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Research Article

Conceptual Economic Evaluation of In-Stream Engineered Wetlands, Agricultural Production, and Land Use-A Case Study

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Abstract

Constructed wetlands are capable of effectively reducing many typical pollutants in industrial and municipal effluents, such as Biological Oxygen Demand (BOD), suspended solids, and nutrients. This type of technology relies on the naturally occurring energies of the sun and wind. The performance of the in-stream wetland treatment system under Egyptian conditions expected to be equivalent to the primary to secondary conventional treatment and based on the designed detention time and aquatic species used. The success of this technique will yield the design criteria for construction of replicates at other drains. This will also allow using constructed wetlands for the reclamation of drainage water for irrigation and for the treatment of sewage water for decentralized communities. The wetland demonstrates an innovative low-cost approach for improving water quality that will lead Egypt to self-sufficiency in this kind of biotechnology. The objective of this paper is to review concepts of economic evaluation with emphasis on evaluation criteria that could use appropriately for the in-stream wetland projects. Such as benefit/cost ratio, to identify in stream wetland costs (capital costs, and running costs) to apply relevant evaluation criteria for reaching a rough estimate of the economic viability of the project, and for recommendations regarding viability of the project. In addition, the paper represents the agricultural production and land use in the study area and surrounded districts in order to duplicate this technique in the area surrounded to get benefit of the drains in beak demand by this new technique that could increase the irrigation production as well. It is concluded that from the research outcomes the conventual Benefit-Cost (B/C) = 12.7, that means every US$ be paid in this project will get gain of US$ 12.7, and the modified B\C = 14.53, that means every US$ be paid in this project will get gain of US$ 14.53. The two methods of B/C give good results for this project. In addition, wetland operation produces two major types of by-products, which could converted to sellable products: Sediments from treatment beds used to make bricks; harvested biomass from treatment cells may composted as compost or could sold directly as animal feed. In addition, the tangible benefits of the technique will Increase agricultural production, quality improvement, and cost reduction. Moreover, Intangible Benefits created outside the project itself will create new job opportunities, better health, reduced incidence of waterborne diseases, and cause environmental improvements.

Keywords: *Non-conventional Wastewater Treatment, Constructed Wetland, Economics Evaluation Method, Cost Benefit Analysis, Project Viability, Agricultural Production, Land Use.*

Introduction

Generally, wetlands are lands, where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface (**Cowardin**, 1979). Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance.

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The natural wetlands in Egypt are:

Northern Lakes, Matruh Lagoons, Qaroun, Wadi El-Rayan Lakes, Wadi Al Natroon and Moughra Lakes, Oasis Lakes, Scattered lakes in Delta and its fringes, Nile River flood plans and islands, Lake Nasser shores and Toshka depressions, Mediterranean Sea shores, Red Sea shores and mangroves, and Suez Canal system (Elmourah and Temsah lakes).

The engineered wetlands in Egypt are:

- Abu Attwa Domestic WWTP (Ismailia),
- 10th of Ramadan Industrial WWTP,

- Maryott (Alexandria) wetland Domestic Waste Water Treatment Plant (WWTP) (2nd and 3rd treatment),
- In-Stream wetland for sewage wastes connected to agriculture drain at Fayoum, Nawasa and Aysha,
- Samaha Village, Dakahleya SSF Sewage Wetland,
- Lake Manzala engineered wetland for treatment of Bahr El-Baqar drain, and
- Stabilization ponds and Sub Surface Flow (SSF) Wetland Waste Water Treatment Plant (WWTP) El-Radwan Village Port Said.

Wetland system can reduce high levels of Biological Oxygen Demand (BOD), suspended solids, and nitrogen as well as significant levels of metals, trace organics, and pathogens [Reed et al., 1988]. The removal of settable organics is very rapid in all wetland systems due to the quiescent conditions in the free water surface types, and to deposition and filtration in the vegetated submerged bed (VSB) systems. Similar results have been observed with the overflow of systems, where close to 50% of the applied BOD is removed in the first few meters of flow downstream, as shown in Table 1.

Table 1: Expected performance of the wetland systems, Reed et al., (1988)

Parameter		Inflow	Outflow	%Removal
TSS	mg/l	130	21	84
BOD	mg/l	40	17	57
COD	mg/l	200	92	54
Total P	mg/l	5	2.5	50
Total N	mg/l	12	5	58
NH4-N	mg/l	10	5	50
FC	MPN/100ml	$3*10^5$	$3*10^4$	One order

TSS: total suspended solids; BOD: Biological Oxygen Demand, COD: Chemical Oxygen Demand, Total P: total phosphorus, Total N: Total Nitrogen

Wetlands' Benefits to the Environment

By retaining floodwaters and then slowly releasing the waters later in the season, wetlands help to control floods. The heavy organic soils of wetlands act like sponges. Wetlands stabilize shorelines by slowing runoff. The plants and fibrous roots help the soil and protect the shorelines. Many wetlands have an abundance of wildlife. Wetlands often have a complex food chain that supports many organisms and wildlife species. Wetlands range in complexity from simple wetland pastures, often reed canary grass, to forested swamps. Complex wetlands with many plant species and wetland zones may be more valuable to the ecosystem. Wetlands also function in groundwater recharge. Some of the floodwaters that wetlands capture during storms percolate to groundwater. Groundwater and the water table are near the surface in a wetland. It is often difficult to separate ground and surface water in a wetland; they interconnect. Wetlands can provide a major environmental benefit in cleaning up contaminated water. Water managers construct artificial wetlands to purify wastewater from sewage treatment plants, from storm water runoff and even from fish rearing ponds.

