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THE IMPACT OF IRRIGATION IMPROVEMENT ACTIVITIES ON WATER AND SALT BALANCE FOR THE IRRIGATED LAND IN NEKLA CANAL (EL-BEHIRA GOVERNORATE)

[188]

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ABSTRACT

Three representative mesqas, i.e. Arfa Mousa at the head, Elafeer2 at the middle and Elbanna at the tail of Nekla canal. El-Behara Gov., were selected to evaluate the impact of the implementation of activities and processes of field irrigation system development on crop yield, water saving, water productivity, water and salt balance.

Results indicated slight increases in yield of the tested crops either irrigated from head - Arfa Mouse, middle - Elafeer2 or Tail - Elbanna mesqas. The average increases were about 6.98, 5.99 and 7.19% respectively. The average increases in crop water productivity were about 19.9, 19.5 and 20.0 % for crops irrigated from the three mesqas respectively. The average increases in crop water productivity for wheat, rice, Egyptian clover, cantaloupe and watermelon pulp as affected by field irrigation system development were about 15.3, 21.5, 22.9, 18.5 and 20.6% respectively. The average increases in water saving were about 10.8, 11.2 and 10.6 % for crops irrigated from the three tested meqas respectively. The average increases in water saving for wheat, rice, Egyptian clover, cantaloupe and watermelon pulp as affected by field irrigation system development were about 7.36, 12.9, 13.7, 10.6 and 9.88% respectively.

Results revealed that the net water balance (NWB) values decreased to about 87.6, 76.7 and 85.5% as affected by field irrigation system development relative to values before development equal to 100 for wheat, rice and Egyptian clover respectively under irrigation from Arfa Mousa mesqa at the head of Nekla canal. Similar results were also observed for wheat, rice and Egyptian clover irrigated from Elafeer2 at middle, and Elbanna mesqa at tail of Nekla canal. The average amount of salts added into soil cultivated with wheat, rice, Egyptian clover, cantaloupe and watermelon pulp were 800, 2350, 1255, 848 and 454 kg/Fed respectively before and 702, 1939, 1026, 719 and 388 kg/Fed after field irrigation system development. The average amount of salts removed from soil cultivated with wheat, rice, Egyptian clover, cantaloupe and watermelon pulp were 722, 2456, 1337, 802 and 454 kg/Fed respectively before development and 567, 2887, 591, 598 and 309 kg/Fed after field irrigation system development.

It could be concluded that field irrigation system development has a positive effect on water saving, crop yield, water productivity and reducing salt accumulation in crop growth medium because field irrigation system development prevent seepage and weed growth increases in the developed mesqas and made water available all the time in the mesqa.

Keywords: Impact of irrigation; Salt balance; Nekla canal

INTRODUCTION

Egypt is unique among the nations of the world due to its main dependence upon a single water source, the River. Water demands in Egypt are growing rapidly due to the population explosion. The available fresh water per capita in Egypt dropped from 1893 cubic meters per person in 1959 to 800-900 cubic meters in 2000 and tends to decline further to the values of 670 cubic meter by 2017 and 600 by 2025 (**Malashkia, 2003 and MWRI, 2005**).

According to statistics, if the available fresh water per person drops below 1700 cubic meters, countries are considered as water stress regions. When per capita water use falls below 1000 cubic meters, countries undergo a chronic water scarcity, and less than 600 cubic meters of water per person would mean absolute water scarcity (**Malashkia, 2003**).

Egypt by year 2025 will face absolute water scarcity. The consumed water for irrigated agriculture is about 85% of the budget of MWRI while 10% are dedicated to services for the water supply and sanitation sector, and 5 % attributed to the industrial sector (**MWRI, 2005).**

In the final report of the integrated irrigation improvement and management project (IIIMP), **Simons et al (2012**) reported that one of the main measures that have been taken to solve problems related to the distribution of water in the irrigation network is the application of continuous flow, as a replacement of the typical system of rotational flow. Water delivery services to the farmers are improved and the flexibility of the water management system is increased. The flow in the branch canal is determined by regulation of the discharge at the head of the canal, while taking into account the area served by the canal and its cropping pattern (i.e. crop water demands). Lifting of the water from the branch canal into the mesqa network has been centralized through an electric pump set at a single control point, with the purpose of increasing the equity of water distribution and reducing operational cost. Water losses through seepage from the mesqas are reduced by piping of the tertiary canals, also allowing for pressurized water delivery. Similar improvements have been made to under IIIMP, either by lining of the canals with brick and mortar or piping by low-pressure pipes up to the on-farm gate.

Inadequate water supply in a canal command area is a major limiting factor for sustainable crop production, as well as for adoption of the suitable crops. **Satyendra et al (2013)** indicated that the interventions were able to save a substantial amount of irrigation water (3-46%) compared to surface methods, along with higher yields, a doubling of water productivity and more profits per mm of irrigation water. The study clearly showed that micro-irrigation in conjunction with an auxiliary reservoir should be recommended in canal-irrigated commands in order to improve water productivity and farmers' income in arid regions.

A significant volume of water was lost from small-scale irrigation systems in Ethiopia mainly because farmers' water application did not match crop needs **(Derib et al 2011)**. They found that the high cost resulted by pumped irrigation positively affected water management by minimizing water losses and forced farmers to use deficit irrigation. Improving water productivity of small-scale irrigation requires integrated interferences including night storage mechanisms, optimal irrigation scheduling, empowerment of farmers to preserve canals and proper irrigation schedules. **Noory et al (2011)** pointed out that improving water management can decrease mean drainage water (22-48%) and salts (30-49%), compared with current water management without adverse effects on relative transpiration and root zone salinity.

In evaluation the effects of controlled irrigation and drainage on water productivity in paddy fields, **Gao ShiKai et al (2018)** found that the controlled irrigation and drainage reduced irrigation water without a significant impact on grain yields and increased the irrigation water productivity.

