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Land Degradation Indicators for Nile Delta: DPSIR Approach

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DPSIR (Driving forces-Pressure-State-Impact-Response) framework is used to structure and classify information and to assist in the identification of the key set of indicators that best describe how farmers and other land users are managing their land and the impacts of this management. The DPSIR (LADA 2002) is a convenient representation of the linkages between the pressures exerted on the land by human activities, the change in quality of the resource, and attempts to release the pressure or to rehabilitate land that has been degraded. The interchanges among these form a continuous feedback mechanism that can be monitored and used for assessment of land degradation indicators. Following indicators were assisted for the Nile Delta of Egypt.

Driving force indicators: population growth, poverty, land resources stress, water stress and sea level rise.

Pressure indicators: sea-water intrusion, urban encroachment, soil scrapping and water quality.

State indicators: shoreline erosion, salt affected soil, waterlogged soil and soil and water pollution.

Impact indicators: land productivity decline.

Response indicators: legislations (Law 1983, 1985, Law 4 1994), land improvement and conservation, shoreline protection, investment in land and water resources, second national drainage project (2001-2007), Commitment to International Convention.

Keywords: Land degradation indicators, Nile Delta, DPSIR approach, LADA.

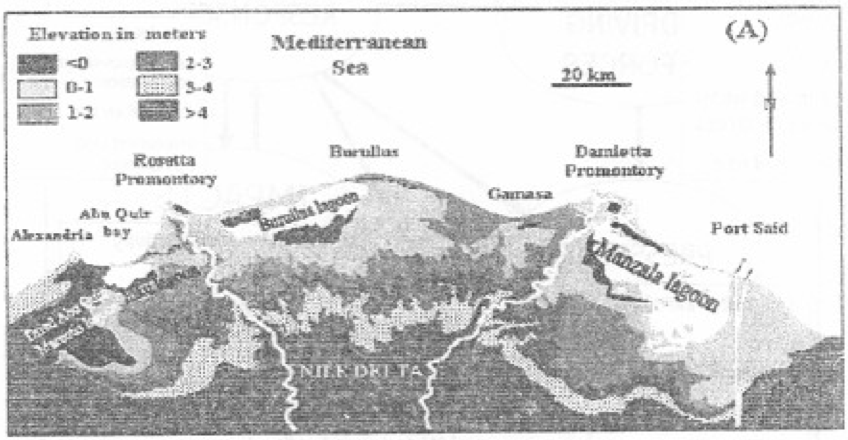
Agricultural productivity in Egypt is limited by the area extent of arable lands, by the quality of these lands and by significant land degradation processes risk. In the Nile Delta, productivity has been restricted, in part, by high soil salinity levels and by encroachment of urban settlements onto previously productive lands (Metz, 1991). Agricultural practices changed after the completion of the

Aswan High Dam in 1964. Perennial, furrow irrigation replaced basin flooding, and multiple cropping replaced the single crop per year resulting in shorter fallow periods. Soil nutrients declined due to intensive cultivation practices coupled with a lack of systematic nutrient replacement and a loss of alluvium deposits (Metz, 1991). Also, in some areas, over irrigation combined with inadequate drainage resulted in increased soil salinity and elevated water table. The likely challenges to the sustainability of water resources in Egypt include salinity, water logging, and decline in fresh water as a result of the continuous discharge of usually untreated domestic and industrial wastewater into the Nile. Agricultural drainage water affects the salinity of the main river downstream and in the delta. The quality of water in the river decreases gradually towards the delta and the coastal plains. Also, likely to aggravate pollution is the use of chemical fertilizers, which has increased fourfold in the last two decades, partly in response to the Aswan High Dam's reduction of the flow of silt downstream. The use of herbicides to control submerged weeds in canals and water hyacinths in drains has caused serious environmental ecosystem hazard's water intrusion phenomena are of main concern in almost all coastal aquifers around the globe. The problem is more sever in arid and semiarid regions where the groundwater constitutes the main fresh resources.

