Centre for Development Innovation

Evaluation of the use of fresh water by four Egyptian farms applying integrated aquaculture – agriculture

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Study Report

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This study was carried out in 2010 by the WorldFish Center as part of the work specified in a contract with Wageningen UR Centre for Development Innovation.

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Evaluation of the use of freshwater by four Egyptian farms applying aquaculture – agriculture integration

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February, 2012
Centre for Development Innovation, Wageningen University & Research centre

This report describes a study done in 2010 by researchers of the WorldFish Center on water use in Egyptian farms that apply aquaculture – agriculture integration. Two of the four farms that were monitored derived the main income from farming and selling fish, the two other farms were mainly agricultural farms that used reservoirs that were built to store irrigation water for growing fish. The volume of water in which fish were raised from fingerling to market size and that was subsequently used to irrigate agriculture crops was estimated. The water quality was monitored, the quantity and value of the fish and the value of the agricultural crop were determined. Estimates were made of the amount of fertilizer that was saved by growing fish in irrigation water.

Photo:
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Preface

Although its freshwater resources are limited and most of the country consists of desert, in the last two decades Egypt has become the number one aquaculture country in Africa. Its annual production of 700,000 metric tonnes of farmed fish is composed mostly of freshwater species (Nile tilapia and carp species). The use of freshwater for fish farming is a subject of debate in Egypt. The debate is hampered by scarcity of data on volumes of water used in Egyptian fish farms, especially integrated fish farms. The study described in this publication has been undertaken to bring missing information on water use by integrated fish farms and the effects of such integration, into the debate.

Dr. A.J. Woodhill
Director Wageningen UR Centre for Development Innovation

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Executive summary

The study aimed to generate quantitative information about water use and water quality changes in integrated fish farming systems under Egyptian conditions. The study was part of the project 'National strategy on efficient use of fresh water by application of integrated aquaculture, Egypt', funded by the Netherlands Ministry of Economic Affairs, Agriculture and Innovation.

Four commercial farms based in Sharkia Governorate (1), North Sinai Governorate (1) and Behera Governorate (2) participated in the study. They were visited monthly between May and December 2010 by researchers of the WorldFish Center who collected data on water use and farm production. Also samples of the water source and of the water in the ponds were taken and analysed in the WFC laboratory.

In two farms the water was derived from wells and used for intensive tilapia farming in concrete tanks varying in size between 12 and 200 m^3. Fish densities reached 30 to 35 kg/m^3 tank volume at harvest time. The water drained from the tanks was used to irrigate fruit trees, vegetables, flowers and alfalfa. For these farms fish was the main source of income.

The two other farms extracted Nile water from nearby irrigation canals. These farms had constructed water reservoirs to be able to irrigate the fruit trees and vegetables when the water supply from the irrigation canal was not sufficient. Tilapia was stocked in the reservoirs to obtain an extra income. Crops and fruit were the main source of revenue for these farms, and fish was a minor secondary crop.

Data obtained made it possible to estimate the total water use of the four farms. The two farms that had the sales of fish as the major component of the revenue used the water most efficiently, requiring 2.7 and 3.1 m^3 of water per kg of fish produced. In the other two farms that used Nile water to irrigate the crops and trees, water requirements were determined completely by crop requirements, and without any extra water use these farms were able to grow 30 to 70 tons of fish/year in the reservoirs.

Differences in nutrients levels (N, P, and K) between water source and fish farm effluents showed that in three farms, the level of nutrients increased due to the use of water for fish farming. The farms with a fish culture component should therefore require less fertilizer for the trees and crops.

The salinity of the source water was 0.2 to 1.0 ppt. In three of the four farms no significant effect of fish farming on water salinity could be observed. In one farm the average salinity increased from 1.0 gram/litre in the source water to 1.3 gram/litre. This had no effect on the fruits and crop harvest (in 2010).

The study concludes that it is possible to improve water use efficiency through integrating agriculture and aquaculture. The use of chemical fertilizers can be reduced and farm income can increase through increasing productivity per unit of water.

List of abbreviations and acronyms

CDI	Wageningen UR Centre for Development Innovation
EFC	Egyptian Fish Council (EFC is under the Egyptian Agribusiness Association)
EGA	Egyptian Agribusiness Association
Wageningen UR	Wageningen University & Research centre
WFC	WorldFish Center Egypt

1 Aim of the study

The study aimed to generate quantitative information about water use and water quality changes in integrated fish farming systems under Egyptian conditions. The study was part of project BO 010-011-102 “National strategy on efficient use of fresh water by application of integrated aquaculture, Egypt” that is funded by the Netherlands Ministry of Economic Affairs, Agriculture and Innovation, under supervision of Agricultural Counsellor at the Netherlands Embassy in Egypt. The following institutions took part in implementing the project:

- Wageningen UR, Centre for Development Innovation (CDI);
- The Egyptian Fish Council;
- The WorldFish Center (Egypt).

A major component of the BO 010-011-102 project was a study that monitored during one production season the quantity of water used and the main water quality parameters at a number of Egyptian farms that had already applied aquaculture – agriculture integration for some years.

2 WorldFish Center role

The role of WorldFish Center in the study was to:

- Provide scientific data on the lay-out and management of farms as well as recent production data. Data requirements were specified in the MS Excel sheet designed by Dr Nasr-Alla and Mr Van der Heijden, and were used to provide a brief description of the farms involved in the study;
- Visit each of the four farms once per month during the study period. During these visits the WFC scientist:
    - collected the above-mentioned farm baseline data;
    - discussed with the farm manager the progress of the fish production cycle and recording of water use data;
    - amended incomplete or erroneous measurements, and collected data on water use of the farm since the last visit;
    - collected samples of pond water (up to 3 ponds/tanks per farm) and analysed samples at the laboratory facilities of WorldFish, Abbassa, or in other appropriately equipped laboratories for total nitrogen, ammonia, nitrate, nitrite, phosphorus and potassium, salinity, conductivity, dissolved oxygen and pH;
    - provided technical advice to the participating farms to ensure good water quality and high fish growth rates by monitoring growth through monthly samples.
- Assist with the analysis of the data and with the presentation of results in seminars and workshops that were organized in April 2011 during which the results of the study were shared with the Egyptian Fish Council (EFC) members, staff of relevant Ministries and Departments and others.

The MOU between WorldFish Center and Stichting DLO (represented by the Director of CDI) was signed on 30 April 2010.

3 Importance of integrated systems

Egypt is almost entirely dependent upon a single water resource, the Nile, and uses 100% of its water allocation of 55.5 billion m^3, allocated under the terms of the 1959 Nile water agreement (Radwan 1998). Agriculture presently accounts for an estimated 86% of water use in Egypt (CAPMAS 2008). In the face of growing demand for - and dwindling supplies of - water, evidence based water allocation policies will be needed to help make the most productive use of water.

