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Research Article

Sustainability of Agriculture in Closed Basin of Koum Oshim, Fayoum, Egypt

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Abstract

Closed drainage basins present a unique environmental or water quality challenge. Evaporation ponds may be an appropriate means for disposing of drainage water. However, these ponds may lead to other environmental problems. The closed basin of Koum Oshim is a new reclaimed area in the Northern East of Fayoum governorate. It suffers from high water table, salinity and the presence of three surface ponds (Berkas) in spread sites. The Berkas have no outlet and the drain water impounded is subject to evapo-concentration. As a result of severe shortage of irrigation water in the area especially in summer, some arable lands are left fallow and other areas are irrigated with mixing drainage water. These conditions affect the crop productivity and public health. These practices have led to reduce the efficiency of water management due to lack of an integrated agricultural drainage network. The objective of this paper is to improve the water management conditions of the closed basin. Water Board is recalled and activated to help the farmers facing the water shortage and unequal distribution of irrigation water. The sustainability of agriculture in the closed basin depends on the reuse of drainage water for irrigation with the cooperation of farmers.

Keywords: *Closed drainage basins, Water quality challenge, Crop productivity*

1. Introduction

Ultimate disposal of drainage water to a river or sea is not always possible. Closed drainage basins present a unique environmental or water quality challenge. In such situations, evaporation ponds may be an appropriate means for disposing of drainage water. In these ponds, drainage effluent is evaporated at high temperatures and percolates into the groundwater underneath (Javed and Abdul Hafeez, 2004). Evaporation ponds are the only economic drain water disposal option in San Joaquin Valley, California (Tanji *et al*., 2002). However, these ponds may eventually lead to other environmental problems. For example, toxic substances could accumulate in the ponds. The contamination problems that may be originated from atmospheric depositions, applied commercial fertilizers, pesticides, manures, waste disposals and may be discharge of untreated domestic sewage (Abd Elgawad *et al*., 2007). Lakes and ponds occur in a wide range of depths, sizes, and permanence from deep lakes having a permanent body of surface water to shallow ponds having water for only a few weeks each year. Many hydrological processes are sensitive to changes in climate. Climate affects the lake water balance by changing the amount of stream flow and groundwater flow into the lake (Hayashi and van der Kamp, 2007). Water-level changes in ponds and lakes occur as a result of the water input exceeding output or vice versa. Because inputs and outputs are controlled by hydrological processes, understanding the water-level changes and resulting ecological responses requires understanding the individual processes. It is particularly important to realize the intimate link between lakes and their catchments. Disturbance in the catchment, such as major land use change, can cause a dramatic change in hydrological processes, which ultimately affects the lake water level (van der Kamp *et al*., 2003). The cultivation of considerable areas within the dry land closed drainage basins have developed widespread waterlogging particularly in the areas underlain by shallow soil and buried fluvial channels. The proportion of cultivated lands within each catchment, the irrigation water requirements and methods, and evaporation from drainage ponds should be balanced, to prevent waterlogging. Waterlogging is the major threat facing the development of the Saharan areas. Extensive waterlogging hazard has occurred as the geomorphologic setting was not considered when developing new agricultural areas. The buried channels of closed drainage basins are the most vulnerable areas for waterlogging, particularly when the soil of higher surrounding areas is cultivated (El Bastawesy *et al*., 2013). Furthermore, in arid climates, as pure water evaporates from the pond, the concentration of the remaining water approaches that of brine. The health of waterfowl, fish and other aquatic biota which use the pond could be negatively affected. Other environmental problems associated with evaporation ponds include the use of the pond to collect

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wastewater from homes; human health problems caused by consuming water from the ponds and the need to ultimately dispose of the accumulated concentrated chemicals in the ponds. In some cases, dry toxic materials may be spread by the wind. Furthermore, these ponds could become habitats for snails and mosquitoes, thereby causing malaria and schistosomiasis epidemics. In addition, if not properly managed, new waterlogged and saline areas will develop adjacent to the ponds (FAO, 1997). Potential environmental and health impacts of surface water pollution in the closed basin are multi-faceted and can be classified under direct and indirect impacts depending on the exposure pathway. Direct impacts are the result of direct exposure to low quality water such as the consumption of polluted water that could result in a variety of adverse implications to human, animal, and aquatic well-being. Indirect impacts are the result of indirect exposure to polluted water such as the consumption of damaged plants, impacted animals, fish, or food products, and the development of eutrophication associated with algal blooms that in turn damage agricultural equipment, restrict water use in the lake, and produce foul odors and insects (Hussein *et al*., 2008).

