. RAP is a process of collection and analysis of data both in the office and in the field. The process examines external inputs such as water supplies, and outputs such as water destinations (evapotranspiration (ET), surface runoff, etc.). It provides a systematic examination of the hardware and processes used to convey and distribute water internally to all levels within the project. According to Burt and styles [2] RAP is classified into:

External indicators: They examine what goes into and what leaves a project, whether it is money, water, water quality or other items. They can be very useful in comparing the conditions before and after applying a project.

Internal indicators: Examines how things function, and what internal factors might affect. They help to show what processes might be changed and how to impact the external indicators.

4. Results and analysis

4.1. External indicators

Water balance data of El-Kahwagy and Daqalt command areas for 12 months of year 2003-2004 were collected. The data include water supply, crop pattern, crop water requirements, volume of recirculated water in the project, special crop needs for the preparation of the land and climate data. Water requirement for ET_0 were calculated by

Penman Monteith equation [15]. External indicators were calculated based on the previous data to show the relative performance of the projects in terms of water supply and agricultural production. Unfortunately, there are no available discharge data of El-Kahwagy canal before and even after applying IIP. According to the available water levels and gates openings at head regulators, the discharges into El-Kahwagy and Daqalt canals were estimated. External indicators are divided into indicators of water supply and indicators of agricultural output due to irrigation. The calculations of agricultural output are based on an exchange rate 1 U.S $ equals 6.25 L.E. Fig. 2 illustrates the selected external indicators that introduced by the RAP.

4.1.1. Indicators of water supply

These performance indicators help to determine various efficiencies related to water supply in the command areas. Comparisons between the water supply indicators in different projects as evaluated by Burt and Styles

[2] and the corresponding values for El-Kahwagy and Daqalt areas are introduced.

4.1.1.1. Relative water supply (RWS) and relative irrigation supply (RIS) Relative Water Supply (RWS) is an annual value which

compares the total water supply (irrigation water and non irrigation water) that enters the command area against the net irrigation water requirements. If relative water supply is less than 1.0 it compresses need of water (crop stress). Fig. 3 shows the value of relative water supply in
different irrigation projects as evaluated by Burt and Styles [2].

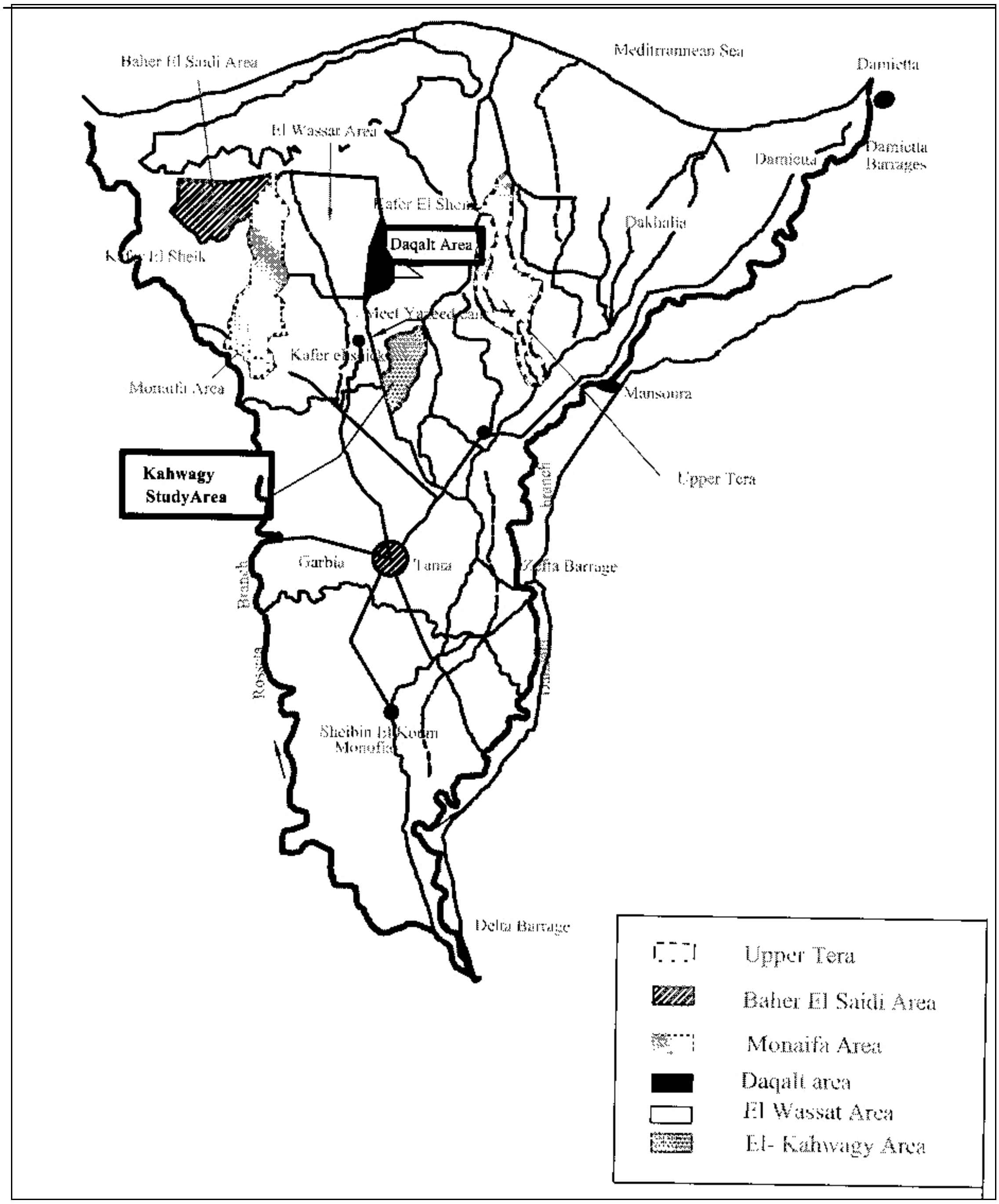


Fig. 1. Location map of IIP command areas in middle delta directorate [16].

