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Research Article

Integrated Agri-Aquaculture as a Solution for Food Security in Egypt

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Abstract

Food security is one of the main problems which facing the Egyptian Government nowadays. Bread is the main component of Egyptian meals. The shortage in wheat production and problems of importing it from abroad is a chronic headache for the successive cabinets. Gap between the national production and needs can be decrease using the fish ponds as land for wheat cultivation using the drainage water which used to be released to the Northern Lakes and Mediterranean and new fish ponds can be created using part of this water.

The study was conducted at two levels, firstly a pilot experiment was carried out in Qarada research station of the water management research institute and two fish ponds close to Burullus Lake in Kafr El Sheikh to check the possibility of cultivating wheat in fish ponds and to economically compare between the field and pond wheat. Secondly an investigation for generalization the idea in all coastal fish ponds and reclaim new lands using the drainage water to be cultivated with wheat.

The study concluded that the majority of the fish ponds salinity is suitable for cultivation of wheat which can increase the national production with about 1.5 million ton (18% of the total national production) as well as increase the water use efficiency. Wheat cultivation in fish ponds is a must and the ministries of water resources and irrigation and agriculture and land reclamation have to espouse this idea to overcome the problems of shortage of bread, increase the water use efficiency and increase the income of the owners of farms.

Keywords: Aquaculture; Drainage water; Fish pond; Integration; Wheat

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Introduction

Wheat is one of the oldest and most important cereal crops in Egypt. Although wheat production per unit area in Egypt has significantly increased during the past years, it supplies only 40% of its annual domestic demand [1]. The total wheat area is about 3,000,000 feddan (4200 m^2) with total production 8.1 million ton while the consumption is amounted at 19.6 million ton with annual import of 11.5 million ton [2].

The lack of ability of Egypt to produce sufficient wheat for domestic consumption are: A) The total cultivated area represents less than one quarter of the amount consumed by the population; B) Egypt had one of the highest rates of wheat consumption per capita of any country in the world (200 Kg per capita, compared with a world average of less than 60 to 75 Kg per capita); C) The population growth rate (2.1% annually) increases more than the increase of wheat production; D) Little efforts are made for improving salt tolerant wheat crops, e.g., only two genotypes (Sakha 8 and Sakha 93) among Egyptian wheat genotypes are tolerate to salinity; and e) The competition among cultivated lands with wheat, forage and cotton crops [3].

Egypt is importing wheat for about 276 million US $ annually [4]. Therefore, the Egyptian Government needs to make a great effort to increase wheat productivity. Extending wheat growing outside the Nile valley is the first effort toward overcoming wheat problems. No more land for wheat cultivation except the fish ponds, which offer an opportunity as a complementary action to increase farmer's income and in turn reduce the total import to reduce the hard currency problem; therefore, integrated agri-aquaculture is an important solution for wheat production. Especially for the new wheat varieties, which tolerate salinity and water saturation conditions of fish ponds.

Most aquaculture activities are located in the Northern Nile Delta region, with fish farms usually found clustered in the areas surrounding the four Delta Lakes. According to digital maps and remote sensing directorate, master information center of ministry of water resources and irrigation the total area of fish ponds in Egypt amounted to 254,387 feddans. The area is scattered around Manzala, Burullus, Edco and Mariout Lakes.

The study was carried out at two levels; firstly a pilot study carried out in Qarada research station of the water management research institute [5], national water research center and the fish ponds around Burullus Lake area to verify the possibility of wheat cultivation in fish ponds and compare economically between field and pond wheat. The second level is the national level in which the data of fish ponds and drain water quality were collected to estimate the total lands which can be cultivated and the total production and return.

Materials and Methods

Pilot level

A field experiment was conducted in winter season of 2014/2015 in two private fish farms near Burullus Lake, Kafr El Sheikh Governorate, Egypt as shown in figure 1. The two farms take their water from El Arab Drain which takes its water from Drain No. 7. The first fish farm area is about 30 feddans with wheat cultivated area about 25 feddans. The second fish pond area is about 20 feddans with wheat area of 12 feddans. The planting date was mid of November and the harvesting date was second week of April; the fertilizer for the first pond was 100 Kg from ammonium sulfate and no fertilizer for the second pond.