Water productivity can be expressed as agricultural production per unit volume of water. The United Nations, World water assessment programme calls for crop water productivity increases with the aim of reducing pressure to develop new supply sources or increasing water allocation to agriculture (**UNESCO, 2009**). **FAO (2012**) considers demand management as an important option to cope with water scarcity, with increasing agricultural water productivity as the single most important avenue for managing water demand in agriculture.

For wheat, rice and clover crops, the water productivity with respect to evapotranspiration is typically reported to be around 1.0-1.2 kg/m^3 for wheat (**French and Schultz, 1984**), 0.6 to 1.6 kg/m^3 for rice (**Hsiao et al 1984**) and 1.0–2.6 kg/m^3 for Egyptian clover (**Grimes et al 1992**).

The main objective of this work was to evaluate the impact of the implementation of the activities and processes of the development of field irrigation systems on crop yield, water productivity water saving, water balance and salt balance of some of the cultivated crops.

MATERIALS AND METHODS

The main objectives of this study were achieved by track the change in the characteristics of irrigation water and soil in different locations along Nekla canal representative by three mesqas, (Arfa Mousa at the head, Elafeer2 at the middle and Elbanna at the tail) before and after field irrigation system development. In addition, crops yield, water saving, crop water productivity were determined for some of the cultivated crops in the areas irrigated from these mesqas before and after the implementation of activities and processes of the development of the field irrigation systems.

The activities and processes of the development of the field irrigation system included the conversion of the unlined canals to buried pipes operating under water pressure head or to lined canals and changing the multiple lift points to a single lifting point at the head of the mesqa and the replacement of the hand control gates to the mechanical control gates for each canal feeder. In addition to the replacement of sharing water lifting machines with diesel or electric pump (lifting machines). The development of field irrigation system extended to establish of water users' associations at the branch canal level and the water council at the main canal level.

Water samples were collected several times from irrigation canals and mesqas under study to represent their properties at head, middle and tail before and after the development of field irrigation systems then subjected to chemical analyses **(Table 1)**. Soil samples were taken using soil auger from investigated sites at the beginning and at the end of each crop growth season from the soil layers at 0-15, 15-30, 30-45 and 45-60 cm depth. The collected soil samples were air dried and ground to pass through a 2 mm sieve, and then the different determinations of soil physical properties were conducted according to **Klute (1986)** and represented in **Tables (2 and 3)**.

Table 1. Chemical analysis of water samples taken from Arafa Mousa (AM) at the head, Elafeer2 (EF2) at the middle and Elbanna (EB) at the tail mesqas, before and after field irrigation system development

Site		pH	EC dS/m	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	$SO_4^{=}$
				meq/l					
AM head	Before	8.22	0.57	2.80	2.00	1.00	0.22	0.50	4.50
	After	8.15	0.53	1.90	1.40	1.45	0.77	0.50	4.00
Mean		**8.19**	**0.55**	**2.35**	**1.70**	**1.23**	**0.50**	**0.50**	**4.25**
EF2 middle	Before	8.13	0.57	2.33	2.00	1.00	0.47	0.50	4.00
	After	7.80	0.54	2.25	1.50	1.00	0.77	0.50	4.10
Mean		**7.97**	**0.56**	**2.29**	**1.75**	**1.00**	**0.62**	**0.50**	**4.05**
EB tail	Before	8.20	0.57	2.45	2.00	1.00	0.22	0.50	4.00
	After	8.03	0.55	1.90	1.72	1.00	0.97	0.50	3.85
Mean		**8.12**	**0.56**	**2.18**	**1.86**	**1.00**	**0.60**	**0.50**	**3.93**
Mean	Before	8.18	0.57	2.53	2.00	1.00	0.30	0.50	4.17
	After	7.99	0.54	2.02	1.54	1.15	0.84	0.50	3.98

Table 2. Soil bulk density and some soil moisture parameters of the served area by Arafa Mousa (AM), Elafeer2 (EF2) and Elbanna (EB) mesqas, before field irrigation system development

Site	Soil depth cm	bulk density g/cm^3	Soil moisture parameters %		
			FC	PWP	TAW
Arafa Mousa at head	00-15	1.1	46.1	24.8	21.4
	15-30	1.2	41.2	21.3	19.9
	30-45	1.2	36.8	20.4	16.5
	45-60	1.3	34.9	19.1	15.8
Mean	**00-60**	**1.2**	**39.8**	**21.4**	**18.4**
Elafeer2 at middle	00-15	1.1	46.5	25.3	21.2
	15-30	1.1	40.2	21.8	18.3
	30-45	1.3	38.3	20.8	17.5
	45-60	1.3	34.3	18.6	15.6
Mean	**00-60**	**1.2**	**39.8**	**21.6**	**18.2**
Elbanna at tail	00-15	1.1	46.7	25.4	21.3
	15-30	1.2	40.4	21.9	18.4
	30-45	1.2	37.2	20.2	17
	45-60	1.3	34.2	18.6	15.6
Mean	**00-60**	**1.2**	**39.6**	**21.5**	**18.1**

Table 3. Particales size distribution of the served area by Arafa Mousa (AM), Elaffaira2 (EF2) and Elbanna (EB) mesqas, before field irrigation system development

Site	Soil depth cm	Particales size distribution - %			Texture
		Sand	Silt	Clay	
Arafa Mousa at head	00-15	13.4	31.3	55.3	Clay
	15-30	21.3	29.1	49.6	Clay
	30-45	22.1	31.2	46.7	Clay
	45-60	23.1	34.2	42.7	Clay
Mean	00-60	20.0	31.5	48.6	Clay
Elafeer2 at middle	00-15	12.3	33.3	54.4	Clay
	15-30	20.2	34.2	48.6	Clay
	30-45	20.4	34.5	45.1	Clay
	45-60	21.1	35.7	43.2	Clay
Mean	00-60	18.5	34.4	47.8	Clay
Elbanna at tail	00-15	13.8	31	55.2	Clay
	15-30	20.9	34.3	44.8	Clay
	30-45	21.7	38.7	39.6	Clay
	45-60	22.1	39.7	38.2	Clay
Mean	00-60	19.6	35.9	44.5	Clay

Electrical conductivity values (EC) in dS/m were measured in the collected water samples or in the extract of saturated soil paste using electrical conductivity meter according to the method described by **(Jackson, 1958)**.