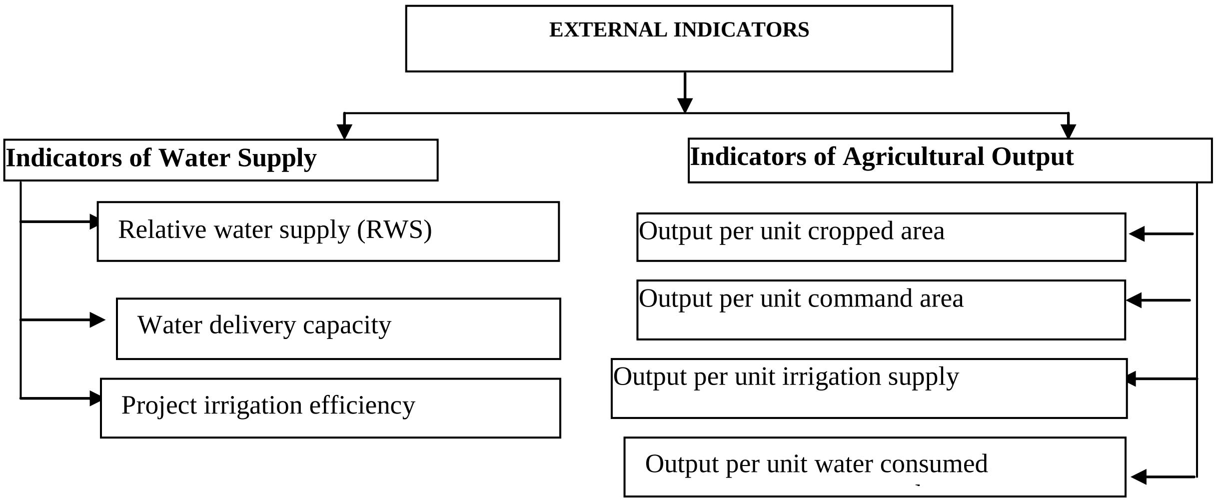
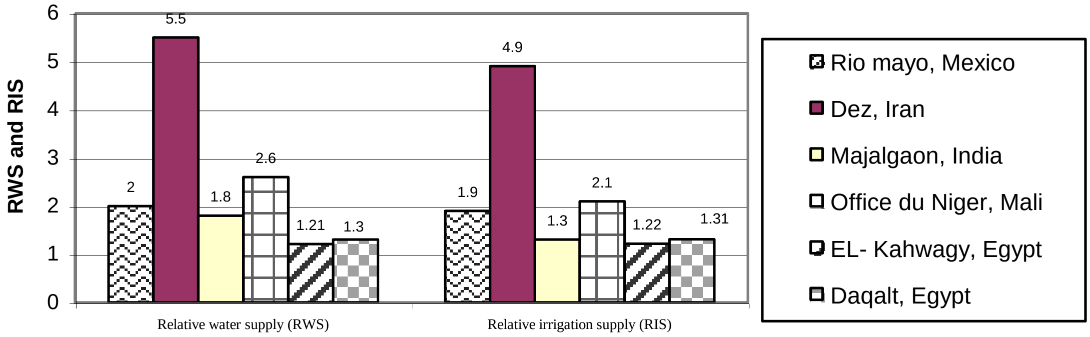


Fig. 2. The selected external indicators computed by the RAP.



$$RWS = \frac{\text{surface irrigation water supply} + \text{rainfall} + \text{net aquifer withdrawl}}{(\text{ET} - \text{eff. rainfall}) + \text{salt control} + \text{special practices}}$$

$$RIS = \frac{\text{surface irrigation water supply} + \text{net aquifer withdrawl}}{\text{crop ET} - \text{efficitive rainfall}}$$

Fig. 3. Relative water supply and relative irrigation supply in different projects.

compared with the corresponding values for El-Kahwagy and Daqalt areas. El-Kahwagy and Daqalt projects have values of 1.17 and 1.29, respectively, which are considered satisfactory compared with other projects. Dez project in Iran [2] has a value of 5.5. This high value reflects the high volumes of water supplied to the project, which is uneconomic. It is noticed that the relative water supply of Daqalt project is higher than in El-Kahwagy project as shown in fig. 3. This means that Daqalt area receives more water than its need. RIS is the ratio between irrigation supply and irrigation demand. Since the amount of rainfall in El-Kahwagy and Daqalt areas are very small and consequently, negligible differences between RWS and RIS values are noticed in fig. 3.

Fig. 4 shows a comparison between RWS before and after implementation of IIP in El-Kahwagy area. It shows a decrease of about 15% in relative water supply after implementation of IIP in El-Kahwagy area. This means a reduction in water supplied to the command area after applying IIP. This is due to applying continuous flow system, reduction of water loss at canal ends and increase of conveyance efficiency due to canal lining and improved mesqas.