Research Problem

In three main locations (Mit Ghamr, Sinbillawayn and **Aga (Study Area)**), are located at the Dakahleya Governorate, Egypt, where groundwater is used for drinking, and high concentrations of iron and manganese exist. The quality of the groundwater for irrigating a broad range of plants is generally satisfactory. However, as is to expected in the case of both the sub-soil and sand dune water, cropping is restricted to salt tolerant plants. Groundwater aquifers are threatened by salinization and pollution from agricultural (nitrates and pesticide residues) practices as well as, in some cases, from industrial activities. Irrigation canals and agricultural drains experience eutrophication, excessive growth of weeds and accumulation of pesticides. Coastal wetlands and shorelines also threatened by a variety of pollutants, which affect fishing and tourism activities, **CAPMAS,** (2002). The Ministry of Health in Dakahleya has shown that the quality of potable water at the treatment plants meets the specified standards in terms of ammonia, nitrites, iron and magnesium, there is other evidence, which suggests that the water supplied by the compact units is substandard, **CAPMAS,** (2002).

Some areas of the Governorate suffer from a shortage of public water supply, notably Bilqas, Shirbin, Talkha and Sinbillawayn Districts. Agricultural drainage waters are a potential source of irrigation water. However, the conductivity of that water, coupled with pesticide and fertilizer residues, in some locations give cause for concerns. Indeed, there is evidence that in both the southern and northern parts of the Governorate the salinity of the drainage water exceeds acceptable levels for the normal suite of agricultural crops. **CAPMAS,** (2002).

The biggest single environmental problem in the Governorate is the poor quality of potable water. There is a high incidence of water supply leakages, which are responsible for contamination by raw sewage, industrial and other effluents. *Water quality said to be deteriorating in association with increased population and industrialization, more intensive agricultural practices, accompanied by inadequate treatment of industrial and municipal wastewaters, agricultural run-off, and solid waste disposal along the Dumyat Branch banks* **EEAA** (2002).

Generally, less than 50% of the rural population has access to clean water, compared with urban areas, where 80-100% connected to a water supply network. The main source of irrigation water is the irrigation canal (fresh water), and the secondary source is the drainage water. All landholders suffer from shortage of irrigation water around the year, especially in the summer season. Consequently, more than 70% of the farmers use the agricultural drainage as irrigation water, while the others use unofficial deep wells. The cost of digging a deep well is about US$ 175-265. The deep well irrigates about 24 to 48 hectares. Up to 8 landholders share the expenses and use of each deep well, while the number goes up to 20 participants in other areas. **CAPMAS,** (2002). More than 90% of the landholders know that the drainage water is not suitable for irrigation, but they have no other cheap alternative. Moreover, some of them express that the canal irrigation water is not available.

2. Materials and Methods

The objective of this study is to find a low-cost technique for drainage treatment in the study area. As the study area has a major problem of pollution from agricultural practices (nitrates, phosphates and pesticide residues), an in-stream wetland is a good choice technique in such rural areas for drainage treatment. In addition, it intended to review concepts of economic evaluation with emphasis on evaluation criteria that could use appropriately for the in-stream wetland project. Such as benefit/cost ratio, for identifying in stream wetland costs (capital costs, and running costs), applying relevant evaluation criteria to reach a rough estimate of the economic viability of the project, and giving recommendations regarding the viability of the project.

The research first highlights the Egyptian experience in wetland treatment system, wetlands' benefits to the environment. Second, we collect the data for Dakahleya Governorate, (*population densities, water resources, ground water source, problems of water supply systems*, *agricultural land use*: winter crop yields / summer crop yields) in order to easily duplicate this technique in other governorate districts. Then the research descripts the social and economic conditions of the study area (Nawasa El Ghait Village - Aga- Dakahleya Governorate).

After that, we describe the in-stream engineered wetland for the study area, its elements of in-stream wetland design, and its design steps and wetland outcomes and water quality efficiency. We collect the data about irrigation water resources and agricultural land use in the study area. Cropping pattern in the study area: *Crop Yield - Crop Production Returns*. Then we highlight how to measure the economic evaluation for the study area, its methods for calculating B\C Ratio, and calculate the in-stream engineered wetland costs: capital costs / running (maintenance) costs. Moreover, thereafter we evaluate in-stream wetland conceptual economic for the study area by calculating the B\C Ratio by two methods.

2.1. Dakahleya Governorate Data Collection

Population Densities

The total population of the Governorate in 1994 estimated to be 4,197,640, with an approximate rural/urban proportion of 3:1. The total population forecast to grow from 4.2 million to over 8 million by 2020. The rural/urban proportion predicted to remain broadly 78:22. The urban population is concentrated in 17 centers, in contrast to approximately 445 rural settlements (*109 main villages and 336 satellite villages*) dispersed throughout the Governorate. A significant trend is the change in the size and character of many previously rural villages, which are in the process of becoming towns. As a result, the encroachment on agricultural land has been growing (**CAPMAS,** 2002).

The demographic trends in terms of rates of births, deaths, infant mortalities, family size, etc., confirm the expectation that population pressures will grow significantly over the next 25 years.

Table 2: Population Densities of the Dakahleya Governorate Districts in 1995

Country and District	Population	Area (km²)	Population Density (Person/km²)
Mansoura	756,961	346.6	2,184
Talkha and Nabaruh	431,034	298.7	1,443
Shirbin	275,419	268.1	1,027
Bilqas	354,424	761.2	466
Aga (Study Area)	**337,529**	**233.6**	**1,445**
Sinbillawayn and Timayy Al Imdid	478,049	443.2	1,079
Mit Ghamr	520,968	244.8	2,128
Dikirnis and (Bani Ibayd)	323,229	359.6	899
Minyat An Nasr	195.352	189.2	1,033
Manzala/Matariya/Gamaliya and Mit Salsil	440,414	3,142.3	140
Total	**4,113,379**	**6,287.1**	**654**

Source: Dakahleya Environmental Affairs Department Information Unit, 1995

Water Resources

The surface water resources of the Governorate comprise the River Nile (Dumyat Branch), the main irrigation canals, the irrigation-drainage network, and open ditches. Under the 1959 treaty, the Nile River contributes in total to approximately 55.5 billion m³/year (BCM/a) to the freshwater balance of Egypt. Groundwater resources (sand dune water, subsoil water, and groundwater) by comparison amount to only 4.5% of that figure, of which about 50% is infiltration water from the Nile. The groundwater source is a confined aquifer, which has an average thickness of more than 700 meters. The aquifer dominated by permeable sands and gravels with minor clay lenses. Deep percolation from flooded irrigation fields plays a major role in aquifer re-charge.

