International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 08, August-2020

Analyzing the Evolution of Environmental Impacts due to Fish Farms Expansion

A Pilot Study in The Northern Nile Delta

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Abstract—**Transforming the agricultural lands into fish farms leads to several negative environmental impacts. This research paper aims at analyzing the environmental impacts of the privately-operated fish farms expansion in two study areas in the North of the Nile Delta of Egypt occurred during the period (2014-2018). The analysis considered fish farms' water requirements, consumption, effluent disposal, drainage rates, drainage water quality, groundwater heads and salinity and socio-economic aspects. Multispectral Landsat-8 images was used to determine the change in fish farms area between 2014 and 2018 the Principal Component Analysis (PCA) was conducted before classifying the images. The classified images combined with actual measurements and scientific analysis was used. This research focused on a pilot area about 637,755 feddans (acers), located in "the Northern parts of El-Gharbia Drain Catchment and the Southern parts of Lake Burullus" in Egypt. The overall increase in privately-operated fish farms area was estimated at 7.42% in the study areas during the period (2014-2018), equivalent to 18,419 feddans. The estimated increase in water requirements for the fish farms was 17,803 m^3/feddans/year, equivalent to 82.0 million m^3/year in the study areas during (2014-2018). Ratio of water requirements (fish vs. crops) in the study areas was almost double. The increase in disposed effluent from the privately-operated fish farms including high biological and nutrients loads to either nearby drains or lakes was 5,756 m^3/feddans/year, equivalent to about 26.5 million m^3/year from the study areas during (2014-2018). Nevertheless, the resultant was a decrease in drainage rates in the study areas by more than 30%, that decrease could be attributed to the increasing unofficial reuse of drainage water for irrigating agricultural crops as well as the expanded fish farms activities in the study areas. Consequently, high water pollution concentrations were monitored in El-Gharbia Drain during the period (2014-2018), some parameters exceeded the Environmental Law limits by several folds. The privately-operated fish farms expansion in the study areas contributed to the deterioration of water quality of the final reaches of El-Gharbia Drain as a result of disposing fish farms effluents. Consequently, the privately-operated fish farms in the Northern Nile Delta inherit various environmental impacts thus should be strictly banned and/or controlled as one of the rigorous actions to alleviate water pollution in Egypt.**

Keywords— Impacts of fish farms (Aquaculture), Drainage rates, Agricultural drainage water quality, Groundwater heads and salinity, Economic and social impacts, El-Gharbia Drain, Northern Nile Delta of Egypt, PCA, Change Detection.

I. INTRODUCTION

At a global glance, the main fish farms (Aquaculture) producers in 2016 were: China (49.2 million tons), India (5.7 million tons), Indonesia (4.9 million tons), Viet Nam (3.6 million tons), Bangladesh (2.2 million tons), Egypt (1.4 million tons), Norway (1.3 million tons), Chile and Myanmar (1.0 million tons) and Thailand (0.96 million tons). The top ten producers collectively contributed 89.3% to the world production by quantity in 2016 [1]. Fish farms, if are well-designed, constructed and operated based on the specified standards and assigned safe-guards are safe and have no environmental risks. However, Egyptian-Dutch Advisory Panel on Water Management (APP) proved that the random privately-designed and poorly operated local fish farms imbed several environmental risks and hazards [2].

A. Fish farming in Egypt and worldwide

Fish farming, if well-designed, operated and managed is beneficial. Constructing local illegal fish farms without proper planning nor operating contributes to environmental degradation [3]. In Egypt, there is high competition on water resource among the various sectors (municipalities, irrigation, electricity, industry, navigation and tourism). Furthermore, the freshwater resources of Egypt are limited and consequently comes to be a key national challenge. The escalating population and water pollution increase in Egypt are the main threatening factors. Fulfilling the current and future water demand of the Egyptians are on the top of the agenda of the Egyptian leaders and policy makers. Thus, they strive for identifying the viable and suitable national/regional water strategies and implementation actions that should be applied for future water sustainability and food security for its future generations. Several technical studies and official reports assured that fish farming, if integrated with agricultural cropping cycles, well-designed, operated and managed, is beneficial, from the economic and social perspectives and has no negative environmental impacts. On the contrary, converting agricultural plots into fish farms without good design, operation nor permits is prohibited according to the Egyptian Farmland, Fishery, Marine Wildlife and Aquaculture Conservation Law (Law No. 124 for the Year 1983), due to its higher water consumption and negative environmental impacts. One of those key actions according to the Egyptian water resources strategy is limiting water pollution resulting from the expansion of the privately-operated fish farms, especially in the Northern parts of the Nile Delta, which is the focus of this research paper.

The traditional fish farm systems consist of constructed earthen ponds with size of about one feddan (acre) each, with higher dykes allowing water depths to reach (0.75–1.6) meters with average of 1.0 m. It is noted that fish feeding allows for growth of Biological Oxygen Demand (BOD) in ponds water. Sanyu (2016) mentioned that ponds have a rate of water renewal to compensate for oxygen shortage, evaporation and seepage. That rate is about (0.4-0.8)% of pond volume equivalent per day, occurs periodically through the year using fresh water, agricultural reused drainage water with reasonable quality or nearby shallow brackish groundwater with reasonable salinity less than 5000 ppm (part per million) [4]. The total water requirements for fish farms operation is the sum of water required to initially fill the ponds, the daily renewal water, the evaporation water from the free surface of the ponds and the quantity of seepage water from the bottom of the pond to the soil. Usually the disposed water from fish farms is within half the remaining water in the pond as the rest is fish biomass consumption [5].

According to Sallam (2017), in El-Tina Plain in North Sainai of Egypt, land reclamation and soil salts leaching was done concurrently with operation of fish farms. Each fish farming cycle was 9 months (270 days). Renewal water was about 6% of pond capacity per day. Evaporation rate in El-Tina Plain (semi-arid region ranges between 0.4 to 0.8 cm/day), was considered 0.6 cm/day. Seepage water depended on soil type and compaction ratio of the ponds' side banks. Therefore, seepage rate of heavy clay soil was assumed as 0.5 cm/day [6]. Estimation of total water consumption for reclamation/leaching and operation of one feddan of fish farms in El-Tina Plain using low saline water was large (about 128,058 m^3/feddan/cycle), equivalent to about 474 m^3/day/feddan. That leaching process did not last for long period. The required water for soil leaching and fish farms operation in El-Tina Plain consumed about 12 times of the annual agriculture crops water requirements (two successive crops per year, each consumes about 4500-5000 m^3/feddan) [7]. David Molden et al. (2009) proved that, the annual average water requirement for governmental fish farm operation in Egypt was in the range of (10,806-9,284) m^3/feddan/cycle [8].

It was proven also by Sallam (2017) that soil leaching process in El-Tina Plain in North Sainai reduced soil salinity at the beginning, however due to the random operation of fish farms by local inhabitants and small business groups, it was found that soil salinity of the surface layer within the fish ponds increased again by about 20% in relation to its value before fish farms operation. However, for the lower soil layers, soil salinity increases by about 95%. That phenomenon of increased soil salinity after operation of fish farms used to happen in all heavy soils, as well as because of the fish food remainders, residuals and fish faeces decomposition in the pond water. Ali et al. (2006) proved that the resultant effluents from fish farms used to include nutrients, phosphorous and biological loads that might be used as agricultural fertilizers, yet if mixed with high concentrations to the recipient surface drainage water and/or shallow groundwater might cause significant pollution [9].

B. Fish farm design

A study prepared by APP (2010) inferred that the total area classified as fish farms in the Northern Nile Delta of Egypt amounts to approximately 248,000 feddan. Cultivation season is from (April 1–November 1) meaning (214 days), Flushing/renewal water could amount to some 20% of the pond storage per month, which would lead to a maximum additional water requirement of around 6,000 m^3/feddan over the fish cultivation season, evaporation from open water is in the amount of 0.6 cm/day , no rainfall contribution during the fish cultivation season (arid and semi-arid zone), pond bottom at 0.5 m below soil surface and a water depth is about 1.0 m, resistance of puddled bottom layer and clay cap resistance in association with the fish food residuals and fish faeces make seepage from the bottom soil of the fish pond almost nil, few months after operation. As a reflection, the estimation of APP with such assumptions seemed to be conservative to some extent regarding the overall water consumption volume in fish farms per feddan per cycle [2].

Abdel-Fattah et al. (2015) informed that about 2.38 million feddans (~26% of total irrigated agriculture lands in Egypt which is about 9.1 million feddans during the study period) is infested with salinity problems among other water pollutants due to practices depending on reuse of agricultural drainage water and saline shallow groundwater. Also, it was mentioned that, the phenomenon of increasing the privately-operated inland fish farms (illegal and poorly managed) constituted a threat to the Egyptian drainage network and Northern Lakes' water quality, as those fish farms' effluents disposal included high biological and nutrients loads. It is also known that there are unfortunately additional microbial and heavy metals spills from villages and small industrial facilities to some drainage water network in Egypt [10].