4.1.1.2. Water delivery capacity this external indicator compares the inflow rates by the project in terms of the canal capacity. It is the value of design canal capacity divided by peak irrigation water consumptive demand. Fig. 5 provides a comparison between the water delivery capacities in different projects as evaluated by Burt and Styles [2] compared with the corresponding values for El-Kahwagy and Daqalt areas. It can be seen that El-Kahwagy and Daqalt canals have the highest value of this indicator, being 261% and 208%, respectively. This is because the cross sections of these canals are designed to pass huge volumes of water in short time during flood period. Accordingly, wider cross-sections are occurred and high capacities of water delivery are obtained. It can be also noticed that El-Kahwagy canal has a higher value of water delivery capacity compared to Daqalt canal. This is because El-Kahwagy canal feeds several branches compared with Daqalt canal. Wider canals allow more storage and more flexibility, easy operation, better water controllability and less spills.

4.1.1.3. Annual project irrigation efficiency this indicator is the ratio of water requirement and water delivered to the project. If irrigation efficiency is properly understood and defined it helps to avoid double counting of water and unwarranted expansion. Fig. 6 shows a comparison between the results of the study in El-Kahwagy and Daqalt areas and the corresponding values of the projects irrigation efficiencies as evaluated by Burt and Styles (1999). El-Kahwagy and Daqalt projects have high values of project irrigation efficiency, being 92% and 83 %, respectively. These values indicate that almost all the irrigation water supply is being beneficially used. The low values of project efficiency like Dez, Majalgaon and Office du Niger projects indicate a potential for plans to increase the irrigated area with the same amount of water supply.

Fig. 7 shows an increase of about 26% in annual project irrigation efficiency after applying IIP into El-Kahwagy area. This is due to the decrease of water supplied to the command area due to applying continuous flow system. The value of annual project irrigation efficiency of El-Kahwagy area showed a higher value compared with Daqalt area. This is due to recirculation of drainage water using a mix pump station in El-Kahwagy area.

4.1.2. Indicators of agricultural output due to irrigation

4.1.2.1 Output per unit cropped area it is the total annual value of agricultural production divided by irrigated cropped area (including multiple cropping). Fig. 8 shows that Daqalt and El-Kahwagy areas have values of output per cropped area 1623 $/ha and 1410 $/ha, respectively. There is a relation between the production value and the crop intensity on the production. It's the value of total annual cropped area divided by the served area in the project. El-Kahwagy and Daqalt projects have crop intensity of 2.23 and 2.34, respectively. Productivity of Majalgaon project in India is

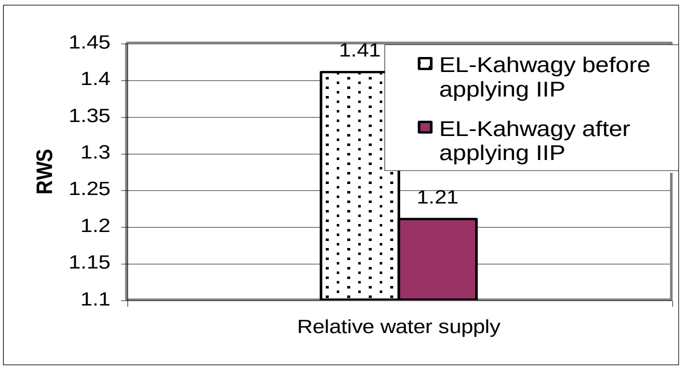
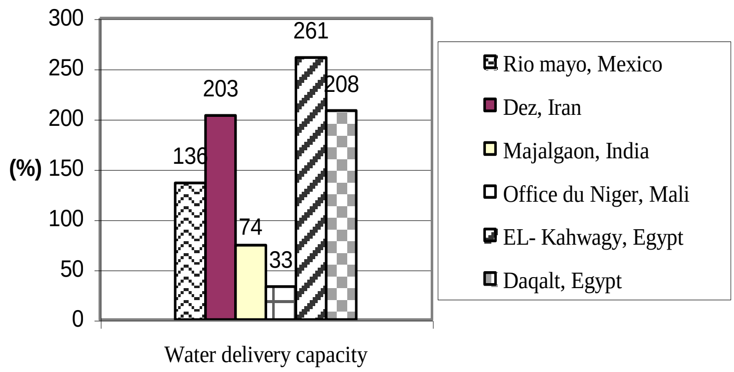
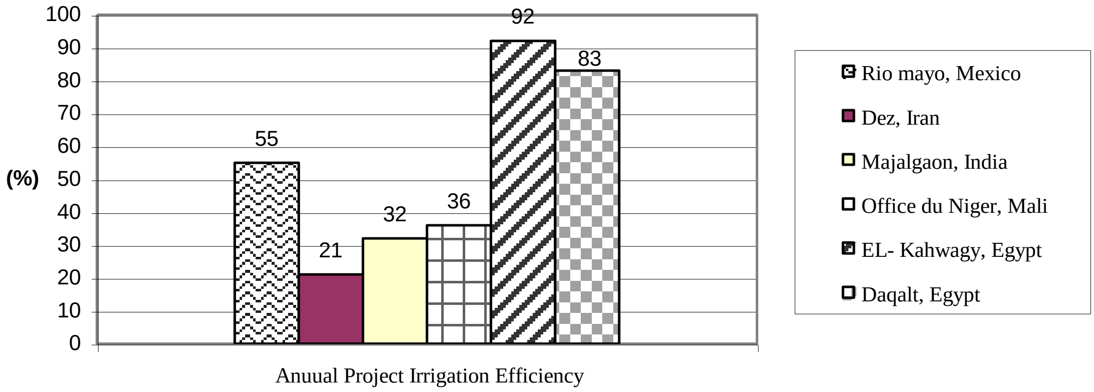


Fig. 4. Comparison of RWS before and after applying IIP in El-Kahwagy area.



$$\text{Water delivery capacity} = \frac{\text{Main canal capacity}}{\text{peak monthly net irrigation water requirement}}$$

Fig. 5. Water delivery capacity.



$$\text{Annual command area irrigation efficiency} = \frac{(\text{Total net irrigation water requirement}) \times 100}{\text{surface irrigation water diversions} + \text{Net aquifer withdrawl due to irrigation in the area}}$$

Fig. 6. Annual project irrigation efficiency.

the lowest because its crop intensity is only 0.3. Fig. 8 shows also that Daqalt has more productivity than El-Kahwagy. This difference may be attributed to that the crop intensity in Daqalt area is higher than El-Kahwagy area. Moreover, the improved area in El-Kahwagy project is only 27% of the total area, while all the served area in Daqalt is improved. This makes the overall field irrigation efficiency of El-Kahwagy area is low compared with Daqalt area.

