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Assessment of Irrigation Water and Water Delivery Performance at Branch Canal Level in the Nile Delta

Abd El Ghany SH[1*]
Swelam A[2]
Nassar A[3]
ElFetyany M[4]

[1]Lecturer, 10th of Ramadan Higher Technological Institute, Civil Engineering Department Egypt, Ph.D. of Civil Engineering, Irrigation and Hydraulics, Ain Shams University, UK
[2]Professor, Agricultural Engineering Department, Zagazig University, currently, ICARDA, UK
[3]Professor, Water Management Research Institute, National Water research Center, UK
[4]Researcher, Water Management Research Institute, UK

Abstract

Egypt currently facing a critical water scarcity situation. The agriculture sector remains the main and the largest consumer of available fresh water consuming about more than 80% of Egypt's water resources. In addition, the increasing food demand with less water consumption is of a great importance and a great challenge in the same time due to the rapid increase in population. Therefore, water allocation among different water use sectors is in a highly competitive situation with the agricultural sector.

This study examines water delivery performance and its effects on farmers of the command area of Alfia branch canal with an area served of 3883 ha (9240 feddans) located on eastern Nile Delta. Water supply system was evaluated at the canal level, using the adequacy, efficiency, dependability and equity indicators. These indicators calculated for 24-months irrigation seasons of 2016 and 2017, using measured water deliveries and calculated crop water requirements, water quality analysis, along the canal.

The findings of the study showed that there is a direct relationship between water level at the head of the branch canal and the corresponding drain due to the presence of well-functioning subsurface drainage. Water availability in the canal command area is sufficient throughout the year fulfilling adequacy because farmers located at the tail end of the canal are conjunctively using the shallow groundwater to overcome the shortage of delivered water. Farmers located in the head of the canal are occasionally use the groundwater comparing to farmers suited in the tail end due to better water accessibility in the head of the canal. However, they grow rice which is high water consumer crop while the irrigation duty supply for the canal is released based on other crops excluding rice. For this reason, farmers substitute the deficit water amount from the groundwater.

Keywords

Water balance; Irrigation and drainage; Water delivery performance; Water management

Introduction

Agriculture sector uses the main and the largest amount of the available water resources in Egypt fresh water consuming more than 80% of Egypt's water resources. In addition, the increasing need to produce more food with less water consumption is a great challenge due to the rapid increase of population.

Although the agricultural sector in Egypt has developed recently achieving a growth of about 3.1% in 2008 (Global Arab Network, 2009). However, the country still facing many challenges in the water management to meet the water requirements of different sectors. These challenges include: rapid population growth, water and food security, expansion of the use of modern irrigation methods, and land fragmentation [1].

Egypt's agriculture sector suffers from issues related to water scarcity and misuse, as well as the low availability and mismanagement of agricultural lands (SIT, 2010). The issue of water scarcity is of a particular importance given that Egypt's agriculture sector is almost entirely dependent on Nile water for irrigation. Egypt receives a fixed annual share of renewable water with amount of 55.5 billion cubic meters, as per the 1959 Nile Waters treaty. However, the country's current yearly water consumption stands at 83 billion cubic meters, Moreover, water transportation and field irrigation systems are largely inefficient; with more than 30% of Nile water being lost on its way to the fields through an outdated irrigation systems, the efficiency of which is estimated at only 50%.These issues, in addition to others related to agricultural land availability and food security, are compounded by Egypt's rapidly increasing population.

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***Corresponding author:**
Abd El Ghany SH
Lecturer, 10th of Ramadan Higher Technological Institute
Civil Engineering Department
Ph.D. of Civil Engineering Irrigation and Hydraulics
Ain Shams University, Egypt
E-mail: samasarah@yahoo.co.uk

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One of the main objectives of irrigation improvement projects in Egypt is to have equity and better distribution of water between farmers [2]. Discuss how irrigation improvement projects improved farm distribution system. In 2013 Siraj Dutta discuss how Mesqa and Marwa under irrigation improvement projects affects the water management in Delta [3]. Document how irrigation improvement projects in Egypt affecting the socio-technical innovations perform on the ground, how it affects change water distribution.

Egypt is known as an arid country where the rainfall is negligible and suffering from desertification, degradation of soil quality, changes in the land use, scarce water resources and high pressure due to growing urbanization and socioeconomic activities. In addition, decrease of cultivated land due to urbanization is a great challenge to the agricultural sector in Egypt,

Many laws and decrees have been issued trying to control urbanization of agricultural land such as: Decree No. 1/1996, Law 3/1982. Nevertheless, rapidly growing population still of a great threat to the Egyptian agricultural development. Also, the land tenure system in Egypt resulted in land fragmentation, where about 80% of the farm size of the cultivated area in the old lands is less than 2 acres [4].