Where water resources are limited the availability for agricultural production is constrained and consequently the need to increase water productivity - the ratio of the net benefits from crop, forestry, fishery, livestock, and mixed agricultural systems to the amount of water required to produce these benefits (CA, 2007) - becomes essential in order to increases the availability of water for other human productive and non-productive uses.

Egypt's aquaculture production, which is largely located in the Nile Delta, is derived from levee ponds which are filled and maintained by water from agriculture drainage canals or groundwater wells. Most studies of agricultural (including aquaculture) water productivity have focused on biomass or crop value as the measure of benefits. But as has been argued by Nguyen Khoa *et al.* (2008) and others, a much wider perspective of benefits is required, especially if assessments are to be used to inform policies on water allocation. For example, aquaculture uses few chemicals in relation to agriculture (WHO 1999, Howgate *et al.* 2002); aquaculture effluent contains no metals or residues from potentially harmful pesticides.

However, Egypt is increasingly constrained by lack of suitable land and water. For example, aquaculture at present may only use groundwater and agricultural drainage water. To meet agriculture (including fish) production targets, there is a need to intensify production methods and better use of available water and land is essential.

Limitation of water resource reduces its availability for agriculture and increasing water productivity is therefore essential. Growing more food with less water would make more water available for other natural and human uses (Molden and Rijsberman, 2001; Rijsberman, 2001). Moreover, increasing the productivity of water in agriculture will play a vital role in easing competition of scarce resources (Molden *et al*, 2003).

Agriculture in desert areas in Egypt has expanded greatly since the early 1990s. Farmers pump wellwater to irrigate their crops. Water pumping costs have been increasing as result of increasing fuel and electricity costs, forcing farmers to improve use of scarce water resources through storing wellwater in tanks/reservoirs and growing fish in the water before using it for irrigation.

Integrated intensive fish farms and orchard farms that use ground water for fish farming and then use fish tank (or pond) effluent water for field irrigation exist in the desert area. Integrated aquaculture and agriculture farms in the desert have grown rapidly in number since the beginning of the millennium. Desert aquaculture began with growing fish in the reservoirs that stored water for irrigation. These farms use flow water systems and mechanical aerations and produce around 10-30 kg of tilapia/m^3 tank volume /year. Another assumed advantage of such practices is that fish farming effluent is rich in nutrients, thereby reducing the costs of crop fertilization. Rigorous investigation of the benefits of using fish farm effluent to irrigate crops has not yet been carried out in Egypt.

4 Farm selection

Four private farms that had already applied integrated aquaculture-agriculture for some years were selected for the study. During selection the source of water for the farm was a primary consideration. Two farms which used ground water and two farms which relied on surface water (Nile water) were selected. In all farms water was used first for fish production and then for crop irrigation.

EFC (under the Egyptian Agribusiness Association) screened candidate farms for the study to ensure that farm owners/managers were willing to collaborate in the study.

The four farms selected were:

- Ground water farms
  - Farm 1 in Sharkia Governorate (East Delta)
  - Farm 2 in Behera Governorate (West Delta)

- Surface water farms
  - Farm 3 in North Sinai Governorate (North Sinai)
  - Farm 4 in Behera Governorate (North Delta)

5 Farmer response to the study

Farm managers and owners responded positively and supported the study and all were prepared to carry out water quality analysis of their fish ponds as part of the study. Some farmers asked research staff to carry out more extensive water sampling and analysis than proposed in the study and the researchers did their best to accommodate these requests.

6 Problems encountered

During early visits to Farm 2, discussions with the farm manager revealed that the farm was not representative of integrated farms in the region. After consultation with project partners (Mr Van der Heijden and EFC) another integrated farm that used ground water and which is located in Wadi Natroun was selected as replacement. All references to Farm 2, including the farm details provided below, refer to the replacement farm.

7 Data collection

Monthly visits were made to each farm to collect data on water use in fish tanks/ponds and to collect water samples for water quality analysis in order to monitor change of nutrients level (N, P, K) in water reservoir and effluents as a result of fish farming. Regular farm visits began in early May 2010, and continued until the end of December 2010. Analyses of water samples were carried out and the results are presented in Appendix 2. Changes in water quality due to use of water in fish farming are discussed in detail in Section 8. Data on the quantities of water used at different stages of fish farming were collected and are summarized in Appendix 1. The following section of the report describes the farms studied and provides information on farm area, crops and fish species that were farmed. Data on farm revenues and output per cubic meter of water used (quantity and value) are also found in Appendix 1.

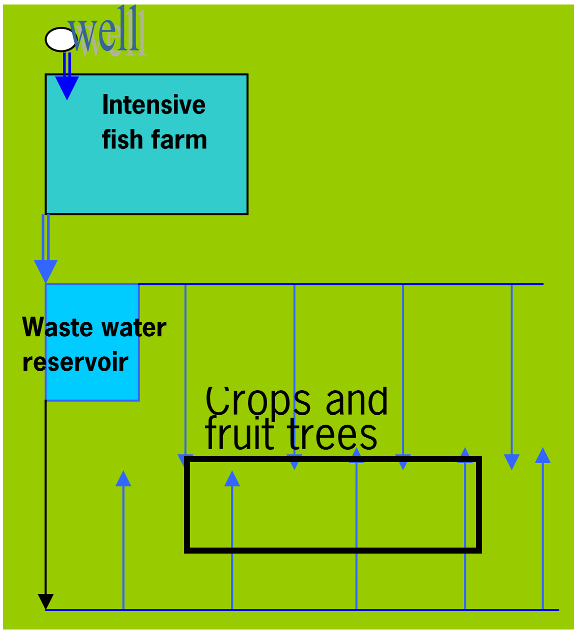

Figure 1. Water flow in integrated farms using ground water

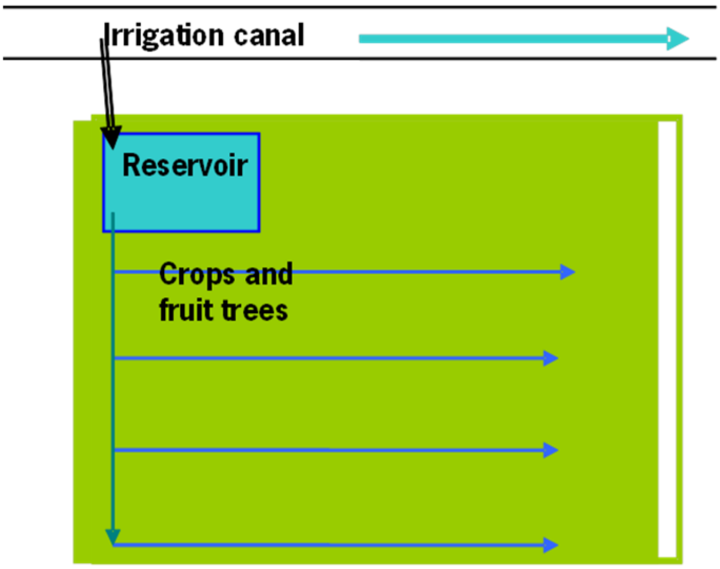

Figure 2. Water flow in integrated farms using surface water.

