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Assessment of Water Balance and Traditional Surface Irrigation Practices in the Northern Nile Delta

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ABSTRACT

Water balance analysis helps in managing water supply. Therefore, matching between water supply and demand is very important to overcome water shortage.This study aims at presenting comprehensive analysis to understand the nature of operating system in the traditional surface irrigation systems aiming to establish a comprehensive analysis to sustain the irrigation system, considering the problems of water supply, inequity, water quality deterioration, and poor irrigation and drainage management. Analysis in this study was done in two hubs. Firstly, study the parameters affecting water supply and demand; secondly, assessing water availability, adequacy, equity and distribution of irrigation during 24 hours' cycle.The study area is located in Kafr El-Dawar irrigation district, El-Beheira governorate in the western part of the Nile Delta.The findings show that the differences in water balance per feddan (feddan is an Egyptian land unit equals 4206 m^2) at all tertiary canals (meskas) are small; At the head of the canals, no night irrigation or drainage water reuse events during the irrigation seasons were observed; and the irrigation rotation is irregular. These findings elaborate that the location on the canal and the presence of subsurface drainage are mainly affecting the water balance in the study area.

Keywords: Water Balance, Performance Assessment, Irrigation and drainage practices

INTRODUCTION

In the 50's, Egypt didn't suffer from water shortage as they adequately met the total demand for water requirements of different water use sectors. However, Egypt gradually passed to the situation of water scarcity (MWRI, 2005). Agriculture sector is the largest fresh water consuming sector as it consumes about 80% of the Egyptian water resources. Moreover, most of water losses of irrigation systems and agricultural areas are irreparable partially through evapotranspiration and the disposal of land drainage to the Mediterranean Sea and/or coastal lakes (Arafat *et al.*, 2010).

Water balance analysis used to help in managing water supply and predicting water shortages in irrigation system (Burt, 1987). Therefore, matching between water supply and demand is considered a very important tool to overcome the valuable water lost in irrigation practices due to overirrigation (Chambers, 1988). Therefore, delivering appropriate amount of water at the due time saves water and increases crop water productivity and, as a result, will make more water available to other farmers and possibly raise their income. The goal of producing more crops per drop is the key issue of achieving both food and environmental security (FAO, 2003). Therefore, water consumption depends on water management practices and distribution. The way in which water is to be distributed will affect the entire design of the scheme under consideration. There are several concepts of water distribution, which needs full understanding by people responsible for irrigation design and management. One of the first steps of the irrigation design should take into considerations how water is going to flow around the scheme and how much flexibility to be considered in the design. In the past, these issues were confined to design engineers, but this needs to be changed.

Any irrigation system consists of two main parts, which are software and hardware systems. The software system includes institutional components such as the irrigation district engineer, gatekeeper of the canal (*El-Bahar*) and farmer. While the hardware system includes the infrastructure components such as the irrigation canals and drains, irrigation methods, groundwater and water quality (Laycock, 2007).

The main problem facing water managers all over the world is the lack of performance assessment as an essential tool to achieve successful irrigation management. In this regard, this manuscript is trying to discuss and define the importance and tools for irrigation performance assessment to achievi more efficient irrigation management through the iterative feedback for continuous enhancement (Hvidt, 1996). The objectives of this research paper are to establish a comprehensive analysis for sustaining the irrigation system to set some strategies and practices for enhancing crop water productivity at the branch canal and tertiary (mesqa) levels, taking into consideration the problems of water supply performance and efficiencies, inequity of water distribution, water quality deterioration, and poor irrigation and drainage management/practices. The assessment of water balance of this study was employed at two hubs: First, is the analysis of the entire water balance parameters between water supply and demand in the study area; second, is the measurement of the water availability, adequacy, equity and distribution of irrigation within a 24-hour cycle. (Molden and Gate 1990).

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MATERIALS AND METHODS

Study area

The study area is located on the eastern edge of Kafr El-Dawar city and the northern edge of Damanhur city in El-Beheira governorate in the Nile Delta as shown in Figure 1. The site of the study area was selected to represent traditional farming practices of the Nile Delta, of which it has three main features. First, the dominant irrigation system is surface irrigation, the soil classification is clay, and the cropping pattern includes the main Egyptian crops. Second, the farm size is small and ranged from about 1-3 acres. Third, the site is a portion of the Egyptian irrigation improvement project. Ultimately, the seven hundred Feddan (1 feddan = 1 Acer) of the area under investigation are fully improved, and the application of the new technologies will thus reflect significant impact, whether positive or negative. irrigation improvement project in Egypt is a national project to improve the existing canal delivery network and its infrastructures. One major initiative involves applying the water delivery based on the actual requirements in the main irrigation system (demand management). To apply this approach, automated downstream control gates were installed in the branch canals. The tertiary canals improvement used to be characterized in two systems: raised above ground level, or pressurized pipelines (which is more applicable nowadays) to raise the efficiency of water distribution along the length of the canal based on a single lifting point (pump unit) at the head of the tertiary canal, (Mohsen, *et al.,* 2012).