Water application at mesqa field level is calculated based on the discharge from the pumps and the operation hours of this pump. The calibrate the pumps depends on the type of this pump either improved (fixed) or unimproved (movable) pumps. In the unimproved pumps, where water pumping freely to farm canal (Marwa), flumes are used to measure discharge from pumps. In this method, the discharge is defined based on the water depths at the upstream (Ha) and the downstream (Hb) of the cut throat flume. The discharge can be obtained from the corresponding tables based on the coefficient C that is calculated using the following equation described by **Water measurement manual, USA (2001)**:

$$C = (Ha - Hb) / Ha$$

In improved mesqas, the ultrasonic flow meter is used to measure the discharge, with reflective type (V). In type (V), both transducers mounted on one side of the pipe, and the distance between them is defined based on the characteristics of the pipelines and the measured liquid. The flow is recorded in (lit/sec). The flow from the pump depends on the pressure (head), and the pressure consists of suction head and delivery head. Suction head is related to the water level in the suction side. Delivery head depends mainly on the friction losses, and therefore, it depends on the opened valve(s). The head is measured around the pumps (suction and delivery heads) for different scenarios of opening valves to define the range of the flow from the pumps.

With the flow from the pump, the operation hours should be collected/recorded to define total water supply from the mesqa. The simple way to get the operation hours is to collect them manually. The operator of the mesqa record the daily starting and stopping hours of the pumps. Other time, advanced techniques are used to define such starting and stopping hours. A data logger that is connected to the electric circle is used for this purpose. The device is recording the situation (on/off) each time interval. The recorded data is analyzed to define the starting and the stopping time for each pump such recorded data.

Level and salinity values of water table are recorded automatically using automatic recorders. A recorder (Solinst) was used for this purpose. The recorder was installed inside a pipeline (piezometer). The time interval for recording the data is defined during the setup, and normally it is half an hour. The recorder is defining the water depth above its datum, and using the level of this datum, such depths could be converted into levels. The salinity is measured directly.

Weather data for the experimental site were obtained from Nekla agro-meteorological station. Monthly values of solar radiation, minimum, maximum and mean air temperature, relative humidity, wind speed, and pan evaporation (R_s, T_{min}, T_{max} and T_{mean} , RH, U and E_p respectively) are presented in **Table (4)**. Where: R_s is Solar radiation in (MJ/m^2/day), T_{max} is Maximum air temperature C°, T_{min} is Minimum air temperature C°, T_{mean} is Average air temperature C°, T_{dew} is Dew point temperature in C°, P is Precipitation in mm/day, U is Wind speed in km/h and RH is Relative humidity in %.

Water Consumption for crops (WU) after or before field irrigation development was determined by tracking the change in the soil moisture content before each irrigation. Soil moisture content (θg) was gravimetrically determined in soil sample taken before each irrigation from the active root zone (D_s) at 0-60 cm depth (**Hansen et al 1979**). Field capacity (θ_{FC}), permanent wilting point (θ_{PWP}) and soil bulk density (ρ_s) were determined according to **Klute (1986)**. Seasonal crop water consumptive use for each of the studied crops (WU) in mm or m^3/feddan were calculated using the following equation:

$$WU = \sum ((\theta_{FC} - \theta g)/100) \times (\rho_s/\rho_w) \times D_s \times 4200 \ m^3/Fed$$

Where: WU is crop water consumptive use of the tested values through growth season of each crop in mm or m^3/Fed, θg is soil moisture percentage before irrigation in % (w/w), θ_{FC} is Soil field capacity in % (w/w), D_s is soil layer depth or active root zone in m, ρ_s is soil bulk density in g/cm^3 and ρ_w is water density in g/cm^3.

Change in soil moisture storage (CSMS) was gravimetrically determined in soil sample taken from active root zone before and after the development.

Water productivity (WP) is a simple ratio between crop yield in kg/m^2 and water consumptive use (WU) in m^3/m^2 as shown in the following equation **(El-Bably et al 2015).**

$$WP = Crop\ yield / WU$$

Table 4. Monthly agro-meteorological data recorded for El-Behaira - Nekla during 2017

Months	R_s	T_{max}	T_{min}	T_{mean}	T_{dew}	RH	U	P
Jan	12.4	17.6	5.97	10.9	3.54	61.2	3.80	0.00
Feb	15.2	20.0	6.71	12.4	4.94	60.6	3.90	0.00
Mar	19.8	24.1	10.1	16.3	5.95	51.5	5.90	0.00
Apr	23.7	28.5	12.2	19.9	6.58	43.5	5.10	68.1
May	27.2	33.4	16.8	24.7	9.40	39.1	1.70	0.00
June	29.6	36.6	19.8	28.0	12.6	39.4	1.30	0.00
July	29.1	38.6	22.1	29.92	15.5	42.3	1.20	0.00
Aug	26.9	37.1	22.2	29.0	16.7	47.4	1.40	0.00
Sept	23.6	30.5	15.5	22.2	11.3	45.3	3.00	0.00
Oct	18.9	29.5	16.3	22.2	11.4	51.2	3.10	0.00
Nov	14.0	24.3	12.2	17.4	8.98	58.4	3.20	0.00
Dec	10.4	21.3	10.3	14.9	7.92	63.5	4.00	0.00
Mean	**20.9**	**28.5**	**14.2**	**20.6**	**9.57**	**50.3**	**3.13**	**68.1**

In this work the actual crop water productivity was calculated as the ratio between crop yield in kg/Fed and applied irrigation water (AIW) in m^3/Fed.