Fish farms activities are permitted by the Egyptian Government policy as far the appropriate safeguards are fulfilled. Most of the governmental (official) and local fish farming are located in the Northern parts of the Nile Delta regions and in Sinai. The illegal expansion of privately-operated fish farms increased in Egypt two decades ago. Construction of fish farms is permitted by the Egyptian Environmental Laws in lands that are unsuitable for any other beneficial agricultural activities. The Egyptian General Authorities for Fisheries Resources Development (GAFRD) is responsible for giving licenses to construct safe fish farms. Increased attention of the relevant governmental authorities in Egypt has been given to: impose rigorous regulatory safeguards for fish farms operation, improve drainage water efficiently and expand the construction of drainage water treatment plans, so as to sustain human health, healthy crops production and environmental quality [11].

Although converting agricultural plots into fish farms is prohibited according to the Egyptian Law (No. 124 for the Year 1983). It was noticed that the privately-operated fish farms had increased in the Northern parts of the Nile Delta during the last two decades, due to its much higher profitability if compared to the traditional agricultural crops. The total area of official fish farms in Egypt is estimated at 283,000 feddans, which represent about 3.1% of the total area of agricultural land (during 2014-2015). Almost an equal area is used as private non-official fish farms activities [4]. Each official fish farm consists of large number of fish ponds (underground impoundments). Fish ponds vary in size from 1 to 25 feddans. The proper spatial planning of the official fish farms zoning, site selection and design of ponds considers the social, economic, environmental and governance objectives of sustainable development make it of great benefits and environmentally safe [12]. However, the production of official fish farms is low due to the conservative quality measures, if compared to the privately-operated fish farms. The main reasons of the privately-operated fish farms expansion are the easy, cheap, random and quick construction, possible usage of saline soil and poor-quality water in the proximity of the fish farms (drainage water and/or brackish groundwater) and thus speedy growth of fish due to nutrients exist in the polluted used water leading to high and quick profitability [4].

Regarding fish water consumption, Boyd & Tucker (1998) informed that most fish farms species' biomass is about 75% water. Thus, one ton of biomass contains about 0.70 to 0.75 m^3 of water. According to Boyd (1982) and Yoo & Boyd (1992), seepage to the shallow groundwater aquifer and evaporation from the free fish ponds surface are other elements needed to estimate amount of effluent disposal in the water balance equation of the fish farms [14][15]. APP (2010) mentioned that fish biomass growth includes 75% of the fish's weight as water, meaning that fish growth biomass should be among water consumption components in fish farms water balance equation.

C. Information technology tools used

Remote sensing is proven to be a powerful tool for monitoring changes occur in the physical earth features, either natural or human-induced activities. To detect and monitor such spatial and temporal changes in considerably large areas, multi-temporal satellite imageries can be used. Huang & Fipps (2006) described the Landsat satellite multi-spectral imageries as a promising technique, for example, used for urbanization analysis and for identifying area of irrigated crops plots [16]. In addition, the Geographic Information Systems (GIS) has shown great potential in supporting the production of detailed spatial and temporal mapping analysis.

Landsat satellite imageries used in this research paper have medium spatial resolution (30m) compared to other higher spatial resolution satellite images. It is suitable for detecting changes in relatively large areas especially agricultural lands. To perform change detection using remote sensing, the region has to be defined geographically accurately to avoid misleading results. Collecting ground truth is required for results verification. Additionally, the daytime/month was determined based on the phenomenon that required to be sensed. To detect the changes in any region using satellite imageries, either the original imageries should be compared based on the brightness values of its pixels in each band, or the classified imageries are compared [17]. Detecting the changes through comparing the classified imageries is more appropriate to avoid the radiometric differences in the multi-temporal imageries.

The research question which was answered in this paper is how to conduct a comparative analysis of the environmental impacts due to the expansion of the privately-operated fish farms in two pilot study areas in Egypt during the period (2014-2018), since increasing rate of such local illegal fish farms was noticed in that period. That period was also selected according to the availability of latest imageries and the drainage water quantities and qualities data. The analysis tackled several environmental aspects: water requirements, water consumption and disposal, catchment drainage rates, drainage water quality, groundwater heads and salinity and associated socio-economic aspects in the selected study areas. The novelty and originality of this research paper are using a new combination (using GIS and RS techniques, processing actual measurements and conducting scientific comparisons and analysis) in investigating, quantifying and understanding the evolution of the phenomenon of speedy expansion of local and illegal fish farms in the selected study areas, which was not done before in this field through this methodological approach.

II. MATERIALS AND METHODS

Most of the irrigation water for the Middle Nile Delta is provided by Monofy Rayah at El-Qanater and Abase Rayah at Zefta then Bahr Tira, where the Nile water is checked up with barrages. Few supplemental intakes are used for the Middle Nile Delta. The Middle Nile Delta is divided into a number of main drainage catchments, as shown in Fig. 1. El-Gharbia Main Drain (EGD) is located in the central part of the Middle Nile Delta. EGD system discharges annually about 707 million m^3 to the sea with an average salinity of 3029 ppm. The average annual total quantity of official reuse of drainage water for agricultural crops from EGD system is about 1.516 billion m^3. That is in addition to other quantities being extracted from EGD feeders by farmers as unofficial reuse to compensate the deficit in irrigating their agricultural crops [18][19].

Starting 2012 onward, increasing pace of constructing the privately-operated fish farms has been detected in the Northern Nile Delta. The expansion in the privately-operated fish farms in that area might be attributed to the shortage of fresh water needed for irrigating crops, low crop productivity due to soil salinity, fish profitability and possible poor control of local authority led to illegal expansion of private fish farms.

A. The two study areas

This research focuses on two pilot study areas in the northern part of Nile Delta in Egypt as illustrated in Fig. 1. The first one is the Northern part of El-Gharbia Drain Catchment (NEGD) between latitudes 30° 44'N - 31° 30'N and longitudes 30° 53'E – 31° 20'E with area about 485,000 feddans. The second is in the Southern part of the Lake Burullus (SLB) between latitudes 31° 17'N - 31° 32'N and longitudes 30° 35'E – 31° 09'E with area about 152,755 feddans (total study area is 637,755 feddans).

B. Methodology and assumptions

Five relevant research aspects were included in this research paper to fulfill the target of analyzing the evolution of environmental impacts due to fish farms expansion in the study areas. Those aspects include changes in: 1) surface area, 2) catchment drainage rates, 3) surface water quality, 4) groundwater heads and salinity, and 5) economic and social conditions. Determining the fish farms area is essential to estimate the water requirements of fish farms. Knowing the drainage rate is necessary to estimate the disposed effluent

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 08, August-2020

from fish farms in the study areas. As fish farm activities affect both surface and groundwater quantities and qualities, therefore this research paper focused on both drainage water and shallow groundwater. The socio-economic aspects are important as fish farm business is of high profitability, so that banning or controlling it would have negative impacts on families using it for their livelihood and life sustenance.