The irrigation characteristics of the study area that it irrigates from a branch canal called *Nasiri* canal fed from Mahmoudia main canal through two sub-branch canals; *Sabia* and *Habib* canals at km 2.275 and 2.800 respectively, as presented in Figure (1). *Sabia* canal is 6.14 km long serving a command area of 1,533 fed. with an average flow of 45,000 m^3/day. *Habib* canal is about 5.80 km and serves a command area 2,895 fed, with an average flow of 102,000 m^3/day. The selected study area (611 fed.) is irrigated from the two sides, with 201 and 410 fed. from Sabia and Habib sub-branch canals respectively. Water lifting points of farmers in the study area come under two categories: improved lifting points (collective pumps) and mobile individual pumps. Drainage water of the fields is collected in a sub-surface drainage network of laterals drains and collector drains, and flow to the Nasr Allah drain. The drainage laterals consist of corrugated 72 mm diameter PVC pipes. The laterals, spacing is 50 m, discharge into collector drains pipe. The drainage water collectors are made of plain concrete pipes with inside diameters ranging from 150 mm to 400 mm. these pipes are set in the field at different slopes that collect the drainage water into the main and secondary open drains. The average length of the collectors is 1500 m with spacing of 400 m.

Climatic data were collected from meteorological station in El-Mahmoudia area which is the nearest station and used to compute the irrigation requirements. Northern delta climate could be described as typically Mediterranean climate, dry, mild in summer and cool, wet in winter. The collected parameters are temperature, humidity, wind speed, and sunshine data. These data were used in the Penman-Montieth equation to compute evapotranspiration. The calculated *ETo* ranges from 2.17 mm/day in winter to 6.57 mm/day in summer.

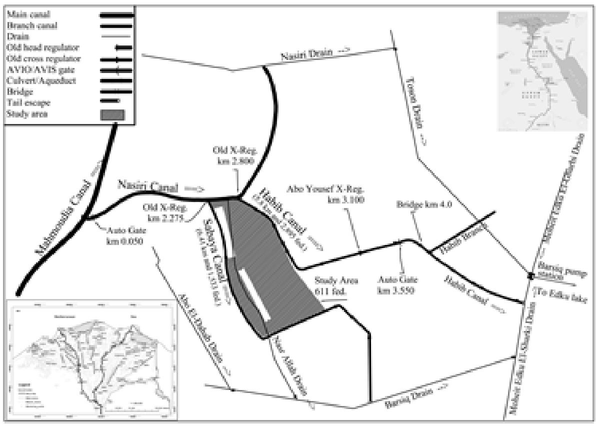


Figure 1. Study area site

Determination of performance indicators

A set of performance indicators have been employed for the evaluation that are related to this study goals. The indicators for evaluating the irrigation management requires different data to be collected such as water level, routine discharges, cropping patterns of branch canals, pump operations for tertiary canals, and irrigation events at selected portable pumps. Data were analyzed and the values of different indicators were calculated for two seasons winter and summer.

- **Water Balance Parameters**

Water use index indicator was used to measure the water delivery performance in the branch canals and selected mesqas. The indicator of water used index rate (WUI) was calculated by the following equation:

$$WUI = Q_{DTotal} / Q_{RTotal} \quad \textbf{(1)}$$

Where **Q_{DTotal} is the diverted water amount (m^3) into the irrigation canals, and Q_{RTotal} is the total irrigation water requirements for the area served (m^3). A value of WUI equal to 1.0 indicates that enough water is being supplied to meet the water demand. Nevertheless, a value of WUI is higher than 1.0 indicates that there is a wastewater through irrigation network and the value of WUI is lower than 1.0 indicates that there is shortage water through irrigation network.**

- **Evaluation of the performance indicators**

Performance indicators used in this study evaluate irrigation in the sample branch canals, mesqas and farmers' practices at the pump level. The use of the four indicators, i.e. adequacy, efficiency, equity, and dependability is concluded to be effective for assessing distribution system performance, (Molden and Gates 1990).

Adequacy Indicator: Required amount distribution (P_A); adequacy objective is to deliver the required water amount to the served area:

$$P_A = (1/T)\sum_T \left\{ (1/R)\sum a_i\, p_{Ai,t} \right\}, \textbf{(2)}$$

Where $p_{Ai,t} = Q_{Di,t} / Q_{Ri,t}$ **, if $p_{A\,i,t} > 1$, then $p_{A\,i,t} = 1$**

Efficiency Indicator: Water resources conservation (P_F); water distribution efficiency objective is to conserve water through matching water delivered and water required:

$$P_F = (1/T)\sum_T \left\{ (1/R)\sum a_i\, p_{Fi,t} \right\}, \textbf{(3)}$$

Where $p_{Fi,t} = Q_{Ri,t} / Q_{Di,t}$ **, if** $p_{Fi,t}$ **>1, then** $p_{Fi,t}$ **=1**

Equity Indicator: Fair water amount distribution (P_E); if we consider that equity is the spatial uniformity of water distribution, then the equity indicator would be the average relative spatial variability ratio of the amount of water distributed to the amount of water required over the time period of interest:

$$P_E = (1/T)\sum_T \mathrm{CV}_R\left(Q_{Di,t}/Q_{Ri,t}\right), \quad (4)$$

Where CV$_R$ is the spatial coefficient of variation of $Q_{Di,t}/Q_{Ri,t}$ over the region *R*.