Fig. 9 shows the effect of IIP on the production value of El-Kahwagy command area. The total annual values of agricultural production and output per unit cropped area are increased by about 15% after applying IIP.

3.1.2.2. Output per unit irrigation water supply it is the production in terms of water supply. Fig. 10 shows output per unit irrigation water supply for El-Kahwagy and Daqalt areas compared with other projects as evaluated by Burt and Styles [2]. It shows that El-Kahwagy and Daqalt have higher values of this indicator than the other projects. That is because the amount of water supplied to the projects is nearly matching crop needs. It is noticed that other projects supply high volumes of water. Fig. 10 shows that El-Kahwagy area has a higher value of output per unit irrigation water supply compared with Daqalt area. This is because continuous flow is applying into El-Kahwagy canal, while Daqalt canal is still under the rotation flow system.

Fig. 11 shows comparison between the output per unit irrigation supply for El-Kahwagy area before and after implementation of IIP. It can be noticed that there is an increase of about 44% in the output per unit irrigation water supply. This is due to the increase of productivity and decrease of water supplied to the command area.

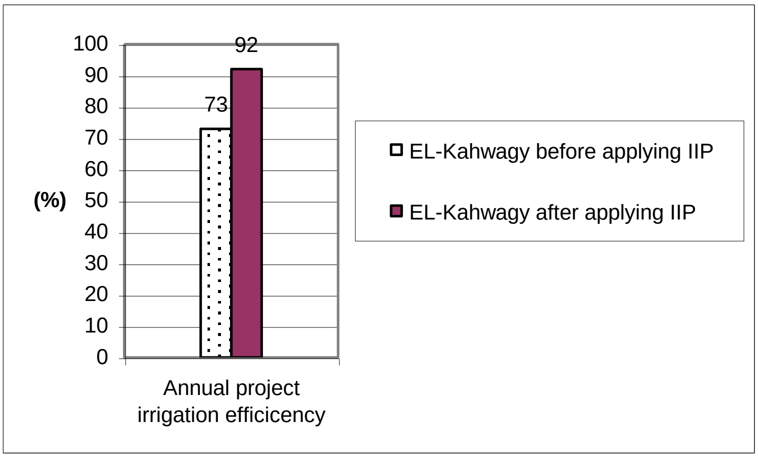
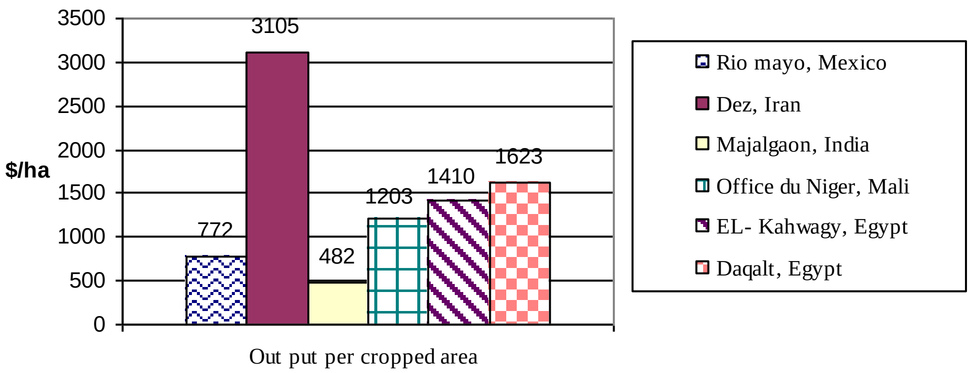


Fig. 7. Comparison of annual project irrigation efficiency before and after applying IIP into El-Kahwagy area.



$$\text{Output per cropped area} = \frac{\text{Total annual value of agricultural production}}{\text{Total annual irrigated cropped area}}$$

Fig. 8. Output per unit cropped area.

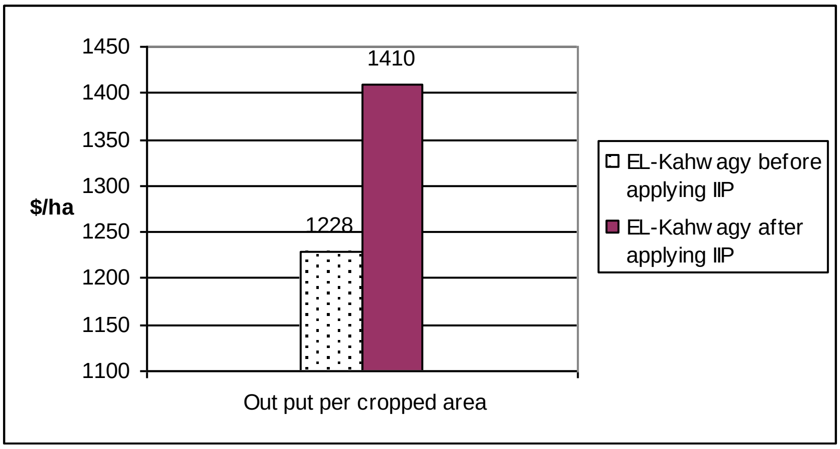


Fig. 9. Comparison between outputs per unit cropped area before and after applying IIP.