This study examines water delivery performance and its economic effect on farmers. Performance was evaluated at the canal level, using the adequacy, efficiency, dependability and equity indicators. These indicators calculated for 24-months irrigation seasons of 2016 and 2017, using measured water deliveries and calculated crop water requirements, analysis, soil, water analysis, along the canal and agro meteorological data were also collected.

Methodology

The study area was selected to be a good representative of the Nile Delta region, of which it has three main features. First, the dominant irrigation system is surface flood irrigation, the soil classification is clay which is the typical Nile delta soil, and the cropping patterns includes the main crops of the Nile Delta, which produce the inputs for several agricultural industries, and contributes to the national economy. Second, the farm size is very small and ranged from about 0.5-3 acres with an average acreage of 0.4 per family. In addition, the water balance parameters were measured due to controlling the water inflow and outflow of the study area. A set of performance indicators that are related to this research goals were selected and applied for the evaluation. The indicators for evaluating the irrigation management requires different data to be collected such as water level (m), routine discharges (m^3/day) and cropping patterns of branch canals (summer and winter crop rotations). Data were collected and analyzed, to verify the selected indicators.

Study area

The study area is located on the eastern part of the Nile Delta in south-east of Sharqia governorate. The study command area is El-Alfia branch canal feed from Bahr Abo-Akhdar main canal serving a command area of about 4000 ha, with 8.95 km length with two sub-branches (Qaraqra and Taqsira canals). Layout of the study area is shown in Figure 1.

The command area in this study managed by Minia El-Kamh engineering district irrigation of East El-Sharqia Irrigation Directorate from Riah Al-Tawfiqi through Bahr Mawis at KM 35.00. The main canal for command area is Bahr Abo Khadir that is fed from Bar Mawis at KM 12.00 and is feeding Mostafa Afandy canal at KM 1.00. The direct canal that is feeding the study command area is El-Alfia canal from Mustafa Afandy at KM 2.00**.**

The main summer crops in the study area are Maize and Cotton however the upstream farmers grow rice illegally as a cash crop and for its necessity for the human and animals' food, while the main crops in winter are Wheat and Berseem (Clover) that occupy about 75% of the cultivated area. Permanent crops, such as citrus trees, occupy about 14% of the cultivated land. Summer and winter vegetables are about 10% of the cultivated area.

Water Resources, Irrigation, and Drainage Systems

The study area uses surface irrigation methods which are suitable for the soil type, the common irrigation method is basin or furrow irrigation is selected based on the crop types (farrow method is used for maize and cotton while basin method is used for wheat, rice and berseem). Water flows mainly by gravity except for tertiary canals (mesqas), where farmers need to pump the water into their fields using small mobile diesel centrifugal pumps.

Private shallow groundwater wells cover a significant part of the area, especially at the downstream part. The drainage water goes out from the area through Abo Lakhdar, Kafr Rabie, Shehata and El Godaida Drains. The area is covered by well-functioning subsurface drainage system. Spacing between the laterals is 30 m with total length ranges between 250 to 300M.

Soil Characteristics

The soil characteristics in the study area were measured in eleven locations randomly distributed in the study area and presented in Table 1. The results indicated that the topsoil layers are predominantly composed of clay. However, lighter textures are observed in some areas. Soils are generally deep and relatively well drained. Figure 2 showed the locations of soil samples in the field.

To estimate the crop water requirements, meteorological data obtained from the nearest agro meteorological station in Zankaloon water research station of the National Water Research Center (Table 2) presents meteorological data during year 2016/17. The calculated reference evapotranspiration (ETo) ranges from 2.17 mm/day in winter to 6.57 mm/day in summer.

Monitoring Parameters

The assessment of the water balance of the study was conducted in two steps. The first step concerns the water delivery performance evaluated based on the indicators of adequacy, equity, efficiency and dependability which were proposed by [5].

The second step is concerns with the full water balance analysis between water supply and demand in the study area, through the monitoring and evaluation of irrigation operations.

Performance indicators used in this study evaluate irrigation in the investigated branch canal, mesqas and farmers' practices at the pump level.

Water use index indicator (WUI) was used to measure the water delivery performance in the branch canals and selected mesqas based on the following equation:

WUI=^{Q} $_{Q}$

Where *QD* Total is the amount of water diverted (m^3) into the irrigation network, and *QR* Total is the total irrigation water requirements for the area served (m^3). When the value of WUI is higher than 1.0 it means that there is a wastewater through irrigation network, and when the value of WUI is lower than 1.0 it means that there is shortage water through irrigation network.

Results and Discussions

Water Balance Parameters

Water balance modeling combined with field experiments were used in this study to give a better understanding of the components of the hydrological cycle from which to develop appropriate management options. The parameters to apply water balance through this study require different kinds of data items on irrigation system as; inflow, outflow, consumptive use, and groundwater. In this study, inflow was measured at main canal and branch canal levels.