Dependability Indicator: Uniform water distribution over time (P_D) indicates the dependability of water distribution as the temporal variability over a region in the ratio of amount distributed to amount required:

$$P_D = (1/R)\sum_{a_i} \mathrm{CV}_T\left(Q_{Di,t}/Q_{Ri,t}\right), \quad (5)$$

Where CV$_T$ is the temporal coefficient of variation of $Q_{Di,t}/Q_{Ri,t}$ over time *T*.

In the process of evaluation of these indicators, weights were estimated to the spatial averages against the surface area of the branch canal irrigation network to consider their relative importance. In this research, the (R) indicating the region consisted of the total served areas, and the period (T) covering five months of summer season (May–September) and seven months of winter season (October–April).

Water delivered and water required were calculated on the basis of an overall two weeks interval for branch canals. From the findings, performance was classified into three categories "good," "fair" or "poor" (Molden and Gates, 1990), as listed in Table (1).

Table 1. Evaluation criteria for different indicators (Molden *et al*. 1990)

Measure	Performance Class		
	Good	Fair	Poor
P_A	0.90 - 1.00	0.80 - 0.89	< 0.80
P_F	0.85 - 1.00	0.70 - 0.84	< 0.70
P_E	0.00 - 0.10	0.11 - 0.25	> 0.25
P_D	0.00 - 0.10	0.11 - 0.20	> 0.20

- **Determination of crop water requirements and water delivery**

The calculation of crop water requirement by CROPWAT model were used in this study, which FAO employs Penman-Monteith equation to calculate the (ET_o) reference crop evaportranspiration, (FAO, 1992). Crop coefficients (k_c) were developed for main crops using FAO's handbook of irrigation manual (FAO, 2002). Water application efficiency was assumed to be equal to 65% (surface irrigation).

For tertiary canal, calibration of pump discharge was performed to calculate actual discharge of the flow extracted from branch canal by the lifting point to fields. Ultrasonic flowmeter was used to measure discharge, with reflective type (V). In this type operates on Faraday's law of electromagnetic induction, which the transducers mounted on one side of the pipe expulsion, and it is used with data logger to record the discharge in (lit/sec) and the total discharge during pumping period in (m^3). For field level, a cut throat flume have been used to measure supplied water discharge to field from pumps.

To apply the determined water balance parameters in controlling the water inflow and outflow of the study area, two sample branch canals were selected for this evaluation at *Nasiri* command area and six tertiary canals (mesqas) equipped with a collective pump were also selected on each selected branch canal, as well as eleven portable individual pumps that are also used to irrigate the target area.

RESULTS AND DISCUSSION

Inflow Parameters

- **Branch canal level:**

The water amounts delivered to specific reaches of the branch canals (*Sabia* and *Habib*) that were extracted on rating curves (a relationship between flow and depth of water at downstream). Then, water levels were monitored continuously by automatic level recorders, therefore, the analysis of the level recordings had to be translated to curves in order to elaborate the relationship between water levels and discharges. Flow levels were converted to discharge by using individual rating curves for each measurement point (at head of selected branch canals). Routine discharge measurements at selected locations on the sample canals. Establishments of the gate calibration through this study depend on data point of discharge measurements on branch canals through combined irrigation seasons of summer and winter, as presented in Table (2). The accuracy of calibration is high for both branch canals, which the coefficient of determination is up to 0.8 and 0.88 in *Sabia* and *Habib* respectively. In addition, the actual measurements of flow through head regulator of both branch canals are matching calibration result of flow.

Table 1. Summary of gate calibration for all canals

Canal	Calibration Equation	R^2	Y	X
Sabia canal	$y = 0.0001\,x^2 + 0.0096\,x - 0.8230$	0.80	Q	WL
Habib canal	$y = 0.0002\,x^2 - 0.0135\,x + 0.2065$	0.88	(m^3/sec)	(cm)

- **Tertiary canal level (mesqa level)**

Calculating the inflow to tertiary canal level was done through recording operation time and calibrating the discharge of pump units. A water volume delivered to tertiary canal is calculated by multiplying the number of operation hours by the nominal discharge of each pump in one given station. The operation time was measured using different ways based on the situation of the lifting point (improved or unimproved). In improved mesqas, operation hours of the pumps were continuously monitored by using thermo manager method. This technology was used to measure the temperature of engine and record it in its built-in data logger, and after that converting it to pumping duration. One sensor records the temperature of the air and another one the temperature of the engine, the difference between the two the temperatures indicates the operation time of the pump is in operation. In individual mobile pumps, the operation time of pumps are collected by operators' farmers, Table (3)