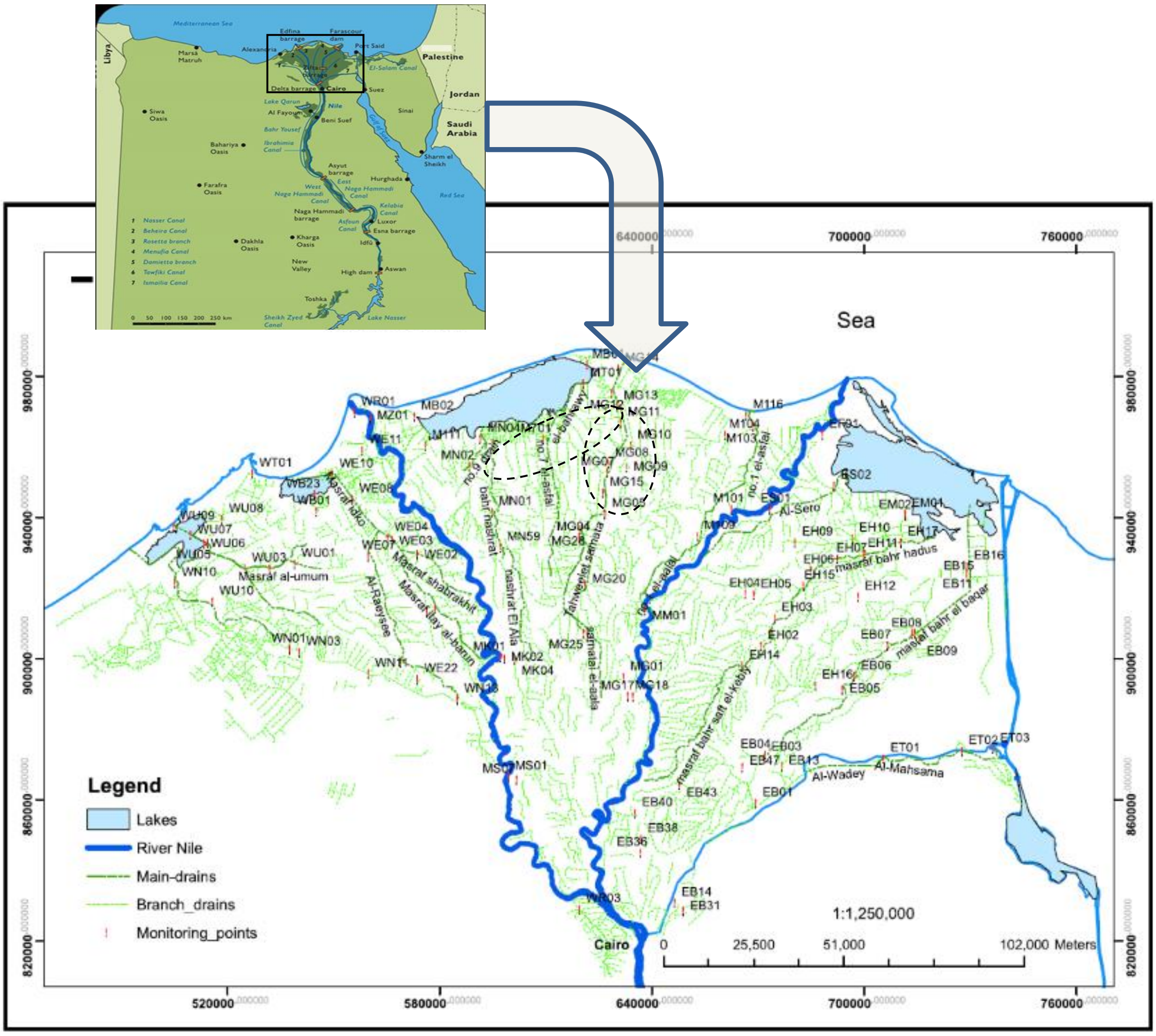


Fig. 1. The two study areas (NEGD and SLB) in Egypt (Source DRI GIS-Database)

Multispectral Landsat-8 imageries were processed, where the principal component analysis (PCA) was conducted to the two dates' images. Then the Landsat imageries were classified and compared. The research period (2014-2018) was selected according to the availability and quality of Landsat-8 imageries as well as drainage water quantity and quality availability.

Estimating the expansion of fish farms during the period (2014-2018) in the study areas was accomplished through Landsat-8 satellite imageries analysis and classification, followed by identification of the fish farms in the images of the two dates. Then the change in land cover (especially the fish farms) were detected and areas were calculated. Verification was made through field checks. The actual measured catchment drainage rates, surface water quality parameters and groundwater heads and salinity status were obtained from authenticated official sources (databases of the specialized research institutions under the National Water Research Center of Egypt) where the three authors belong to.

The following are a set of assumptions used in this research paper:

- The aim is conducting a comparative analysis of the environmental impacts between years (2014) and (2018) rather than environmental impacts assessment. Therefore, the changes and/or differences in estimation of fish farms area, catchment drainage rates, water quality and groundwater status were the focus of this research during the period (2014-2018) not the absolute values nor numbers.
- Expansion of fish farms in the study areas (NEGD and SLB) was attributed to the increasing rate of constructing the privately-operated fish farms by local communities, small business groups and inhabitants. The reason is because the government authorities

emphasized that there were no official fish farms constructed in the study areas during the period (2014-2018).

- Based on the literature review, relevant technical studies, experiences and the various stated characteristics of fish farms design in the Nile Delta of Egypt, the authors determined the characteristics of a typical unit fish pond (one feddan) as shown in TABLE I.
- It was considered that fish biomass amounts to about 50% of the remaining pond water as per the used water balance equation.

- The normal practice followed in villages and local communities in the North Nile Delta of Egypt is that water requirements for their fish farms are pumped from the nearby drainage network and/or abstracted from the shallow groundwater aquifers in the fish farms areas. Then, the effluent discharge is disposed to the closest drain, pond, wetland or lake.

Water balance equation used for each fish pond (unit pond area is 1.0 feddan) is as follows (units used are m^3/feddan/cycle):

- *Volume of the pond + Volume of renewal water = Water equivalent to fish biomass + Evaporation + Seepage + Effluent discharge*

The calculations and analysis in this research paper were conducted based on assumptions, scientific concepts, critical review of literature, land truthing, previous relevant technical studies in similar conditions in Egypt and in other countries as presented in this research paper, as shown above. TABLE I presents accordingly the calculations of fish pond components according to the water balance equation.

III. GIS/RS DATA DESCRIPTION AND PROCESSING

Fig. 2 illustrates the entire Nile Delta Region where four Landsat-8 satellite imageries were assembled. Fortunately, most of the study areas considered in this research paper appears in one Landsat satellite imagery (Path 177, Row 38), covering around 80% of EGD catchment area and the entire area of SLB.

One of the techniques used to analyze the multispectral remote sensing data that has proven to be of value, was the principal components analysis (PCA). In which, the original remotely sensed datasets (bands of satellite imageries) are transferred to a smaller set that is easier in interpretation. Those imageries were uncorrelated and represent most of the information shown in the original datasets [20]. The workflow of processing change detection used in this research is illustrated in Fig. 3. The details of this procedure is as following:

Two Landsat-8 imageries (Path 177, Row 38) representing the two years of comparison (2014 and 2018) were downloaded, from the U.S. Geological Survey (USGS) web site, to determine the changes in fish farms areas expansion within the two study areas “NEGD and SLB”. Since Landsat imageries contain relatively large number of bands, only bands that gave large reparability between classes were considered. However, such agricultural lands needed due attention to distinguish fish farms from the other unclear water bodies (such as rice fields or uncultivated ponds and wetlands). The downloaded Landsat-8 imageries were selected to be acquired within the month of March (2014 and 2018), when the rice crop is not in the field (Rice usually is cultivated in early May and harvested in August every year). That is to avoid confusion in misclassification between rice fields and fish farms, since both rice fields and fish farms are covered by water. The swamp/ponds areas were also excluded based on its identified footprint. Fig. 4 shows the two Landsat-8 imageries for years (2014 and 2018), in false color (R: B4, G: B5, and B: B2).

The second step was rectifying the satellite imageries, where both imageries had to be geometrically corrected to ensure that the study areas are correctly spatially defined on both imageries. In this research paper, no ground control points were available, therefore registering one image to the other was the choice to geometrically correct the imageries.

TABLE I. ASSUMED CHARACTERISTICS OF ONE-UNIT FISH POND (ONE FEDDAN) OF THE PRIVATELY-OPERATED FISH FARMS IN THE STUDY AREAS

Pond Size	1.0	feddan	*Equivalent to 4200 m^2*
Depth	1.2	m	*More than the average governmental official fish farms depth in Egypt (1.0 m)*
Renewal/flushing water	0.6 %	per day	*Relevant estimated ration*
Cycle	214	days	*(7 months) the rest of the year days are for cleaning and preparation*
Evaporation rate	0.6	cm/day	*Relevant estimated value*
Seepage	0.1	cm/day	*Relevant estimated value*
Volume of the pond	***5040***	***m^3***	*1.2 times more than the governmental official fish pond volume (4200 m^3)*
V. of renewal water (214 days)	***6471***	***m^3***	*Compensation for evaporation and for maintaining water quality*
V. of evaporation (214 days)	***5393***	***m^3***	*Annual average according to the Egyptian climatic conditions*
V. of seepage (214 days)	***899***	***m^3***	*Annual average according to the study areas’ soil classification and conditions*

Note: Renewal water is flowing water on regular basis needed to renew the oxygen in the pond water so that periodic flushing is necessary in an average rate of 0.6% the volume of the pond per day.

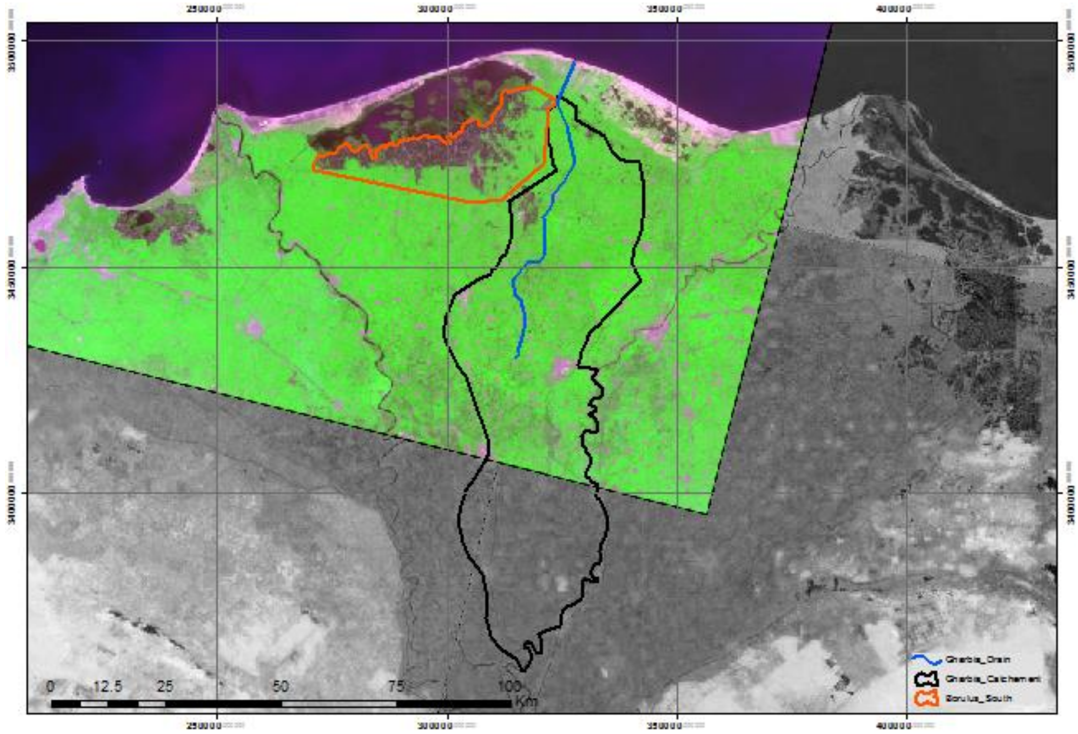


Fig. 2. Landsat-8 satellite imagery of the Nile Delta showing the boundaries of the study areas (NEGD and SLB) - *boundaries in black and red colors*