CWP = Crop yield / AIW

Water balance considers water inflows and outflows from field. Water outflow components at field are crop water consumptive use, deep percolation, runoff, soil moisture storage change. The inflow components are applied irrigation water, effective rainfall, subsurface contributions and surface seepage flows. Subsurface contributions and surface seepage flows were considered zero. Storage change component is soil moisture change in active root zone. Process depletion components are actual evapotranspiration, outflow components are deep percolation, and surface runoff. Deep percolation was calculated from the difference between the total amount of water applied (irrigation application and rainfall) and actual consumptive use. Surface runoff was zero. Drainage outflows are often not measured (**Molden, 1997**), as more emphasis has been placed on knowledge of inflows to irrigation systems. Gross inflow is the total amount of water flowing into the field from rainfall and surface and subsurface sources. Net inflow is the gross inflow plus any changes in storage. If water is removed from storage over the time period of interest, net inflow is greater than gross inflow; if water is added to storage; net inflow is less than gross inflow. Net inflow water is either depleted, or flows out of the field of interest.

Salt balance was determined as a difference between average salinity of water, both rainfall and irrigation water were taken under consideration into the field and average salinity of drainage water before and after growing season. The following are the salt balance equations as described by **Taylor (1996)**:

Incoming salt = outgoing salt + storage of salt
Incoming salt = inflow × salt concentration of the inflow
Outgoing salt = outflow × salt concentration of the outflow

RESULTS AND DISCUSSIONS

The evaluation of the impact of the development of the field irrigation system in this study is based mainly on equitable distribution of irrigation water between the beneficiaries farmers by recognizing the change in crop yield, water saving, crop water productivity, water balance and salt balance for some crops before and after the development.

Effects of irrigation system development on applied irrigation water

Results in **Table (5)** indicate the applied irrigation water (AIW) in m^3 per irrigation and water saving of crops irrigated from Arafa Mouse at head, Elafeer at middle, and Elbanna mesqas at tail of Nekla canal before and after field irrigation system development. The applied irrigation water for wheat, rice, Egyptian clover, cantaloupe and watermelon pulp were ranged between 2169-2029, 6417-5592, 3408-2960, 2329-2072 and 1295-1161 for crops irrigated from Arfa Mousa at the head, 2224-2058, 6406-5589, 3407-2961, 2355-2089 and 1218-1077 for crops irrigated from Elafeer2 at the middle and 2184-2006, 6500-5652, 3504-2989, 2291-2291 and 1222-1128 m^3/Fed for crops irrigated from Elbanna mesqa at the tail of Nekla canal before - after field irrigation system development respectively.

It could be observed the differences in the irrigation water applied by the farmer for all crops before and after field irrigation system development. The applied irrigation water clearly decreased for all crops after field irrigation system development.

The highest difference between AIW before and after field irrigation system development was observed foe rice while the lowest diference was observed for wheat crop. These results may be due to prevailing water control through irrigation development.

Similar trend were also observed by **Tariq (2010)** who found that the relative water supply index varies from 1.66 to 2.02 during summer, whereas in winter it varies from 2.22 to 2.55. Irrigation supplies were reliable over the whole growing season.

Effects of irrigation system development on crop water use and applied irrigation water

Water consumptive uses for some crops irrigated from Nekla canal were determined during growth season of each crop either irrigated from Arafa Mousa, Elafeer2 or Elbanna mesqas, Nekla canal, Elbehaira Gov. before and after irrigation system development and presented in **Table (6)**.

The results showed that there is no specific trend to change the water consumption values of different crops due to the development of the field irrigation system. This may be due to the nature of these estimated WU values which based on crop growth and weather conditions during the different stages of growth and the homogeneous soil moisture in the root-zone and water control along irrigation canal.

As expected, all the estimated values of water consumption use (WU) of different crops are less than that of the values of applied irrigation water (AIW) by the farmer himself during the growing season. That is mean low on-farm irrigation efficiency. In fact, irrigation efficiency is usually reach to the highest whenever the difference between the estimated values of water consumption (WU) and applied irrigation water (AIW) during different stages of growth is in minimal. This is what should looking for.

Seasonal crop water use (WU) for wheat, rice, Egyptian clover, cantaloupe and watermelon pulp irrigated from the head (Arfa Mousa mesqa) were 1422-1465, 2976-2925, 2075-2036 1356-1376 and 822-795. While the WU by the same crops irrigated from the middle (Elafeer2 mesqa) were 1404-1438, 2944-2936, 2069-1977, -1373-1396 and 840-837 and 1438-1425, 2964-2943, 2041-2074, 1343-1325 and 789-845 m^3/Fed for crops irrigated from the tail (Elbanna mesqa) of Nekla canal before - after field irrigation system development respectively **(Table 6)**.

The observed irregular differences between the estimated water consumption (WU) values of the tested crops **(Table 6)** and the regular differences between the applied irrigation water (AIW) values for the same crops before and after field irrigation system development **(Table 2)** may ascribed to the positive effects of the development. One of the most important positive effects of irrigation system development is farmers' conviction at the head, middle and tail of irrigation canals of equitable water distribution.

Effects of field irrigation system development on water saving

Results obtained for the effects of field irrigation system development on water saving at deferent irrigations of crops were presented in **Table (5)**. Water saving is calculated as the difference between applied irrigation water for crops before and after field irrigation system development. Data indicated that the increments in water saving were associated with the increases in the quantity of applied irrigation water for each irrigation during growth season. The highest values of water saving were observed at the sowing irrigations for each crops.