Table 2. Summary of data of mesqas in study area

Mesqa	Area Served area (Fed.)	No. of Pumps	Nominal Discharge (l/sec)	Calibrated Discharge (l/sec)	Average Operation Hours (hr/fed.)		Water Supply (m³/fed)		Water Required (m³/fed)	
					Summer	Winter	Summer	Winter	Summer	Winter
				Sabaia Canal						
Hegazy	35	2	60/60	53.5/38.7	33	8	7279	2083	5270	2855
El Khawaga	45	2	60/60	45.5/62.5	28	10	4573	2267	4620	2835
Soltan	35	2	60/60	55/55	22	7	5948	2157	5090	2926
El Gharania	40	2	60/90	55/57	25	9	5987	2344	5775	3086
Soliman	40	2	60/60	51/51.3	18	9	4369	2185	3865	3074
				Habib Canal						
El Shiekh Abd El kader	50	2	60/90	63.2/88	26	8	6154	2349	4591	3108
Masoud El Gahesh	77	2	60/60	63.2	21	8	4936	2105	4793	2918
El Keleny 2	45	2	60/60	60	20	7	5909	2289	5207	2901
El Keleny 1	59	2	90/90	68.5	15	6	4478	2073	5078	2844
El Eshreen	85	2	60/90	55/58	35	11	5655	2203	5235	2974
Kom Sief	85	2	60/90	47.8/60	18	5	6270	2099	4777	2941

The operation hours for portable pumps per unit area (fed.) in unimproved mesqas was ranged between 9 to 15 hours with average 12 hours in winter and range between 20 to 35 hours with average 30 hours in summer seasons, respectively. While in improved mesqa, the operation hours per unit area was ranged between 3 to 12 hours with average 10 hours in winter season. However, the operation hours are range between 16 to 33 hours with average 25 hours in summer season. The rate of operation hours for both systems in the winter season was constant due to less of water required in this season. On the other hand, the rate of operation hours in summer season for improved system was vary among mesqas due to more control water distribution at head of mesqas, while portable lifting points, the operation was indiscriminately.

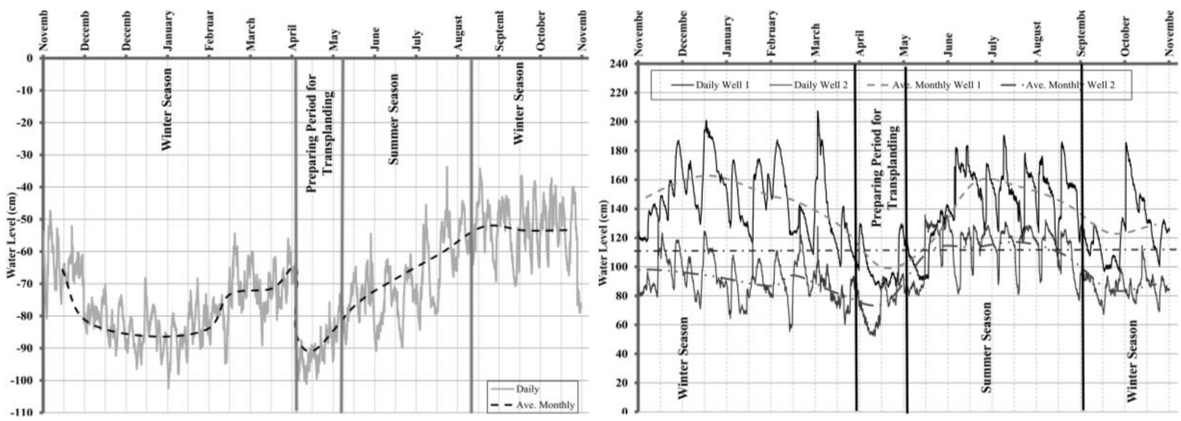
Outflow Parameters

- **Drainage water**

The drain outflow was estimated by measuring the water level and the discharges at the end reach of the drain. The drainage system in the study area is sub-surface drainage with semi-parallel laterals covering all the area served by the selected mesqas. They dispose their drainage water into Nasr-Allah Drain. Automatic recorder with data logger installed at the end of the study at Nasr Allah Drain as well as the observation wells at the area to record the water level to assess the drainage system there. Monthly measured flow in Nasr-Allah Drain, which indicated the flow was fluctuated between 0.0 to 0.1 m through winter season. For summer season, the average flow was fluctuated between 0.1 to 0.3 m.

- **Groundwater**

Groundwater level was measured in four wells, to monitoring farmers' practices through irrigation seasons. Figure (2) presents the daily water levels of the drain and the observed wells in the field. It indicates that there is direct relation between drainage and groundwater level. The drainage system work in very high efficiency and the direct relation among irrigation events in the field and performance of drain is due to the sub-surface drainage applied in the study area. Figure 2 (a) presents daily and monthly water levels of the drains where the level of the drain fluctuated and ranged between (-35) to (-100) cm throughout the year. The water level was (-65) in the beginning of the winter season and reaches (-85) in the middle and increased at the end of the season to reach (-70). The water level drops to (-90) at the period of preparation for transporting and increase gradually to (-50) at the end of the season. Figure 2 (b) presents daily and monthly water levels of wells installed in the study area. The behavior of wells is the same which the water level increase and/or decrease together.



(a) Recoded data of wells in drain **(b) Recoded data of wells in groundwater**

Figure 2. Daily and monthly water levels of wells installed in the study area

Boundary Conditions

The boundary conditions in this study present the water required at lifting points that served the command area. The theoretical crop water requirements of the selected canals and selected fields were calculated for comparing with the actual supply. For this purpose, the cropping pattern data was further analyzed in order to identify the secondary crops (which were lump summed as "vegetables" in the given data) and their water requirements were calculated.