Ground Water Source

For the whole Nile Delta, there is a positive groundwater balance. Indeed, it is estimated that an additional 450 million m³/year (MCM/a) are available for use. Approximately 25% of the total water supply within the Governorate contributed by groundwater. About one third of the Governorates population is dependent upon this water for drinking and domestic uses.

Groundwater, an important water source in the southern part of the Governorate, is deteriorating in quality, which in parts may relate to increased abstraction rates and pollution from agrochemicals and domestic sewage. The salinity levels of groundwater resources vary according to location as follows (in ppm, parts per million):

Table 3: The salinity levels of groundwater resources in Dakahleya Districts

District	Salinity (ppm)
Mit Ghamr	390 – 800
Sinbillawayn	340 – 1,820
Aga (Study Area)	**380 – 1,000**
Mansoura	1,400 – 1,600
Bilqas	5,000
Shirbin	10,000
Manzala/the coast	30,000

Problems of Water Supply Systems

A major problem is associated with the high incidence of water pipes with cracks. It showed that between 35% and 60% of the potable water supply leaks to the soil. The problem compounded by the fact that polluted ground/sub-soil water enters the drinking water system through these leaks and cracks. Table 4 represents the personal solutions for waste disposal practices in Dakahleya Governorate.

Table 4: Personal solutions for Waste disposal practices in Dakahleya Governorate

Service	Solutions Adapted
Reliable Water Provision	• People make their own connections from the main pipes, or dig water wells. • People resort to water from water wells because the flow is more constant and the quality/taste is better (chlorine free) than from the main pipes. • On a limited scale (because of the high costs required), people use motorized pumps to increase their water pressure.
Good Quality Potable Water	• Rare use of filters (because of the high costs required) to remove sewage and other contaminants; sometimes use of cotton wool as filter on taps. • Water frozen in the belief that harmful microbes killed. • Storage of drinking water in containers, which allow sediments to settle. • Use of neighboring water pumps.
Disposal of Household Wastes	• People throw waste onto nearby empty land or onto canal banks, or set on fire. • Use of the organic constituents as fuel for traditional ovens, when available. • Farmers mix solid waste with mud to produce fertilizer. • Urban residents throw waste into municipal waste containers, if available; if not, they throw it to street corners to await collection, unless scavengers intervene. • Some urban residents pay for garbage collection service, until these discontinued. • Hospital and clinical waste thrown into sewage pipes.
Disposal of Sewage and Waste Water	• Abuse of sewage pipes for disposal of garbage, plastic bags etc.

Agricultural Land Uses

Agricultural productivity increased for the main crops over the period 1989-1994. However, in case of some vegetables and fruit crops, the opposite occurred. Special soil problems experienced in many places. These relate to increasing salinity levels, and a high and rising water table, where land drains do not exist. Significant soil improvement programs, involving the application (as well as effective storage) of gypsum, land drainage, and the use of organic amendments (dung and compost) are required in order to raise the productivity level Table 5, and Figure 1 give a survey on the agricultural areas and the production profiles in the Dakahleya Governorate.

Table 5: Land Use in the Dakahleya Governorate

Land Use	%	hectare
Cultivated Land	78.6	1,516,605
Cultivable Land	10.3	199,376
Water Covered Land	1.2	23,143
Public Utilities	9.9	190,600
Uncultivable Land	0.03	512
Total	100	1,930,236

Source: Dakahleya Governorate Environmental Action Plan - Land Resources and Problems, TCOE/Entec.