Depth (cm)	Particle size (%)			TEXTURE	Bulk density(gm/cm³)	Field capacity(%)	Wilting point (%)	Available water (%)	E.C (dS/m)	pH
	Sand	Silt	Clay							
0-15	25.8	28.9	43.5	clay						
15-30	25.1	30.1	42.5		1.25	43.5	23.6	20	1.4	8.1
30-45	26.9	31.5	40.5		1.27	40.5	21.1	19.4	1.22	8
					1.32	37.1	17.6	19.5	1.25	8.1
45-60	29.8	31.5	37.1		1.4	36.3	16.6	19.6	1.05	8
Average	26.9	30.5	40.9		1.32	39.3	11.7	19.6	1.23	8

Table 1: Soil characteristics in the study area

Months	Temp (min.)	Temp (max.)	Humidity %	Wind speed (m/s)	Sun shine (H)	ETo* (mm/day)
Jan	9.1	18.7	69	2.4	7	2.17
Feb	9.6	20.3	66	2.6	7.7	2.81
Mar	11.9	23	63	2.8	8.6	3.82
Apr	14.3	27	62	2.6	9.7	4.88
May	16.7	30.5	59	2.5	10.6	5.87
Jun	21.3	33	62	2.4	11.9	6.57
Jul	23.3	30.3	67	2.4	11.6	6.06
Aug	23.2	33.4	66	2.4	11.3	6.15
Sep	21.4	32.9	64	2	10.4	5.28
Oct	19.1	30.1	61	2	9.3	4.24
Nov	13.7	24.2	65	2	8	2.84
Dec	10.8	20.4	68	2.3	6.7	2.22

* ET_o calculated according FAO Penman-Monteith equation

Table 2: Meteorological data used in the computation of reference evapotranspiration

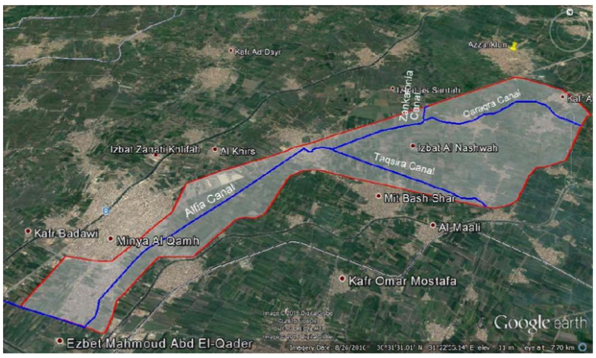

Figure 1: The location and layout of the study area

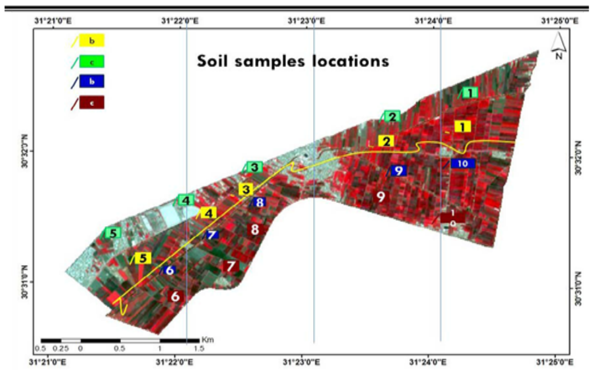

Figure 2: The layout of the command area of Alfia

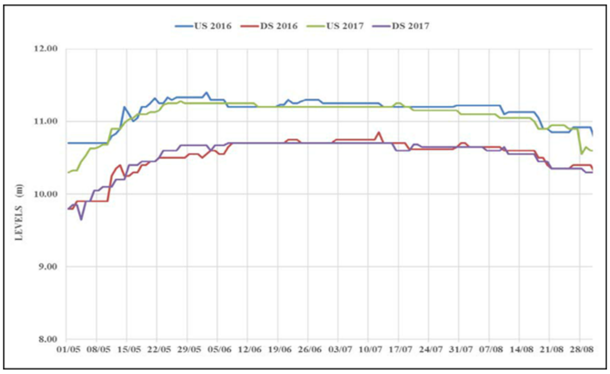

Figure 3: Daily average of water levels of Bahr Abo Khadir's head for Summer Season 2016 and 2017

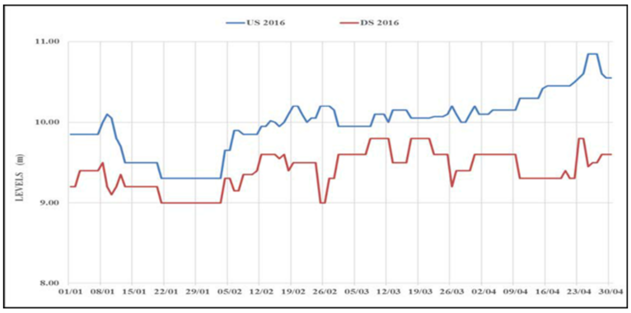

Figure 4: Daily average of water levels of Bahr Abo Khadir's head for Winter Season from January to April 2016