8 Farm descriptions

8.1 Farm 1

The farm is located east of the Delta and occupies more than 60 feddan[1] of new land. The farm owner began work on the farm more than 10 years ago, developing it as an integrated farming enterprise (aquaculture, poultry and agriculture). The fish production component of their facility extended to more than 20 feddan. Annual fish yield is on average 200 tonnes of market-size (350:500 g) Nile tilapia (*Oreochromis niloticus*). The poultry production component is no longer active due to the spread of avian flu disease, which hit the country a few years ago. The agriculture component currently utilizes 40 feddan as follows: 15 feddan mango, 5 feddan banana, 10 feddan vegetables (tomato, cucumber and pepper) and flowers, and 10 feddan of uncultivated land.

The fish farm applies intensive production methods to raise tilapia in concrete tanks. Fish culture tanks/ponds vary in size from one growing stage to another. The fish farm consists of four sections (hatchery; nursery, fingerlings and grow-out). To increase fish production per cubic meter of water, paddle wheels are used in grow-out tanks to eliminate carbon dioxide and to add oxygen to the tank water. In the other sections of the farm (hatchery, nursing and fingerlings) water is aerated by air blowers. The farm produces 35 kg per m^3 tank space. Average body weight is 350 – 500 g, which is the best marketing size in Egypt at present. Ground water is pumped daily to fish tanks and effluent water of fish culture tanks is flushed out to an earthen reservoir pond. Another water pump, fitted with a filter, pumps the water from the reservoir to the crop area, according to plant needs.

Daily water exchange rate of all tanks is 20% of tank volume, in order to maximize water use efficiency in the fish production component of the farm. According to the farmer the use of fish tank effluent water for crop irrigation reduces farm fertilizer requirements and saves about 25 – 40% on fertilizer costs (farmer's estimation). However, our calculation of reductions was estimated to be 100% on nitrogenous fertilizers, resulting in cost savings as shown in Appendix 1. The sequence of water use on the farm is shown in Figure 1. Sometimes fresh water coming from Ismalia canal is pumped to irrigate crops when the plants do not need fertilizers.

8.2 Farm 2

The farm is located in the West of the Delta, occupying more than 30 feddan of new land. The farm owner started work on the farm more than 3 years ago, as an integrated farm (agriculture, animal production and aquaculture).

The agriculture component currently utilizes 20 feddan, distributed as follows: 10 feddan mango, 2 feddan alfalfa and 8 feddan where in 2011 tomatoes will be cultivated. The animal production component includes a small number of sheep and large animals (there is no further information on this). The fish production facility extends to more than 10 feddan.

The fish farm applies intensive management of concrete tanks to produce Nile tilapia. It comprises four units: hatchery, nursery, fingerlings and grow-out. Tank/pond sizes and shape vary from one section to another. To increase production per cubic meter of water, paddle wheel aerators are used in the grow-out tanks, helping to eliminate ammonia and carbon dioxide and adding oxygen to the system. Air blowers are used elsewhere (hatchery, nursing and fingerlings). The fish farm produces 15-20 kg per m^3 of tank volume of 350 – 500 g fish, which minimizes feed costs and reduces the risks associated with higher intensity culture. The average water exchange rate in all tanks is currently set at 5% tank volume per day in order to maximize water use efficiency in the fish production component of the farm.

[11] One feddan = 4200 m^2

Ground water is pumped to the fish ponds, 5% of the water volume in the ponds being exchanged daily and pumped to a reservoir pond. A water pump fitted with a filter moves the water from the reservoir to the crop production area according to crop needs. The sequence of water use in the farm is described in Figure 1. Use of water first by the fish farm reduces fertilizers requirement of the farm and saves costs of nitrogen fertilizers required to produce mango and alfalfa (Appendix 1).

8.3 Farm 3

The farm is located to the East of the Suez Canal and occupies in excess of 1600 feddan of previously uncultivated land. The project began more than 12 years ago with the aim of producing organic horticulture and agriculture crops to meet the increasing local and export market demand for organic produce. Horticulture crops grown on the farm include oranges, mango and grapes. Many varieties of vegetables are also produced, including spring onions, baby corn, mangetout peas, green beans, fine beans, sugar-snap, holiday peas and cherry tomatoes. The farm relies on periodic use of Nile water to irrigate horticulture crops and vegetables cultivated in the farm. Farm management practices required the establishment of water reservoirs to store water for irrigation during periods when Nile water was unavailable.

The company developed 8 basins (earthen ponds, lined with synthetic material) as water reservoirs. Total basin capacity has increased this year to store 50,000 m^3 of water. Each basin irrigates specific areas of the farm, as illustrated in Figure 2. The fish on the farm fertilize the water, thereby reducing the use of chemical fertilizers.

Tilapia culture in the reservoir was started in 2004. Total fish production from the 8 basins during the last few years has reached approximately 30 tonnes/year. The reservoirs vary in volume from 4000 to over 18.000 m^3. All-male Nile tilapia fingerlings are purchased from a commercial hatchery and stocked in April-May at densities of 2.5 to 3/m^2. Fish are fed with an extruded floating fish feed (25-32% protein and 6-7% lipid) to reduce feed waste and to improve utilization of the nutrients in the feed. Fish are fed 2-4 times daily to visual satiation levels. Fish are harvested and sold during December - March, according to market price. During the present study tilapia were sold without grading at an average price of 9 LE/Kg. Savings on expenditure on fertilizers resulted from a reduction of 10-20% of nitrogen fertilizers used on crops, as detailed in Appendix 1.

8.4 Farm 4

The farm is located in the North of the Delta, occupying an area of 360 feddan of old farmland. It produces horticulture crops for export and to meet the increasing local market demand. Horticulture crops grown in the farms included banana, lychees (bashmala) fruits, kaki (persimmon) and grapes. The farm depends on Nile water for irrigation of the horticulture crops cultivated in the farm. Fresh water is available periodically, encouraging the farm management to establish water reservoirs to store water for irrigation when it is unavailable directly.

The company developed 3 concrete basins as water reservoirs to store water. Total basin area is five feddan and mean basin depth is 5 m. As in Farm 3, the fish held on the farm fertilize the water and reduce the use of chemical fertilizers in the production of a secondary crop of fruits and vegetables from the same water. The farm usually produces 25 tonnes of fish per pond per year, which are sold to traders in Alexandria.

During the study period, 180.000 all-male Nile tilapia fingerlings were bought and stocked during April-May at a density of 2.5 - 3 /m^3. Fish were fed to visual satiation level once a day, with extruded floating fish feed (25% protein and 6% lipid). Every year farm manager sells harvested fish between December and March, depending on market price. This year fish prices between December and March were less than in the previous year and the farm manager decided not to sell his fish until fish prices increased.