One of the major problems in the management of surface water lakes is the estimation of all water budget components (Tanny *et al*., 2008). Investigations of water budget are increasing rapidly, because of the dependence of human life on aquatic ecosystem (Chikita *et al*., 2004). The problem of ground water via surrounding lands is important to basin management efforts aiming at mitigating hazardous flow events and optimizing surface water and groundwater resources and also has significant ecological implications (Korkmez *et al*., 2009). Ground water discharge to a lake is one of the most difficult components of the water balance to measure. In the case of lake systems, they may also be limited by very low hydraulic gradients, which can be difficult to accurately measure. Water balance methods that measure other components of the water balance and calculate groundwater inflow by difference are limited by the errors in the other water balance components, which may be larger than the groundwater inflow term (Cook *et al*., 2008).

Desert and arid lands aquaculture should be developed by adopting policies and practices that ensure environmental sustainability, especially through the use of environmentally sound technologies and appropriate water management. The establishment of efficient farming systems that are integrated into environmental management plans will enable more efficient use of water, land, seed and feed inputs. The Socio-economic aspects can be another tool as establishing cooperatives and farmers associations for small-scale aquaculture (FAO, 2011). Communities often have a great deal of capacity and experience in dealing with their local environment. They demonstrate a great ability to provide water equitably, especially when it becomes increasingly scarce. Farmer communities have been able to handle O&M successfully without a formal legal status. Water User Association (WUA) was responsible for irrigation service performance and tackling the dilemma of unequal distribution of irrigation water also focuses on the awareness of water shortage problem and its effects (Batt and Merkley, 2010).

2. Research objectives

The study area was chosen because it represents the water shortage problem that emerges due to unequal distribution of water along canal and land expansion.

The present study aimed to meet the following objectives:

- To improving the water management conditions in the Koum Oshim closed basin by developing the water balance model for the three Brekas in the basin;
- To recall, activate and sustain the Water Board WB of Al-Gomhoria canal especially at the tail end of canal to help them facing the water shortage and tackling the dilemma of unequal distribution of irrigation water in the basin.

3. Materials and Methods

3.1 Study area

Fayoum governorate is one of the oldest agricultural areas of the world. It is an oasis, a fertile land and surrounded by desert. Irrigation water is delivered from the Nile through Bahr Youssef canal and Bahr Hassan Wassef while the excess and drainage water discharges into Lake Qaroun and Wadi Rayan depression. Koum Oshim study area is located in the north east of Fayoum governorate; it is about 80 km to south west of Great Cairo. It is a clearly defined basin forms a closed drainage basin with no outlet. The closed basin of Koum Oshim (30^{o} 91.7 east longitude, 29^{o}58.4 north latitude) is a new reclaimed agricultural area (7600 acre) which is bordered from its northern and western sides by desert and from its south eastern side by the Cairo - Fayoum main road and the Koum Oshim industrial region as shown in Fig.1. The topography of the area is characterized as land slopes from northern desert, 15 m above MSL, to -1 m below MSL. The climate in area is arid and characterized by a hot and dry summer with scanty winter rainfall and bright sunshine throughout the year. The average temperature is varied between 20 ^{o}C and 22.5^{o}C. The average annual precipitation is varied between 10 mm and 15 mm (Nour El-Din, 2013) and (SNC, 2010)). The geology formations (respectively 50 m and 180 m thick) are composed of hard, brownish limestone, shale, and marl bands with sandstone beds in the upper part.