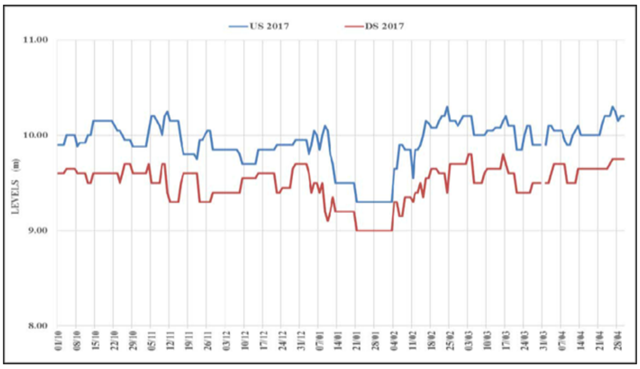

Figure 5: Daily average of water levels of Bahr Abo Khadir's head for Winter Season from January to April 2017

Water level

Water levels were continuously monitored using automatic recorders, so it was necessary to establish a relationship between water levels and discharges to enable conversion of these records. Flow heights were converted to discharge using individual rating curves for each measurement point.

Water levels were recorded upstream and downstream of the branch canal head regulators twice daily. The readings were taken off existing marble staff gauges. The data was recorded on designed forms. Erroneous or suspicious readings were highlighted and sent back to the field staff for correction and/or clarification. The water levels at the cross regulators on the main canals serving the command area are usually recorded twice daily by the Irrigation Sector (IS). Relevant water level data from the Irrigation Districts in the command area were also collected.

Figures (3, 4 and 5) show the average daily water level at the head of Bahr Abo Khadir. These charts cover irrigation seasons as winter seasons 2016/2017 that starts from first of October until the end of April. For summer seasons 2016/2017 starts from first May until the end of September. Theses charts give an indication of water surface profile in the main canal. It indicates that the water level in downstream of Bahr Abo Khadir was almost fixed and stable through irrigation seasons. In addition, the water levels in the same seasons 2016 or 2017 were close to the same levels at upstream or/and downstream. At the beginning of the summer season, the water level rises from 9.5 to 11.15 m and after that, the water level was flowing at fixed level 11.15 until the end of August month. At the end of season, the water level was dropped from 11.5 m to 10.0 m. Almost, the opening gate of Bahr Abo Khadir's regulator was fixed opening through summer season.

In the winter season, the water level was varying through days of season which the water level ranged around 10.0 m until the beginning of January. The winter closer was clear in the season which the water level was dropped through January and after that it raised slowly until the end of season to 10.7m.

Flow

Routine discharge measurements at selected locations on the sample canals were carried out by an acoustic Doppler current profiler (ADCP). It is a hydro acoustic current meter similar to sonar, used to measure water current velocities over a depth range using the Doppler effect of sound waves scattered back from particles within the water column. The term ADCP is a generic term for all acoustic current profilers [6] although the abbreviation originates from an instrument series introduced by RD Instruments in the 1980s.

Flow heights were converted to discharge using individual rating curves for each measurement point. The rating curves of these canals, approximated by geometric shapes, were checked at each measurement point by using the flow velocities measured by current meters and the area of the flow cross section.

Establishments of the flow calibration through this study depend on data point of discharge measurements on the main canal through combined irrigation seasons of summer and winter, as presented in the following equation.

$$= 72.59 \quad - 119.69 \qquad h \qquad = 0.97$$

The accuracy of calibration is high, which the coefficient of determination is up to 0.97. Figures 6,7 represent the water flow that calculated from calibration relation of flow. These figures indicate the summer season start at beginning of May until end of September with average flow of 104 m^3/sec and maximum flow around 130 m^3/sec at downstream of head of Bar Abo El-Akhdar canal. For winter season, starting at beginning of October until end of April with average flow of 39.7 m^3/sec and maximum flow around 65 m^3/sec.

The water flow in Alfia canal after coverage zone is divided to two paths, 70% of total flow volume go the lift side (El -Zankonlya and El-Karakra canals) and 30% of total volume go right side (EL-Tasksira and Aly Heidar canals).

Outflow Parameters

Groundwater

In this study, the outflow was estimated at the end of command area through groundwater level. Groundwater level was measured in six wells, to monitoring farmers' practices through irrigation seasons. Data were collected and interpreted to outline the hydro geological environment of the Nile Delta groundwater aquifer.

Equity of Water Distribution

The WUIs evaluated at the heads of the monitored branch canals (Mostafa Afandy canal (MC), El - Alfia canal (BC), and El- Karakra canal (SBC)) in study area. The following notes could be made related from Figures 8,9.

