



## **NILE DELTA CHALLENGES AND OPPORTUNITIES, A STATE OF THE ART REVIEW**

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### **ABSTRACT**

The Nile Delta and its coastal zone are populated regions in Egypt and contain a variety of development activities. Those human activities which provide income and source of life to many also generate constraints to Nile delta region. . This review attempts a comprehensive and concise summary of recent research related to challenges in Nile delta regions. In addition, possible opportunities are included. This study mainly reviewed five themes of research namely land use challenge, coastal erosion, potential impacts of sea level rise (SLR), water quality deterioration, and sea water intrusion. The paper reviewed suggested proposed or/and implemented adaptation or/and mitigation acts for each challenge. The article concluded that further integrated research based on solid reliable field databases is urgently needed.

**Keywords:** Nile Delta, Challenges, Opportunities, Soil Salinization, Climate Change, Adaptation

### **1 INTRODUCTION**

The Nile delta of Egypt is one of the earliest deltaic systems in the world (Banna & Frihy, 2009) . It was formed by sedimentary processes between the upper Miocene and present and built up by the alluvium brought by the old former seven active branches of the Nile. Those branches have been silted up and replaced at present by Damietta and Rosetta Branches (Stanley & Warne, 1993) . There are many low-laying areas forming salt- crusted sabkhas. The headland is inundated periodically by seawater during winter sea surges (Hereher, 2011).

The Nile Delta covers only about 2% of Egypt's area but hosts about 41% of the country's population and comprises nearly 63% of its agricultural land (Hereher, 2010), (Mabrouk,et al., 2013). It is among the most densely populated agricultural areas in the world, with 1,360 inhabitants per km<sup>2</sup>. Egypt faces great challenges owing to its limited water resources, which is due to (i) its fixed share of Nile River water and its characteristics of aridity ( Aly, et al., 2012), (ii) the newly Nile-water-based development plans in the upstream countries such as Ethiopia and Sudan. In terms of economic activities, the fish productivity is about 185000 Tons/year from the northern lakes (Maryut, Manzala, Edkua and Burullus) (Oczkowski & Nixon, 2008). About 40% of all Egyptian industries are located in Nile Delta. Most of the investments and economic activities apparently go towards the delta region. In recent decades, as a result of rapid economic development, increasing population in the delta region and associated industrialization exerts high environmental pressures. Industrial wastes and municipal effluents have been largely pumped into the delta coast lagoonal wetlands, causing eco-environmental degradation with significant public health concerns (Herzog et al., 2012).This study presents the evaluation of the challenges across Nile Delta, proposed mitigation and adaptation scenarios and opportunities.

## 2 NILE DELTA CHALLENGES

The main five challenges of Nile Delta region is Land use challenge, coastal erosion, and potential impacts of sea level rise, sea water intrusion, and water quality deterioration. Figure 1 show the main reasons for each challenge. Each challenge will be presented in some details in the upcoming sections.