Table 1 Surface area of Berkas

Area (m^2)	Gross Surface Area	Water Covered Area
Large Berka (1)	2,063,007	515,751
Small Berka (2)	199,643	99,822
Artificial Berka (3)	442,311	221,156

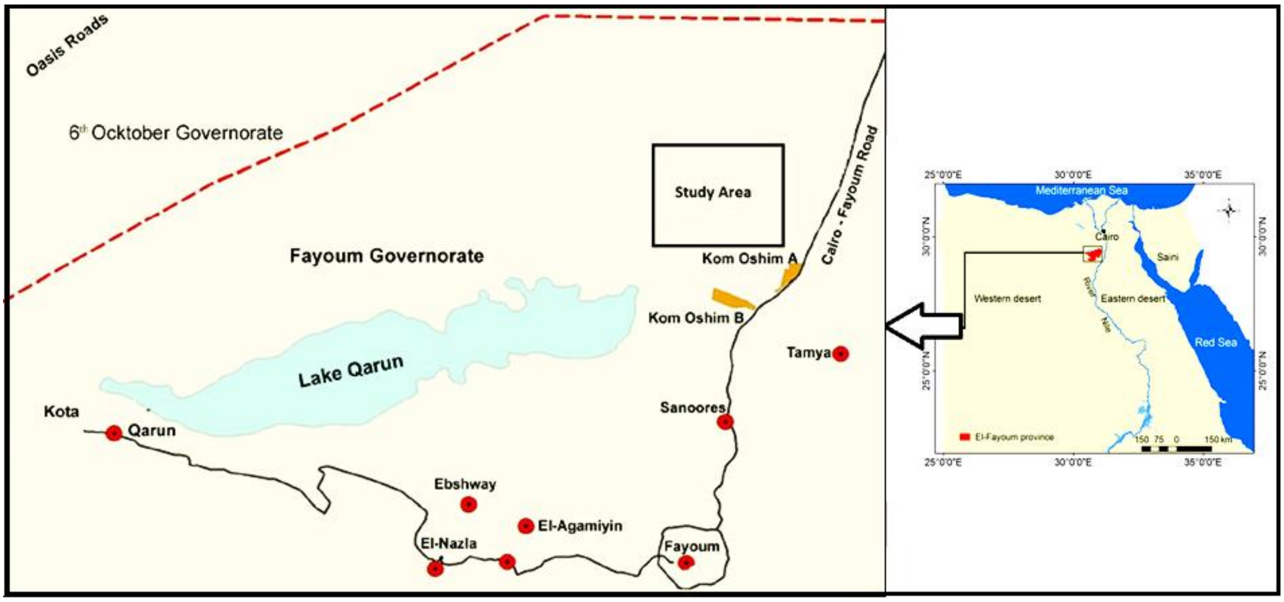

Fig. 1 Study area location

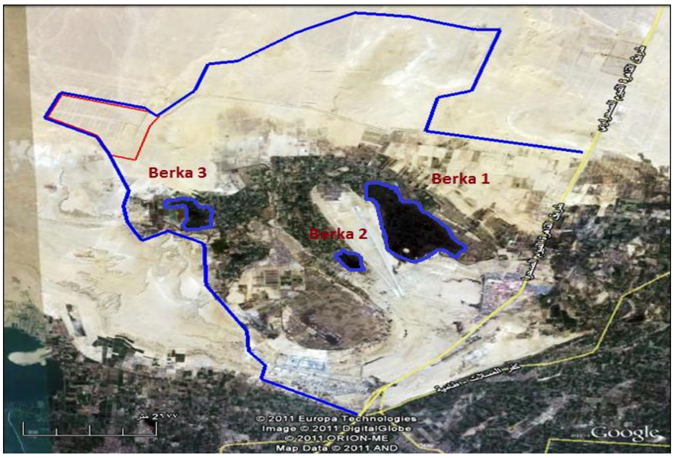

Fig. 2 Koum Oshim closed basin area and its Berkas

The beds are highly fossili ferous (Said *et al*., 1972). The soils are varying between sandy loam in the north to clay in the south. The main crops are wheat, bear and berseem in winter and maize and vegetables in summer. The study area is suffering a shortage of irrigation water around the year. Al-Gomhoria canal which is fed from Koum Oshim main canal irrigates the study area. The water duty for Al-Gomhoria canal and its four branches is 15 m^3/acre/day. The reused drainage water is mixed with irrigation water at two mixing stations on Al-Gomhoria canal. The inland closed basin of Koum Oshim has three ponds (inter depressions). They are locally known as Berkas. Large Berka (1), small Berka (2) and artificial Berka (3) are the three Berkas as shown in Fig.2. The gross area and the average water covered area for each Berka during the study period are tabulated in Table (1). The drainage effluent is being disposed into these Berkas by gravity through a network of surface drains services the agricultural catchment area. The Berkas have no natural outlets and water leaves it mainly through evaporation. The population of rural inhabitants is 8515 in 2010 census (MOLD, 2011).

3.2 Water Balance Items

3.2.1 Irrigation and Drainage

Irrigation water for Koum Oshim is diverted from El Gomhoria main canal. The irrigation discharge varied between 0.52 m^3/sec. and 0.56 m^3/sec. The irrigation water salinity is varied between 1.68 dS/m and 2.25 dS/m. The drainage water flow from different surface drains to the three Berkas is measured monthly between February 2013 and September 2013. The total drainage discharge to the three Berkas is ranged between 262 $X10^3$ m^3/month in dry season to 5 12 $X10^3$ m^3/month in wet season. The drainage water salinity in these drains is varied between 3.88 dS/m to 10.69 dS/m during the study period.