9 Impact of integrating aquaculture into agriculture on water quality and nutrients levels

Water quality parameters were monitored at all four farms. The common physicochemical parameters were measured with emphasis on nutrient content of the water. Monthly water samples were collected throughout the study duration, from the source of farm water, from fish ponds and from the farm effluent. Water temperature, pH, dissolved oxygen, total ammonia nitrogen, nitrite, nitrate, potassium, salinity and conductivity were measured. In the following section the results from the analysis of these parameters are described in detail.

Data for each water quality parameter showed different trends among farms. The four farms studied use fresh water, water salinity ranging from 0.16 to 1.90 g/l. No marked changes in water salinity between farm water source, ponds and farm effluent were observed.

With the exception of Farm 2, pH fell between farm water source and effluent (Figure 3). By contrast, the pH of effluent water from Farm 2 was higher than in the source water. Average pH levels of water source for all four farms ranged from 8.61 to 8.89. The corresponding levels for effluent ranged from 8.66 to 9.59 while pond water pH ranged between 9.05 and 9.3.The pH values at the four farms, however, were within acceptable limits for fish farming.

Table 1 Range of water pH value (min and max) at the different farms

	Water Source	**Pond**	**Effluent**
Farm 1	8.6 - 8.83	8.9 : 9.25	8.28 : 8.96
Farm 2	8.4 - 8.87	8.8 : 9.45	8.76 : 10.2
Farm 3	8.5 - 9.1	8.38 : 9.11	8.41 : 9.1
Farm 4	8.62 - 9.2	8.81 : 9.85	8.8 : 9.7

Total Nitrogen (TN) content (i.e. the sum of NH_4-N, NO_3-N and NO_2-N) behaved differently among the four farms of the study. TN levels on Farm 1 were a factor of 5.5 times higher in the effluent than in the source water. In Farms 2 and 4, the TN levels found in the effluents were 1.75 and 1.85 times higher than the original levels in the source water, respectively. No such changes in TN levels were observed on Farm 3. The variation in TN levels among the four farms is due to differences in stocking and management i.e., stocking density, amount of feed and/or fertilizers used and water exchange rate.

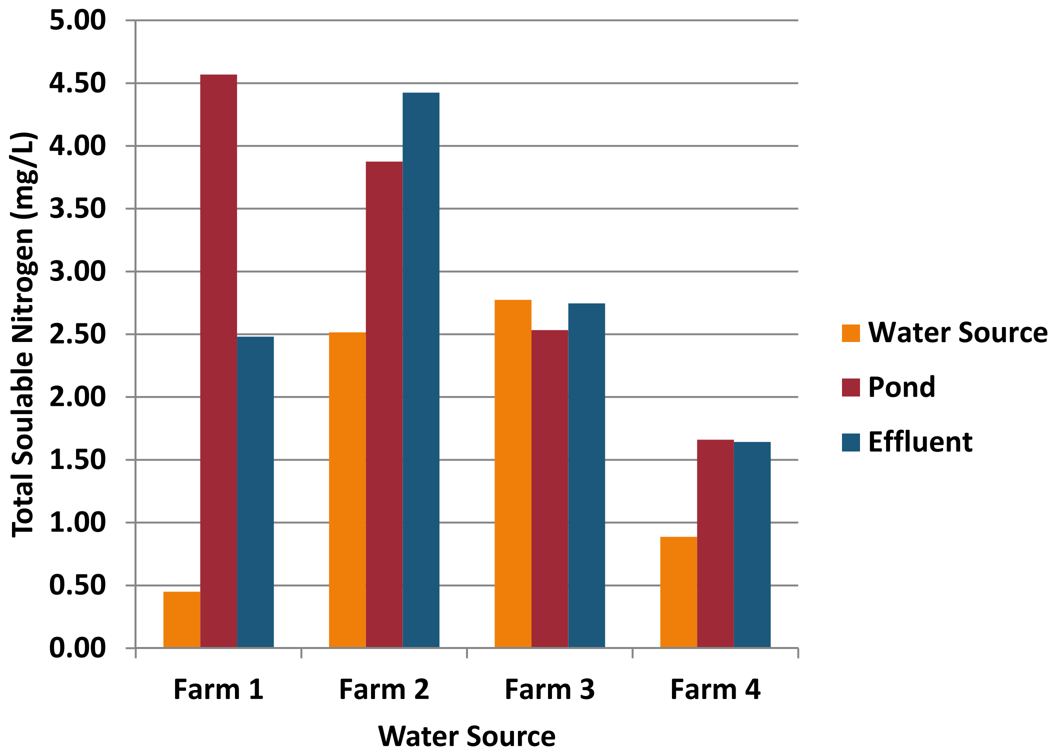

Figure 3. Comparison of Total Nitrogen (TN) (mg/l) in different water sources from different farms over the study period

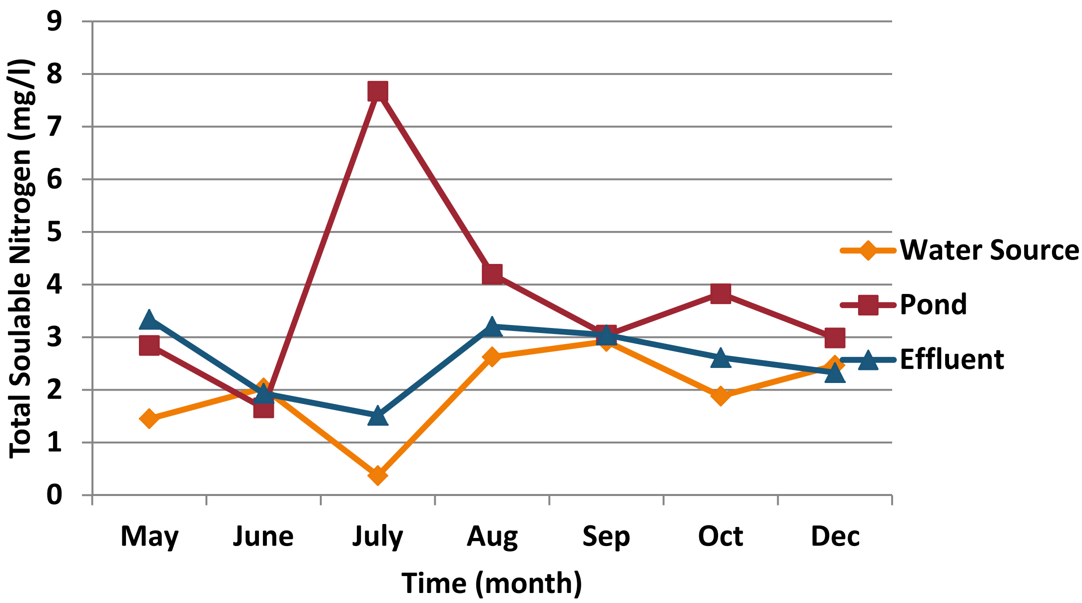

Figure 4. Changes in mean monthly Total Nitrogen (TN) levels in water from different source during the study period

Available phosphorus (soluble reactive phosphorus) in water of the four farms also showed different levels due to the different pond management regimes at each farm. The available phosphorus levels of the water source, of the ponds and of the effluent at each farm are shown in Figure 5. In Farm 1, no change was observed between water source and farm effluent, while the effluent of Farm 2 showed an increase (1.8 x that of water source) in available phosphorus levels. Farm 3 showed a decrease by around two-thirds in available phosphorus between the water source and effluent. By contrast, available phosphorus levels in source water for Farm 4 were undetectable and there was a notable increase in available phosphorus level of the effluent water compared to pond water.