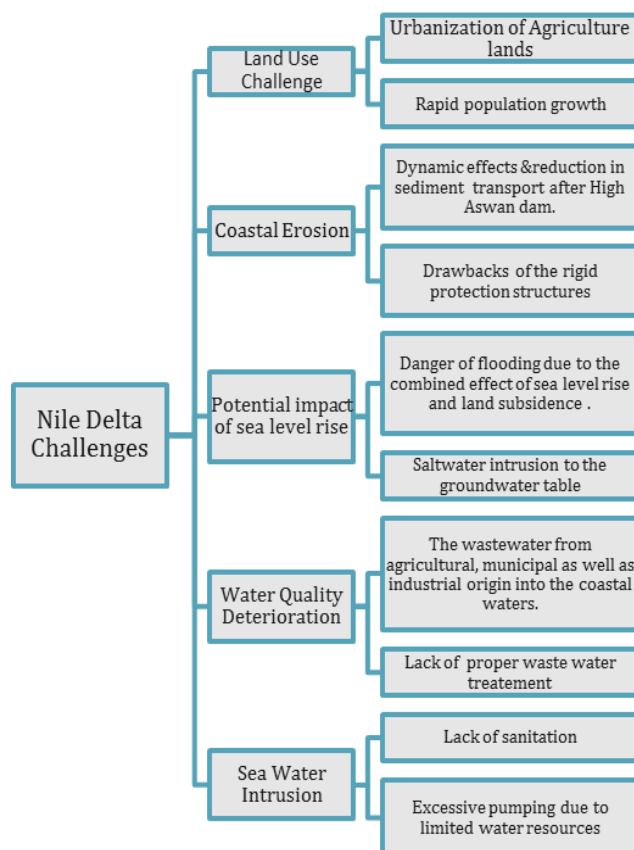


Figure1. Challenges facing Nile Delta and their reasons

### 2.1 Land use challenge

A recent study (Shalaby, 2012) stated that a total expansion of urban area amounted to 2536.3 km<sup>2</sup> during the study period from 1984 to 2006. Another study added that evidence of land degradation processes was observed, which were mainly due to human activities, such as the formation of quarries, free water bodies and Sabkhas (a specific type of land cover found on dry lands and salt-affected soils) (El-Kawy, et al., 2011) . Egyptian government is demanding to control the urban encroachment and the loss of agricultural land in Nile Delta throughout applying an effective horizontal urban expansion and reclaim more land along the desert areas and near the fringes of the Nile Delta (Hegazy, et al., 2008). A recent paper recommended that the urban expansion should be strongly prohibited over the fertile agricultural land, and the expansion of the agricultural land toward the desert areas should be wisely selected to peruse a water-saving plan (Elhag, et al., 2013).

Figure 2, 3 show the land use in the delta region and the land use change computed though remote sensing techniques (Elhag et al., 2013).

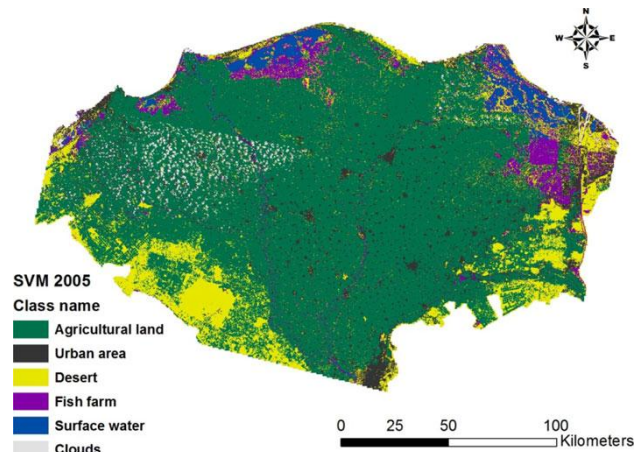


Figure 2. A 2005 classification map based on Landsat ETM satellite image adopted from (Elhag et al., 2013)

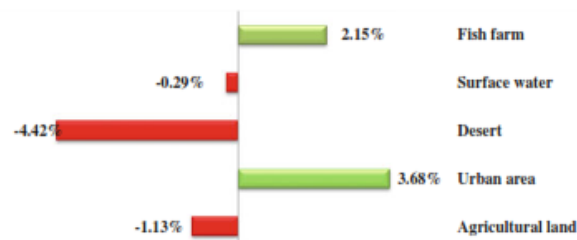


Figure 3. land use changes from the year 1984 till the year 2000 adopted from (Elhag et al., 2013)

## 2.2 Coastal erosion

The study conducted by (Banna & Frihy, 2009) utilized Landsat Enhanced Thematic Mapper imagery (ETM) of 2002 and aerial photography of 1955, combined with published charts and field observations to interpret geomorphological changes in the coastal zone. They concluded that the erosion/accretion patterns denote the natural processes of wave-induced long-shore currents and sediment transport, in addition, the impact of man-made coastal protection structures.