Table 5. Average values of applied irrigation water (AIW) and water saving of crops irrigated from Nekla canal before and after field irrigation system development

Crops	Applied irrigation water in m^3/Fed								
	Arafa Mousa			Elafeer2			Elbanna		
	Before	After	WS%	Before	After	WS%	Before	After	WS%
	Field irrigation system development								
Wheat	2169	2029	6.45	2224	2058	7.46	2184	2006	8.15
Rice	6417	5592	12.9	6406	5589	12.8	6500	5652	13.0
Eg. clover	3408	2960	13.1	3407	2961	13.1	3504	2987	14.8
Cantaloupe	2329	2072	11.0	2355	2089	11.3	2291	2076	9.4
Watermelon pulp	1295	1161	10.3	1218	1077	11.58	1222	1128	7.69

Table 6. Seasonal crop water use (WU) of some crops irrigated from Arafa Mousa at the head, Elafeer2 at the middle and Elbanna mesqas at the tail of Nekla canal, Elbehaira Gov. before and after irrigation system development

Crops	Crop water consumptive use in m^3/Fed					
	Arafa Mousa		Elafeer2		Elbanna	
	Before	After	Before	After	Before	After
	Field irrigation system development					
Wheat	1422	1465	1404	1438	1438	1425
Rice	2976	2925	2944	2936	2964	2943
Egyptian clover	2075	2036	2069	1977	2041	2074
Cantaloupe	1356	1371	1373	1396	1343	1325
Watermelon pulp	822	795	840	837	789	845

A substantial increases in water saving for all the tested crops irrigated from Arafa mousa at the head, Elafeer2 at the middle and Elbanna meaqa's at the tail of Nekla canal as affected by field irrigation system development. The average increases in water saving were about 10.8, 11.2 and 10.6 % for crops irrigated from the three tested meqas respectively. These results are in agreement with that obtained by **Radwan (2017)** who concluded that the expected minimum, maximum, and average annual water saving from improved on-farm irrigation projects in Egypt are about 2.6, 6.72, and 4.67, respectively.

The average increases in water saving for wheat, rice, Egyptian clover, cantaloupe and watermelon pulp as affected by field irrigation system development were about 7.36, 12.9, 13.7, 10.6 and 9.88% respectively **(Table 5)**. The average increases in water saving for wheat, rice, Egyptian clover, cantaloupe and watermelon pulp as affected by field irrigation system development were about 7.36, 12.9, 13.7, 10.6 and 9.88% respectively.

Effects of field irrigation system development on crop yield and water productivity

The yields of the tested crops were determined from the field data collected through the farmers' interviews. Results obtained for the effects of field irrigation system development.on crop yield and crop water productivity (CWP). Concerning crop yield as affected by field irrigation system development. Results in **Table (7)** indicated a slight increases in yield of the tested crops either irrigated from head - Arfa Mouse, middle – Elafeer2 or Tail -

Elbanna mesqas. The average increases were about 6.98, 5.99 and 7.19% respectively. The average relative increases in crop yield of wheat, rice, Egyptian clover, cantaloupe and watermelon pulp as affected by field irrigation system development were about 6.84, 5.83, 6.11, 6.01 and 6.68% respectively. These increase in crop yield may be attributed to the development of field irrigation system and enhanced water allowance. This result is in agreement with that obtained by **Tariq (2010)** who found a significant increase in crop yield as a response to irrigation systems modernization. Date showed that the expected improvment in water distribution equity after field irrigation system development was more effective in increasing crop yield irrigated from the tail of Nekla canal (Elbanna mesqa). This increase in crop yield was more pronounced for wheat, Egyptian clover and watermelon pulp. Crop water productivity, as defined by **Molden, et al (2010**) is the ratio of crop yield or crop value, to a selected measure of water consumed, applied, or evaporated in the process of growing a crop. In this work crop water productivity in kg/m^3 is calculated by deviding the crop yield in kg/Fed on applied irrigation water in m^3/Fed.

Data in **Table (7)** revealed a substaintial increases in crop water productivity for all the tested crops irrigated from Arafa Mousa at the head, Elafeer2 at the middle and Elbanna meaqa's at the tail of Nekla canal as affected by field irrigation system development. The average increases in crop water productivity were about 19.9, 19.5 and 20.0 % for crops irrigated from the three meqas respectively. The average increases in crop water productivity for wheat, rice, Egyptian clover, cantaloupe and watermelon pulp as affected by field irrigation system development were about 15.3, 21.5, 22.9, 18.5 and 20.6% respectively. The results of crop water productivity (CWP) found in this work are in agreement with that obtained by **French and Schultz, (1984)** for wheat**, Hsiao et al (1984)** for rice and **Grimes et al., (1992)** for clover.

The increases in crop yield and crop water productivity may be due to the positive effects of field irrigation system development on regular availability of water in the irrigation canals and the ease of the application by the farmers with more accuracy and with less effort, which ultimately lead to improve rationalize the use of water resources. It is worthy to mentioned that, **Ashour et al (2010)** found that the positive effects of field irrigation development may be ascribed to the improvement process preventing seepage and weed growth increases. It also made water available all the time in the mesqa, better scheduling of irrigation and higher flow rate at the field level has also contributed to reduce the irrigation time. The irrigation time does not only include the time when the pump is actually operating, but also the time to transport the water to the land. The losses are only due to evaporation from free water surface, which was also reduced by reducing mesqas' cross section.

Effects of irrigation system development on water balance

Results presented in **Table (8 and 9)** showed the water balance components and net water balance for crops irrigated from Arafa Mousa at the head, Elafeer2 at the middle and Elbanna mesqas at the tail of Nekla canal, Elbehaira Gov. before and after field irrigation system development. Results revealed that the net water balance (NWB) values decreased by about 87.6, 76.7 and 85.5% as affected by field irrigation system development relatve to values before development equal to 100 for wheat, rice and Egyptian clover respectively under irrigation from Arfa Mousa mesqa at the head of Nekla canal. Similar results were also observed for wheat, rice and Egyptian clover irrigated from Elafeer2 at middle, and Elbanna mesqa at tail of Nekla canal.