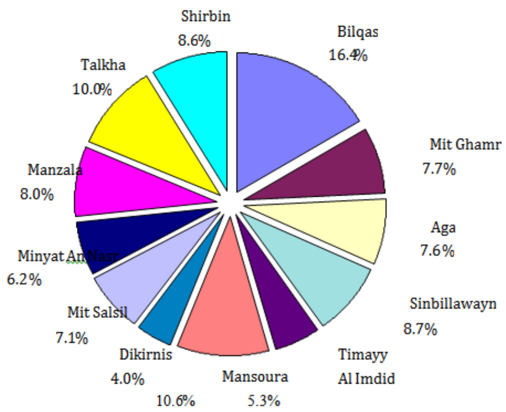

Figure 1: Cultivated land Use in Dakahleya Governorate by Districts

Table 6: Winter Crop Yield in Egyptian Governorates

Governorate	Wheat (Ardeb/fed)		Barely (Ardeb/fed)		Beans (Ardeb/fed)		Clover (Tons/fed)		Tomato (Tons/fed)	
	Old Land	New Land	Old Land	New Land	Old Land	New Land	Old Land	New Land	Old Land	New Land
Nobaria	15.54	11.03	8.49	8.87	7.91	9.44	28.27	19.40	8.90	13.77
Alxandria	17.04	13.00	13.83	8.18	10.72	7.00	23.84	20.00	7.23	
Beheira	16.75	13.63	17.05	8.23	10.06	4.00	25.77	14.50	9.73	
Gharbia	17.58	14.42	11.97	12.87	9.75	6.00	21.38	14.00	9.17	
Kafr Elsheikh	17.05	13.36	17.50	8.24	8.59		21.96	17.00	7.24	
<u>Dakahleya</u>	14.41	13.01	9.22	10.30	9.64		25.35	26.60	6.55	
Damietta	17.1	13.13	16.52		6.36		14.11		13.76	
Sharkia	13.87 8	14.18	13.52		7.00		15.08		29.18	
Ismailia	13.19	6.76	4.00		6.88		19.98		6.00	
Port Said	17.99		13.99		8.92		28.18		8.70	
Suez	16.79		16.00		8.91		33.34		8.98	
Menoufia	12.06		17.74				19.51		14.16	
Qaliobia			13.50						7.91	
Cairo										
Total for Lower Egypt	**17.03**		**14.16**		**9.34**	**9.37**	**25.40**		**14.28**	**13.77**
Giza	20.67	14.00	18.55	13.00	8.50		32.73	13.00	14.24	
Beni Suef	15.86	14.00	13.77	12.00	5.91		32.80	20.00	14.26	
Fayoum	16.81	13.00	11.70	10.64	7.64		18.60	12.00	9.90	
Menya	19.39		12.79		6.88		22.00		11.02	
Total for Middle Egypt	**17.71**		**12.08**		**6.92**		**24.41**		**12.24**	
Assuit	16.49	12.44	14.10	8.84	8.05	6.98	35.52	39.50	15.35	
Sohag	16.96	14.00	12.63	11.22	6.96	5.64	34.26	23.34	25.07	
Qena	15.79	11.45	10.95		6.16	6.50	23.58		25.64	
Aswan	15.99	5.00	8.94		6.02		21.65		6.06	
Luxor	18.13	10.56	0.00		7.50		26.11		13.00	
Total for Upper Egypt	**16.49**		**11.00**		**7.59**	**6.01**	**34.25**		**21.77**	
Total for Nile Valley & Delta	**17.06**	**12.11**	**13.50**	**9.38**	**8.55**	**9.28**	**25.84**	**20.29**	**16.78**	
New Valley	12.83		10.24	12.31	7.49		23.65		13.15	
Matrouh	1.17		1.73		8.50		22.00		4.00	
North Sinai	1.56		1.81						10.53	
South Sinai	4.14		0.00							
Total for Desert Governorate	**3.95**		**2.23**	**12.31**	**7.84**		**23.32**		**10.07**	

(Source: MALR, 2013) Note: Ardeb = 150 kg; feddan = 0.42 hectares; old land: land in Nile delta region; new land: land irrigated by new irrigation techniques

Table 7: Summer Crop Yield in Egyptian Governorates

Governorate	Sorghum (Ardeb/fed)		Maize (Ardeb/fed)		Rice (Tons/fed)		Sugar Cane (Tons/fed)		Cotton(hair) (Qentar/fed)	
	Old Land	**New Land**	**Old Land**	**New Land**	**Old Land**	**New Land**	**Old Land**	**New Land**	**Old Land**	**New Land**
Nobaria		8.25	18.10	21.22	3.21		40.00	21.76	6.52	
Alxandria			23.40	14.47	3.65		24.73		5.81	
Beheira			22.70	17.00	3.41		41.75		5.39	
Gharbia			20.63	16.44	3.39		31.94		5.85	
Kafr Elsheikh			21.85	20.00	3.65		31.20		6.21	
Dakahleya			19.98		3.05		31.25		7.95	
Damietta			20.28		3.48		39.37		3.78	
Sharkia			18.72		3.04		29.46		4.74	
Ismailia			8.48		2.29		36.01		8.19	
Port Said			15.73		2.00		40.30		9.06	
Suez			19.79		2.71		28.81			
Menoufia			20.33		3.41					
Qaliobia			12.27							
Cairo										
Total for Lower Egypt		**8.25**	**21.25**		**3.51**		**36.07**	**21.76**	**6.97**	

Giza	15.82		22.74	5.95	2.96		33.51		4.14	
Beni Suef	19		18.75	19.50			25.63		8.75	
Fayoum	11.1		19.13				31.33		6.17	
Menya	14.78		21.92				46.54		9.04	
Total for Middle Egypt	**11.74**		**21.07**		**2.96**		**44.33**		**8.20**	
Assuit	14.09	12.45	20.12	20.00	3.49		40.77	42.49	11.80	
Sohag	12.89	11.65	20.60	13.61			47.66		10.64	
Qena	12.74		18.72	8.00			46.88		4.18	
Aswan	11.65		15.95				47.42			
Luxor	10.37		15.63				48.95			
Total for Upper Egypt	**13.4**	**11.07**	**19.77**				**47.22**	**42.49**	**11.42**	
Total for Nile Valley & Delta	**13.11**		**20.98**	**19.57**			**46.73**	**40.47**		
New Valley	11.49		8.81		2.76		20.00			
Matrouh			14.00							
North Sinai										
South Sinai										
Total for Desert Govern.	**3.95**		**2.23**	**12.31**	**7.84**		**23.32**		**10.07**	

(Source: MALR, 2013), Note: Qentar = 50 kg for cotton; old land: land irrigated by river Nile; new land: areas irrigated by ground water mainly and irrigated by new techniques

Winter Crop Yields

Table 6 presents the crop yield in Egyptian governorates (MALR, 2013). It includes Wheat, Barely, Beans, Clover, and Tomato. It can be seen that there are no big differences of wheat yields in Lower, Middle and Upper Egypt, where the average yields are 17.03, 17.71, and 16.49 Ardeb/fed, respectively, (1 Ardeb = 150 kg, 1 fed(an) = 0,42 ha). However, there is a significant difference in yields for tomato crop. The average yield of tomato was 14.3, 12.24, and 20.29 in Lower, Middle and Upper Egypt regions, respectively. This may indicate the impact of low water quality on tomato production.

Summer Crop Yields

Table 7, shows the crop yields for sorghum, maize, rice, sugar cane, and cotton. There is no significant difference in maize yields among different regions in Egypt. Nevertheless, cotton yields showed a significant variation among the regions. Cotton yields were found to be 6.97 Qentar/fed (1 Qentar = 50 kg) in Lower Egypt, 8.2 Qentar/fed in Middle Egypt, and 11.42 Qentar/fed in Upper Egypt. These figures indicate the impact of water quality on cotton yields among different regions.