The values of WUI for all branch canals in two irrigation seasons 2016 and 2017 indicated that the water management in the study area has not changed dramatically. Some WUI values were larger than 1.0 indicating that water delivered at the head of the branch canal was typically larger than actual crop water and soil leaching requirements in order to account for conveyance and field application losses. On the other hand, a WUI values that is well below 1.0 indicated severe water shortage.

- The WUI values for Mostafa Afandy canal were over than 1.0 through irrigation seasons which indicates over irrigation. For summer season, the values were closed to 2.0, while in winter season, the values were closed to 3.0 except the period of winter closure.
- The performance of Alfia canal through irrigation seasons for both summer and winter was almost stable and fixed which it is close to WUI value of 1.0,
- While the El-Karakra canal's values were lower than 1.0 through irrigation season. So, the famers in these areas were using alternative methods for irrigation as shallow well for groundwater.

Economic analysis

Nowadays, most of Egyptian farmers are facing deficits and challenges related to continual water availability in irrigation canals. To solve these problems, farmers constructed shallow groundwater wells in their lands to get ground water and face the scarcity of irrigation water. The current study concentrated on the farmer's attitudes towards ground water based on measurable and observable data and information about the status and trends in groundwater quantity and quality.

A sample of 70 farmers farm holdings irrigated from Al-Alfia canal has been drawn, 35 of which have farm holdings near the head of "Mesqa", while the other 35 have farm holdings near the tail of "Mesqa".

Classifying the types of farmers according to farm size indicated the presence of one category: small farmers/beneficiaries as shown in Table 3.

Results presented in (Table 4) indicate that, during the winter season, the majority of farmers with holdings near the head and the tail of the "Mesqa" grow long clover and wheat. However, only one farmer at the head of "Mesqa" cultivated onions. At the head of "Mesqa", there are two farmers cultivated eggplant, where one cultivated green beans.

During the summer season, the majority of farmers with holdings near the head and the tail of "Mesqa" grew rice and maize. However, some farmers at the tail of "Mesqa" grew other crops: four grew eggplant, one grew cabbage, and the two grew citrus trees.

The change in summer cropping pattern due to the water problems and vegetable crops are more sensitive to the water quality. However, the number of farmers plating rice has decreased at both the head and tail because of the increasing demand for maize to process it as "a silage" to feed animals, particularly at the end of summer time.

	Location			
Farmer Category	Head of Mesqa		Tail of Mesqa	
	No.	%	No.	%
Small Farmer/ Beneficiary	35	100	35	100
Small Investor	0	0	0	0
Total	35	100	35	100