On the other hand a field experiment carried out at the Qarada research station of the water management research institute on an area of 3 feddans. The planting date of wheat was on the second week of November and the harvesting date was on first week of May. All the agronomic practices and fertilizer amounts were done according to farmer's experience. Superphosphate at rate of 250 Kg/feddan (15.5% P_2O_5), potassium sulfate at rate of 50 Kg/feddan (48% K_2O) and ammonium sulfate at rate of 250 Kg/feddan (20.5% N) were used. Superphosphate was added at soil preparation, potassium sulfate was divided in two doses, the first one was added after thinning and the second one after 15 days of thinning. Ammonium sulfate was divided into three doses; the first one was added after thinning, the second one after 15 days of thinning and the last one after 30 days of thinning.

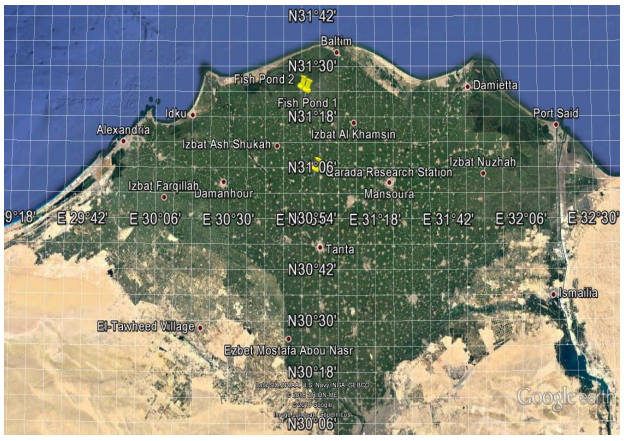

Figure 1: Location of fish ponds and research station field.

The total added water for the field wheat was estimated at 2220 m^3/feddan. The quantity of water was measured by flow meter installed at the intake of the station. The added water for the first fish pond was 420 m^3/feddan meanwhile for the second one was almost zero. The quantity of water was measured by installing water level sensor at the entrance of both farms, immediately after the Sakia for the first farm and the pump for the second one to determine the operation hours of the pump. The operation time is the period in which the water level increases than the regular level of the inlet channel as shown in figure 2. The discharge of the pump was calibrated several times using electromagnetic flow meter during the summer season. The water volume calculated according the following equation:

Water Volume = Operation Time × Calibrated Discharge

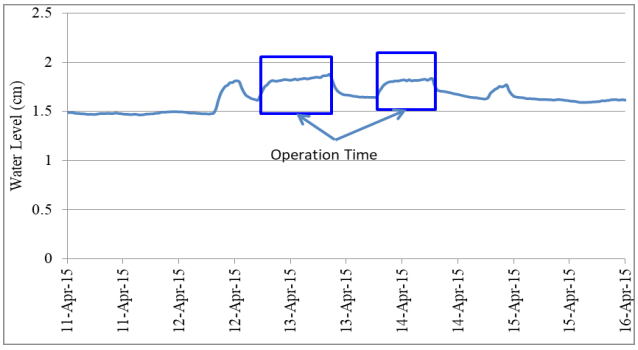

Figure 2: Water level in the entrance of fish ponds.

Drain water quality

The Electrical Conductivity (EC) and pH of Drain No. 7 which feed Bahr El Arab Drain were carried out by drainage research institute during the winter period of 2013-2014 as shown in tables 1 and 2. The pH ranged from 7.66 to 8.06 which at the normal range which is 6.5 to 8.5 and the salinity ranged from 2.45 to 5.00 ds/l [6].

Parameter	November	December	January	February	March	April
PS NO. 7 in 2013-2014						
pH	7.66	7.71	7.80	7.69	8.06	8.03
EC (ds/m)	3.69	3.64	2.45	4.29	5.00	4.66
Qarada Research Station						
pH	7.4	7.4	7.5	7.4	7.5	7.5
EC (ds/m)	0.83	0.72	0.75	0.79	0.84	0.73

Table 1: Summary of monthly water quality.

Economic analysis

The economic evaluation carried out by calculating the net return per feddan (L.E/feddan) (L.E is Egyptian Currency) and the water productivity (L.E/m^3) according to the prices of ministry of agriculture and land reclamation for grain and straw (Grain=2,800 L.E/ton-straw=1,400 L.E/ton), the productivity of the field wheat (2468 Kg/feddan) and pond wheat (1800 Kg/feddan and 1500 Kg/feddan for the first and second pond respectively) and the following equations:

Total Cost (L.E/feddan) = Land Preparation + Seeds + Fertilizer + Labor + Irrigation + Harvesting

Total Return (L.E/feddan) = Grain Price + Straw Price

Net Return (L.E/feddan) = Total Return - Total Costs

Water Productivity (L.E/m^3) = Net Return/Added Water

National level

According to digital maps and remote sensing directorate [7], master information center of ministry of water resources and irrigation the total area of legal fish ponds in Egypt amounted to 254,387 feddans plus illegal fish ponds which exceed than 150,000 feddans. These areas scattered around Manzala, Burullus, Edco and Mariout Lakes. The water sources of these areas are mainly drainage water. As shown in figure 3, there are more than 170,000 feddans of saline land or desert located at the North and East of Burullus Lake, South of Mariout Lake and South East of Manzala Lake.