2.2. Description of Social and Economic Conditions for the Study Area (Nawasa El Ghait Village -Aga-Dakahleya Governorate)

This site is located adjacent to a small agricultural community near Nawasa El-Ghait village, Aga District in Dakahleya Governorate. It is located about 7 km from Mansoura and about 110 km from Cairo. Figure 2 shows a map of the study site, including the Faraa El Bahwo Drain. Population of the Nawasa El-Ghait village is about 3,000 capita; houses are concentrated in a single residential site. There is a sewage wastewater network installed at the Nawasa El-Ghait village streets, which constructed of heavy-duty PVC pipes and concrete manholes. The sewerage network collects wastewater and transports it to discharge at the beginning of an agricultural drain called Faraa El-Bahwo Drain. The collected wastewater is not treated. However, deep wastewater collecting tanks are under construction, which will act as a primary treatment facility before the wastewater dumped into the drain. Tap drinking water is available at houses, and domestic water use estimated as 120 L per capita and day.

Faraa El-Bahwo Drain is a 4th order agricultural drain. Its effective length is about 1710 m, and its tail-end discharges in El-Bahwo drain, a 3rd order agricultural drain, which in turn partly discharges into Mit-al-Aamel Drain.

Faraa El-Bahwo Drain contains mainly agricultural drainage water from the outlets of subsurface drainage collectors, some municipal wastewater from private pipes of individual houses. The drain bed width is about 5 m, and there are two side roads of 3-4 m width along the drain sides.

Drainage depth in Faraa El-Bahwo Drain is greater than 2.5 m, which allows for using the drain as an in-stream water body/facility. Industrial wastewater and/or solid wastes not observed along the drain, since no industrial activities are located in the vicinity.

Natural vegetation survey showed also that weeds exist at the nearby watercourses. Water hyacinth noticed floating on the drain water surface.

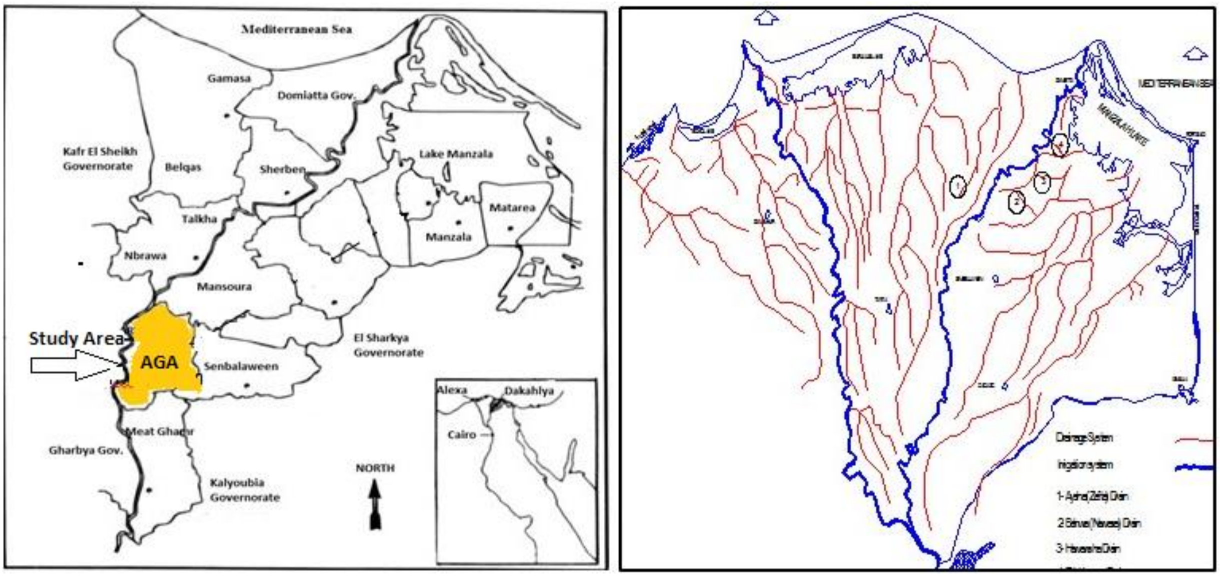

Figure 2: Location of the pilot drain (Faraa El-Bahwo)

In-stream treatment technology has applied at small and dispersed rural communities of Lower Egypt (the three Nile Delta Regions) that do not possess adequate wastewater treatment facilities, and consequently discard their wastewater in nearby tertiary drains. El-Bahwo drain selected to demonstrate the usage of in-stream treatment systems (El-Bahwo Drain in Gharbia Governorate). This drain receives bio-waste loads from the rural communities in its catchments areas, and nutrients loads from the surrounding agricultural lands. The catchment areas of the drain do have neither a sewage collection system nor functioning sanitation network coverage.

Nawasa El-Ghait Catchment is located near Aga District in Dakahleya Governorate, about 110 km from Cairo. Nawasa El-Ghait Catchment consists of four villages, Nawasa El-Bahr, Sanbakgot, Telbet, and Ezab El-Bahr. Population of the Nawasa El-Ghait Catchment is about 15,690 capita, 51% are male and 49% female. Nawasa El-Ghait Catchment's houses are made of concrete buildings with 3-4 floors. It has a sewage wastewater network, where manual sanitary network is available. The annual consumption of each house is equivalent to LE 300 for electrical power and public water supply system. The majority of big landowners in Nawasa El-Ghait Catchment live outside the catchment, so they rent their land to small farmers or share it with them.

Socio-Economic Condition in El-Bahwo Drain

In the village, drinking water supply network, sewage wastewater collection network, and electrical power network serve most of the village houses. In Nawasa El-Ghait Village, the majority of big landowners rent their lands to other small farmers and sometimes shares the profit with them instead of renting.