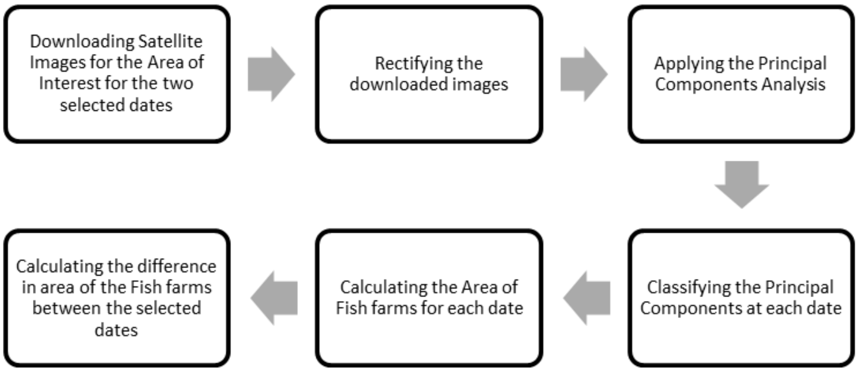
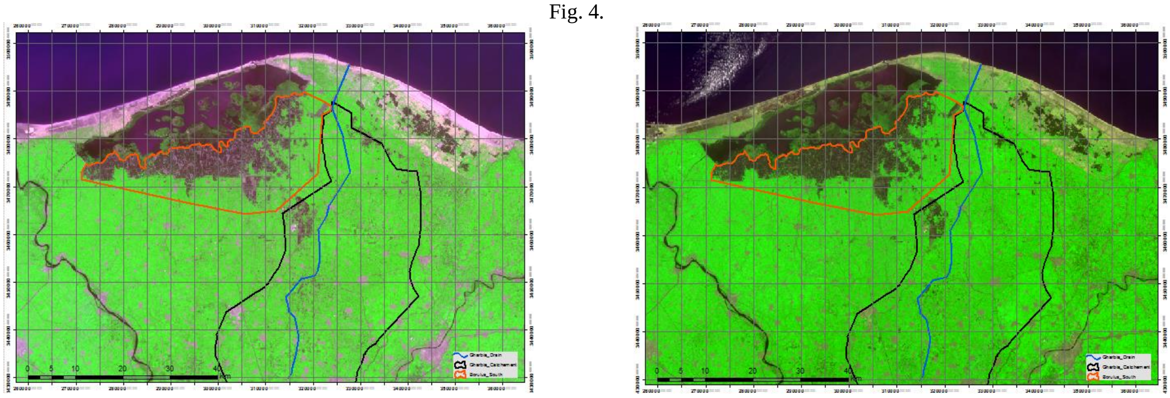


Fig. 3. Procedure of Using Remote Sensing in Change Detection of Fish farms

Fig. 4.



(a) (b)

Fig. 5. Landsat-8 Imageries in a) March 2014 and b) March 2018, boundaries in black and red colors represent the study areas (NEGD in black and SLB in red)

The downloaded imageries were geo-referenced; hence, the spatial location of both imageries was compared. It was found that both imageries were coinciding, and no further registration was required. Nevertheless, twenty well distributed points were selected inland on both imageries to act as check ones. By comparing the positions of the twenty points, it was found that the total root means square error (RMSE) is about 4.6 m.

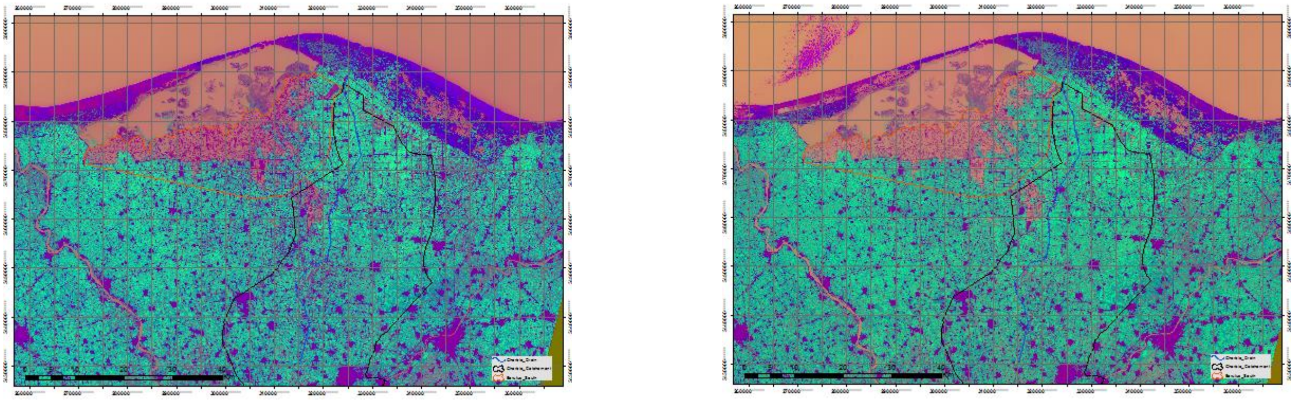
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 08, August-2020

The third step was applying the principal components analysis where the important information of the Landsat-8 bands concentrated on the first three uncorrelated bands. Fig. 5 illustrates the PCA images for the 2014 and 2018.

For change detection processing, when the imageries are classified first then the classification results are compared, no radiometric correction is required [17].therefore in the fourth step, the principal components imageries were classified using the “Maximum Likelihood Classification Algorithm” for both emageries of the years 2014 and 2018. The Maximum Likelihood Classifier is a supervised classification technique that intensively used with the multi-spectral remote sensing data. In this algorithm the probability of each pixel to be belonging to each of the predefined classes is calculated. Then the pixel is assigned to the class of the heights probability [17]. The classification results within the study areas (NEGD and SLB) are illustrated in Fig. 6.

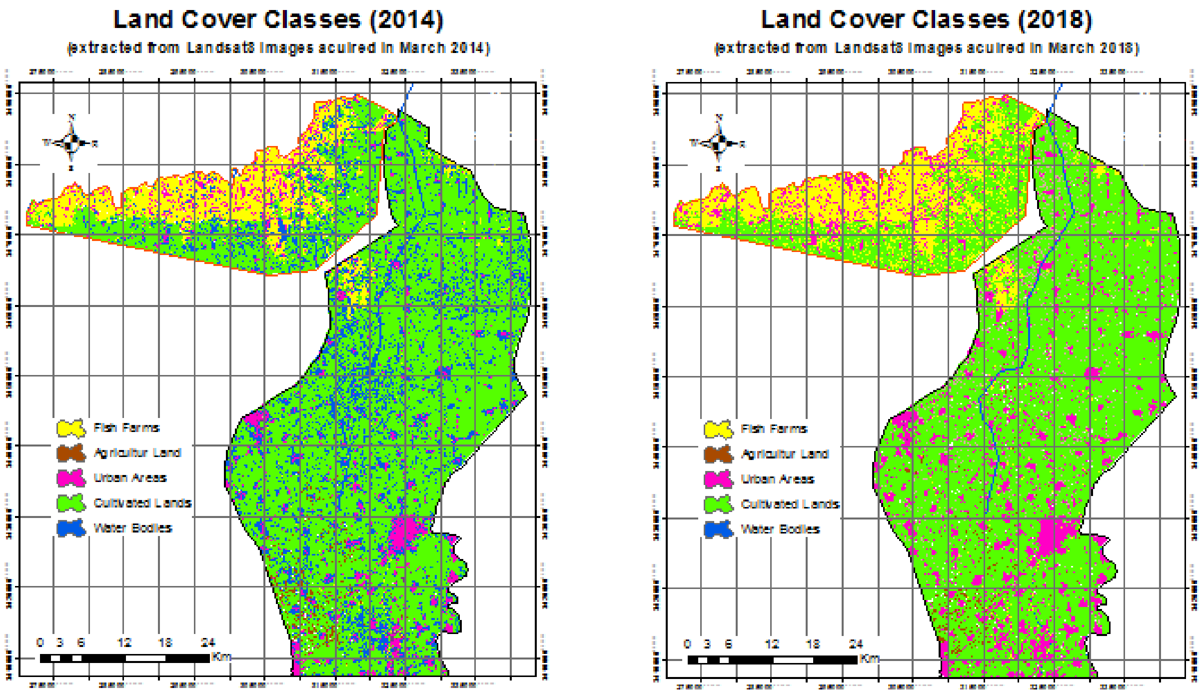
A number of locations that were classified as fish farms were selected to be used as ground truthing for verifying the classification results. The coordinates of the selected fish farms were determined from the satellite images. The ground truth was collected by technicians from the DRI, the locations were identified using the Global Positioning System (GPS) in association with those locations coordinates.