Another remote sensing based research that conducted by (Hereher, et al., 2010) the control of the River Nile flooding to the previously mentioned reasons of erosion. , This study showed that coastal erosion was severe near Damietta promontory and decreased eastward. However, accretion was observed near Port-Said. About 50% of the coastal strip was under erosion and 13% was under accretion. In addition, a remarkable decline (34.5%) of the Manzala lagoon surface area was estimated. The impact of constructing Damietta harbor was investigated by (Dewidar, et al., 2010). They found that Damietta harbor disturbed the shoreline stability causing downdrift erosion and updrift accretion on both sides of the harbor breakwaters.

## 2.3 Potential impacts of sea level rise (SLR)

According to the Intergovernmental Panel on Climate Change fourth report (IPCC) in 2007 (Parry, 2007), Nile delta region is one of the most extremely affected river deltas in the world by climate change impacts. The prediction made by (Mabrouk, et al., 2013) about impacts of climate change on the Nile delta indicated that intensified threads to water security. Increasing potential evaporation (in response to increasing temperature) in combination with decreasing water levels in the Nile river, reduced precipitation and groundwater recharge and deteriorating groundwater quality, imposes great challenges to ensure the supply of drinking water and irrigation. The study recommended that current irrigation strategies are highly inefficient and must be replaced by new and adapted systems (whenever possible).

Moreover, using 1990 as the base year (El-Nahry & Doluschitz, 2009) computed SLR by applying the quadrant equation for 10-year intervals. Mediterranean SLR along the Nile Delta coast could be estimated considering three different scenarios (low 0.20 m, medium 0.50 m, and high 0.90 m). Impacts of SLR are divided into (1) primary and (2) secondary impacts. Over the coming decades, it is expected that the Nile Delta might face greater threat due to SLR and land subsidence as well.

The climate change might have an impact on level of sea water intrusion in coastal aquifers. A numerical study conducted by (Werner & Simmons, 2009) concluded that large areas in the coastal zone of the Nile Delta might be submerged by seawater and the coast line might shift landward by several kilometers in the eastern and western sides of the Delta.

## **2.4 Water quality deterioration**

Prior to human intervention, all of coastal lakes now receiving agriculture, domestic and industrial waste waters were open to the sea have proper exchange rates with the Mediterranean Sea. While three of the four lagoons currently have fewer exchange rates with the sea (Maryut does not) (El-Adawy et al., 2013; Oczkowski & Nixon, 2008). The continuous charging of these waste water changes the ecosystem of the coastal lakes. It affected negatively the fish production quantity and quality. There are large spatial gradients in lagoon salinities. For example, data from Manzalah Lagoon in September 1995 show ranges in salinity from 2.7 to 39.1, with the highest salinity near the breachway and lowest salinities inshore (Oczkowski & Nixon, 2008).

## **2.5 Sea water intrusion**

Due to lack of sanitation and Random and excessive groundwater pumping, Nile delta is now affected by sea water intrusion. Most of the studies did not consider the possible effects of the seawater rise on the inland movement of the shoreline and the associate changes in the boundary conditions at the seaside and the domain geometry (Werner & Simmons, 2009). Such effects become more evident in flat, low land, coastal alluvial plans where large areas might be submerged with seawater under a relatively small increase in the seawater level.

Based on numerical approach (Javadi, et al., 2014), using a finite element model FEFLOW, the seawater intrusion problem in the Nile Delta aquifer in the areal view at the seawater level was simulated. The study concluded that, large areas in the coastal zone of the Nile Delta might be submerged by seawater and the coast line will shift landward by several kilometers in the eastern and western sides of the Delta. The one meter rise in sea level scenario represents the worst case under which the volume of freshwater might be reduced to about 513 km<sup>3</sup> (billion m<sup>3</sup>).

# **3 PROPOSED MITIGATION, ADAPTATION SCENARIOS AND OPPORTUNITIES**

This section will present some proposed mitigation scenarios that will not only face challenges but also create opportunities.