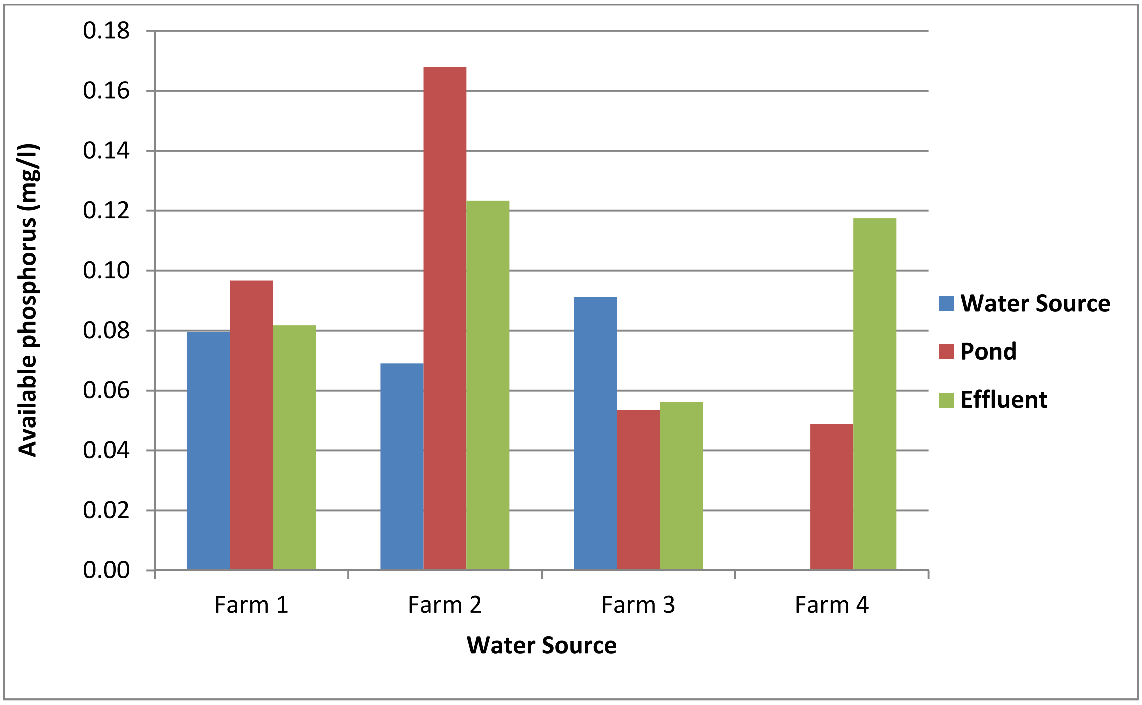

Figure 5. Comparison of available phosphorus (mg/l) in different water sources from different farms over the study period

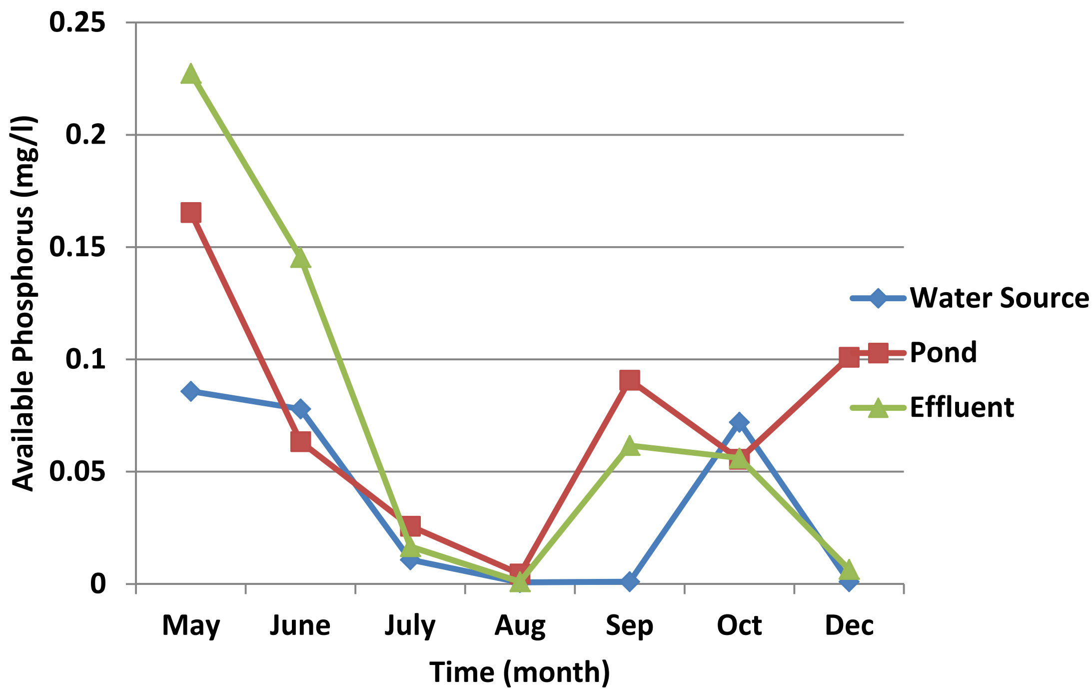

Figure 6. Changes in mean available phosphorus levels at all four farms during the study

Potassium levels in the water of the farms studied showed an increase in the effluent of farms 1 and 2, while the effluent of farm 3 showed a decline in potassium level in comparison to levels in the water source (Figure 7). There was no large increase in potassium levels between water source and effluent at Farm 4.