The privately-operated fish farms were found in the proper locations as in the imageries with 95% accuracy. In addition, the identified fish farms were found inside the drainage catchments of Segaaya pump station (P.S.) called (MG02), Mahallet Ruh P.S. called (MG03), Sematay P.S. called (MG04), P.S. No 5 called (MG05) and P.S. No 6 called (MG07) within EGD catchment. In the fifth step, the area of the fish farms in both imageries were calculated. And the difference in areas between years 2014 and 2018 for the two study areas were determined and shown in TABLE II.



(a) (b)

Fig. 6. Processing imageries – principle components of Landsat-8 imageries: a) year 2014 and b) year 2018 in the study areas



(a) (b)

Fig. 7. Processing of imageries - classification results of Landsat-8 imageries: a) year 2014 and b) year 2018 in the study areas

IV. RESULTS AND DISCUSSIONS

A. *Expansion in fish farms areas*

One of the objectives of this research paper is to determine the change in area of fish farms during the period (2014-2018). Since the GAFRD reported that there were no additional official fish farms constructed in the two study areas (NEGD and SLB) during that period, the expansion in fish farms was certainly due to the construction of the privately-operated fish farms, without knowledge of local authorities.

Based on the analysis (change detection process) of the Landsat-8 satelite imageries, it was found that fish farms area had incrased from about 248,194 feddans to about 266,613 feddans during the period (2014 to 2018), as illustrated in TABLE II. Expansion in the privately-operated fish farms area during the period (2014-2018) was recorded along those four years in NEGD about +7,508 feddans (27.11%) and in SLB about +10,911 feddans (4.95%) of the study areas. The overall increase in fish farms area was estimated about 7.42% of the study areas during the period (2014-2018), which is equivalent to about +18,419 feddans.

TABLE II. ESTIMATED EXPANSION IN AREAS OF THE PRIVATELY-OPERATED FISH FARMS – CHANGES DURING (2014-2018) IN THE STUDY AREAS

Year	Privately-operated Fish Farms Areas (in feddans)	
	NEGD	SLB
2014	27,698	220,496
2018	35,206	231,407
Expansion (feddans)	+7,508	+10,911
Expansion (%)	+27.11	+4.95

B. *Estimation of water requirements of the privately-operated fish farms*

Total annual water requirements for one feddan of the privately-operated fish farms in the study areas was estimated about 17,803 m^3/feddan/cycle (year), based on calculations in TABLE I. That amount is equivalent to about 82 million m^3/year (328 million m^3 in four years 2014 till 2018), based on TABLE II. That amount was pumped by the private fish farms operators from the nearby sub-drains of EGD as well as abstracted from the shallow groundwater aquifer in the study areas. TABLE III shows the details of increase in water requirements for the privately-operated fish farms expansion in the study areas during the period (2014-2018).

TABLE III. ESTIMATED TOTAL ANNUAL INCREASE IN WATER REQUIREMENTS IN THE PRIVATELY-OPERATED FISH FARMS EXPANSION IN THE STUDY AREAS DURING THE PERIOD (2014-2018)

	NEGD	SLB
Expansion in Fish Farms Area (in feddans) during (2014-2018)	7,508	10,911
Water Requirements in Fish Farms (million m^3/year)	33.5	48.5
Total increase in water requirements for fish farms expansion in the study areas was 82 million m^3/year, equivalent to 328 million m^3 in four years (2014-2018)		

The average crop water requirement per season in Egypt is about 5000 m^3, while there is a rotation of two sets of main crops in Egypt (Summer crops and winter crops). Therefore, total crop water requirements in Egypt per year is about 10,000 m^3/feddan. Accordingly, ratio of crop water requirements to fish water requirements in the study areas during the study period was about (1:1.8), almost double.

The fish biomass was assumed about 50% of the remaining pond volume of water which was about 5700 to 5800 m^3/feddan/year. According to the water balance equation used, total effluent discharge from the privately operated fish farms was estimated about 5,756 m^3/feddan/year during the period (2014-2018), equivalent to about 26.5 million m^3/year (106 million m^3 in four years). That significant amount of effluent with high pollution loads (biological, nutrients and microbial) used to be disposed into the nearby water bodies causing pollution problems possibly affecting all surrounding activities (human, agricultural crops, cattle and sheep production and fish production in the neighborhoods of the recipient drains and lakes). El-Gammal in (2016) affirmed that the most likely reasons of water quality deterioration in the last reaches of El-Gharbia Drain were excessive usage of draiage water to suplement the shortage in fresh irrigation water and in addition, the improper privately-operated fish farming practices [21]

C. *Changes in catchment drainage rates within the study areas during (2014-2018)*

The drainage rates (DR) is defined as sum of agricultural drainage water (from crops and fish farms), sewage effluents and industrial effluents of a catchment to a certain point on a drain. The DRs of the drainage network in Egypt used to be measured and calculated by DRI of the National Water Research Center of Egypt. The drainage rates estimation is based on the multiplication of catchment area served by each drainage pump station (P.S.) within the study areas by its measured discharge (in mm/day). Based on the actual geographic layout of the study areas, the authors realized that the NEGD catchment could be represented by three pump stations: Segaaya P.S. (MG02), Mahallet Ruh P.S. (MG03) and Sematay P.S. (MG04), whereas SLB catchment could be represented by two pump stations: P.S. No 5 (MG05) and P.S. No 6 (MG07). All five pump stations are located inside the study areas (NEGD and SLB). TABLE IV presents the details of estimating the annual change in drainage rates resulting from all human activities in the study areas during the period (2014-2018).

Accordingly, it was estimated that drainage rate decreased in NEGD by (-0.03) mm/day, while decreased by (-0.11) mm/day in SLB during the period (2014-2018). The reuse of drainage water in agriculture (due to shortage in fresh irrigation water) as well as the operation of the private fish farms in the study areas consumed large amount of El-Gharbia Drain water causing that decrease in drainage rates and consequently drainage quantities in the study areas (this reduction was estimated in average as 41.2 million m^3/year) during the period (2014-2018).

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TABLE IV. ESTIMATED AVERAGE ANNUAL DECREASE IN DRAINAGE RATES FROM THE STUDY AREAS DURING THE PERIOD (2014-2018) IN MM/DAY

Study Areas	**2014/2015**			**2015/2016**			**2016/2017**		
NEGD	MG02	Segaaya P.S.	2.04	MG02	Segaaya P.S.	2.28	MG02	Segaaya P.S.	1.39
	MG03	Mahallet Ruh P.S.	0.58	MG03	Mahallet Ruh P.S.	0.66	MG03	Mahallet Ruh P.S.	0.60
	MG04	Sematay P.S.	3.43	MG04	Sematay P.S.	3.77	MG04	Sematay P.S.	3.96
SLB	MG05	P.S. No 5	1.89	MG05	P.S. No 5	1.62	MG05	P.S. No 5	1.55
	MG07	P.S. No 6	2.67	MG07	P.S. No 6	2.90	MG07	P.S. No 6	2.79
Drainage rate decreased in NEGD by (mm/day)									**-0.03**
Drainage rate decreased in SLB by (mm/day)									**-0.11**

The available measured historical average annual catchment drainage rates during the period (1984-1990) were collected from the DRI database to illustrate evolution of annual drainage rates within the study areas. Fig. 7 presents the analysis done in this research on the drainage rates data sets showing an overview of the changes in drainage rates within the study areas during the period (1984-1990) compared to the study period (2014-2018). That analysis showed annual decreasing trend of drainage rates. It was found that continuous reduction in drainage rates by more than 30% if the two periods are compared. This could be attributed to the expansion in agriculture activities and unofficial reuse of drainage water in the study areas, which agreed with the authors' findings in this research paper.

Same findings were also emphasized by DRI (2016). It added that portion of the drainage water flowing to Lake Burullus from the study areas (through El-Gharbia Drain) decreased during the yeas (1984 till 2018). That could be attributed to the expansion in unofficial reuse of drainage water for irrigating agricultural crops as well as to fish farms operation. However, DRI also proved that the annual average drainage water flowing into Lake Burullus from all its feeders increased from (0.53 to 0.71) billion m3/year during the same period.

D. Changes in water quality of agricultural drainage water within the study areas during the period (2014-2018)

Observing the drainage water quality status in the study areas based on the DRI Databases during the years (1984 till 2018), it was noticed that:

Salinity of the drainage water flowing to Lake Burullus from El-Gharbia Drain increased during (1984 till 2012), yet continued to increase with higher pace after that till 2014 and afterwards. Salt load of the drainage water flowing into Lake Burullus from El-Gharbia Drain increased from (1.5 to 2.1) million ton/year during the period (2014-2018). That finding was evident of multiple reuses of drainage water practice by farmers for securing irrigation water for their crops in the study areas.