In Egypt, the absence of objective indicators and replicable scientific methods in previous attempts to assess land degradation risks and desertification, and the increasing urgency to stem and reverse the accelerating land degradation, was a primary reason for calling to initiate a comprehensive land degradation indicators assessment system in Egypt, Abdel-Kader (2003 & 2004). Such a comprehensive land degradation indicators assessment system is urgently needed to respond to international donors, the UN-Convention to Combat Desertification (CCD)/Convention on Biological Diversity (CBD)/ Intergovernmental Panel on Climate Change (IPCC) /Millennium Assessment (MA) and the Government of Egypt. The national environmental monitoring system should be able to assess key land degradation indicators in Egypt that reflect the bio-physical, Scio-economic and institutional causes. The established environmental database will serve as a repository of national/regional land degradation indicators as well as a linkage tool with of concerned national/international data bases. (Abdel-Kader, 2004) .This paper addresses this gap by proposing a minimum data set of degradation indicators that describe the biophysical land qualities and socioeconomic conditions for Nile Delta of Egypt. The DPSIR - Conceptual Framework (LADA, 2002) will be used to describe the interrelation among: the driving force that is identified by factories influencing the environmental conditions; the pressure that identifies the variables directly responsible for land degradation; the state that is descriptive indicators of the state of land system; the impact that measure the system state variation, and the response that gives the social feedback subsequent to degradation of resources.

Study Area

"Egypt is the gift of the Nile" as expressed by Herodorus for several centuries ago. The Nile Delta and its fringes occupy at total area of 22000 km^2. The level of the Delta ranges between + 17 m above the sea level at the south boundary to less than one meter at the north boundary (Farid, 1985). The lower Nile delta showing main topographic feature below mean sea level up to 4 m contour (Frihy, 2003) (Map1). The Nile Delta with its classic fan shape has been evolving since Upper Miocene time (Said, 1981). The Nile Delta coast forms a unique depositional environment, in which sedimentation is controlled by a combination of environmental factors such as waves, currents, tides, and river discharge. The Nile Delta aquifer is naturally bounded northward by the Mediterranean Sea and eastward by the Suez Canal. The western boundary extends well into the desert. At the south, the aquifer of Upper Egypt by an aquiclude approaching the clay cap near Cairo. The Nile Delta complex was formed by sedimentary processes which occurred between the upper Miocene period (Nielsen, 1977) and present. In classical times, from 500 BC to 1100 AD the Nile had several branches (Said, 1981; AL-Askary & Frihy, 1986; Coertelliery & Stanley, 1987; Stanley,1988,1997; Stanley & Warne,1993, 1994) which have subsequently silted up and been replaced by the present two branches namely Rosetta and Damietta. The sediment supply by the Nile was estimated to be more than 100 million tons per year (Hammad *et al.,* 1979). It came from as far away as the Ethiopian Mountain's, some 2,240 km distant. Old maps (Sestini, 1976) showed that between 1800 and 1900, the Rosetta promontory advanced 3.6 km (36 m/yr) while the Damietta premonitory advanced about 3 km 1994(30 m/yr).



Map 1. The lower Nile Delta showing main topographic features below and above mean sea level up to 4 m contour (Frihy, 2003).

Methodolgy

Land degradation indicators for the Nile Delta of Egypt were assessed through in depth reviewing of numerous studies available in national and international journals as well as at the World Wide Web (WWW) sites. Following indicators according to LADA (2002) were considered (Fig.1).

Driving force indicators: Population growth, poverty, land resources stress, water stress and sea level rise.

Pressure indicators: Sea-water intrusion, urban encroachment, soil scrapping & water quality.

State indicators: Shoreline erosion, salt affected soil, waterlogged soil, and soil & water pollution.

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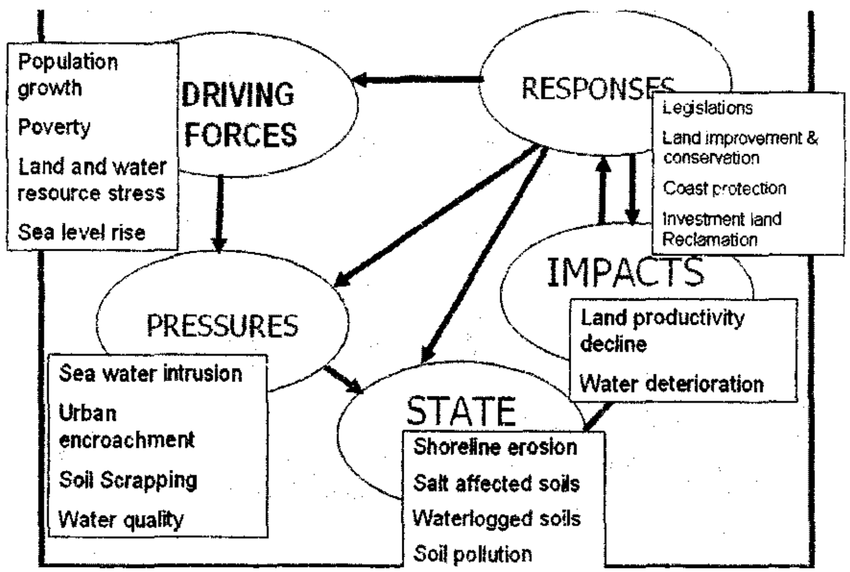


Fig. 1. LADA's pressure-state-response-framework in Nile Delta.