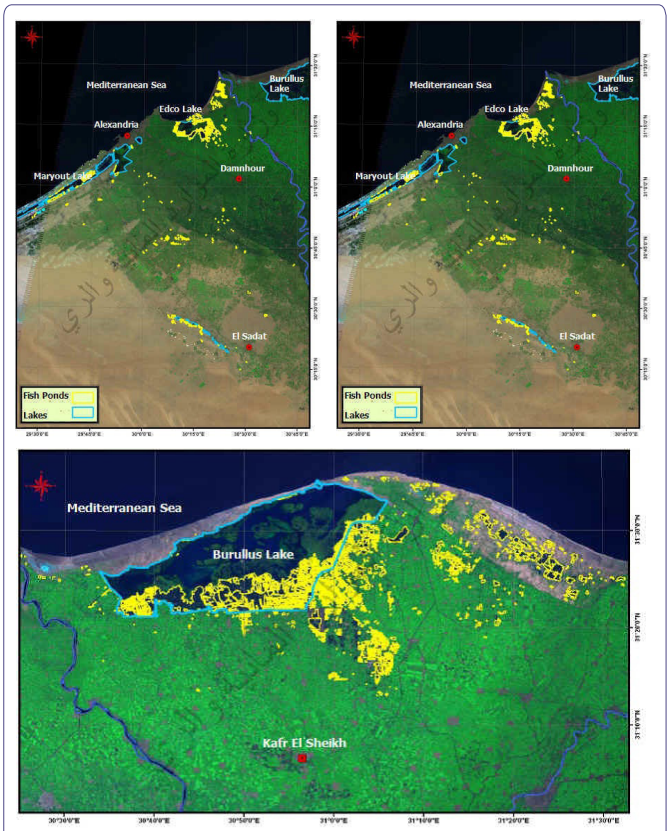

Figure 3: Locations of fish ponds around the Northern Lakes.

The salinity of the drains feeding the Northern Lakes and their surrounding area were monitoring long time ago by drainage research institute and their data used to publish in annual basis. Sample from these data are presented in figure 4. The salinity ranges between 2.3 and 4.8 ds/m^3. It is clear that the pilot area of fish ponds located at the most saline part of the fish ponds all over the costal Lake areas which means that the experiment can be replicated anywhere within the domain of the Northern Lakes which have less drains salinity and pH within the permissible limits for agriculture according the law 48.

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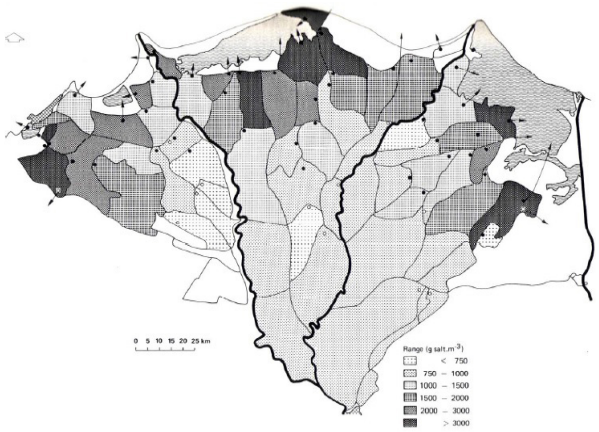

Figure 4: Delta drainage water salinity.

Results and Discussion

Pilot level

The survey done by the staff of the Australian funded project on water and salt management in the Nile Delta in 2014, indicated that, the farmers cultivate wheat for several reasons; A) To produce food for them and their animals, B) To clean up the ponds from the organic matters and fish residuals from nitrogen and phosphorous which are very useful for wheat and at the same time reducing the mud which impedes the movement of the farmers in the basins and C) Finally to save the money needed for cleaning and preparation of ponds.