In general, majority of the recorded water pollutants in El-Gharbia Drain were high (nutrients, biological, microbial and heavy metals constituents), beyond the environmental law "Protection of River Nile & its Tributaries from Pollution" number 48 for the year 1982 (modified in Sep., 2018), illegal fish farms activities and disposal into the small drains flowing into El-Gharbia Drain and Lake Burullus could be direct reason for those high recorded water pollutants.

A more in-depth overview of the average annual water quality parameters values in the drainage water within the study areas due to expansion in reuse of drainage water as well as in privately-operated fish farms in NEGD and SLB during years (2014, 2016 and 2018) are shown in TABLE V.

It is obvious from TABLE V that high pollution concentrations were detected in El-Gharbia Drain during the period (2014-2018). The privately-operated farms expansion in the study areas contributed significantly to deteriorating water quality of the surface drainage water during the study period as a result of: 1) reusing drainage water multiple times and 2) disposing fish farms effluents with high pollution of biological and nutrients loads. Previous studies concurred with those findings, as they agreed that intensive fish farming can lead to higher proportion of organic matters and fertilizers residuals such as ammonia, nitrite and phosphate compounds as well as high proportion of heavy elements in the water and sediments [22, 23, 24, 25, 26, 27, 28]. Abdel Meguid (1998 and 1999) mentioned that as a consequence of having fish farms activities, its nutrients effluent caused increase in phosphates and nitrates concentrations in the drainage water, probably causing spread of algae of various kinds, as well as formation of a suitable environment for the growth and spread of many diseases that can lead to health problems for the consumers (either in direct and/or in-direct contacts) [29, 30].

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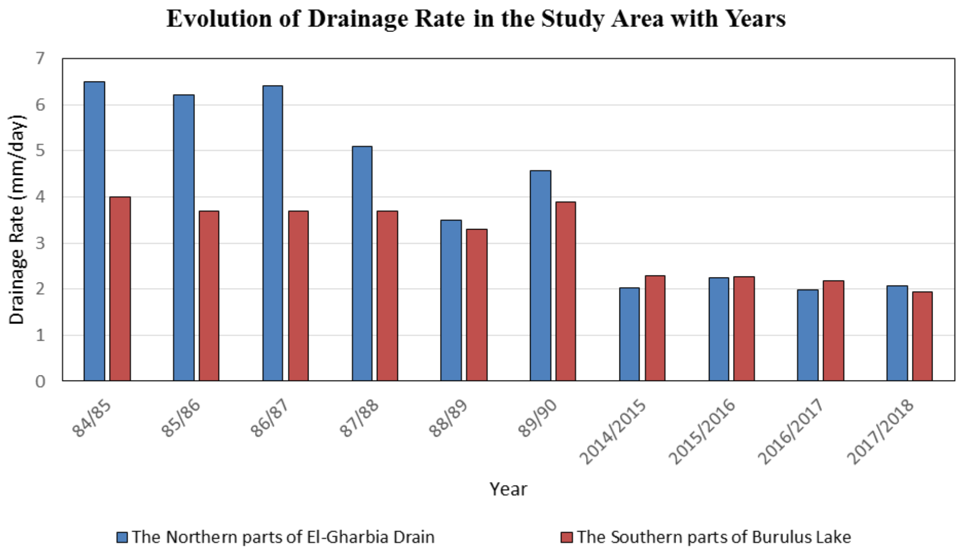

Fig. 8. Changes in average annual drainage rates in (NEGD and SLB)

Fig. 9. Average annual values of selective water quality parameters in the surface drainage water within the study areas (NEGD and SLB) in years (2014, 2016 and 2018)

Study Areas/ Year	g/m³								EC dS/m	Salt Load mill. ton	Heavy Metals g/m³		
	DO	TSS	TDS	pH	TP	TN	Adj SAR	HCO_3			Cu	Zn	Pb
2014													
NEGD	1.86	22.33	838.67	7.69	0.88	15.84	9.06	5.00	1.30	0.20	0.03	0.02	0.01
SLB	1.88	18.00	1141.50	7.81	0.58	20.67	12.05	5.28	1.79	0.22	0.03	0.01	0.01
2016													
NEGD	1.80	17.67	1012.00	7.92	0.94	17.43	8.87	6.03	1.49	0.16	0.06	0.01	0.05
SLB	2.37	19.50	1073.00	7.74	0.71	19.05	9.77	5.15	1.64	0.19	0.08	0.02	0.08
2018													
NEGD	2.28	27.00	930.67	7.69	1.19	10.16	8.53	5.79	1.37	0.17	0.04	0.06	0.01
SLB	3.15	19.00	1126.50	7.62	0.73	11.22	10.13	5.64	1.72	0.17	0.03	0.05	0.01

Also, in this context, the previous researches informed that consumption of food and deposition of fish fecal matters in the surface drainage water network may further stimulate the growth of phytoplankton and filamentous algal because of the presence of nutrients [22, 23, 26, 31, 32, 33, 34, 35]. Such nutrients may constrain water use in ponds by enhancing the process of eutrophication, increasing the inorganic and organic sedimentation and causing ecological environmental pollution (water, sediment, flora and fauna). It was also mentioned that anoxia may be established in the water column a few centimeters from the zooplanktons, benthos and fish particularly diminish causing sensible pollution [9, 27]. Therefore, expansion of illegal fish farms in the Northern parts of the Nile Delta affects all surrounding activities (human, agricultural crops and cattle and sheep production in the catchments of the recipient drains and lakes). Thus, impacts of the privately-operated fish farms should be strictly overcome by all means to sustain water, food and environment in healthy state. This may require relevant awareness programs to the local communities, inhabitants, cooperatives and small business groups in the study areas, its surroundings and the whole Nile Delta aiming at explaining the danger of spread of illegal fish farms.

E. Changes in groundwater status within the study areas during (2014-2018)

The ministries responsible for water resources and agriculture in Egypt declared the official fish farms that depend on brackish groundwater in Egypt. The privately-operated fish farms were not included in that declaration, Fig. 8. The concerned study areas were located within that zone above the Northern Middle Nile Delta aquifer. The Nile Delta aquifer is one of the largest aquifers in Egypt. It starts at the south of the Delta at El-Qanater City with an average thickness of 200 m and gets deeper when heading towards the North, reaching a saturated depth of 1000 m at the sea coast. The Nile Delta aquifer has a complex geological formation. The northern part of the aquifer comprises of a multi-layered aquifer system, while in the southern part the aquifer consists of sand and gravel facies [36].

The salinity of its groundwater changes according to the depth of the water beneath the soil surface and its closeness from the sea. Groundwater categories ranging from fresh to brackish to saline to brine groundwater [39]. Brackish and saline groundwater can be used for all fish farming activities. During the concerned study period (2014-2018), groundwater heads and salinity data were utilized from National Groundwater Quality Monitoring Network (NGWQMN). NGWQMN is established in the nineties to provide

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information needed for planning, management and development of ground-water supplies to meet current and future water needs and ecosystem requirements. The network consists of groundwater observation wells distributed all over the country, with focus on areas with high agricultural and industrial activities. The observation wells were implemented to monitor different depths in the aquifers (from 40 to 1100 m), in terms of groundwater heads and salinity. Fig. 9 shows the depth to groundwater in the study areas during (2014) and (2018), investigated and interpolated from NGWQMN database.

It was found, based on the few available groundwater data (groundwater depths and heads) within the study areas, that there was a general increasing trend in groundwater depths, which means decrease in groundwater heads. The change could be interpreted by the unplanned increase in groundwater extraction by farmers and could also be explained by the expansion of privately-operated fish farms and supplementary crop irrigation in the study areas. This situation, also affected the salinity of the groundwater but in a lesser impact. The salinity of the shallow groundwater has decreased slightly in the study areas in a range from 50 to 1100 ppm during (2014-2018) [36, 37]. This could be attributed to the seepage of excess irrigation water downward into the shallow groundwater (mainly drainage water with less salinity that the groundwater in that area).

However, to study the particular impact of the privately-operated fish farms expansion, it is recommended that shallow groundwater observations wells (10–20 meters depths) to be drilled around those fish farms locations in the study areas. The wells have to be implemented with different distances from the fish farms. Hence, these wells can monitor, locally, the change in groundwater heads and salinity when regularly observed. The impact of those fish farms on groundwater could then be determined accurately, in terms of quantity and salinity.