Table (3). Sample Classification by Farmer Category

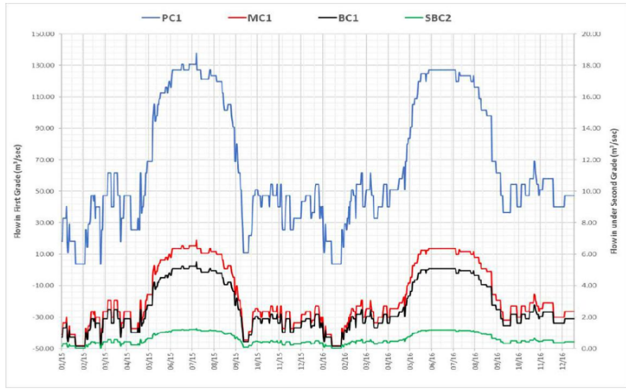

Figure 6: Water flow at downstream of head regulators irrigation canal

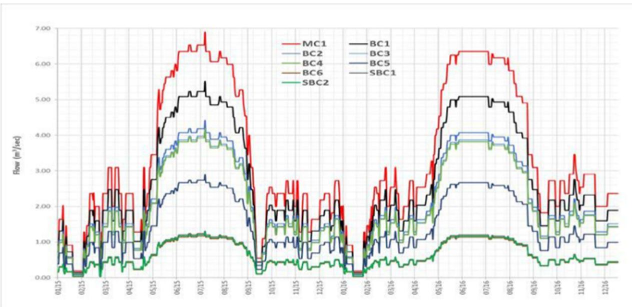

Figure 7: Water flow through irrigation canal networks

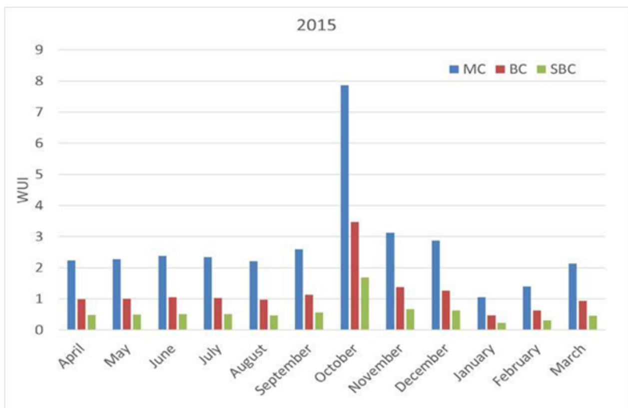

Figure 8: Monthly WUI at head branch canal level for Season 2016

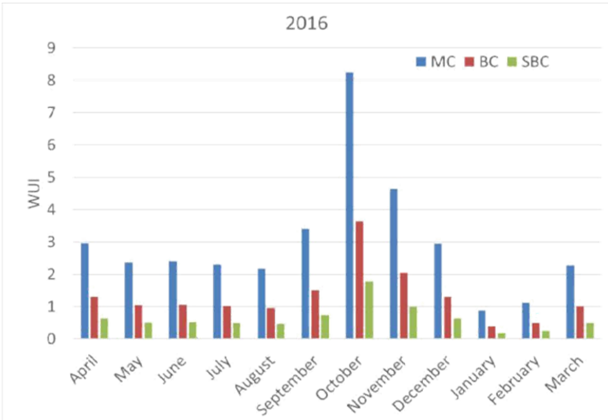

Figure 9: Monthly WUI at head branch canal level for Season 2017

Cropping Pattern	Head of Mesqa			Tail of Mesqa		
	No	%	Average Area	No	%	Average Area
Winter Crops						
Long Clover	19	34%	0.42	15	33%	0.42
Wheat	33	59%	1.04	31	67%	0.65
Lentil						
Onions	1	2%	0.42		0%	
Garlic						
Green beans	1	2%	0.21		0%	
Eggplant	2	4%	0.42		0%	
Total	**56**	**100%**		**46**	**100%**	
Summer Crops						
Rice	18	37%	0.58	9	24%	0.63
Maize	26	53%	1.3	18	49%	0.83
Eggplant	4	8%	1.6		0%	
Cabbage	1	2%	0.42		0%	
Total	49	100%		37	100%	
Citrus				2	100%	1
Total					**100%**	

Table (4). Sample Classification by Adopted Cropping Pattern

Source: Data collected from the sample survey

To compare the efficiency of water use, the current study utilizes the crop budget tool. Crop budget is considered one of the economic tools to estimate the net return or profit. From the crop budget, a comparison is applied between the estimated profit, crop water productivity, net return of water unit in addition to other indicators at the head and tail of "Mesqa" respectively.

Crop budget can be organized and presented in several different formats, but they typically contain three different sections: income, variable costs and fixed costs. Following are the steps followed to estimate these sections in details:

Income or Total Revenue

The first step to estimate income is to estimate the total production. Total production includes main and by product yield and the associated prices of these outputs for crops, these variables are considered as the average at the sampling level and could be considered a good estimate for the actual case in the previous agricultural year.

Variable Costs

The variable costs include seed, fertilizer, machinery, labor, machinery repairs, fuel and other items of variable cost. The variable costs are calculated by multiplying the quantities of each input by the associated price. The study also estimated the charge for the opportunity cost on capital invested in the variable costs. This charge covers the time period between expenditure of the capital and harvest when the income is received. Within the current study, an average time period of 6 months is assumed and a 10% opportunity cost is charged on the value of variable costs and 12 months for citrus crops.

To elaborate more about the socio-economic data uses in the calculation of variable cost, the main crops cultivated in winter season were long clover, wheat, eggplant, onions, green beans, long clover, and wheat. The inputs for the variable costs were seeds, manure, urea (46.5%), nitrate (33.5%), phosphate, potassium, leaf fertilizer, other fertilizer, pesticides, irrigation practices and transportation. The total variable costs for the cultivated crops in the winter season were 847.6, 1475, 2590, 6260, 1600, 1247, 1493 L.E/Fed respectively.

On the other hand, the main crops cultivated in the summer season at the mesqas near the head of the canal were rice, maize, eggplant, cabbage, and for the mesqas near the tail of the canal, the cultivated crops were rice, maize, citrus. The total variable costs for the same inputs for crops cultivated in the summer season were 1117.7, 3192, 2359, and 1150 L.E/Fed for the head mesqas, and 1356, 2164, and 4427 L.E/Fed for the tail mesqas respectively.

Fixed Costs

Fixed costs in the crop budget include machinery fixed costs and land charge. In the Egyptian circumstances, most of machinery work is hired and could be calculated as variable costs. Therefore, the fixed costs here are the charge of land. Land charge is the opportunity cost of land and represents the return for its use in crop production. Three methods could be adopted to determine the land charge: (1) an interest opportunity cost based on the current value of the land, (2) the owner's rental income from a typical crop share lease, or (3) a typical cash rent charge. The current study adopted the third method because of available knowledge for the cash rent of each crop in advance as can be obtained in the Egyptian rural societies.