## **3.1 Land use challenge adaptation**

As a part of a comprehensive study, conducted by (Eitzinger, et al., 2009) , reported and assessed some suggestions to face land use challenge. It concluded that Land use change trends in the Nile Delta region could have both negative and positive roles in the agriculture adaptation of climate negative. The two main suggestions are: 1- Gradual decrease in the current cultivating area to obtain a higher level of crop management. 2-Switch cropping activates to aquaculture.

The Government of Egypt implemented El-Salaam Canal project to reuse drainage water, to create new communities along the Canal and to re-charting Egypt's population map. Diverting considerable amounts of drainage water after blending of the Nile water to newly reclaimed areas for

irrigation of 643,560 acres of new lands in the northeastern Delta and northern Sinai peninsula are planned by using El-Salaam Canal water (Hafez, et al., 2008).

### **3.2 Coastal erosion/accretion adaptation**

Recently, (Frihy & El-sayed, 2012) analyzed the risks, ranking the vulnerability and suggesting adaptation measures to mitigate the impact of the SLR along the Mediterranean coast of Egypt. The main proposed adaptive options of the study are: 1- Rehabilitation and strengthening the existed engineering coastal structures, particularly on the low-lying lands and areas at risk, to adapt with the likely impacts of the SLR. 2- Adopting and developing quantitative risk assessment approach for the impact of the SLR along Egypt's Mediterranean coast. 3- Considering human and fund resources mobilization plans and developing an early warning system. Another two connected studies (El-Adawy et al., 2013; Masria, et al., 2014) applied advanced numerical modeling on the Rosetta coastal zone and an integrated proposed solution that helps in controlling the pollution inside El-Burullus Lake and erosion problems at Rossetta (one outlet of the River Nile). The main aim was to improve the stability of the outlet cross section. It was proposed to increase the discharge through the outlet by diverting two drains discharging into El-Burullus Lake to discharge into Rosseta directly, decreasing the cross section by center outlet jetty, and/or eliminating the sediment supply by constructing jetty in the nodal point of the sediment transport which is located just east of the entrance.

### **3.3 Potential impacts of sea level rise (SLR) adaptation**

A research (McCarl et al., 2013) concluded that climate change would have large impacts on Egypt agriculture and water use with the damages increasing over time. A coupled modeling approach (Mabrouk, et al., 2013) of the land surface hydrological model WASIM-ETH and the hydrological model MOD-Flow was utilized to simulate and project the future impact translation of climate projections into hydrological impacts on Nile Delta. The study concluded that current irrigation strategies are highly inefficient and must be replaced by new and adapted systems (whenever possible).

In a meeting (Egyptian Water Partnership & Partnership, 2013) gathered Egyptian experts in the field of impacts of climate change on Nile delta highlighted: 1- The importance of changing the cropping patterns in the Nile Delta as a strategic Climate Change adaptation measure. Crops with high tolerance to salinity should be introduced to agricultural areas close to the Mediterranean. 2- The importance of developing Integrated Coastal Zone Management (ICZM) plans for all coastal governorates and cities considering natural coastal protection measures such as sand dunes, along with other structures such as seawalls and considering the protection of the coastal highway. 3-The importance of developing coastal protection policies that go in line with ICZM plans, such policies should specify a distance from the coast where the damage is expected.

### **3.4 Water quality deterioration adaptation**

A GIS based study (Shaban, et al., 2010) developed a tool for planning and managing the reuse of agricultural drainage water for irrigation in the Nile Delta. This is achieved by classifying the pollution levels of drainage water into several categories using a statistical clustering approach that may ensure simple but accurate information about the pollution levels and water characteristics at any point within the drainage system. A recent study (Abdel-Shafy, et al., 2014) investigated different hybrid treatment processes for handling the grey water for unrestricted reuse. An innovative approach namely down-flow hanging sponge system (Fleifle, et al., 2013) was suggested to make effective reuse of agricultural drainage water. In addition, they developed a model that was found to be a simple and useful tool for design and operation of a DHS system treating ADW in practical applications.