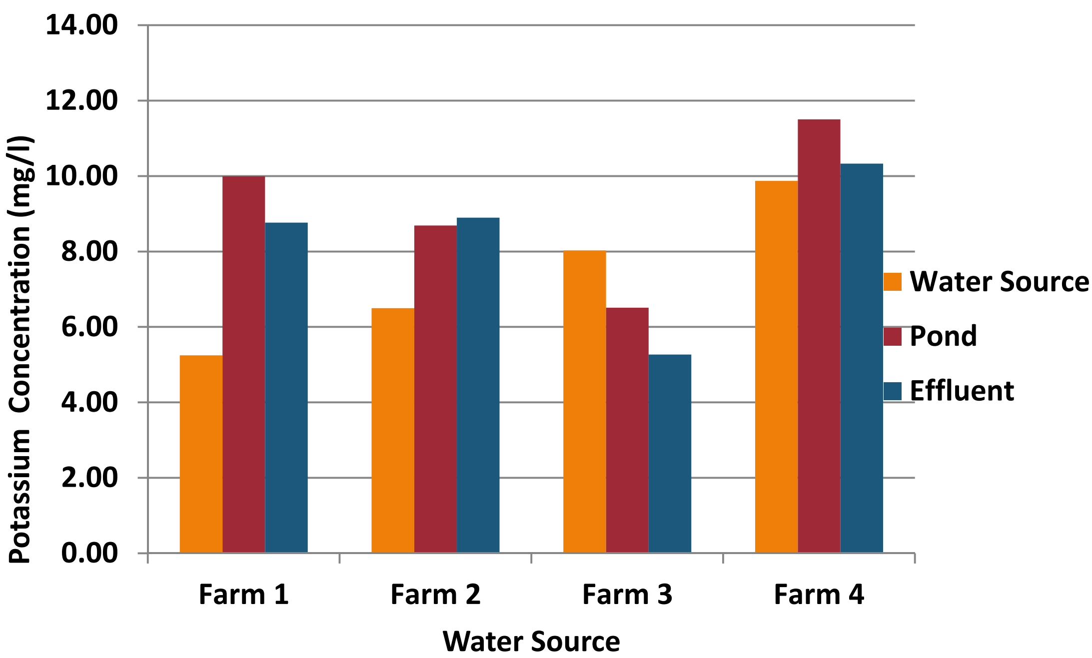

Figure 7. Mean potassium (mg/l) concentrations at different farms during the study period

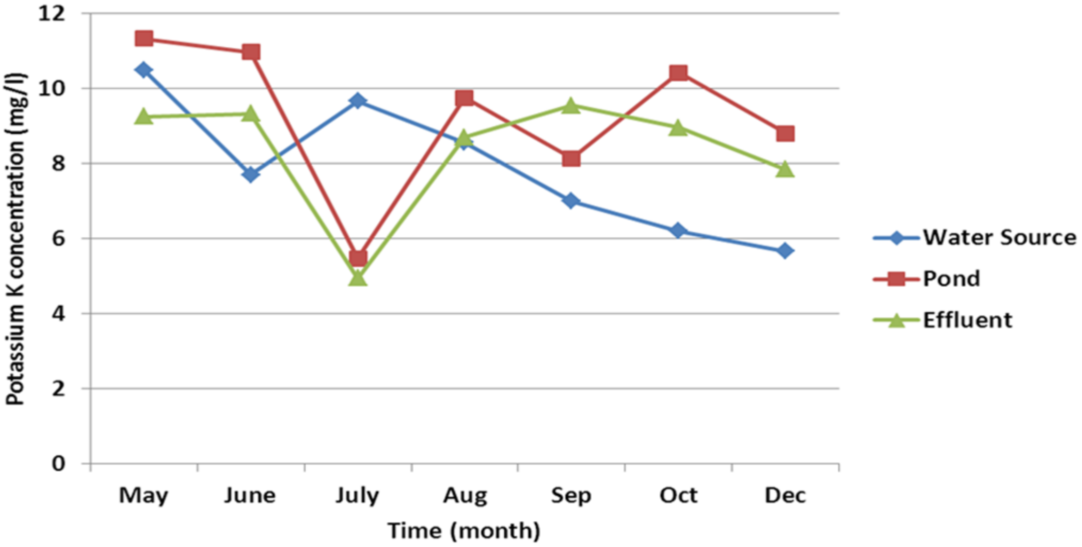

Figure 8. Changes in mean potassium concentrations in water at all farms during the study period

In summary, the effects of fish farming on water quality in farm reservoirs were found to vary considerably. Farming of fish, however, increased effluent nutrient (N P K) levels in most cases, and the effluent was subsequently used to irrigate crops and orchards. These findings suggest that farming of fish may be able to reduce the required amounts of fertilizers for agriculture.

Changes in nutrients levels (N P K) between water source and fish farm effluents in the farms showed that in three farms, the level of nutrients increased due to the use of water for fish farming (Table 2). Mean nutrients released in farm effluents are calculated in terms of kg/day based on water exchange rate and differences between average dissolved nutrient concentrations of source water and drain water. In Farm 3, the levels of N, P and K were higher in the inlet water than in effluent water. This may have been due to the lower fish biomass in the tanks, or the higher level of nutrients in the water inlet than in the other farms (it may have been mixed with agriculture drainage water), or due to the high rate of water exchange.

Table 2.	Changes in dissolved nutrients (N P K) resulting from use of water for fish farming and mean quantities of nutrients added daily to the effluents											
	Farm 1			**Farm 2**			**Farm 3**			**Farm 4**		
	TN	Av P	K	TN	Av P	K	TN	Av P	K	TN	Av P	K
Mean Nutrient in source (mg/l)	0.45	0.08	5.25	2.515	0.07	6.5	2.774	0.09	8.03	0.887	0	9.87
Mean Nutrient in effluent (mg/l)	2.482	0.082	8.765	4.425	0.123	8.898	2.747	0.056	6.324	1.642	0.117	10.33
Nutrient increase in effluent water as result of fish farming (mg/l)	2.032	0.002	3.515	1.91	0.053	2.398	-0.027	-0.034	- 1.706	0.755	0.117	0.46
Average quantity of water exchang e (m^3/ day)	1070			320			5104			7390		
Mean quantity of nutrients released (Kg/day)	2.17	0.002	3.76	0.61	0.02	0.77	-0.14	-0.17	-8.71	5.58	0.86	3.40

Some changes in salinity resulting from the use of water in fish culture were observed at most farms throughout the study period (Appendix 2). Changes in mean salinity levels are shown in Figure 9. Salinity levels increased in Farm 1 from 1.05 gram per litter (g/l) in source water to 1.31 (g/l) in effluent water. Similarly, in Farm 2, salinity increased from 0.48 in inflow water to 0.58 g/l in effluent water. Also, salinity in Farm 4 increased from 0.2 to 0.27 g/l between water source and effluent, while in Farm 3 water salinity did not vary between inflow and effluent, which may be attributed to the high rate of daily water exchange (45%) because of the higher requirements of crop irrigation.

In Farm 2 the main horticulture crop was mango, which grew very well, implying that the increases in salinity had little effect on mango production. Similarly, in Farm 3 mango was also the key crop and grew very well.