Traditional crops are cultivated in the village: Berseem and Wheat in the winter season, Rice and Maize in summer season.

The socio-economic survey questionnaire designed to measure and to assess the impacts of drainage water use on soil, crops, and human health. Data collected from 10 farmers in the winter season 2012/2013 and summer season 2013. About 90% of landholders in Nawasa El-Ghait village own or share an irrigation water pump. The main amount of irrigation water comes from the freshwater canal, while drainage water is a secondary source.

More than 90% of the landholders agreed that water quality of the drains is not suitable for irrigation, and some of them expressed that the irrigation water is not sufficient. Agrochemical fertilizers and organic matter are very important for soil and plant productivity. All landholders use several kinds of fertilizers such as urea, superphosphate, ammonium nitrate, and ammonium sulfate for most crops.

All houses served by the sewage wastewater network, which discharges directly to the agricultural drain. Most landholders understand the positive effects of the wastewater collection network in lowering the groundwater table as compared to the situation two years ago.

The average crop yields per feddan are 11 ardeb for wheat, 3 tons for rice, 16 ardeb for maize, and 20 tons for onion for Nawasa El-Ghait Village. Onion and peas production make good profits for landholders in Nawasa El-Ghait Village.

2.4. In-Stream Engineered Wetland for the Study Area (Nawasa El-Ghait Village)

Elements of In-Stream Wetland Design

The proposed typical elements of the In-Stream Wetland channel consist of three main zones as follow as shown in Figure 3. The first zone is the sediment trap zone. This zone proposed for the collection of suspended solids, therefore, placed near the inlet.

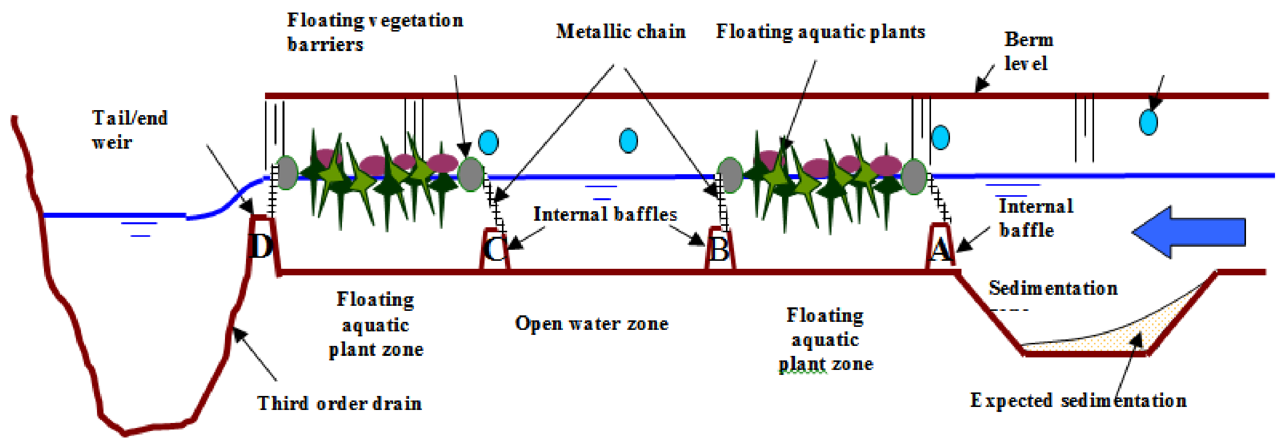

Figure 3: Typical x-section of a passive in-stream wetland (PIW)

Based on the TSS (total suspended solids) measurements, the expected length of this zone is of the order of 400 m. The sediment trap zone followed by two floating aquatic plant zones, separated by an open water zone. The task of the floating aquatic plant zones is to uptake nutrients and to support microorganisms, which can degrade pollutants into less harmful forms. Internal baffles/berm-weir barriers and/or end weirs separate each zone. For easiness, it suggested to mark the internal/external weirs alphabetically. The typical height of the internal baffles is 0.25 m, and the proposed length of the whole In-Stream Wetland channel reaches about 1.5 km with an average zone length of about 400 m.

Design of In-Stream Wetland

It has presented that the detention time could significantly increase from its typical current value of 6-8 hrs to more than 68 hrs (3 days) by using simple elements like a sedimentation trap and an end weir, forming a typical arrangement. After examining the significance of each element (sedimentation trap, end weir, and baffles) in the typical arrangement, it has found that:

- The end weir plays the most important role in controlling the detention time throughout the Passive in Stream Wetland (PIW) channel system. The higher the crest of the end weir, the longer the produced detention time of the system.
- Interior baffles do not have significant effects on the detention time of the system.
- Aquatic floating plants have small effects on the resulting detention time. It is found that as the thickness of the aquatic floated plants gets bigger and/or the plants' aerial density gets higher, the detention time gets longer.
- It has also noticed that discharge variation has a non-linear response to the detention time. For example, an increase of Discharge (Q m^3/s) by 50% will cause a detention time decrease by 36%, whereas a decrease of Discharge (Q) by 50% will cause a detention time increase by 91%.
- The preliminary computational results of this study showed that a removal efficiency of 60% for BOD could be easily achieved using the proposed design arrangement. Moreover, the preliminary analysis figures out that the expected removal efficiency for fecal coliform is expected to be within the range of 32-70%. It should mentioned that the proposed In-Stream Wetland requires at least a bimonthly removal of sludge deposition from the sediment trap. A reduction of the efficiency of the system might take place if the depositions not regularly removed.
- It should also mentioned that the effects of aquatic floating and emerged plants on the removal/absorption/fixation of the pollutants not covered mathematically in this chapter, however it believed that the removal efficiency would enhanced. During the monitoring period, it recommended that the monitoring program should include the effects of aquatic plants and fecal decay coefficients.