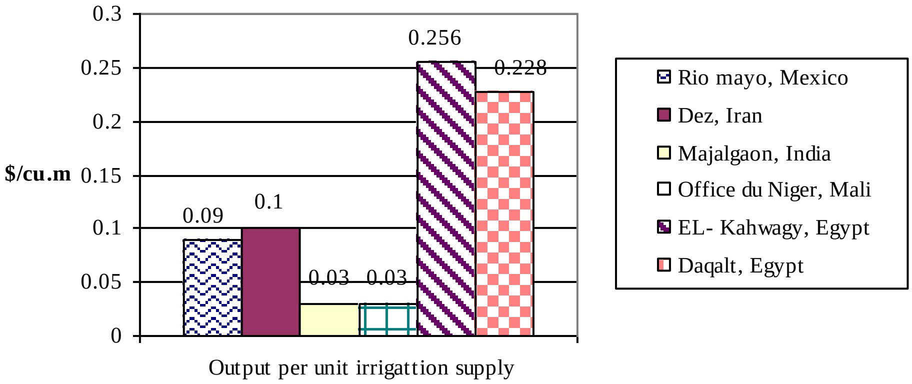
4.2. Internal indicators

The objectives of the internal indicators are to identify the key factors related to water control throughout projects and to define the level of water delivery service provided to the users. The objectives are also to examine specific hardware and management techniques and processes that used in the control and distribution of water. This information combined with the detailed results of the RAP to provide a guideline of the items where project authorities should focus the future activities and budget priorities.

Table 1 lists the studied internal indicators and their sub-indicators. Each internal indicator has assigned a value of 0 to 4. The zero value indicates the least desirable, while 4 denotes the most desirable. Data from field visits and several hundred questions are answered in a standardized format covering topics such as water supply, personnel management, canal structures, level of water delivery service throughout the project. Numerous related topics were collected for all levels of canals in El-Kahwagy command area. The value of each indicator is determined by applying Burt and Styles [2] relative weighting factors to each sub-indicator then summing up them to produce the overall values of indicators and adjusting them based on possible scale of 0-10 (10 indicating the most positive conditions).

4.2.1. Actual water delivery services to various levels of canals

The actual water delivery service to the field level is the measure of flexibility, reliability, equity and measurement of water supply to individual fields. Fig. 12 shows an overall value of actual water delivery service to individual fields for El-Kahwagy area compared with other projects that evaluated by Burt and Styles [2]. It shows that Rio Mayo project in Mexico has a value of 7.8. It is the highest value of this indicator. It has a high flexibility in water delivery service to individual fields and a very high density of turnouts. In this project, operators know the flow rates in advance throughout the project reasonably well. They have excellent communications and mobility and work quickly and quite to provide flexibility. For the five projects, the average value of actual water delivery service to the fields is 5.44 of 10. El-Kahwagy canal has a value of 6.0, which is higher than the average value, but it can be improved if the project authorities pay attention to flow measurements in fields Fig. 13 shows a comparison between actual water delivery service before and after implementation of IIP. Due to increasing of flexibility, reliability and equity after the application of continues flow to El-Kahwagy area, the actual water delivery service to individual fields improved from a value of 2.25 to 6.0 of 10.



Output per unit irrigation supply

$$= \frac{\text{Total annual value of agricultural production}}{\text{surface irrigation water from outside the area + total annual ground water pumping (if any)}}$$

Fig. 10. Output per unit irrigation water supply.

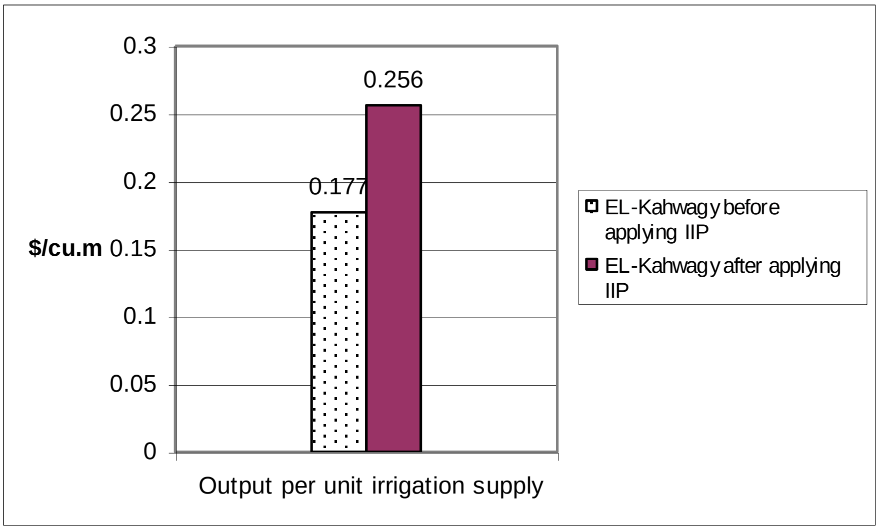


Fig. 11. Comparison between outputs per unit irrigation supply before and after applying IIP.

4.2.2. Water Users Associations (WUA)

WUA have received much attention in the last two decades. In many cases, discussions appear to assume that if a WUA is formed, many irrigation project problems will disappear. However, the WUA must empower by water and law in order to be effective. Strong WUA can be formed if there are reliable water supply, financial management by WUA, autonomy, good training (both farmers and engineers) of technical managerial skills.