Crop Budget Indicators

Net Revenue

Net revenue calculated as the difference between the total revenue; total production multiplied by their farm gate prices, and the total costs calculated from the three items above. The net revenue here is not similar as its value published in agricultural economic bulletin because of the sharp increase in the price of fertilizer, energy, labor wages and land rent in addition to the high increase of the output prices. On the other hand, each crop budget estimated the shadow prices of all owned inputs and estimated all the other items of irrigation cost that included fuel and oil, custom application, equipment rent, depreciation, taxes and insurances. The price of water as a resource was considered as a cost recovery of water resource. Therefore, the net return here is expressing the economic profit.

Water Productivity

Different indicators for water productivity could be used. In the current report, crop water productivity focuses on the field level. Water productivity at the field level refers to the amount of crop output in physical terms (crop yield in kilogram) or monetary terms (crop yield times its price in financial or economic terms) divided by the amount of water consumed (evaporated from the soil and transpired by the plant, the evapo - transpiration) - in other words, the crop per drop. However, productivity is a measure of performance expressed as the ratio of output to input. Productivity may be assessed for the whole system or parts of it. It could account for all or one of the inputs of the production system giving rise to two productivity indicators:

Water productivity (WP) is a partial-factor productivity that measures how the systems convert water into goods and services. Its generic definition can be recognized as: Water Productivity (WP) = Output Derived from Water Use/ Water Input.

Indicators of Crop Water Productivity

Water productivity is a very robust measure that can be applied at different scales to suit the needs of different stakeholders, (Shetty, 2006; Sharma, 2006). This is achieved by defining the inputs of water and outputs in units appropriate to the users' needs.

The numerator (output derived from water use) can be defined in the following ways:

Physical output, which can be total biomass or harvestable product;

Economic output (the cash value of output) either gross benefit or net benefit.

Season/Crop	*Head of Mesqa*					*Season/ Crop*	*Tail off Mesqa*				
Winter Season	*Main Product*		*Byproduct*		*Total Revenue*	*Winter Season*	*Main Product*		*Byproduct*		*Total Revenue*
Crop	*Quantity (Ton)*	*Price (LE)*	*Quantity (Ton)*	*Price (LE)*	*(TR) (LE)*	*Crop*	*Quantity (Ton)*	*Price (LE)*	*Quantity (Ton)*	*Price (LE)*	*(TR) (LE)*
Long Clover (Cerate/Cut)	79.1	95.3	0	0	7538	***Long Clover (Cerate/ Cut)***	75.1	94.3	0	0	7088
Wheat	2.8	3688	17.9	192	13847	***Wheat***	1.7	3695	18.7	192	7762
Egg plant	4	2000			8000						
Onions	5.5	1500			8250						
Green beans	0.8	3000			2225						
	Summer Season						***Summer Season***				
Rice	2.1	2987	104.4	4	6605	***Rice***	2	3204	100	4	6603
Maize	4.1	2923	0	0	12009	***Maize***	2.4	2949	0	0	7019
Eggplant	5.5	1563			8597						
Cabbage*	3000	2.5			7500						
						Citrus	8.5	2500	0	0	21250

Table 5: Revenue from Plant Production per Feddan

Location		**Head of Mesqa**								**Tail of Mesqa**					
Summer Season															
Input	Unit	Rice		Maize		**Eggplant**		**Cabbage**		Rice		Maize		Citrus	
		Q	**V**	**Q**	**V**	**Q**	**V**	**Q**	**V**	**Q**	**V**	**Q**	**V**	**Q**	**V**
Seeds	Kg/Fed	56.5	299.5	14.0	700	1	440	1	400	63	325	9	450		
Manure	m^3/Fed	0.0	0.0	13.0	380							9	210	22	770
Urea (46.5%)	Kg/Fed	30.0	60.0	265.0	760	175	525			50	100	220	500	250	813
Nitrate (33.5%)	Kg/Fed	45.0	140.0	300.0	750			150	450	50	150	150	350	25	44
Phosphate	Kg/Fed	40.0	50.0	50.0	50							200	200	175	175
Potassium	Kg/Fed													50	375
Leaf fertilizer	Kg/Fed					5	625							1	700
Other Fertilizer	Kg/Fed														
Pesticides	Liter/Fed	0.7	18.5	1.0	50	4	400			1	75	2	120	1	400
Irrigation	L.E/Fed		509.4		461		356		300		655		296		1150
Transportation	L.E/Fed		40.3		41		13				51		38		
TVC	L.E/Fed		1117.7		3192		2359		1150		1356		2164		4427
Rent	L.E/Fed		1688.0		2370		1600		1000		1828		2319		7750
Tax	L.E/Fed		33.1		77		31		25		45		52		138
TFC	L.E/Fed		1721.1		2447		1631		1025		1873		2371		7888
Total Cost	L.E/Fed		2838.8		5639		3990		2175		3229		4535		12315