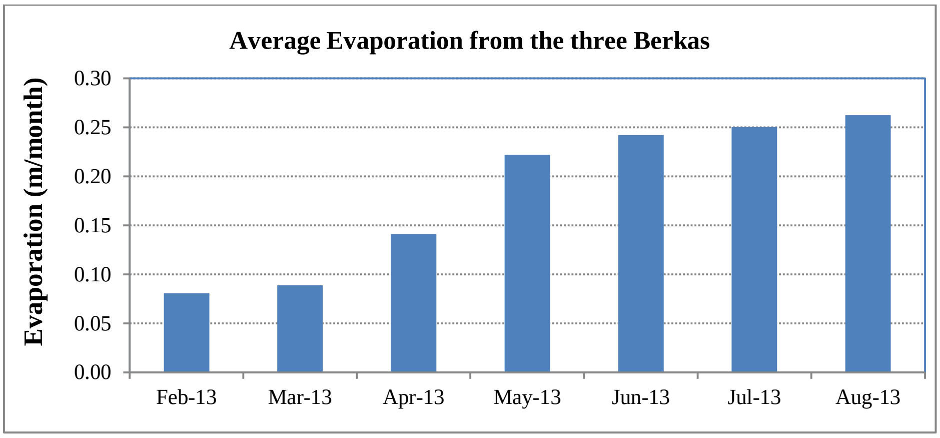

Fig. 3 Average Evaporation from the three Berkas

3.2.2 Evaporation from Berkas surfaces

The water salinity in the three Berkas varied between 6.7 dS/m and 8.2 dS/m during the study period. The evaporation rates from the three Berkas surface have been measured using floating circular Class A evaporation pan. The maximum evaporation is recorded during August 2013 while the minimum evaporation is recorded during February 2013. The average evaporation from the three Berkas is shown in figure (3).

3.2.3 Evapotranspiration from cultivated areas

Table 2 Evapotranspiration from different crops in the area

Crop		Area (acre)	ET (mm/day)
Fall	Fallow	1850	~
	Tomatoes	200	1.8
	Sugarbeet	450	2.8
	Onion	500	1.9
	Wheat	1200	1.7
	Barley	1100	2.6
	Clover	1700	2.7
	One-cutClover	120	1.8
Summer	Fallow	3850	~
	SummerTomatoes	220	6.9
	Maiz	1900	6
	SummerOnion	500	7.8
	Berseem	650	7.6
	Olive & palm trees	140	2.7

Evapotranspiration (ET) consists of the combination of evaporation and transpiration by plants. Water is transferred from ponds and lakes to the atmosphere by direct evaporation from the water surface and transpiration by emergent plants. CROPWAT computer program is used for the calculation of crop water requirements based on monthly inputs of climate and rain data, coupled with crop parameters and soils data. The data required are cultivation areas, cropping pattern, planting date, crop coefficients and growth stage length. A comprehensive review of methods to estimate ET is found in Drexler *et al.* (2004). The estimated ET from different crops in the area is shown in table (2).