- **Branch Canal Level**

Figure (3) depicts the cropping patterns for selected parts of the command area of Sabia and Habib canals compared to the global command area of Sabia and Habib canals during irrigation seasons for the summer and winter seasons. As shown, rice is the most important (summer) crop in the study area. It is very important for farmers and to government, rice is a cash crop as well as a subsistence crop for farmers, whereas for the government, rice is considered as one of the highest water-consuming crops in the Nile Delta with governmental decrees to define the rice areas among other areas in the delta where the agricultural activities are regulated in a free cropping pattern. The maximum allowable area to be cultivated by rice is 50% of the canal's served area in certain governorates of the Nile Delta. The rice crop areas in commend area and selected study area follow this quota. Cotton was the second main summer crop and occupied 38% of cropping pattern. Maize was the third main crop and occupied 10% of cropping patterns. The secondary summer crops (others), mainly vegetables, occupied 8% of cropping patterns. Wheat is considered to be the most favorable crop in winter to farmers. It occupied 45% of the cropping patterns of branch canals during the studied winter seasons. Alfalfa was the second main winter crop and occupied 35% of cropping. The secondary winter crops (others), mainly vegetables, generally occupied less than 3% of the studied winter cropping patterns. As we noted, the cropping pattern of the selected study area is roughly the same of the command area. Therefore, the study area is representing the global command area in this study.

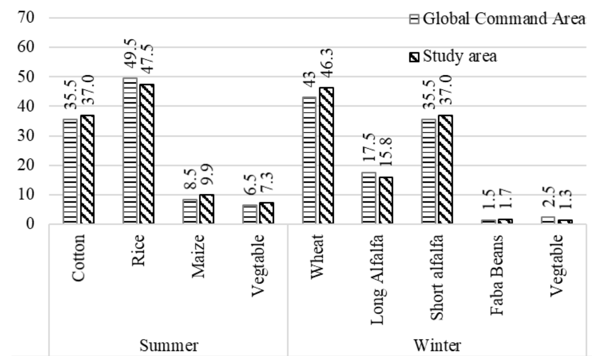


Figure 2. Cropping pattern percentile of the study area

- **Mesqa Level**

For the selected mesqas in winter, wheat and long alfalfa crops are the rain fed crops on the selected mesqas and accounted for up to 58% and 7% for wheat and long alfalfa crops, respectively. While in summer crops, rice crop in some mesqas exceed 50% and reached 87% in El-Gharania mesqa. On the other hand, mesqas as El-Khawaga and Soliman in Sabia, the rice was replaced by cotton.

Performance of the Delivery System

- **Water delivery performance of the branch canal**

This section studies monthly performance of water delivery among irrigation canals represented in a spatial function and the differences between the two canals Habib to Sabia as a temporal function.

a.Spatial Values of Performance Indicators

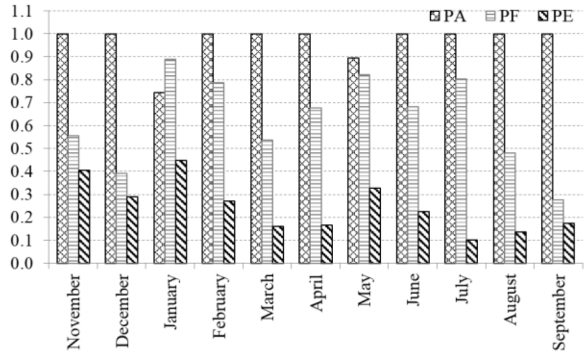
Spatial function in months for adequacy values are given in Figure (4) (a). The Adequacy Indicator PA values were close to 1.0 in all months of studying except January month in winter season and May month in summer season. While, the spatial values of efficiency PF were variable in all months and not stable that indicated a reflection of the extreme water delivery for the irrigation systems than available water consuming main crops as rice paddy in summer and wheat crop in winter seasons. This mean the head regulators of branch canals are out of control for water deliver into system and there are high losses of water and impact on the irrigation system in end of reach of main canal. According to performance standard, adequacy performance during summer seasons was evaluated as "good" and during winter seasons was "poor" in middle season, while it was "good" in the first months of this season. According to performance standard, efficiency performance during summer season was evaluated as "poor" during irrigation seasons. These results mean that water use is not efficient due to large amounts being supplied without being used. Values of the equity indicator *PE* for irrigation months, were noticed to be uniformly good, lower (better) than 0.2 in months peak through summer season and over than 0.20 in winter season. This performance confirms the more equitable water delivery among irrigation canals in summer season. This indicates that the downstream control gate system allows the flow from main canal to branch canals whenever the water levels in the branch canal are decreased under a certain level. While, equity was between fair and poor in winter because of the manipulation of the rotation irrigation system, as well as, some damage at the branch canals' head regulators which allowed some leakage. According to performance standard, equity performance throughout the irrigation seasons was evaluated as "poor".