Parameters	Depth of Soil (cm)					
	0-20		20-40		40-60	
	Qarada	Fish pond	Qarada	Fish Pond	Qarada	Fish Pond
Physical Properties						
Clay content (%)	44.1	41.5	40	42	40	39.5
Silt content (%)	28.6	56.9	29.7	46.3	31	44.3
Sand content (%)	27.3	1.6	29.3	11.7	29	16.2
Dry bulk density (g/cm^{-3})	1.28	1.47	1.34	1.42	1.35	1.37
Wilting point (%)	26.7	28.4	24.3	26.6	24.2	25.3
Field capacity (%)	40.3	41.8	37.8	40.2	37.8	38.6
Saturation capacity (%)	51.7	53.8	49.6	52.4	49	50.4
Chemical Properties						
pH 1:5	8.2	8.4	8	8.3	8.2	8.25
EC1:5 (dS m^{-1})	3.7	2.1	3.4	2.4	2.9	2.9
SAR	24.5	23.6	23	22.8	22.8	22.4

Table 2: Physical and chemical analysis of the soil of research station.

From an economic point of view, the cultivation of wheat is very important, since it happens during the off season (winter) of the ponds, the high productivity and the short duration in land and the minimal costs. It is only cultivated based on the water infiltrated into the ponds from surrounding ponds and drains and sometimes with very minor quantity of added water and minor quantity of fertilizers.

As shown in figure 5, the wheat productions of the two farms were healthy despite the fertilizer dose was less than the normal dose of the field wheat due to the fish residuals, which are very rich in nitrogen and phosphorus. A complete economic evaluation was done. Table 3 indicates that the net return of the wheat cultivated in the fish ponds is higher than the field one by about 30% and 12% for the first and second pond respectively keeping in mind that the total cost is only about 44% and 39% of the field wheat cost. The added water is almost 20% and 0.0% of the field wheat. This quantity of drainage water is used at the last point of the drain immediately before losing it to Burullus Lake then to the Mediterranean Sea, which increases the water use efficiency of drainage water to almost 100% before depleting it to the sea.

Figure 5: Sample of the wheat production.

The net return of one cubic meter of fresh water in field wheat is only 2 L.E meanwhile the net return of the drainage saline water is 11 L.E which is 689% of the normal case. The wheat cultivation of this pond saves about 3000 L.E/feddan which is the cleaning and preparation of the ponds before the new fish season. It is worth to mentioned that the straw residue in the ponds are used as feed for the fish fingerlings which also saves at least 1500 L.E as a food for the fingerlings.

National level

The fish ponds are scattering around the Northern Lakes using the drainage water before it is disposed to the Mediterranean Sea. According to the pilot experiment, all of these ponds can be used as wheat fields due to the similarity between the water salinity in the pilot area and the other location of the ponds along the north coast of Egypt. As presented in figures 4 and 6 the most saline drains are the drains feeding Burullus Lake, where the experiment took place, which ensures the validity of all the areas around the Northern Lakes for cultivating wheat in fish ponds.

Cultivation of legal and illegal fish ponds with wheat can increase the national production of wheat by about 12%. Areas located at North and East of Burullus Lake, South of Mariout Lake and South East of Manzala Lake (near Ismailia) can be used as a fish pond or can be reclaimed by the drainage water for two or three years to decrease the soil salinity then cultivated with wheat. The soil salinity of Lake Manzala Engineered wetland area decreased from 6.7 ds/l to 2.4 ds/l in about 1.5 year of filling the ponds with drainage water from Bahr El Baqar Drain, which allowed papyrus, which is not salt tolerant crop, to be cultivated there [8].

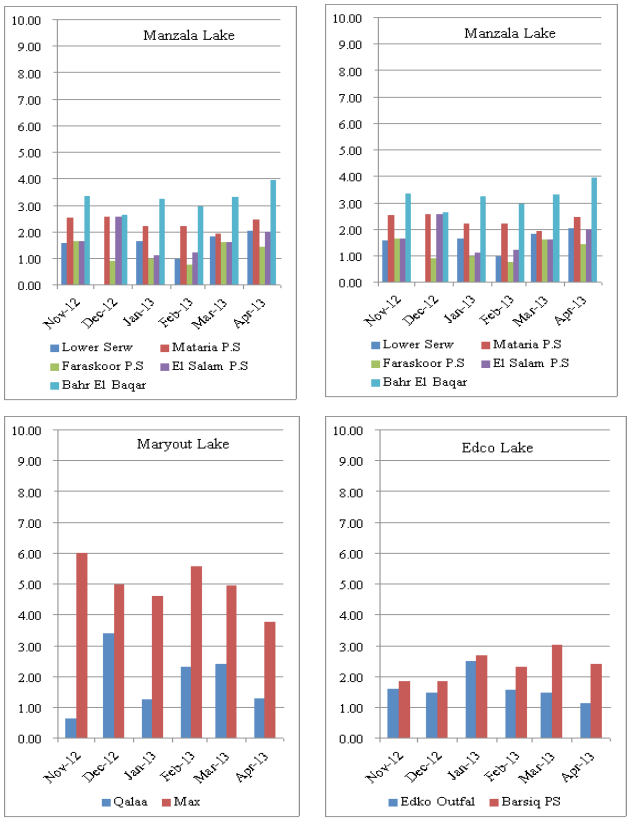

Figure 6: Salinity of drainage water of Northern Delta Lakes.