3.2.4 Groundwater flow

Lakes and ponds are almost always connected to groundwater. Therefore, groundwater inputs and outputs always affect the water and dissolved mass balance of lakes and ponds (Hayashi and Rosenberry, 2002). The groundwater flow is estimated according to (Rosenberry *et al.*, 2008). The shoreline surface of each Berka is divided into segments, as the number of segments depending on the location and number of nearby wells. Eighteen piezometer wells were installed in the Koum Oshim basin with 10 meters depth. For each shoreline surface segment of the Berka and associated well, hydraulic conductivity and the gradient between the well and the surface water of the Berka are applied to the entire segment. The Darcy equation is used to calculate the groundwater flow of water that passes through the vertical plane associated with each segment which has relatively permeable sand followed by underlain impermeable bedrock.

$$Q = K * (m * b) * \frac{(h1 - h2)}{L} \quad (1)$$

where Q is flow through a vertical plane that extends beneath the Berka (L^3/T); K is horizontal hydraulic conductivity (L/T); A is the area of aquifer vertical plane through which all water must pass to or leave the shoreline surface of Berka, depending on the direction of flow [segment length (m) × effective thickness of the aquifer to the bedrock (b)]; h_1 is the piezometric head in the piezometer well (1) (L); h_2 is the piezometric head in the piezometer well (2) (L); and L is distance between the two wells (L).

3.3 Water Balance of Berka

All water balance equations are based on the premise that the difference between water inflow and water outflow over a given time period for the hydrologic system of a pond (Berka) must equal the change in water storage in that system. The Berka water budget is computed by measuring all of the Berka's water gains and losses and measuring the corresponding change in the Berka storage over the same period. The discharge water via the open drains represents the major part of the inputs. Evaporation is also the largest components of the water outputs since the contribution of groundwater is very small comparing with the drainage inlet flow. The water-balance equation for the Berka is then given by:

$$Q_{in} - Q_{out} = \pm \frac{\Delta S_B}{\Delta t} \quad (2)$$

Where $Q_{in}[L^3T^{-1}]$ is the sum of all water inputs, $Q_{out}[L^3T^{-1}]$ is the sum of all outputs and ΔS_B is the change in water storage in the Berka $[L^3]$ over a time period Δ_t [T]. The water regime of a Berka is determined by the seasonal variability of Q_{in}- Q_{out}. Therefore, understanding the water regime requires some knowledge of the hydrological processes controlling Q_{in} and Q_{out}. The inputs include perennial and intermittent water discharge via the main drains (Q_D), direct rainfall (R) and groundwater flux (Q_{GW}). The outputs include evaporation (E), Aquatic plants (Reeds) evapotranspiration (Q_{ET}) estimating that 50% of the Berka's surface area is covered by Reeds and about 10% of Q_D is reused drainage water or supplementary irrigation (Q_{RI}).

3.4 Community-managed irrigation and sustainability

A history of self-organization in community-managed irrigation demonstrates that farmers have the desire and ability to develop functional self-sustaining norms of collective action in order to manage the allocation and distribution of a common water resource. Community-managed irrigation was promoted with Dutch Cooperation in Fayoum Water Management Project (FWMP) sponsored by the Government of Netherlands (1993-2004). It encourages farmer's participation in specific governmental water management tasks. Since 1995, a number of 32 pilot Water Boards (WBs) was initiated in Fayoum. Activities of these WBs include both irrigation and drainage. The project tested the pilot formation of a federation of WBs in 2004 in order to improve water distribution in the whole command area. WBs involved in planning and monitoring of construction, rehabilitation and maintenance of civil works executed by Fayoum Irrigation and Drainage departments, execution of channel maintenance works by the WBs, weed control in canals and drains and participation in planning and design of sub-surface drainage systems. The development of WBs has had positive effects on changes in the cropping patterns and the water distribution within the secondary canal system. There was a marked decrease in the areas under fallow, especially during the summer seasons (Allam, 2004).