b. Temporal Values of Performance Indicators

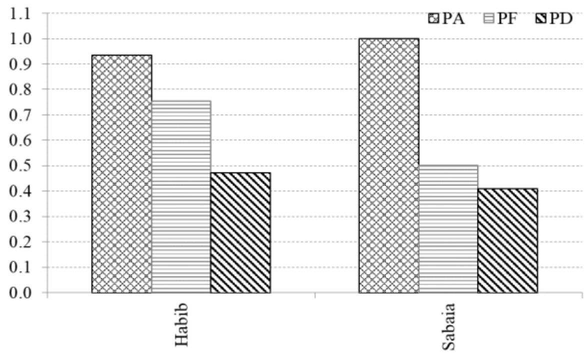
The temporal values of *PA* for both irrigation canals are close to 1.0 as shown in Figure 4 (b). The most noticeable effect that was identified is when continuous flow is applied among irrigation canals. This indicated the amount of water losses through head regulator for both irrigation systems. According to performance standard, adequacy performance for both irrigation canals was evaluated as "good". The temporal value of *PF* for Habib canal was better than Sabia canal which PF of Habib was 0.73 and 0.5 for Sabia canal. The PF value indicates the losses of water through Sabia canal was 50% through irrigation months in summer and winter. According to performance standard, efficiency performance for both irrigation systems was evaluated as "poor". The dependability indicator *PD* was generally poor (over 0.2). The reason was the successful application of continuous flow irrigation system on the main canal rather than the previous rotation system. This means that farmers could plan for a reliable water delivery, even of an inadequate supply, by growing different crop.

- **Water delivery performance of the mesqa**

This section analyzes monthly water delivery performance among selected improved mesqas through Habib and Sabia canals as a spatial function and the location of mesqas through the irrigation systems as a temporal function.



(a) Spatial Values



(b) Temporal Values

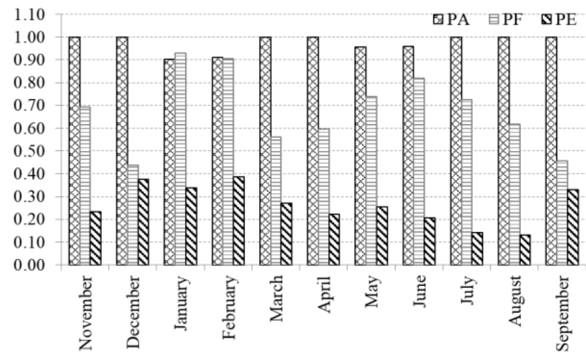
Figure 3. Performance indicator values at branch canal level

a.Spatial Values of Performance Indicators

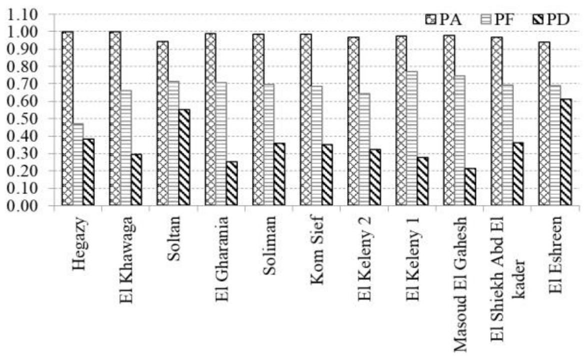
For improved mesqas, the values of *PA* in Figure 5 (a) were closed to 1.0 through the months of irrigation seasons because the requirement for irrigation water was lower than deliver flow by units' pumps in improved lifting points. In the areas with improved irrigation system, the (*PA*) adequacy of supply, was good in all irrigation season and the rate of adequacy was stable through months of irrigation. The better adequacy of supply in the areas with improved irrigation system could be explained by the constant head created by the supply pumps and determined the operation hours among lifting points due to succeed of WUAs (water Users associations) operation among tertiary canals. The average values of *PF* were 0.50 in the beginning of winter season because the requirement for irrigation water was low in those months and after that increased to 0.90. In summer season, the values of *PF* decreased through months of irrigation season and closed to 0.50. In the improved system, the efficiency of supply (*PF*) was fair and poor in winter and summer, respectively indicating the delivery more than required in the field. The values of PE in improved system were over 0.25 in winter months. Due to high water deliver through of the season, that causes uneven distribution of water supply among tertiary canals. In summer season, the trend values of *PE* were stable among the months of the season which most of its values were between 0.20 and 0.10. This shows that equitable water delivery was achieved at tertiary canal level in improved system. Therefore, the equity of supply (*PE*) was poor and good in winter and summer, respectively.

b. Temporal Values of Performance Indicators

In the areas with improved irrigation system, the supply adequacy (*PA*) monthly values for selected positions on the mesqa ranged between 0.90 and 1.0 as shown in Figure 5 (b), However, the values of *PA* among these locations were similar, this indicated that irrigation opportunity was the same. The cooperation between Water Users' Associations (WUAs) under the use of single operation point for mesqas was noticed, this could be justified by the need of water users to give chance to irrigate with equal chances for different locations without need to reuse drainage water to overcome the shortage. According to performance standard, adequacy performance throughout the mesqas location was evaluated as "good". In the areas with improved irrigation system, the yearly values of water supply efficiency (*PF*) by position on the mesqa were mostly close to 0.7, with slight differences between pumping stations of the mesqas. Only the first station, Hegazy, has a lower efficiency (under 0.5) which reflects some over-irrigation allowed by its favorable position. According to performance standard, efficiency performance throughout the irrigation seasons was evaluated as "poor". In the improved irrigation areas, the values of *PD* were higher than 0.2 through all locations. Lower variability in summer was due to scheduled pumps operation according to WUAs (Water Users Associations) rules. On the other hand, in winter pumps were operated simultaneously due to water availability in the improved system. According to performance standard, dependability performance throughout the irrigation seasons was evaluated as "poor".