The average total inflow values for crops irrigated from Nekla canal before field irrigation system development were 2691, 6591, 3901, 2465 and 1365 m^3/Fed for wheat, rice, Egyptian clover, cantaloupe and watermelon pulp respectively. While the average total inflow values for crops irrigated from Nekla canal after development were 2405, 5741, 3363, 2219 and 1242 m^3/Fed for wheat, rice, Egyptian clover, cantaloupe and watermelon pulp respectively.

The average total water outflow values for crops irrigated from Nekla canal before field irrigation system development were 2192,6441, 3440, 2325 and 1245 m^3/Fed for wheat, rice, Egyptian clover, cantaloupe and watermelon pulp respectively. While the average total inflow values for crops irrigated from Nekla canal after development were 2031, 5611, 2969, 2079 and 1122 m^3/Fed for wheat, rice, Egyptian clover, cantaloupe and watermelon pulp respectively as shown in **Table (9)**.

Table 7. Applied irrigation water (AIW), crop yield and crop water productivity (CWP) of some crops irrigated from Arafa Mousa at the head, Elafeer2 at the middle and Elbanna mesqas at the tail of Nekla canal, El-Behaira Gov before and after field irrigation system development

Area in Fed	Crop	AIW		Yield		CWP		
		m³/Fed		kg/Fed		kg/m³		%
		Before	After	Before	After	Before	After	
		Before and after field irrigation system development						
Arafa Mousa mesqa at the head of Nekla canal								
17	Wheat	2169	2029	2700	2892	1.25	1.43	14.5
20	Rice	6417	5592	4160	4320	4.59	5.5	19.2
27	Eg clover	3408	2960	29433	31000	1.22	1.46	21.3
5	Cantaloupe	2329	2072	4180	4530	1.79	2.19	21.8
9	Watermelon	1295	1161	390	430	0.30	0.37	23.0
Elafeer2 mesqa at the middle of Nekla canal								19.9
49	Wheat	2224	2058	2710	2870	1.22	1.39	14.4
15	Rice	6406	5589	4124	4350	4.65	5.72	20.9
19	Eg clover	3407	2961	29757	32000	1.21	1.47	23.7
25	Cantaloupe	2355	2089	4200	4510	1.78	2.16	21.1
10	Watermelon	1218	1077	386	400	0.14	0.16	17.2
Elbanna mesqa at the tail of Nekla canal								19.5
21	Wheat	2184	2006	2678	2879	1.23	1.44	17.0
15	Rice	6500	5652	4000	4330	4.52	5.5	24.5
21	Eg clover	3504	2987	29398	31000	1.14	1.45	23.7
3	Cantaloupe	2291	2076	4364	4470	1.90	2.15	13.0
9	Watermelon	1222	1128	365	410	0.30	0.36	21.7
Average values for Nekla canal								20.0
87	Wheat	2192	2031	2696	2880	1.23	1.42	15.3
67	Rice	6441	2969	29529	31333	4.58	5.58	21.5
50	Eg clover	3440	5611	4095	4333	1.19	1.46	22.9
33	Cantaloupe	2325	2079	4248	4503	1.83	2.17	18.5
28	Watermelon	1245	1122	380	413	0.25	0.30	20.6

CWP: Crop water productivity

Table 8. Water balance components for crops irrigated from Arafa Mousa at the head, Elafeer2 at the middle and Elbanna mesqas at the tail of Nekla canal, El-Behaira Gov. before and after field irrigation system development

Crop		Inflow in m^3/Fed				Outflow in m^3/Fed			NWB
		AIW	R	SS	Total	WU	Dp	Total	m^3/Fed
Arafa Mousa mesqa at the head of Nekla canal									
Wheat	Before	2169	277	150	2596	1445	724	2169	427
	After	2029	244	130	2403	1445	584	2029	374
Rice	Before	6417	0	150	6567	2940	3477	6417	150
	After	5592	0	130	5722	2940	2652	5592	130
Eg clover	Before	3408	291	170	3869	5058	-1650	3408	461
	After	2960	244	150	3354	5058	-2098	2960	394
Cantaloupe	Before	2329	0	140	2469	1348	981	2329	140
	After	2072	0	140	2212	1348	724	2072	140
Watermelon	Before	1295	0	120	1415	811	484	1295	120
pulp	After	1161	0	120	1281	811	350	1161	120
Elafeer2 mesqa at the middle of Nekla canal									
Wheat	Before	2224	276	150	2650	1428	796	2224	426
	After	2058	244	130	2432	1428	630	2058	374
Rice	Before	6406	0	150	6556	2936	3470	6406	150
	After	5589	0	130	5719	2936	2653	5589	130
Eg clover	Before	3407	291	170	3868	2024	1383	3407	461
	After	2961	244	150	3355	2024	937	2961	394
Cantaloupe	Before	2355	0	140	2495	1386	969	2355	140
	After	2089	0	140	2229	1386	703	2089	140
Watermelon	Before	1218	0	120	1338	840	378	1218	120
pulp	After	1077	0	120	1197	840	237	1077	120
Elbanna mesqa at the tail of Nekla canal									
Wheat	Before	2184	277	150	2611	1445	739	2184	427
	After	2006	244	130	2380	1445	561	2006	374
Rice	Before	6500	0	150	6650	2953	3547	6500	150
	After	5652	0	130	5782	2953	2699	5652	130
Eg clover	Before	3504	293	170	3967	2058	1446	3504	463
	After	2987	244	150	3381	2058	929	2987	394
Cantaloupe	Before	2291	0	140	2431	1340	951	2291	140
	After	2076	0	140	2216	1340	736	2076	140
Watermelon	Before	1222	0	120	1342	819	403	1222	120
pulp	After	1128	0	120	1248	819	309	1128	120