Fig. 14 shows that the value of this indicator in El-Kahwagy command area is very low and equals 1.5. This is because there are no strong WUA's in the area. El-Kahwagy area was the first pilot area of the IIP, so there were some problems which made the farmers not satisfied with the services received. The most noticeable factor which needs to accom pany a reliable supply to the WUA is a high density of manageable turnouts (requiring very little or no inter- farmer cooperation) with the WUA itself. Daqalt project has better performance of WUA compared with El-Kahwagy project. This is because of the better infrastructures available in Daqalt area. It can be noticed that Dez project in Iran and Office du Niger project in Mali have zero value because they do not have WUA.

4.2.3. States of main canal control structures, management and operation

Fig. 15 shows comparison between the results of main canal management internal indicators for El-Kahwagy and other projects evaluated by Burt and Styles [2]. It illustrates five internal indicators for the main canal.

The first internal indicator is the cross regulator hardware. This indicator examines ease of operation, level of maintenance, fluctuations of target levels and travel time of flow rate changes through the length of canal. It is noticed that El-Kahwagy and Majalgaon projects have higher values of this indicator compared with other projects. This is because using radial gates along the main canals. This type of gates allows very easy operation and control. In El-Kahwagy, it is recommended for IIP authorities to pay attention to the maintenance level of cross regulators and to the problems of design and installation.

The second internal indicator is turnouts from the main canal. Turnouts designs vary widely in their ease of operation and in how well operators can control and measure flow rates. In El-Kahwagy, the value of this indicator is 5.75, which is considered low compared with the average of other projects, which is 6.83. Although there are simple manual gates easy to operate, there is no maintenance of these gates and broken parts are noticed in the project. There are problems in passing the maximum desired flow rate, where some offtakes level is high and, consequently, the levels of water don't reach the outlet of

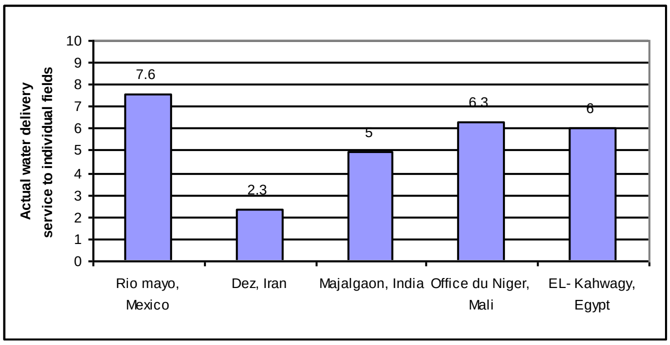


Fig. 12. Overall values of actual water delivery service to individual fields.

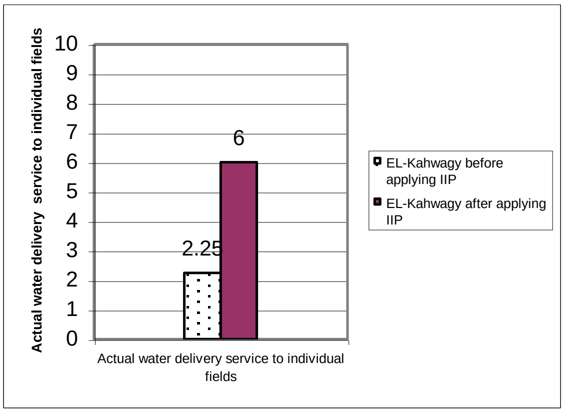


Fig. 13. Comparison of actual water delivery service to individual fields before and after applying IIP.

Table 1
Internal indicators and sub-indicators computed by the RAP

Internal indicator	Sub-indicator	Wt. factor
Actual water delivery service to individual fields	Measurement of volumes to individual fields	1
	Flexibility to individual units	2
	Reliability to individual units	4
	Apparent equity to individual units	4
Actual water delivery service from main canal to sub-main	Flexibility	1
	Reliability	1
	Equity	1
	Control of flow rates to the submain as stated	1.5
Social order indicator –evidence of orderly behavior throughout the canals that are operated by paid employees	Degree to which deliveries are NOT taken when not allowed, or at flow rates greater than allowed	2
	Noticeable non-existence of unauthorized turnouts from canals.	1
	Lack of vandalism of structures.	1
Employee indicator	Frequency and adequacy of training of operators and middle managers (not secretaries and drivers). This should include employees at all levels of the distribution system, not only those who work in the office.	1
	Availability of written performance rules	1
	Power of employees to make decisions	2.5
	Ability of the project to dismiss employees with cause.	2
	Rewards for ememplary service	1
	Relative salary of an operator compared to a day laborer	2
Water user association indicator	Percentage of all project users who have a functional, formal unit that participates in water distribution	2.5
	Actual ability of the strong Water User Associations to influence real-time water deliveries to the WUA.	1
	Ability of the WUA to rely on effective outside help for enforcement of its rules	1
	Legal basis for the WUAs	1
	Financial strength of WUAS	1
Turnouts indicators	Ease of turnout operation under the current target operation. This rating indicates how easy or difficult it would be to move the turnouts and measure flows to meet the targets.	1
	Level of maintenance	1
	Flow rate capacities	1
Cross regulator hardware	Ease of cross regulator operation under the current target operation. This does not mean that the current targets are being met; rather this rating indicates how easy or difficult it would be to move the cross regulators to meet the targets.	1
	Level of maintenance of the cross regulators.	1
	Lack of water level fluctuation	3
	Travel time of a flow rate change throughout this canal level	2
Main canal communications	Frequency of communications with the next higher level? (hr)	2
	Frequency of communications by operators or supervisors with their customers	2
	Dependability of voice communications by phone or radio.	3
	Frequency of visits by upper level supervisors to the field.	1