Table (6). Cost of Production Inputs at the Head/Tail of “Mesqa” during the Winter and (Value in LE/unit)

	winter season							summer season						
	Head of Mesqa					Tail of Mesqa		Head of Mesqa				Tail of Mesqa		
	Long Clover	Wheat	Eggplant	Onions	Green beans	Long Clover	Wheat	Rice	Maize	Eggplant	Cabbage	Rice	Maize	Citrus
Total Fixed costs (L.E/Feddan)	1648	2007	1495	1275	515	1530	1933	1721	2447	1631	1025	1873	2371	7888
Total Variable costs(L.E/Feddan)	848	1475	2590	6260	1600	1247	1493	1118	3192	2359	1150	1356	2164	4427
Total Costs (L.E/Feddan)	2495	3482	4085	7535	2115	2777	3426	2839	5639	3990	2175	3229	4535	12315
Total Costs (L.E/Ton)	32	1244	1021	1370	2644	37	2015	1352	1375	725	1	1615	1890	1449
Total Revenue (L.E/Feddan)	7538	13847	8000	8250	2250	7088	7762	6605	12009	8597	7500	6603	7019	21250
Gross Margin (L.E/Feddan)	6691	12372	5410	1990	650	5841	6269	5487	8817	6238	6350	5247	4855	16823
Net Return (L.E/Feddan)	5043	10365	3915	715	394	4311	4336	3766	6370	4607	5325	3374	2484	8935
Net Return (L.E/Ton)	64	3702	979	130	492	57	2551	1793	1554	838	2	1687	1035	1051
Water Net Return (L.E/ m3)	3	7	5	6	2	2	4	1	4	3	2	1	2	4
Productivity Water (Kg/m3)	37	755	373	271	1864	39	1243	2524	732	553	1	2651	1251	648

Table (7). Main Indicators of grown crops at the Head/Tail of "Mesqa" during the Winter and Summer Seasons 2016 *(Value in LE/unit)*

Results of the main indicators of winter crops at the Head and Tail of "Mesqa":

Revenue per Feddan from Plant Production

Revenues earned from plant production activities in the study area during the winter and summer seasons have been calculated. Results indicate that, during the winter season, farmers near the head of "Mesqa" produce 79.1 and 2.8 tons of long clover and wheat worth LE 7538 and LE 13847, respectively, compared to 75.1 and 1.7 tons worth LE 7088 and LE 7762 for farmers near the tail of "Mesqa", respectively (Table 5).

For the summer season, farmers near the head of *"Mesqa"* produce 2.1and 4.1 tons of rice and maize worth LE 6605 and LE 12009, respectively, compared to 2 and 2.4 tons worth LE 6603 and LE 7109 for farmers near the tail of *"Mesqa"*, respectively. Also the two farmers who plant citrus produce 8.5 tons worth LE 21250. Farmers near the head of *"Mesqa" also* produce 5.5 tons of eggplant and 3000 heads of cabbage worth LE 8597 and LE 7500 LE 12000.

Cost of Production Inputs (LE/Feddan)

Cost of production inputs for crops grown by farmers with holdings near the head/tail of *"Mesqa"* during the winter and summer seasons are presented in (Table 6). It is clear that the cost of production for long clover at the head of "Mesqa" is higher compared to the tail (LE 2495 versus LE 2777) while conversely in the case of wheat. The cost of wheat is LE 3482 versus LE 3426 at the head and tail of "Mesqa" respectively. Of course, there are eggplants, onions and green beans grown at head of "Mesqa" in winter season.

At the summer season, there are also eggplants and cabbage grown at head of "Mesqa" because of regular water availability to satisfy their needs. However, costs of crops differ at the two sites (Head and Tail) not only because of water availability but also the quantity of inputs and their related prices as represented in (Table 5).

Main Indicators of grown crops

Based on the data collected about the cost of production and revenues, there are main indicators of grown crops calculated from the crop budget of these crops. In all cases, indicators are higher at the head of "Mesqa" compared to that similar at the tail; (long clover wheat in winter and rice & maize in summer). The water net return as an indicator for water use efficiency is higher at the head compared to the tail for the similar crops in addition to plant some vegetable crops at the head because of water availability (Table 7) below.

Conclusion

- The top soil layers are predominantly composed of clay. Soils are generally deep and relatively free drained;
- 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 this area use more water than their needs because they located at the head of the branch canal;
- The average operation hours for portable pumps per unit area is 15 hours and 35 hours in winter and summer seasons, respectively. While on improved mesqa, the average operation hours for portable pumps per unit area is 10 hours and 20 hours in winter and summer seasons, respectively.
- 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.

Recommendations

Water balance analysis is used to help managing water supply and identifying water shortages in irrigation. 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. The findings of study were concluded as following:

- Linking to land use planning and practices, attentive to cultural and historical traditions of the society and based on participatory approach, involving relevant indicator users.
- Conduct more research of using ground water at pure and mixing water (surface and ground) to assess the crop water productivity in the two cases, particularly of stress water circumstances.

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