Table 9. Average net water balance for crops grown on areas irrigated from Nekla canal, El-Behira Gov. before and after field irrigation system development

Crop		Inflow in m^3/Fed				Outflow in m^3/Fed			NWB
		AWI	R	CSMS	Total	WU	D_P	Total	m^3/Fed
Wheat	Before	2192	277	150	2619	1439	753	2192	427
	After	2031	244	130	2405	1439	592	2031	374
Rice	Before	6441	0	150	6591	2943	3498	6441	150
	After	5611	0	130	5741	2943	2668	5611	130
Eg. clover	Before	3440	292	170	3901	3047	393	3440	462
	After	2969	244	150	3363	3047	-77	2969	394
Cantaloupe	Before	2325	0	140	2465	1358	967	2325	140
	After	2079	0	140	2219	1358	721	2079	140
Watermelon pulp	Before	1245	0	120	1365	823	422	1245	120
	After	1122	0	120	1242	823	299	1122	120

Assuming runoff = 0
AIW: Applied irrigation water
R: Rainfall
CSMS: Change in soil moisture storage
Dp: Deep percolation = AIW - WU
Total water **inflow =** AIW + Rainfall + Soil Storage
Total water **outflow =** WU + Runoff + Deep percolation
NWB: Net water balance = Inflow - Outflow

Effects of irrigation system development on salt balance

Results in **Table (10 and 11)** show the salt balance components and net salt balance for the diferent crops grown on areas irrigated from Arafa Mousa at the head, Elafeer2 at the middle and Elbanna mesqas at the tail of Nekla canal, Elbehira before and after field irrigation system development. Results ravealed that salt balance in plant growth medium depends mainly on the quantity of salts added through applied irrigation water and partialy through the quantity of rainfall and salt removed mainly by leaching through drainage water.

As expected, the results showed that the amount of salts added (SA) to rice-cultivated soil irrigated from Arafa Mousa at the head, Elafeer2 at the middle or Elbanna mesqas at the tail of Nekla canal were higher before than after field irrigation system development.

While the amount of salts removed from rice-cultivated soil irrigated from Arafa Mousa at the head, Elafeer2 at the middle or Elbanna mesqas at the tail of Nekla canal tail was lower before than after field irrigation system development.

The amount of salts removed (SR) from the cultivated land with wheat, Egyptian clover, cantaloupe and watermelon crops was higher before than after field irrigation system development. This may be attributed to the reduction in irrigation water associated with field irrigation system development which led to reduce the amount of salts added and reduce the amounts of salts removed from the soil.

Concerning This may be attributed to the large quantities of irrigation water that farmers added to soil cultivated with rice crop either before or after field irrigation system development where. The large quantatity of irrigation water may increase the amount of salt added and salt remove by leaching.

It could be observed from **Table (10)** that the average amount of salts added into soil cultivated with wheat, rice, Egyptian clover, cantaloupe and watermelon pulp were 800, 2350, 1255, 848 and 454 kg/Fed respectively under irrigation from Nekla canal before development and 702, 1939, 1026, 719 and 388 kg/Fed after field irrigation system development.

Table 10. Salt balance components for crops grown on soils irrigated from Arafa Mousa at the head, Elafeer2 at the middle and Elbanna mesqas at the tail of Nekla canal, El-Behira before and after field irrigation system development

Crop		Salt - IN			Salt - OUT				
		AIW m^3/Fed	TSS_{iw} mg/l	SA kg/Fed	Q_{dw} m^3/Fed	TSS_{dw} mg/l	SR kg/Fed	NSB kg/Fed	RSR %
Arafa Mousa mesqa at the head of Nekla canal									
Wheat	Before	2169	365	791	728	960	699	92	88
	After	2029	346	701	588	960	564	137	80
Rice	Before	6417	365	2341	3979	640	2547	-206	109
	After	5592	346	1933	3154	960	3028	-1095	157
Eg clover	Before	3408	365	1243	1350	960	1296	-53	104
	After	2960	346	1023	902	640	577	446	56
Cantaloupe	Before	2329	365	850	981	832	816	33	96
	After	2072	346	716	724	832	602	114	84
Watermelon pulp	Before	1295	365	472	484	1024	496	-23	105
	After	1161	346	401	350	1024	358	43	89
Elafeer2 mesqa at the middle of Nekla canal									
Wheat	Before	2224	365	811	796	960	764	47	94
	After	2058	346	711	630	960	605	106	85
Rice	Before	6406	365	2337	3470	640	2221	116	95
	After	5589	346	1932	2653	960	2547	-615	132
Eg clover	Before	3407	365	1243	1383	960	1328	-85	107
	After	2961	346	1023	937	640	600	424	59
Cantaloupe	Before	2355	365	859	969	832	806	53	94
	After	2089	346	722	703	832	585	137	81
Watermelon pulp	Before	1218	365	444	378	1024	387	57	87
	After	1077	346	372	237	1024	243	130	65
Elbanna mesqa at the tail of Nekla canal									
Wheat	Before	2184	365	797	731	960	702	95	88
	After	2006	346	693	553	960	531	162	77
Rice	Before	6500	365	2371	4062	640	2600	-228	110
	After	5652	346	1953	3214	960	3085	-1132	158
Eg clover	Before	3504	365	1278	1446	960	1388	-110	109
	After	2987	346	1032	929	640	595	438	58
Cantaloupe	Before	2291	365	836	943	832	785	51	94
	After	2076	346	717	728	832	606	112	84
Watermelon pulp	Before	1222	365	446	411	1024	421	25	94
	After	1128	346	390	317	1024	325	65	83

Table 11. Net Salt balance for the different crops grown on areas irrigated from Nekla canal, El-Behira before and after field irrigation system development