(a) Spatial Values



(b) Temporal Values

Figure 4. Performance indicator values at mesqa level

- **Water delivery performance of the individual pumps**

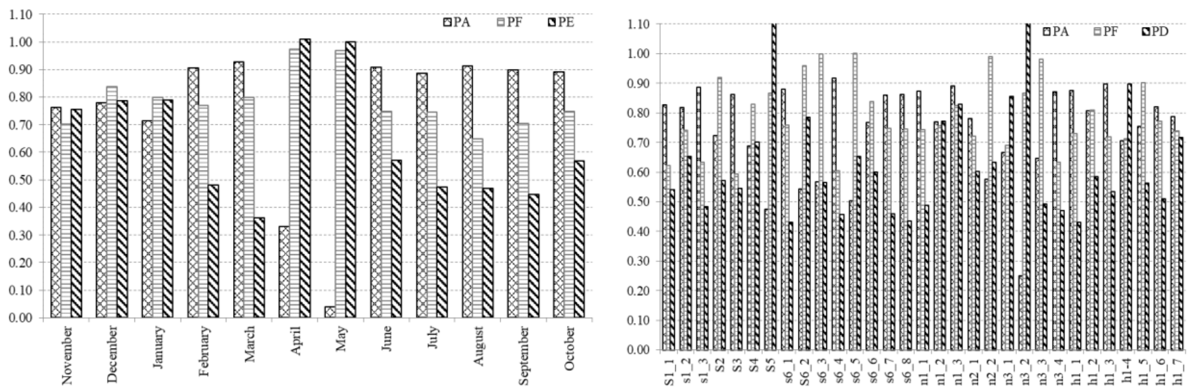
This section analyzes monthly water delivery performance among selected individual pumps through Habib, Sabia canals and direct irrigation canal as a spatial function and the location of mesqas through the irrigation systems as a temporal function.

a.Spatial Values of Performance Indicators

For portable pumps in Figure 6 (a), the values of PA in winter season increased at end of the season, which the values of PA were 0.75 in November and after that increased to 0.90 in March. In summer season, the values of PA decreased through beginning of the seasons, which the value of PA in April and May was 0.35 and 0.05, respectively. In addition, after, the values increased to 0.90 through summer season. In the areas with traditional (unimproved) irrigation system, the adequacy of supply PA was only good in winter and poor of beginning in summer seasons. The reason for this case is that normally farmers use their individual pumps to extract water from any location of the branch canal without accountability or coordination among farmers. The values of PF in irrigation seasons were stable through months. The values of PF were 0.80 in through winter months and after that increased to 0.95 in April and May. In summer season, the values of PF decreased through months of the season, which the value of PF in June was 0.75 and after that decreased to 0.65 in August and increased again to 0.75 in October. According to performance standard, efficiency performance throughout the irrigation seasons was evaluated as "fair". The values of PE were over than 0.25 in irrigation seasons. This is due to the farmer in this system irrigated this field with any rate at any time for any duration. Therefore, the equity was poor through irrigation season.

b. Temporal Values of Performance Indicators

In portable pumps in Figure 6 (b), the values of PA closed to 0.8. This indicates that some pump units' locations face shortage of water during the irrigation season. Water availability in the branch canal due to law irrigation practices in winter resulted in having better values in winter than in summer inside the branch canal with no restrictions on water extraction among mesqas. According to performance standard, adequacy performance throughout the mesqas location was evaluated as between "fair" and "poor". The values of PF were variable between ranges 0.60 to 1.0. This indicates some lifting points faced shortage of water during the irrigation season. According to performance standard, efficiency performance throughout the irrigation seasons was evaluated as "poor". In the areas with traditional irrigation system, the values of PD were higher than 0.2 through all locations. In the traditional irrigation system, the values were increased from different locations. This indicated that farmers in these locations are accelerating to irrigate because of water availability while other locations were facing water shortages and had to reuse drainage water to complete irrigation water requirements. According to performance standard, dependability performance throughout the irrigation seasons was evaluated as "poor".



(a) Spatial Values **(b) Temporal Values**

Figure 5. Performance indicator values at individual pumps level

CONCLUSION AND RECOMMENDATION

Water balance analysis is used to help managing water supply and identifying water shortages in irrigation process. Therefore, matching between water supply and demand is considered as a very important issue to overcome the substantial amount of water losses in irrigation due to delivering more amount than crop requirements. Delivering the amount of water at the due time saves water and increases crop water productivity, and as a result may increase water to other farmers and raise overall income. The goal of producing more crops per drop is the key issue of achieving both food and environmental security.