2.5. Economic Evaluation Measures for the Study Area

Benefit-Cost (B/C) Analysis is an economic tool to aid social decision-making, and typically used by governments to evaluate the desirability of a given intervention in markets.

The benefit and cost of impacts of an intervention evaluated in terms of public willingness to pay for benefits or to pay for avoiding additional costs. The guiding principle is to list all of parties concerned by an intervention, and place a monetary value of the effect it has on their welfare, as it would value by them.

Benefit-cost analysis attempts to put all relevant benefit and cost on a common temporal footing. A discount rate chosen, which then used to compute all relevant future costs and benefits in present-value terms. Most commonly, the discount rate used for present-value calculations is an interest rate taken from financial markets **R.H. Frank,** (2000). During the benefit-cost analysis, monetary values may also assigned to less tangible effects, such as the various risks, which could contribute to partial or total project failure, loss of reputation, market penetration, long-term enterprise strategy alignments, etc. This is especially true when governments use this method, for instance to decide whether to introduce business regulation, build a new road, or offer a new drug on the state healthcare. In this case, a value must put on human life or the environment, often causing great controversy. The benefit-cost principle says, for example, that one should install a guardrail on a dangerous stretch of mountain road, if the dollar cost of doing so is less than the implicit dollar value of the injuries, deaths, and property damage thus prevented (**R.H. Frank**, 2000). Benefit-cost calculations typically involve using time value of money formula. This usually done by converting the future expected streams of costs and benefits to a present value amount.

Cost-benefit analysis is mainly, but not exclusively, used to assess the value for money of very large private and public sector projects. This is because such projects tend to include costs and benefits that are less amenable to being expressed in financial or monetary terms (e.g., environmental damages), as well as those that can be expressed in monetary terms. Private sector organizations tend to make much more use of other project appraisal techniques, such as rate of return, where feasible. The accuracy of the outcome of a benefit-cost analysis is dependent on how accurately benefit and cost have estimated. Another challenge to cost-benefit analysis comes from determining which costs should be included in an analysis (the significant cost drivers). This is often controversial as organizations or interest groups may feel that some costs should be included or excluded from a study. In estimating the benefits of some inland waterways navigation projects, it is used an economic model, called the tow-cost model.

U_p = Total annual cost of the users for the present
U_f = Total annual cost to the same number of users for the future
$U_n = U_p - U_f$ = Net user benefits

The present value is the cash salvage value that would receive now, if the existing facility sold or demolished the existing facility maintained in place, this cash value left invested in existing facility, so the capital cost of existing facility is the cash salvage value.

C_f = Capital cost of the proposed (future) facility (annual basis)
C_p = Capital cost of the existing facility (present salvage value) (annual basis)
$C_n = C_f - C_p$ = Net capital cost of replacing.

Operation and Maintenance costs are the owner's costs for O&M the facility

M_f = Operation and Maintenance costs of the future facility
M_p = O&M costs of the present
$M_n = M_f - Mp$ = Net O&M cost ($\pm$)

Methods for Calculating B\C Ratio

A benefit-cost analysis commonly used to evaluate public projects. Difficulties involved in public project analysis include the following: Identifying all the users who can benefit from the project, identifying all the benefits and dis benefits of the project, quantifying all benefits and dis benefits in dollars or some other unit of measure, and selecting an appropriate interest rate at which to discount benefits and costs to a present value.

And it is calculating by using Conventual B\C or by Modified B\C, as the Conventual B\C is calculated by $\frac{Un}{Cn+Mn}$, and Modified B\C is calculated by $\frac{Un-Mn}{Cn}$.
The decision rule is if ***B/C(i) > 1***, the project is acceptable.

2.6. Irrigation Water Resources and Agricultural Land Use Economical Study in the Study Area

The main source of irrigation water is the irrigation canal (freshwater), and the secondary source the drainage water. All landholders suffer from shortage of irrigation water around the year, especially in the summer season. Consequently, more than 70% of the farmers use the agricultural drainage water for irrigation, while the others use unofficial deep wells.

The cost of digging a deep well is about US$ 375-563. A deep well irrigates about 24-48 hectares; up to 8 landholders share the expenses and use of each deep well, while the number goes up to 20 participants in other areas.

Generally, more than 90% of landholders know that drainage water is not suitable for irrigation, but they have no other cheap alternatives. Moreover, some of them complain that the canal irrigation water is not available.

Cropping Pattern

The questionnaire answers showed that the traditional crops grown in the village are as follows:

Nawasa El-Ghait Village: Berseem, wheat, onion and peas are cultivated in the winter season. In the summer season, the majority of farmers cultivated rice, while only 28.5% cultivated maize and few of them also peas. The interview reported that the landholders consider onion and peas as their main summer crops.

(a) Crop Yield

Nawasa El-Ghait Village

As shown in Table 8, the average crop yields based on questionnaire results in the year (2012/2013) was 11 ardab/feddan for wheat and 20 tons/feddan for onion. The average crop yield for rice was 3 tons/feddan, and for maize was 16 ardab/feddan.

Table 8: Crop Productivity in Nawasa El Ghait Village (Season 2012/2013)

Type of crop	Average crop production per feddan
Wheat	11.0 ardab
Rice	3.0 ton
Maize	16.0 ardab
Onion	20.0 ton

(b) Crop production Returns

Estimated average crop returns, based on landholders' responses for the season 2012/2013, summarized in Table 9, for wheat, berseem, peas, onion, maize and rice.

Table 9: Crop productivity in Nawasa El-Ghait Village (Season 2012/2013)

Crop produced	Unit	Productive Value Return (USD)
Wheat	Ardab	16
Berseem	Feddan	200
Peas	Feddan	625
Onion	Tons	47
Maize	Ardab	14
Rice	Tons	125

As shown in Table 9, the average productive value return was (US$ 16 per ardab) for wheat, (US$ 47 per ton) for onion, and (US$ 14 per ardab) for maize. The product return was (US$ 625 per feddan) for peas, and (US$ 200 per feddan) for berseem, while for rice, the product return was (US$ 125 per ton) at the beginning of harvest and reached (US$ 16 per ton) at the end of season. In general, onion and peas considered profitable crops for landholders.