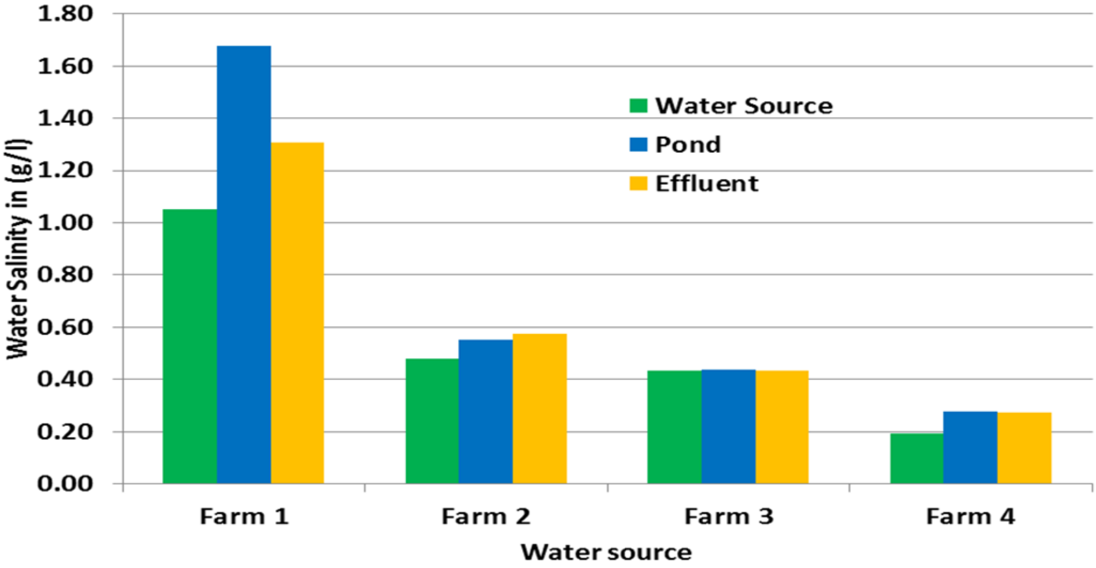

Figure 9. Mean salinity levels (g/l) in source, pond and effluent waters from different farms over the study period

10 Training Course

A specially designed training course on integrated aquaculture - agriculture - for farm managers/owners who participated in the study was planned for the start of the project. Thanks are given to the EFC, which facilitated the participation of other farmers who operated similar types of integrated systems. The 5-day course, 'Practical Consideration in Managing Integrated Aquaculture Agriculture in Egypt', was implemented on 25th of July 2010. We thank Mr Peter Van der Heijden and Dr Marc Verdegem for their substantial contributions to the course. Their lectures and presentations extended to almost three days.

11 Conclusions and recommendations

- It is possible to increase water use efficiency through integrating agriculture and aquaculture, thereby reducing use of chemical fertilizers and increasing farm income through increasing productivity per unit of water. Also, in remote areas such integration can help in producing affordable food sources of animal origin for surrounding residences (Appendix 1).
- However, in order to optimize water use efficiency in integrated farming systems it is necessary to understand the relationship between water requirements for both the fish ponds and crop irrigation.
- In Farm 3 and possibly also Farm 4 fish production could be increased without using more water or negatively affecting the agriculture system.
- There is a need to develop low-cost water recycling systems to reduce water inputs to amounts needed only to compensate for losses resulting from effluent water carrying system waste and evaporation and to increase fish yield per cubic meter of water productivity, which will lead to increase of farm revenue.

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Appendix 1 – Summary information of farms that were studied

Farm number	1	2	3	4
Total farm size (feddan)	60	30	1600	380
Area for fish farming (feddan)	20	2	5	5
Water source for fish farm	Groundwater, 25°C, fresh, 70 m deep	Groundwater 25°C, fresh, 80 m deep	Canal	Canal
Water source for crops	Fish pond effluent plus canal	Fish Farm effluent	Fish Culture Reservoir	Fish Culture Reservoir
Type of fish culture systems	Intensive	Intensive	Semi-intensive	Semi-intensive
	tilapia	tilapia	tilapia	tilapia, mullet, com carp
	concrete basins	concrete basins	irrigation reservoir with plastic lining	concrete reservoirs
	Aeration	Aeration		full exchange in 48 hrs
Fish Productivity (kg/ m^3)	30-35	30	1	0.5
Tilapia: Average sales prices (LE/Kg)	9.5	12 (LE) in 2009 and 9.5 (LE) in 2010		10/kg - 12/kg

Crops			Res. 1	
1	Mango 15 feddan	Mango 10 feddan	Mango 90 feddan	Banana 200 feddan
2	Banana 5 feddan	Alfalfa 2 feddan	Orange 52 feddan	Lychees (Bashmala) 80 feddan
3	Vegetables, pepper, flowers 10 feddan		Res. 4	Mandarin (Kaka) 30 feddan
4	Orange 10 feddan		Mango 17.5 feddan	Orange 30 feddan
5			Orange 65 feddan	uncultivated 20 feddan
6			Grape 30 feddan	
7			Vegetables 15 feddan	
Fish Farm Data				
	No of Ponds			
Production ponds	9	12	8	3
	36	16		
Fingerlings ponds	60	16		
Hatchery ponds	60	16		
	Water Volume (m^3)			
Production ponds	200	200	4,000	35,700
	100	100		
Fingerlings ponds	25	50		

Hatchery ponds	12	15		
Total Water Volume (m^3)	7,620	5,040	8,000	107,100
Water exchange rate (%) in fish tanks	20	6	45	8
Fish yield (kg/year)	189,000	40,800	6,000	0
Crop use of water (m^3/day)	420	280	2,520	4,800
	150		624	1,600
	300	40	490	630
	200		650	360
			750	
			70	
Average water use (m^3/day)	1,070	320	5104	7,390
Total water use per (m^3/year)	584,000	110,376	1,862,960	2,697,350
Water use efficiency in fish production (m^3/kg)	3.09	2.71	310.00	–
Fish Yield per m^3 of water (kg/m^3)	0.32	0.37	0.003	0.000
Value of fish sale (LE/Year)	1,701,000	367,200	54,000	0
Total Value of crops (LE/Year)	450,000	10,000	4,339,000	6,630,000

Total farm /unit income (LE/Year)	2,151,000	377,200	4,393,000	6,630,000
Total savings on fertilizers (LE/year)	42,000	21,400	7185	12,200
Total benefit of water use (LE/year)	2,193,000	398,600	440,0185	6,642,200
Revenue per cubic of water (LE/m^3)	3.76	3.61	2.36	2.46
Fish Value to Farm Revenue	79%	97%	1%	0%

Appendix 2 – Water quality parameters measured monthly in farms during the study period