Continues of Table 1

	Existence and frequency of remote monitoring (either automatic or manual) at key spill points, including the end of the canal	1
	Availability of roads along the canal	2
General condition of the main canal	General level of maintenance of the canal floor and canal banks	1
	General lack of undesired seepage (note: if deliberate conjunctive use is practiced, some seepage may be desired).	2
	Travel time from the maintenance yard to the most distant point along this canal (for crews and maintenance equipment)	1
	Availability of proper equipment and staff to adequately maintain this canal	1
Operation of the main canal	How frequently does the headworks respond to realistic real time feedback from the operators/observers of this canal level? This question deals with a mismatch of orders, and problems associated with wedge storage variations and wave travel times.	2
	Existence and effectiveness of water ordering/delivery procedures to match actual demands. This is different than the previous question, because the previous question dealt with problems that occur AFTER a change has been made.	1
	Clarity and correctness of instructions to operators.	1
	How frequently is the whole length of this canal checked for problems and reported to the office? This means one or more persons physically drive all the sections of the canal.	1

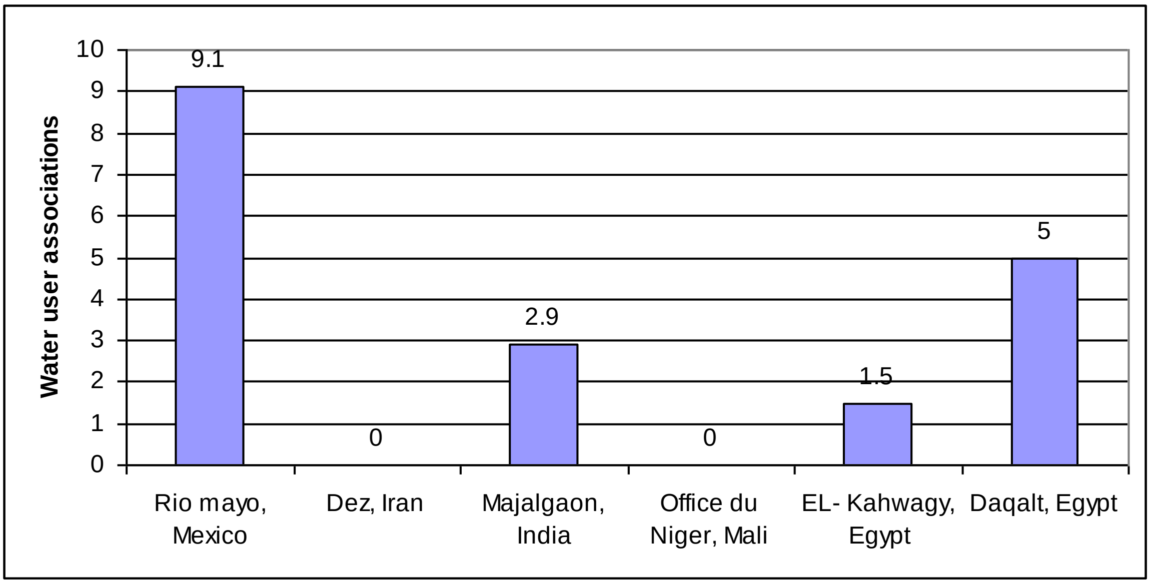


Fig. 14. Overall value of water user associations indicator.

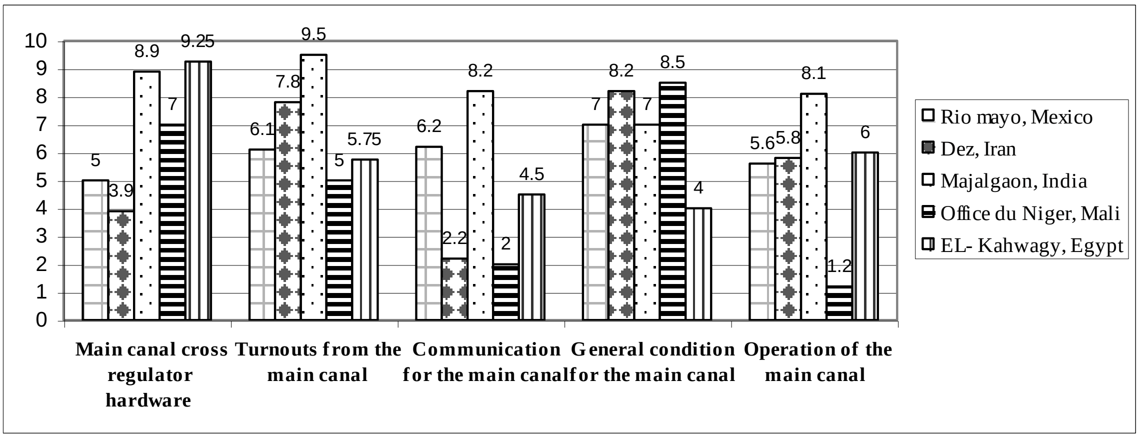


Fig. 15. States of main canal control structures, management and operation.

offtakes. The value of this indicator can be improved by increasing the level of maintenance of turnout gates.

The third internal indicator is the communication. A major consideration in canal management is the communication between operators and monitoring of water levels and flows at key control or spill points.