2.7. In Stream Engineered Wetland Economic Study
Capital costs

The capital costs include construction of civil works, equipment and transportation in addition to the international and national consultancy. The calculations of these shown in Table 10.

Table 10: Costs of construction of civil works for In-Stream Wetland (in US$)

Items	Established year
Construction of civil work	30000
Equipment and transportation	7000
International and national consultancy	15000
Total	52000

Running (Maintenance) costs

- Operation and Maintenance of electro-mechanic equipment.
- Operation and Maintenance of treatment cells.
- Operation and Maintenance of Buildings.
- Monitoring Plan.

Table 11: Expected Costs of In-Stream Wetland for 20 years (in US$)

Years / Items	1	2	3-20
Operation and Maintenance of electro-mechanic equipment	Zero	Zero	Zero
Operation and Maintenance of treatment cells	1,250	1,250	1,250
Operation and Maintenance of Buildings	Zero	625	625
Monitoring Plan	6,250	6,250	6,250
Total	7,500	8,125	8,125

2.8. In Stream Wetland Conceptual Economic Evaluation

It expected to increase the agricultural area by using the In-Stream engineered wetland by about 2381 hectares of the crops wheat, berseem, peas and onion in winter, and for rice and maize during summer, as all landholders suffer from shortage of irrigation water around the year, especially in the summer season. Consequently, more than 70% of the farmers use the agricultural drainage water for irrigation, while the others use unofficial deep wells.

Main products and agricultural areas

Table 12 shows the productive return values for about 2381 hectares of crops in winter (wheat, berseem, peas and onion) and summer (rice and maize).

Table 12: The Total Productive Return Values for the Study Area

Type of crop	crop production per feddan	Season Productive return value (US$)	Total production per total area	Unit	Total productive return value (US$)
Wheat	11 ardab	18	2,750	ardab	49,500
Berseem		95	250	feddan	23,750
Peas		625	250	feddan	15,6250
Onion	20 ton	47	5,000	tons	235,000
Maize	16 ardab	14	8,000	ardab	112,000
Rice	3 ton	125	1,500	tons	187,500
Total					**764,000**

Conventual B\C = $\frac{Un}{Cn+Mn}$ = $= \frac{764000}{52000+8125}$ = 12.7

That means every US$ be paid in this project will get gain of US$ 12.7.

Modified B\C = $\frac{Un - Mn}{Cn}$ = $\frac{764000-8125}{52000}$ =14.53

That means every US$ be paid in this project will get gain of US$ 14.53.

The two methods of B/C give good results for this project. In addition, wetland operation produces two major types of by-products, which could converted to marketable products. The sediments from treatment beds could use to make bricks, and Harvested biomass from treatment cells could composted sold as compost, or sold directly as animal feed.

Tangible Benefits of Agricultural and Irrigation Projects as it (Increased agricultural production**,** Quality improvement**,** and Cost reduction).

Intangible Benefits: ***These are benefits created outside the project itself****: (Creation of new job opportunities, Better health, reduced incidence of water borne diseases, Environment*)

Conclusions and Recommendations

Conclusions

It is concluded that from the research outcome that Conventual B\C = 12.7. That means every US$ be paid in this project will get gain of US$ 12.7, and Modified B\C = 14.53, that means every US$ be paid in this project will get gain of US$ 14.53. The two methods of B/C give good results for this project.

In addition, Wetland operation produces two major types of by-products, which could converted to sellable products: Sediments from treatment beds used to make bricks; harvested biomass from treatment cells may composted as compost, or could sold directly as animal feed.

Tangible Benefits of Agricultural and Irrigation Projects: Increased agricultural production**,** quality improvement**,** cost reduction.

Intangible Benefits: ***These are benefits created outside the project itself****: Creation of new job opportunities, better human health, reduced incidence of water borne diseases, environmental protection.*

The success of this technique will yield the design criteria for construction of replicate at other drains. This will also allow using In-Stream wetlands for the reclamation of drainage water for irrigation, treatment of sewage water for decentralized communities. Finally, the In-Stream Wetland demonstrates an innovative low-cost approach for improving water quality that will lead Egypt to self-sufficiency in this kind of biotechnology.

Recommendations

The following topics considered important for future investigation:

- The government should develop policy measures and legislation to ensure the sustainable use of wetlands, recognizing best multicultural practices in both public and private sectors, and for planning for the conservation and development of wetlands that should undertake at the appropriate international, national and local levels.
- In-Stream Wetland could replicated to cover larger percentage of Egyptian areas, taking into consideration the capital costs of the project and its running costs.
- The proposed Passive In-Stream Wetland requires at least a bimonthly removal of sludge deposition from the sediment trap. A reduction of the efficiency of the system might take place, if the depositions not regularly removed. Sediments can used for the production of bricks, ceramics, etc., and growing edges of plants free from toxic elements used as fodder or fuel.
- A full pilot scale In-Stream Wetland treatment system should designed under Egyptian conditions. In order to minimize the failure risk, three elements should considered: (i) public acceptance and participation, (ii) dredging management of sediments, and (iii) vegetation control.
- In order to ensure the sustainable utilization and management of wetlands, it is essential that the planning process involves and empowers local communities and indigenous people in ways that mean that their livelihood can improved, whilst maintaining wetlands and their values for the benefit of present and future generations.
- One of the most important factors, which lead to success of the application of this new wastewater treatment technique, is to establish an effective public awareness program. This program should target the treated water use guidelines for the villagers and residents of El-Bahwo Drain catchments.

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