Farm 1	Source							Pond							Drain						
	pH	TN mg/l	Av P mg/l	K mg/l	Salinity g/l	D.O. mg/l	Temp. C°	pH	TN mg/l	Av P mg/l	K mg/l	Salinity g/l	D.O. mg/l	Temp. C°	pH	TN mg/l	Av P mg/l	K mg/l	Salinity g/l	D.O. mg/l	Temp. C°
May	8.83	0.5	0.13	7	1.06	1	26.1	9	1.93	0.303	12.1	1.807	6.93	24.9	8.83	3.4	0.236	13	1.79	5.6	24
June	No sample							9.1	3.772	0.118	14.54	1.54	8.18	26.7	8.96	3.25	0.1	8.21	1.08	4.7	27.3
July	8.6	0.4	0.03	0	1.04	NA*	27.2	8.91	7.673	0.046	1.708	1.708	5.38	27.7	8.28	2.43	0.029	6.36	1.17	5.1	27.3
Aug	NA			8.74			27.4	9.25	4.65	0.008	9.565	1.815	6.98	28.2	8.68	1.9	UD	8.91	1.31	7	27.6
Oct	No sample							9.17	6.072	0.096	11.88	1.628	8.13	24.6	8.58	2.25	0.025	7.9	1.31	7.6	22.7
Dec	No sample							9.13	3.318	0.01	10.17	1.565	7.03	19.8	8.6	1.66	0.018	8.21	1.18	5.7	19.7
AVG.	8.715	0.45	0.08	5.25	1.05	1	26.9	9.09	4.569	0.097	9.994	1.677	7.1	25.3	8.655	2.482	0.082	8.765	1.307	5.9	24.77

NA: not available, UD: undetectable.

Farm 2	Source							Pond							Drain						
	pH	TN mg/l	Av P mg/l	K mg/l	Salinity g/l	D.O. mg/l	Temp. C°	pH	TN mg/l	Av P mg/l	K mg/l	Salinity g/l	D.O. mg/l	Temp. C°	pH	TN mg/l	Av P mg/l	K mg/l	Salinity g/l	D.O. mg/l	Temp. C°
Aug	8.4	3.6	UD	6.37	0.47	7.1	30.5	8.92	4.9	UD	12.01	0.56	11.1	29.1	9.95	6.5	UD	10.94	0.57	1	31
Sep	8.78	2.62	UD	8.2	0.46	4.21	28.1	9.45	3.04	0.063	8	0.53	5.2	27.2	10.2	4.3	0.096	9.3	0.57	4.9	28.2
Oct	8.87	1.32	0.07	6.3	0.49	4.1	24.8	9.02	3.63	0.061	8.5	0.6	7.1	23.8	8.76	3.27	0.151	9.7	0.64	4.4	22.5
Dec	8.7	2.52	UD	5.12	0.49	4.52	25.2	8.8	3.93	0.38	6.24	0.51	5.6	20.8	9.44	3.63	UD	5.65	0.52	6.7	18.6
AVG.	8.688	2.515	0.07	6.5	0.478	4.98	27.15	9.05	3.875	0.168	8.688	0.55	7.25	25.2	9.588	4.425	0.123	8.898	0.575	4.3	25.08

Farm 3	**Source**							**Pond**							**Drain**						
	pH	TN mg/l	Av P mg/l	K mg/l	Salinity g/l	D.O. mg/l	Temp. C°	pH	TN mg/l	Av P mg/l	K mg/l	Salinity g/l	D.O. mg/l	Temp. C°	pH	TN mg/l	Av P mg/l	K mg/l	Salinity g/l	D.O. mg/l	Temp. C°
May	9.1	2.4	0.04	14	0.3	8.5	27.9	8.92	3.3	0.009	8.4	0.25	7.4	27.1	8.8	2.5	0.036	0	0.3	8.6	27.2
June	8.5	3.4	0.15	NA	0.6	9.3	25.8	8.38	0.6	0.071	7.39	0.52	1.95	28.8	8.41	1.9	0.071	7.72	0.535	2.3	27.25
Aug				8.02				8.55	3.615	0.008	6.62	0.5	6.35	29.6	8.6	3.72	UD	5.97	0.37	1.7	30.1
Sep	8.86	3.22	UD	5.8	0.35	4.2	28	8.88		0.175	3.02	0.39	2.95	28.2	8.74	2.64	0.076	5.95	0.375	2.6	26.5
Oct	8.93	2.44	0.08	6.1	0.46	4.98	24.5	8.82	2.8	NA	NA	0.53	4.62	24.6	8.845	3.35	0.043	5.75	0.545	4.8	25
Dec	9.06	2.41	UD	6.22	0.45	6.18	18.2	9.11	2.35	0.004	7.13	0.435	5.71	17.4	9.1	2.37	UD	6.23	0.47	5.3	17.7
AVG.	8.89	2.774	0.09	8.03	0.432	6.63	24.88	7.52	2.533	0.054	6.512	0.438	4.83	25.9	8.749	2.747	0.056	6.324	0.433	4.2	25.63

Farm 4	**Source**							**Pond**							**Drain**						
	pH	TN mg/l	Av P mg/l	K mg/l	Salinity g/l	D.O. mg/l	Temp. C°	pH	TN mg/l	Av P mg/l	K mg/l	Salinity g/l	D.O. mg/l	Temp. C°	pH	TN mg/l	Av P mg/l	K mg/l	Salinity g/l	D.O. mg/l	Temp. C°
May	No sample							9.85	4.985	0.184	13.5	0.415	17	27.5	9.7	4.12	0.41	5.5	0.36	NA	26
June	8.73	0.67	UD	7.7	0.23	4.8	30.1	9.2	0.8	UD	10.98	0.235	13.2	30.6	8.95	0.65	0.265	12.08	0.23	NA	31.7
July	9.2	0.34	UD	10.6	0.16	5.2	29.2	9.1	0.4	0.006	9.245	0.18	11.6	30.1	8.8	0.6	0.004	8.5	0.2	NA	29.8
Aug	8.62	1.65	UD	11.3	NA	NA	NA	9.45	0.55	UD	10.81	0.245	14.8	32.1	9.065	0.7	UD	9.01	0.25	NA	31.3
Sep	No sample							9.27	1.94	0.034	13.4	0.255	10.3	29.9	8.825	2.19	0.014	13.4	0.265	NA	29.9
Oct	No sample							9.45	1.55	0.01	10.9	0.3	13.8	25.5	9.28	1.585	0.006	12.5	0.3	NA	25.1
Dec	No sample							8.81	1.4	0.01	11.71	0.315	10.4	17.9	9.1	1.65	0.006	11.32	0.315	NA	19.65
AVG.	8.85	0.887	UD	9.87	0.195	5	8.471	9.3	1.661	0.049	11.51	0.278	13	27.6	9.103	1.642	0.117	10.33	0.274	NA	27.64

This report describes a study done in 2010 by researchers of the WorldFish Center on water use in Egyptian farms that apply aquaculture – agriculture integration. Two of the four farms that were monitored derived the main income from farming and selling fish, the two other farms were mainly agricultural farms that used reservoirs that were built to store irrigation water for growing fish. The volume of water in which fish were raised from fingerling to market size and that was subsequently used to irrigate agriculture crops was estimated. The water quality was monitored, the quantity and value of the fish and the value of the agricultural crop were determined. Estimates were made of the amount of fertilizer that was saved by growing fish in irrigation water.

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