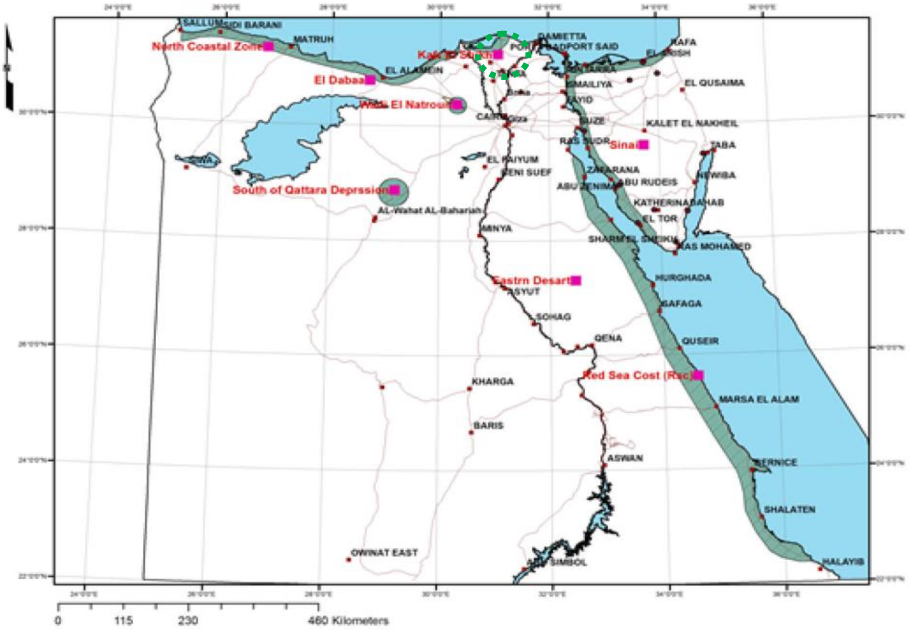

Fig. 10. Official fish farms depending on brackish groundwater in Egypt *(Source: Database of MWRI & MALR of Egypt)*

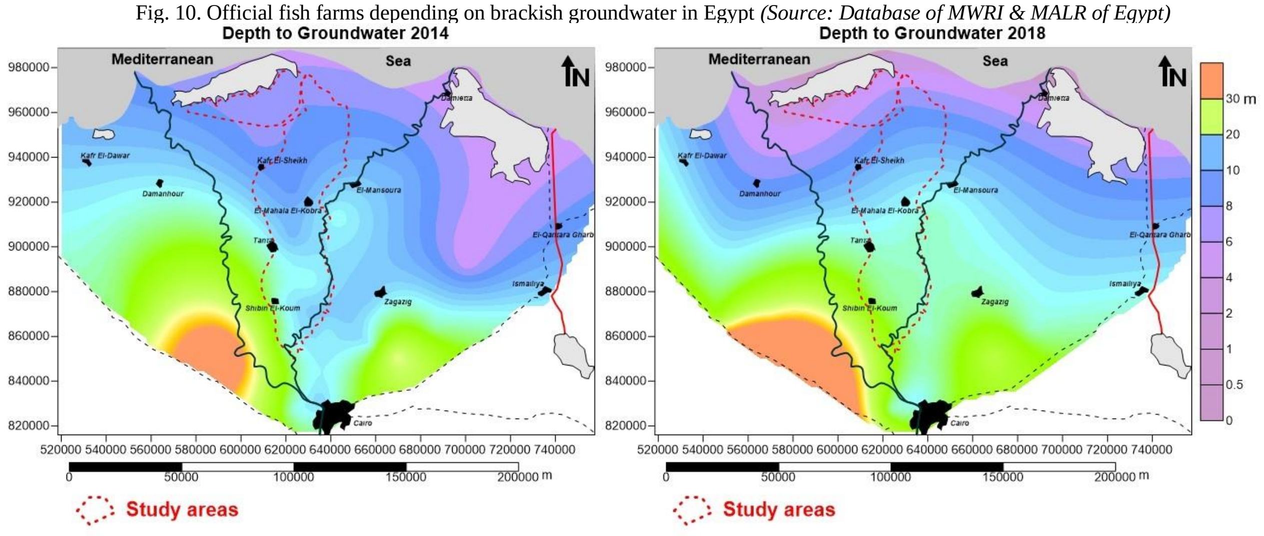

Fig. 11. Depth to groundwater in the study areas in years (2014 and 2018)

F. *Economic and social prospects of fish farms expansion – shading light*

Expansion of the privately-operated fish farms in the Nile Delta in the last decade has been due to its easy, cheap, quick construction and speedy growth of fish due to nutrients exist in the polluted water used, leading to high and quick profitability. Accordingly, thousands of families live in the Northern parts of the Nile Delta became fully dependent on those fish farms jobs (direct and indirect) to cover for their living expenses. On the other hand, converting the agricultural crops plots into fish farms in such large pace affected the national production of agricultural crops. Even the neighboring farmers who stick to cultivating agricultural crops suffered significantly from fresh irrigation water shortage being at the end of the irrigation system as well as shortage in drainage water due to the high-water consumption used in the nearby fish farms. The new Egyptian Water Resources Law issued and endorsed in 2019 by the Egyptian People Assembly as well as its implementation bylaw tackle properly the violation of those privately-operated fish farms. However, it is recommended that a detailed cost-benefit analysis as well as socio-economic study to be conducted on the impacted communities in the study areas and elsewhere. Based on the results of those studies, the Egyptian Government and its local authorities are encouraged to avail alternative suitable jobs opportunities with relatively equivalent earnings to the owners, operators and workers of the privately-operated fish farms in Egypt, so that those inhabitants can continue having good livelihood without hampering the efforts of the Egyptian Government in combating pollution.

V. CONCLUSION AND RECOMMENDATIONS

This research paper proved an increase of 7.42% equivalent to an area of 18,419 feddans of privately-operated fish farms on the expense of the agricultural crops in the study areas in four years during (2014-2018). Also, it was estimated that annual increase in water requirements due to those privately-operated fish farms expansion during (2014-2018) was about 82.0 million m^3/year. The ratio of water requirements (fish vs. crops) in the study areas was estimated almost double. The estimated increase in disposed effluent from the privately-operated fish farms in the study areas to either nearby small drains or lakes was about 5,756 m^3/feddans/year (27 million m^3/year from the study areas), equivalent to an increase in drainage water about 106 million m^3 from the study areas in four years (2014-2018).

Although expansion in the privately-operated fish farms in the study areas during (2014-2018) added large disposed effluent to the drainage system, the resultant was a decrease in drainage rates by more than 30% from the whole study areas. This could be attributed to the growing unofficial drainage water reuse from El-Gharbia Drain system, causing a decrease in drainage rates from the study areas estimated about 41.2 million m^3/year during (2014- 2018).

High pollution concentrations were monitored in El-Gharbia Drain system during the period (2014-2018), a number of water quality parameters sometimes exceeded the Environmental Law limits by many folds. The privately-operated fish farms expansion in the study areas contributed significantly to the deterioration of water quality of the final reaches of El-Gharbia Drain during the study period due to its effluent discharges with high biological and nutrients loads.

It was noticed that a general increasing trend prevailed in groundwater depths in the study areas during (2014-2018). That could be interpreted by the increase in unplanned groundwater extraction by farmers for supplementary irrigating their crops as well as operating the expanded privately-operated fish farms in the last years. However, salinity of the shallow groundwater has slightly decreased in the study areas (ranges between 50 and 1100 ppm) during (2014-2018).

It is recommended that expansion of privately-fish farms in the Northern parts of the Nile Delta should be strictly controlled by law to sustain water, food and environment in healthy state. The National Water Quality Monitoring Network needs to be strengthened and modernized. Its measured data should be processed then integrated in the decision-making systems (research and government institutions). Shallow groundwater observation wells need to be drilled in the study areas for detailed analysis of the impacts of the privately-operated fish farms expansion on the groundwater. It is worth to establish relevant awareness programs and avail alternative suitable jobs opportunities to the local communities, inhabitants and small business groups in Northern Nile Delta to explain the risks and danger of spread of random fish farms.

ACKNOWLEDGMENTS

The authors acknowledge the sincere effort done by the researchers and scientists of the National Water Research Center of the Ministry of Water Resources and Irrigation of Egypt in identifying, collecting, and availing the required data for this research paper, in particular the Drainage Research Institute, the Survey Research Institute and the Research Institute for Groundwater. Deep appreciations are due to the chairpersons, directors, managers and experts of the Ministry of Water Resources and Irrigation of Egypt, who gave sincere advices, enlightening remarks and critically reviewed this research paper. Additionally, the authores would like to thank the USGS to make Landsat images available for research.

REFERENCES

[1] FAO, 2018. Yearbook 2016: Fishery and Aquaculture Statistics, ISBN 978-92-5-130636-9, Rome, Italy, http://www.fao.org/3/i9942t/I9942T.pdf
[2] APP (The Egyptian-Dutch Advisory Panel on Water Management), 2010. Interim Findings of The APP Study on Water Requirements for Fish Farming in the Nile Delta of Egypt, Alterra, Wageningen, The Netherlands, 15 June 2010.
[3] Tiptiwa Sampantamit, Long Ho, Carl Lachat, Nantida Sutummawong, Patrick Sorgeloos and Peter Goethals, 2020. Aquaculture Production and Its Environmental Sustainability in Thailand: Challenges and Potential Solutions - A Review Study, Journal of Sustainability, MDPI, Thailands, URL: chrome-extension://gphandlahdpffmccakmbngmbjnjiiahp/https://res.mdpi.com/d_attachment/sustainability/sustainability-12-02010/article_deploy/sustainability-12-02010-v3.pdf
[4] Sanyu Consultant Inc., 2016. The Project for Drainage Water Quality Control for Irrigation in Middle Nile Delta in the Arab Republic of Egypt, Final Report, March 2016, Funded by Japan International Cooperation Agency (JICA) in Cooperation with the Egyptian Public Authority for Drainage Projects of Egypt.
[5] Claude E. Boyd, 2005. Water use in aquaculture, Department of Fisheries and Allied Aquacultures, Auburn University, Alabama 36849
[6] CMRI (Channel Maintenance Research Institute), 2010. Water Requirements for Aquaculture Farms "case study". CMRI technical

report (Arabic Reference). Channel Maintenance Research Institute, El Qanater El-Khairia, Cairo, Egypt.