3.4.1 Al-Gomhoria canal water board

Koum Oshim closed basin is suffering irrigation water shortage. WBs can help in facing the water shortage and tackling the dilemma of unequal distribution of irrigation water in the basin. Al-Gomhoria canal WB was established by FWMP and implemented for the joint planning, monitoring and execution of irrigation works in Koum Oshim. Meeting is held with the board director to investigate the current activities of Al-Gomhoria canal WB. In the last 5 years WB has no contribution. The efforts started with Fayoum Irrigation Undersecretary to recall, activate and sustain Al-Gomhoria canal WB activities especially the needs to stand stronger in negotiations with the conflict of irrigation management between upstream and downstream farmers. A plan of action is developed to take the WB in operation. It includes activities, who is responsible, time frame, inputs needed, expected outputs. Introduce the current conflict between farmers at the beginning of the canal who take all the water and not enough water is left over for the farmers at the end of the canal. A series of meetings was conducted among the farmers in Koum Oshim to know their problems, requirements and expectations. Fayoum Irrigation Undersecretary can be gradually adopted and transformed to their requirements and needs. Solve the problems of water supply quality and adequacy from the point of view of the users includes (accessing a sufficient quantity of water) and timeliness (getting the amount of water at the right time). Adequate timing and/or predictability of water supply are crucial and often more important than adequacy itself. From a system or social point of view equity (no user gets an excess of water to the detriment of others), water savings (supply is adequate but not in excess of needs, and losses are limited). Cooperate with the Irrigation and Agriculture Authorities in Fayoum to solve irrigation shortage and agriculture requirements.

4. Results

The magnitudes of the various components of the water budget of the 3 berkas were calculated monthly between February 2013 and September 2013 as presented in tables (3,4 and 5). The water budget was computed by measuring or estimating all of the three Berkas water gains and losses. The results demonstrate the importance of the drainage contribution, representing the major part of water added to the Berkas (99.78%). Evaporation is also one of the largest components of the Berkas's water outputs (66.44%). The groundwater fluxe to the three Berkas is calculated from equation 3 and represents very small contribution (0.14%) of the water balance items. The amount of storage provided by a Berka is therefore very dependent upon water supplies from the drainage basin in which is located. During the study period of eight months, the change of stored water volume in the Berkas is increased in winter season while in summer season is decreased. The total change of stored water volume is decreased by $325.123\text{X}10^3$ m^3 in large Berka 1 while it increased in the small Berka 2 by 749.476 $\text{X}10^3$ m^3 and in the artificial Berka 3 is increased by 944.946 $\text{X}10^3$ m^3. This means that there was an abundance of water in the basin of 1369.299 $\text{X}10^3$ m^3 had been stored mainly in the three Berks during the period of study.

Table 3 Monthly changes in the water balance of large Berka 1

Month	Q_{in}			Q_{out}			Storage change 10^3 (m^3/month)
	Rainfall Q_R 10^3 (m^3/month)	Drainage Q_D 10^3 (m^3/month)	GW flux Q_{GW} 10^3 (m^3/month)	Q_{ET} Reed 10^3 (m^3/month)	Evaporation Q_E 10^3 (m^3/month)	Reused Q_{RI} 10^3 (m^3/month)	
Feb-13	0.722	111.680	0.261	9.820	39.197	11.168	52.478
Mar-13	0.619	123.646	0.289	11.192	62.922	12.365	38.076
Apr-13	0.309	119.657	0.280	17.871	81.489	11.966	8.921
May-13	0.000	123.646	0.289	24.622	111.918	12.365	-24.970
Jun-13	0.000	57.140	0.280	26.303	124.812	5.714	-99.409
Jul-13	0.000	59.044	0.289	30.298	127.906	5.904	-104.775
Aug-13	0.000	59.044	0.289	36.773	125.843	5.904	-109.187
Sep-13	0.000	57.140	0.280	34.813	103.150	5.714	-86.258