Also Mohamed Taha [9], proved that soil salinity is not the main dominant parameter for crops cultivation in saturated soil. He used the drainage water of El Gharbia Drain to irrigate papyrus in surface wetland pond. These areas can increase the total national wheat production by another 6% with a total of 18% of the national production.

Some water is required to flow out of the Nile system for environmental needs, such as, to drain out salts, to carry away pollutants that would otherwise concentrate in the Nile water, and to maintain coastal estuaries for fishing. First estimate of minimum outflow is in the order of 8 BCM per year but the minimum outflow requirement is an important value that deserves much more research attention [10]. Drainage research institute [6], estimated the drainage disposal in northern Lakes and Mediterranean at 14.327 BCM which mean that there is about 6.327 BCM can be saved and used in fish ponds then wheat cultivation fields before dispose it to the Lakes (i.e., divert part of Bahr El Baqar Drain near Ismailia to be used for land reclamation by fish ponds or sedimentation ponds in summer and wheat fields in winter.

Item	Unit	Field Wheat	Pond Wheat 1	%	Pond Wheat 2	%
Land preparation	L.E/feddan	600	0	0	0	0
Seeds	L.E/feddan	350	400	114	400	114
Fertilizer	L.E/feddan	1,375	110	8	0	0
Labour	L.E/feddan	1,000	200	20	200	20
Irrigation	L.E/feddan	400	40	10	0	0
Harvesting	L.E/feddan	1,700	1,630	96	1,500	88
Total cost	L.E/feddan	5,425	2,380	44	2,100	39
Grain yield	Kg/feddan	2,468	1,800	73	1,500	61
Grain price	L.E/feddan	6,909	5,040	204	4,200	170
Straw yield	Kg/feddan	1,450	1,370	94	1,310	90
Straw price	L.E/feddan	2,030	1,918	132	1,834	126
Total return	L.E/feddan	8,939	6,958	78	6,034	68
Net return	L.E/feddan	3,514	4,578	130	3,934	112
Added water	m^3	2,220	420	19	0	0
Water productivity	$L.E/m^3$	2	11	689	-	-

Table 3: Comparison between the field wheat and the pond wheat.

Conclusion

Integrated agri-aquaculture is using fish ponds as wheat field to benefit from the soil with high contents of nitrogen and phosphorus and the drainage water which losing in Lakes especially the fish ponds are useless in winter season due to the high cost of fish feeding and very low rate in weight increase of fish and the increase death of fish due to cold weather. The experiment conducted at Kafr El Shiekh Governorate concluded the following:

On the pilot level,

- The healthy production of wheat in fish ponds indicated that the drainage water in Burullus area is valid for wheat cultivation and consequently the less saline drainage water at Manzala, Edco and Mariout Lakes can be used for wheat cultivation.
- Using the integrated agri-aquaculture technique can increase the total income of the farmers by about 12,000 L.E/feddan which is the price of grain and straw, save cost of land preparation and feed for the fish after the wheat season. Also, in remote areas such integration can help in producing affordable food sources for animal origin of surrounding residences.
- It is possible to increase water use efficiency through integrating agri-aquaculture by increasing productivity of water unit once from fish and other one from wheat especially at the end of the drain the water will deplete to the saline and polluted Lakes.

On the national level,

- An area of 370,000 feddans of legal and illegal fish ponds can be cultivated with wheat in winter season and an area of more than 150,000 feddan surrounding the Northern Lakes can be reclaimed with the drainage water before losing it in the Lakes. Within two or three years these lands can be cultivated which increase the national wheat production with about 18% of the current national production.
- Upstream areas such as west of Ismailia can be reclaimed and cultivated with wheat by diverting part of the discharge of Bahr El Baqar Drain as well as the desert west of Umoum Drain beforelosing their water in Manzala and Mariout Lakes respectively. This can add another area of 150,000 feddan to increase the total production using the drainage water and fish ponds to be one quarter of the national production.

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