[7] Sallam, G. A. H, 2017. Comparative Analysis of Using Aquaculture Versus Agriculture Land Reclamation in Saline-Sodic Clayey Soils in Tina Plain Area of Egypt. International Journal of Agricultural Sciences and Natural Resources. Vol. 4, No. 5, 2017, pp. 32-42.

[8] David Molden, Seleshi Bekele Awulachew, Karen Conniff, Lisa-Maria Rebelo, Yasir Mohamed, Don Peden, James Kinyangi, Paulo van Breugel, Aditi Mukherji, Ana Cascão, An Notenbaert, Solomon Seyoum Demise, Mohammed Abdel Meguid and Gamal El Naggar, 2009. CPWF Project Report, Nile Basin Focal Project, Project Number 59, CGIAR Challenge program (Qater & Food), December 30, 2009.

[9] Ali, M.M. and Abdin, A. E., 2003. Environmental impact of the surrounding conditions on the fish culture within floating cages in Damietta branch of the River Nile. J. Egypt. Acad. Soc. Environ. Develop. Vol. (4), No (3), pp. 37-60.

[10] Abdel Fattah K. Mohamed and El-Naka A. El-Sayed, 2015. Empirical approach of leaching curves for determining the efficiency of reclaiming saline-sodic soils in Sahl El-Tina, Sinai, Egypt. International Journal of Plant & Soil Science, 2015, 8 (3): 1-9, 2015, Article no. IJPSS. 18606.

[11] Sallam, G. A. H., Nasralla, M. R. and Ragab, M. A., 2013. Water Use Efficiency for Leaching Saline-Sodic Clayey Soils: Case Study of Tina Plain Area of Egypt, Chapter 48 In: Developments in Soil Salinity Assessment and Reclamation, Innovative Thinking and Use of Marginal Soil and Water Resources in Irrigated Agriculture, pp. 737-747, S. A. Shahid et al. (eds.), DOI 10.1007/978-94-007-5684-7_48, Springer, 2013.

[12] Mirela Cretu, 2016. Environmental Impact of Aquaculture. A Literature Review, Universitatea Dunarea de Jos Galati, Romania, May 2016, URL: https://www.researchgate.net/publication/301346014_Environmental_Impact_of_Aquaculture_A_Literature_Review

[13] Boyd, C. E. and C. S. Tucker, 1998. Pond aquaculture water quality management. Kluwer Academic Publishers, Boston,Massachusetts USA.

[14] Boyd, C. E., 1982. Hydrology of small experimentalfish ponds at Auburn, Alabama. Transactions of the American Fisheries Society 111:638-644.

[15] Yoo, K. H. and C. E. Boyd, 1992. Hydrology and water supply for pond aquaculture. Chapman and Hall, New York, New York USA.

[16] Huang, Y., & Fipps, G., 2006. Landsat Satellite Multi-Spectral Image Classification of Land Cover Change for GIS-Based Urbanization Analysis in Irrigation Districts: Evaluation in Low Rio Grande Valley, District Analysis Report, Irrigation District Engineering and Assistance Program.

[17] Jensen, J. R., 2005. Introductory Digital Image Processing. 3/e, Pearson Prentice Hall, Upper Saddle River, New Jersey, ISBN 0-13-1453361-0: 526p.

[18] DRI (Drainage Research Institute), 2016. Technical Report No. 86 - Year Book (2015-2016) entitled: Drainage Water Status in The Nile Delta, prepared by the Drainage Research Institute, Ministry of Water Resources and Irrigation, 2016, Cairo, Egypt

[19] DRI (Drainage Research Institute), 2015. Year Book (2014-2015) entitled: Drainage Water Status in The Nile Delta, prepared by the Drainage Research Institute, Ministry of Water Resources and Irrigation, 2015, Cairo, Egypt

[20] Zhao, G., & Maclean, L., 2000. A Comparison of Canonical Discriminant Analysis and Principal Component Analysis for Spectral Transformation, Photogrammetric Engineering and Remote Sensing, No. 66 (7), pp 841-847.

[21] El Gammal, H.A.A., 2016. Statistical Analysis of Water Quality Monitoring Network Case Study: Gharbia Drainage Catchments Area, Journal of Advances in Environmental Biology, American-Eurasian Network for Scientific Information (AENSI), 10(4) April 2016, pp: 297-305. ISSN-1995-0756 & EISSN-1998-1066, Journal home page: http://www.aensiweb.com/AEB/

[22] Prowse, G.A., 1971. Experimental Criteria for Studying Grass Carp Feeding in relation to Weed Control. The Progressive Fish-Culturist, No. 33, pp128-131.

[23] Stanley, J. G., 1974. Nitrogen and phosphorous balance of grass carp, Ctenopharyngodon idella, fed elodea, Egeria densa. Trans. Am. Fish. Soc. Journal, No. 103: pp 587-592.

[24] Madhav, K. S. and Lin, C. K., 1996. Phosphorus fertilization strategy in fish ponds based on sediment phosphorus saturation level. Aquaculture142 (3-4): 207-219

[25] Ali, M.M., Abdel-Meguid, M., and Abden, A., 2006. Assessment of floating fish cages impacts on the quality of water, sediment, aquatic weed, fish, fauna, flora and Hydraulics of Damietta Branch. Engineers Research Journal, 104:C91-C117.

[26] Bakry, M., Hosny, M., and Abdel-Meguid, M., 2004. Effective control of nuisance submerged aquatic weed, Ceratophylum demersum in Aswan Reservoir by the herbivorous fish Ctenopharyngodon idella with special emphasis on its environmentalimpact.2nd Regional Conference on Arab Water 2004. Action Plans for Integrated Development.

[27] Jawad, K., Mustapha, H., Mohamed, D., Mohamed, L. and Ahmed Y., 2004. Relation between phosphate and organic matter in fish-pond sediments of the Deroua fish farm (Béni-Mellal, Morocco): implications for pond management. Hydrobiologia, 450(1-3): 57-70.

[28] Tohamy, M., Abdel-Meguid, M., and El-Bably, W. F., 2006. Maximization of economic and environmental benefits of area used in fish production. AQUA Tec, the 11th International Conference on Water Technology and Researches, pp 17-81. (in Arabic)

[29] Abdel Meguid, M., 1999. Histopathological lesions on the gill filaments of the common carp, Cyprinus carpio infected by the developmental stages of the copepod, Lernaea cyprinacea Lin., with special emphasis on their control. Egypt. J. Zool., 32:267-279.

[30] Abdel Meguid, M., 1998. The frequency distribution of Lernaea cyprinacea Linnaeus, 1761 (Copepoda:Cyclopoida) and its histopathological effect on the common carp, Cyprinus carpio. Egypt. J. Zool., 31:53-66.

[31] ILACO, 1983. Grass carp project, Volume 1-Main report, Code 5.09.091, URL: https://journals.ekb.eg/article_49414_0fa02671c1877a54d1133cd2aac46003.pdf

[32] Boyd, C. E., 1971. The limnological role of aquatic macrophytes and their relationship to reservoir management. Am. Fish. Soc. Special Publication, 8:153-166.

[33] Carter, C. C. and Hestand, R. S., 1977. Relationship of regrowth of aquatic macrophytes after treatment with herbicides to water quality and phytoplankton populations. J. Aquatic Plant Management, 15:65-69.

[34] Von Donk, E., Gulati, R. D., Iedema, A. J. and Meulemans, J., 1993. Macrophyte-related shifts in the nitrogen and phosphorus contents of the diiferent trophic levels in a biomanipulated shallow lake. Hydrobiologia, No. 251, pp19-26.

[35] Schriver, P., Bogestrand, J., Jeppesen, E. and Sondergaard, M., 1995. Impact of submerged macrophytes on fish-zooplankton-phytoplankton interactions: Large scale enclosure experiments in a shallow lake. Freswater Biol., No. 33: pp 255-270.

[36] Nofal E.R., 2016. Sea Water Intrusion in Nile Delta in Perspective of Climate Changes and Aquifer Heterogeneity, Ph.D. Thesis, Faculty of Engineering, Cairo University, Egypt.

[37] Nofal E.R., Amer A., El-Didy S.M. and Fekry A.M., 2015. Delineation and Modeling of Seawater Intrusion into the Nile Delta Aquifer: A New Perspective, Water Science Journal No. 29 (2015), pp156–166.