Table 4 Monthly changes in the water balance of small Berka 2

Month	Q_{in}			Q_{out}			Storage Change 10^3 (m^3/month)
	Rainfall Q_R 10^3 (m^3/month)	Drainage Q_D 10^3 (m^3/month)	GW flux Q_{GW} 10^3 (m^3/month)	Q_{ET} Reed 10^3 (m^3/month)	Evaporation Q_E 10^3 (m^3/month)	Reused Q_{RI} 10^3 (m^3/month)	
Feb-13	0.140	163.387	0.060	1.901	7.586	16.339	137.762
Mar-13	0.120	180.893	0.067	2.166	12.178	18.089	148.646
Apr-13	0.060	175.058	0.065	3.459	15.772	17.506	138.446
May-13	0.000	180.893	0.067	4.765	21.661	18.089	136.444
Jun-13	0.000	83.595	0.065	5.091	24.157	8.360	46.053
Jul-13	0.000	86.382	0.067	5.864	24.756	8.638	47.191
Aug-13	0.000	86.382	0.067	7.117	24.356	8.638	46.337
Sep-13	0.000	83.595	0.065	6.738	19.964	8.360	48.598

Table 5 Monthly changes in the water balance of artificial Berka 3

Month	Q_{in}			Q_{out}			Storage change 10^3 (m^3/month)
	Rainfall Q_R 10^3 (m^3/month)	Drainage Q_D 10^3 (m^3/month)	GW flux Q_{GW} 10^3 (m^3/month)	Q_{ET} Reed 10^3 (m^3/month)	Evaporation Q_E 10^3 (m^3/month)	Reused Q_{RI} 10^3 (m^3/month)	
Feb-13	0.310	237.008	0.200	4.211	16.808	23.701	192.798
Mar-13	0.265	262.401	0.221	4.799	26.981	26.240	204.868
Apr-13	0.133	253.937	0.214	7.663	34.943	25.394	186.284
May-13	0.000	262.401	0.221	10.558	47.991	26.240	177.834
Jun-13	0.000	121.262	0.214	11.279	53.520	12.126	44.551
Jul-13	0.000	125.304	0.221	12.992	54.847	12.530	45.156
Aug-13	0.000	125.304	0.221	15.768	53.962	12.530	43.264
Sep-13	0.000	121.262	0.214	14.928	44.231	12.126	50.191

5. Conclusions

Koum Oshim is a new reclaimed agricultural area in the Northern East of Fayoum governorate. Koum Oshim closed-basin has three inland depressions (Berkas). The three Berkas have no outlet. As a result of severe shortage of irrigation water in the area especially in summer, some arable lands are left fallow and other areas are irrigated with mixing drainage water. These conditions affect negatively the land uses, crop productivity and public health. By developing a water balance model, this research answered the question concerning irrigation water management under present conditions in the basin. The discharge water via the open drains represents the major part of the inputs to the Berkas. Evaporation is also the largest components of the water outputs. The groundwater fluxes to the three Berkas are not quantifiable comparing to the other water balance items. During the study period of eight months, the change of water volume in the basin increased by 1369.299 thousand m^3, indicating that there was an abundance of water in the basin had been supplied to the three Berkas. The water salinity in the three Berkas varied between 6.7 dS/m and 8.2 dS/m. Sustaining Al-Gomhoria canal WB activities can be a solution to solve the problems of irrigation water supply with the cooperation of the Irrigation and Agriculture Authorities in Fayoum governorate.

6. Recommendations

The reuse of water in the Berkas with mixing irrigation will contribute to lower Berkas's water level, provide additional water as supplemental irrigation for existing lands which suffer from water shortage, and also develop the excess of available water for enlargement of arable lands which are uncultivated due to soil characteristics or water shortage. The cultivation of salt tolerant crops and trees in the new reclaimed areas of Koum Oshim closed-basin can help in water and salt management strategies. The low irrigation efficiency and unequal distribution of irrigation can be solved by sustaining Al-Gomhoria canal WB activities. Increased farmer participation in planning, operation, maintenance and management of Al-Gomhoria canal is viable and highly desirable means of advancing.

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