Several options and technologies are existed for improving crop water productivity such as crop breeding, best management practices and supporting policies and institutions. Water productivity could be identified as the value of commodities and services produced per unit of water consumed. In the field of irrigation and drainage, modeling has the potential for improvement in water productivity. This study establishes an application of the water productivity model in old land that represents the Nile Delta to support decision and policy makers in determining whether, or not, the performance is satisfactory. If not, which corrective actions should be taken in order to solve or alleviate the problem? In order to apply this model, this monitoring and evaluation study was carried out in order to explore the factors and parameters to support the model users to easily apply it. The findings of study were concluded as following:

- There is direct relationship between water level at the head of the branch canals and the drain due to the success of the policy of subsurface drainage project that applied in the study area;
- Water is available in sufficient quantity throughout the year (adequacy was fulfilled);
- The farmers in the study area use more water than their needs because they located at the head of the branch canal;
- The differences in water used per Feddan at all mesqas

are small, which indicates that the equity among the various mesqas was achieved;

- The average operation hours for portable pumps per unit area is 10 hours and 20 hours in winter and summer seasons, respectively.
- Night irrigation nor drainage water reuse events during the irrigation seasons were observed at the head of the canals, which also suggests that water is adequate; and
- The irrigation rotation is irregular due to the manipulation of the people in-charge in open and closing the gates or farmers at the head of the canals because the operation time during the off rotation is just only a few hours to irrigate the areas adjacent to the intakes.

It is strongly recommended that the study should be extended to at least one more year to include the entire command area to measure the assessment of water balance over this area by monitoring and evaluating water availability, adequacy, equity distribution among various mesqas, night irrigation and reuse of drainage water in irrigation. In addition, the impact of the water delivery system on farmers' behavior should be measured at the head of the branch canals on other locations inside the main canal.

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تقييم الاتزان المائي وممارسات الري السطحي التقليدية في شمال دلتا النيل

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معهد بحوث إدارة المياه – المركز القومى لبحوث المياه

يستخدم تحليل الاتزان المائي للمساعدة في إدارة توزيع المياه والتنبؤ بنقص المياه في نظام الري ، و يعتمد استهلاك المياه على ممارسات إدارة المياه وتوزيعها.الهدف من الدراسة: تهدف إلى تقديم تحليل شامل لفهم طبيعة نظام التشغيل في أنظمة الري السطحية التقليدية بهدف إنشاء تحليل شامل للحفاظ على نظام الري ، مع مراعاة مشاكل توزيع المياه ، وعدم المساواة بين المنتفعين علي الترعة الواحدة أو علي الترع المختلفة ، وتدهور نوعية المياه ، وعدم كفاءة نظم إدارة الري والصرف.منهجية الدراسة :تقع منطقة الدراسة في منطقة كفر الدوار بمحافظة البحيرة في الجزء الغربي من دلتا النيل حيث تم استخدام مجموعة من مؤشرات الأداء المرتبطة بأهداف الدراسة بغرض للتقييم. كما تم جمع بيانات مختلفة مثل منسوب المياه بالترع ، كمية الصرف الزراعي، وطرق الزراعة المستخدمة ، وأسلوب إدارة الترع الفرعية ، وعمليات رفع المياه إلي المساقي. حيث تم تحليل المعطيات وتم حساب قيم المؤشرات المختلفة لموسمي الشتاء والصيف.وقد اعتمد تحليل الاتزان المائي في هذه الدراسة في محورين كالتالي: أولاً: دراسة العوامل المؤثرة في العرض والطلب على المياه؛ ثانياً: تقييم توافر المياه وكفايتها وعدالة توزيع مياه الري خلال ٢٤ ساعة .الخلاصة والتوصيات تتضمن نتائج الدراسة اقتراح الإجراءات التصحيحية التي ينبغي اتخاذها من أجل حل المشكلة أو تخفيفها كما يلي: توجد علاقة مباشرة بين منسوب المياه على أفمام ومآخذ الترع الفرعية والمصارف بسبب نجاح سياسة مشروعات الصرف المغطى (تحت السطحي) المطبق في منطقة الدراسة ؛ تتوفر المياه بكميات كافية على مدار العام (تم تحقيق الجانب الخاص بالكمية الكافية) ؛ يستخدم المزارعون في منطقة الدراسة كميات أكبر من المياه مقارنة باحتياجاتهم لأنهم يقعون على مأخذ الترعة الفرعية ؛ الاختلافات في المياه المستخدمة لكل فدان في جميع المساقي ذات قيمة صغيرة ، مما يدل على أن تحقيق عدالة التوزيع بين مختلف المساقي؛ متوسط عدد ساعات التشغيل لوحدات الرفع (طلمبات الري) المحمولة لكل وحدة مساحة هو ١٠ ساعات و ٢٠ ساعة في فصلي الشتاء والصيف ، على التوالي.و بناءً علي مخرجات تلك الدراسة فيمكن التوصية بدراسات مستقبلية تتضمن تمديد الدراسة إلى سنة أخرى على الأقل لتشمل منطقة الدراسة بأكملها لقياس تقييم الاتزان المائي في هذه المنطقة علي كامل الزمام من خلال مراقبة وتقييم مدى توافر المياه ، وكفاية ، وتوزيع المياه بين مختلف المساقي ، والري الليلي ، إعادة استخدام مياه الصرف الزراعي في الري. بالإضافة إلى ذلك ، ينبغي قياس تأثير نظام توزيع المياه على سلوك المزارعين بالقرب من مآخذ الترع الفرعية في مواقع أخرى داخل الترعة الرئيسية.