The fourth internal indicator is the general condition of the main canal. Examination of general condition of the canal is very important. El-Kahwagy project has a low value of this indicator, which is 4 of 10 compared with the average of projects, which is 6.9. This is because the level of maintenance of the canal bed and banks is not good enough to prevent some decreases in performance of the canal.

The fifth internal indicator is the operation of the main canal. This indicator primarily indicates how well the staff in charge of the main canal understand basic concepts of irrigation, where there are numerous challenges in irrigation projects difficult to understand and solve. In El-Kahwagy project, the value of this indicator is considered high and equals 6.0 compared with the average of the projects, which is 5.34. It still needs to be enhanced by providing proper equipment and staff to adequately maintain the canal and the travel time of these equipments must be small.

Fig. 16 shows a comparison between the above five indicators before and after applying IIP in El-Kahwagy area. The first three indicators are relatively improved. Meanwhile, turnout and communication indicators are still have to be improved. Moreover, the results didn’t show any impacts of IIP on general condition and operation of the canals. Therefore, it is recommended to pay attention to these aspects in the future to improve them.

5. Conclusions

According to the evaluation of the IIP into two command areas the following conclusions are summarized:

1. Relative water supply of El-Kahwagy and Daqalt command areas are 1.17 and 1.29, respectively. These values are higher than 1.0. They are considered satisfactory values compared with other projects. Relative water supply of El-Kahwagy area before applying IIP is 1.41.
2. Project irrigation efficiency of El-Kahwagy and Daqalt is 92% and 83%, respectively. They are considered high values compared with the average of other projects, which is 36%. High values mean that almost all of the irrigation water supply is currently being beneficially used. Project irrigation efficiency of El-Kahwagy area before applying IIP is 73%.
3. Water delivery capacities of El-Kahwagy and Daqalt canals are 261% and 208%, respectively. They are higher than the average of other projects, which is 111%. High values allow more storage, more flexibility, easy operation and less spills.
4. Productivity indicators in Daqalt and El-Kahwagy areas comprise efficient values compared to other projects. Moreover, Daqalt area

has higher values of productivity indicators than El-Kahwagy . Output per unit command area and Output per unit irrigated area for El-Kahwagy increased by about 15% after applying IIP. Output per unit command area is 3148 US$/ha and 3245 US$/ha for El-Kahwagy and Daqalt areas, respectively. Output per unit irrigated area, including multiple cropping areas is 1410 US$/ha and 1623 US$/ha for El -Kahwagy and Daqalt command areas, respectively.

5. Applying continuous flow system in El-Kahwagy canal reduces the irrigation water supplied to the command area. Accordingly, the value of output per unit irrigation supply

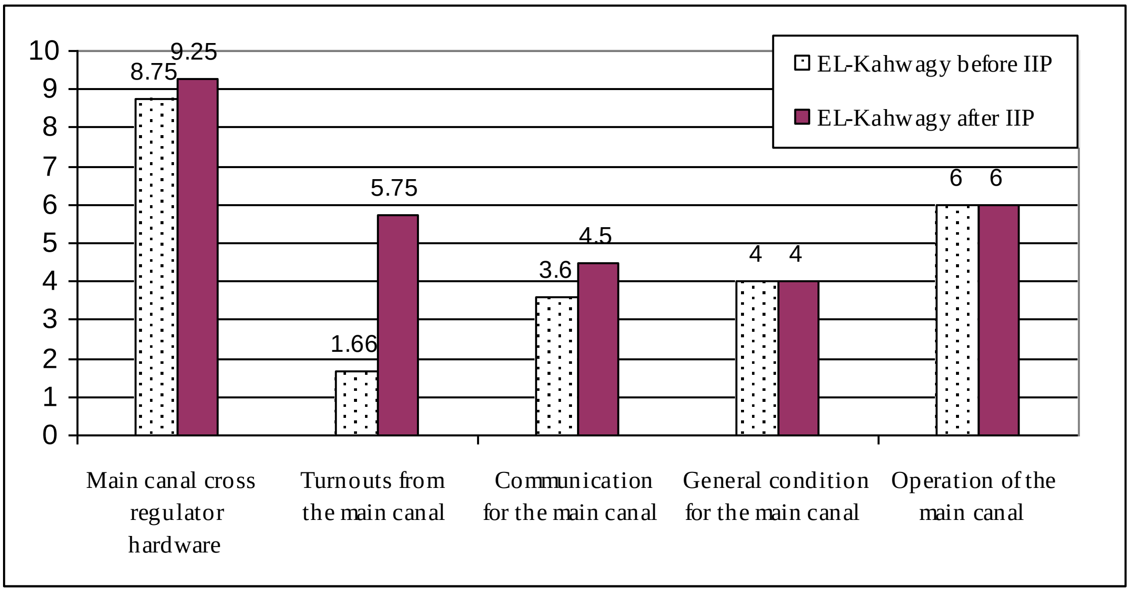


Fig. 16. Impacts of IIP on operation, management, communication and general condition of El-Kahwagy main canal

of El–Kahwagy area is 0.256 US$/m^3, which is higher than the value of Daqalt area 0.2281 US$/m^3 that still supply water in rotation flow system. Output per unit irrigation supply of El–Kahwagy area increases by about 44% after applying IIP

6. Output per unit water consumed is 0.2898 US$/m^3 and 0.2844 US$/m^3 for El-Kahwagy and Daqalt areas, respectively. Output per unit water consumed for El-Kahwagy area increases by about 15% after applying IIP.

7. The value of WUA indicator in El-Kahwagy area is very low compared with the average of other projects. Meanwhile, Daqalt area has a higher value than El-Kahwagy area. This is due to construction of turnouts and improved mesqas in Daqalt area.

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