Crop		Salt - IN			Salt - OUT				
		AIW m^3/Fed	TSS_{iw} mg/l	SA kg/Fed	Q_{dw} m^3/Fed	TSS_{dw} mg/l	SR kg/Fed	NSB kg/Fed	RSR %
Nekla canal									
Wheat	Before	2192	365	800	752	960	722	78	90
	After	2031	346	702	590	960	567	135	81
Rice	Before	6441	365	2350	3837	640	2456	-106	104
	After	5611	346	1939	3007	960	2887	-948	149
Eg clover	Before	3440	365	1255	1393	960	1337	-82	107
	After	2969	346	1026	923	640	591	436	58
Cantaloupe	Before	2325	365	848	964	832	802	46	95
	After	2079	346	719	718	832	598	121	83
Watermelon pulp	Before	1245	365	454	424	1024	435	20	95
	After	1122	346	388	301	1024	309	79	79

AIW: Applied irrigation water.
TSS_{iw}: Total saluble salts of irrigation water.
Qdw: Quantity of drainage water
TSS_{dw}: Total saluble salts of drainage water.
SA: Salt added
SR: Salt removed
NSB: Net salt Balance
RSR: Relative salt remove

As shown in **Table (10)** the average amount of salts removed from soil cultivated with wheat, rice, Egyptian clover, cantaloupe and watermelon pulp were 722, 2456, 1337, 802 and 454 kg/Fed respectively under irrigation from Nekla canal beforedevelopment and 567, 2887, 591, 598 and 309 kg/Fed after field irrigation system development.

The relative net salts outflow or removed from the growth medium of the tested crops were in the descending order: Rice > Egyptian clover > Wheat > Cantaloupe > Watermelon pulp as affected by field irrigation system development **Table (11)**.

It could be concluded that the investiment in irrigation modernization and improvement to make the water delivery system and its management flexible enough to take full advantage of new technologies and effective crop patterns so, it is very important and viable to continue and expand the irrigation improvement activities in the old land of Egypt.

It can recommend that under conditions of water scarcity that we are facing, the development of field irrigation is a must because it improves water management at the field level, increase agricultural productivity; overcomes problems of water distribution among farmers, saves of the irrigation water used and increases the value of water productivity. Besides, maximizing the benefits of return from the unit of land and water associated with economic, environmental and social aspects.

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تأثير تطوير الرى على الاتزان المائى والملحى للأراضى المروية من ترعة نكلا بمحافظة البحيرة

[188]

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الموجـــــــز

أجريت عدة قياسات حقلية في مواقع مختلفة على طول قناة نكلا بمحافظة البحيرة. وقد تم إختيار ثلاثة مساقى متفرعة منها بدءا من فم الترعة وعند وسطها وعند ذيلها لتقييم تأثير تنفيذ الأنشطة والعمليات المختلفة لتطوير نظام الري الحقلى على إنتاجية عدد من المحاصيل المنزرعة بالمنطقة وتروى من ترعة نكلة من أى من مساقيها تحت الدراسة وهى القمح والأرز والبرسيم المصرى والكانتالوب ولب البطيخ. كما إمتد التقييم الى مدى توفير مياه الرى وإنتاجية وحدة المياه بالإضافة الى التوازن المائى والتوازن الملحى والذى ينعكس على إمكانية تقييم ترشيد استخدام موارد المياه.

أدى تطوير نظام الري الحقلى الى زيادة كبيرة في توفير مياه الرى لجميع المحاصيل سواء كانت مساقى الرى عند رأس أو وسط أو ذيل الترعة بعد التطوير.

لوحظ وجود زيادات طفيفة في إنتاجية المحاصيل سواء كانت تروى من رأس أو وسط أو ذيل الترعة بعد التطوير.

أظهر النتائج أن التحسن المتوقع في عدالة توزيع المياه تأثرا بتطوير نظام الري الحقلى كان أكثر فعالية في زيادة إنتاجية المحاصيل المروية من مسقة الرى عند ذيل ترعة نكلا، وكانت هذه الزيادة في إنتاجية المحاصيل أكثر وضوحا بالنسبة للقمح والبرسيم المصري ولب البطيخ.

أوضحت النتائج وجود زيادة واضحة في إنتاجية مياه الرى المضافة لرى جميع المحاصيل تحت الدراسة سواء كانت تروى من مساقى الرى عند رأس أو وسط أو ذيل الترعة بعد التطوير.

أوضحت النتائج أن صافى قيم توازن المياه فى بيئة نمو المحصول (NWB) إنخفضت إلى حوالي 87.6، 76.7 و 85.5٪ تأثرا بتطوير نظام الري الحقلى منسوبة الى القيمة 100 لما قبل التطوير للقمح والأرز والبرسيم المصري على التوالي تحت ظروف الري من مسقة عرفة موسى عند رأس قناة نكلا. كما لوحظت نتائج مماثلة بالنسبة للقمح والأرز والبرسيم المصري المروي من مسقة العفير2 عند الوسط ومسقة البنا عند ذيل قناة نكلا.

أظهرت النتائج أن كمية الأملاح المضافة (SA) إلى التربة المنزرعة بالأرز والمروية من المساقى عند رأس، أو وسط أو ذيل قناة نكلا كانت أعلى قبل التطوير عنه بعد تطوير نظام الري الحقلى في حين أن كمية الأملاح التي تم إزالتها من التربة المنزرعة بالأرز والمروية من المساقى عند رأس، أو وسط أو ذيل قناة نكلا كانت أقل بعد التطوير عنه قبل تطوير نظام الري في الحقل .

يمكن أن نخلص إلى أن تطوير نظام الري الحقلى له تأثير إيجابي على توفير المياه وإنتاجية المحاصيل وإنتاجية المياه وتقليل تراكم الملح في وسط بيئة نمو المحاصيل حيث أن تطوير نظام الري الحقلى يمنع زيادة التسرب ونمو الحشائش في المساقى المطورة ويجعل المياه متاحة لجميع المزارعين .

الكلمات الدالة: تطوير الري على الاتزان، الماء الملحي، ترعة نكلا

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