### **3.5 Sea water intrusion adaptation**

An integrated study by (Eitzinger, et al., 2009), assessed some adaptation and mitigation actions to face threats of sea level rise. The analysis included cost benefit analysis. The proposed actions include: Firstly, Gradual increase in cultivating salinity tolerant crops and switch cropping activates to

aquaculture as forms of adaptation strategy. Secondly, establishing a new drainage system in field, equipped with a suction pumping unit, to remove the excessive water table and control it in a constant level.

Regarding opportunities, a recent research (Abayazid & Al-Shinnawy, 2012) stated that sea water intrusion would result in waters with high salinity levels approaching the ground surface and easier to be used as a source to feed coastal lakes such as Lake Burullus and, hence, increase its water salinity level. This would lead to restore its healthy environmental status.

A comparative study by (Mabrouk, et al., 2013) discussed advantages and disadvantages of different adaptation and mitigation measures for groundwater salinization in Deltas worldwide as shown in Table 1. Some of these suggestions can be suitable for application in Nile Delta. The study concluded that expansion in rice cultivation is uneconomic because of the large amount of water needed but it is suggested that the ministry of agriculture can move some rice cultivated areas towards areas of salinization problems to solve the problem without changing the total required water. Cultivating salt tolerant crops and creating wetlands in salinized areas in low lying areas are very suitable in Egypt.

**Table 1 Different adaptation and mitigation measures for groundwater salinization in Deltas worldwide (Mabrouk, et al., 2013)**

Measure	Advantage	Disadvantage	Conclusion
<b>a. Adaptation</b>			
1. Rice Cultivation (El Gunidy et al., 1987; Kotb et al., 2000)	Soil salinization patterns decrease considerably	Needs a large amount of water which is already a scarce resource.	Not recommended as it is uneconomic
2. Permitting 10 to 20% of the freshwater of irrigation to leach the soil (Abrol et al., 1988)	No salt accumulation, salt export will match salt import and will eventually prevent salt infiltration to groundwater.	This could be risky because it might cause salt returning to the root zone again.	Not recommended
3. Cultivating salt tolerant crops (FAO, 1985)	Tolerant crops can withstand salt concentration in the north	Very limited types of plants.	Highly recommended
4. Creating wetlands in salinized areas (IPCC, 2008)	Egypt has four lakes in the northern coast of the Nile Delta which could be considered as natural adaption.	Only applicable in low lying deltas of the Nile Delta	Highly recommended in Egypt
5. Extraction of saline groundwater (Oude Essink, 2001a)	Getting rid of saline water.	Disposal of extracted saline water could cause another environmental problem.	Not recommended in shallow coastal aquifers
6. Increasing land reclamation (Oude Essink, 2001a)	Increase freshwater recharge	Need of land and fresh water	It is recommended
<b>b. Mitigation measures</b>			
1. Artificial Recharge (Bray and Yeh, 2008; Richard and Johnson, 2005; Luyen et al., 2011; Carrera, 2010)	Increase freshwater outflow to the aquifer. The degree of efficiency of this method depends on pumping/injection rates, depth of the wells, the coastal aquifer properties and the location of the wells.	Needs a large amount of water which is already a scarce resource.	It is recommended in case of water abundance as it is a highly effective method.

## 4 DISCUSSION

After presenting the main challenges, adaptation and mitigation acts in Nile Delta region, it is now evident that proper management will not only contribute in being ready for real challenges but also create opportunities as discussed before. The established plan for adaptation of coastal zone under climate change should be linked to a comprehensive integrated plan for solving all problems found in delta region. For Example, Integrated plans for solving soil salinization, water quality deterioration in shallow coastal lakes, erosion problems at estuaries, and impacts of climate change should be connected.

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