Results and Discussion

Driving forces indicators

Population growth

The population of Egypt exhibits trends shared by many other countries in the Third World. The high rate of population growth, although it is by no means one of the highest in the Third World (compared, for instance, to Nigeria) is nevertheless quite high. The problem of a high rate of growth of the population is compounded in Egypt by geographical factors rendering 95 percent of the land inhospitable and by a high rate of urbanization. Both factors have contributed to a dramatic increase in population density over the last fifty years. Moreover, despite a slight rise in the total increase in population density over the last fifty years. Moreover, despite a slight rise in the total cropped area from 10.79 million feddans in 1960 to 12.16 million in 1985; the rising population in rural areas has led to a decrease in the cropped area per agricultural worker from 3.33 feddans in 1960 to 2.8 in 1985. The harvested area per caput of the whole population is around 0.25 feddans (CAMPAS, 2001). Ninety-nine percent of the population (65 million) lives in a small band alongside the Nile River in the Nile Valley, in the Nile Delta and in coastal areas on about 4 percent of the land. Agriculture is a key sector in the Egyptian economy. It contributes about 40 percent to the Gross Domestic Product (GDP), 22 percent to commodity exports, and 50 percent of overall employment. Thirty-four million people, about 54 percent of Egypt's population, lives in rural areas. Table 1 gives evolution of the number of population, workforce and employment during the fourth five-year plan in Egypt (CAMPAS, 2001). Table 2 shows the population growth in Egypt in the period 1950-2050.

TABLE 1. Evolution of the number of population, workforce and employment during the fourth five-year plan (1996-2001) (CAMPAS, 2001).

Year	No. of population In-land	Work-force	Activity rate (%)	Employ-ment	Employment rate (%)	Open un-employment	Un-employment rate (%)
1996/97	59.449	17.358	29.2	15.825	91.2	1.533	8.8
1997/98	60.706	17.861	29.4	16.344	91.0	1.517	8.5
1998/99	62.013	18.374	29.6	16.874	91.8	1.500	8.2
1999/00	63.305	18.909	29.9	17.419	92.1	1.490	7.9
2000/01	64.584	19.462	30.1	17.984	92.4	1.978	7.6

TABLE 2. Population growth in million (1950-2050).

Years	Real growth			Projections	
Countries	1900	1950	2000	2015	2050
Bangladesh	29.0	41.783	137.439	183.159	265.432
Egypt	10.0	21.834	67.884	84.425	113.840

Poverty

The current arable land/man ratio is less than 500m^2 / man. More than 90% of the Egyptian farmers are typically small farmers with holdings less than two hectares. Poverty, ignorance, chronic and other diseases, the climate and the government bureaucracy are all aligned against the small farmers. Their poverty has a lot to do with their way, and the options they have, in using and managing their resources, (Kishk, 1997). In 1999-2000, almost 11 million individuals in Egypt (16.7 percent of the population) could not obtain their basic food and nonfood needs. The results, using a set of household-specific expenditure poverty lines, are similar or other poverty lines: With the percapita national poverty line traditionally used in Egypt since 1996, 17 percent of the population was poor, and with the $2 a day international measure, 19.8 percent of Egyptians were poor. While poverty was generally higher in rural Egypt than in urban areas, the greatest differences are geographical. Upper Egypt, both rural and urban, has the greatest incidence, depth and severity of poverty, Metropolitan areas have very low poverty, and Lower Egypt has an intermediate level of poverty. Poverty decreased between 1995-1996 and 1999-2000 for Egypt as a whole, but regional patterns are significantly different (Table 3). While poverty declined rapidly in Metropolitan areas, the decline was moderate in Lower Egypt, and poverty actually rose in Upper Egypt (World Bank, 2002).

TABLE 3. Poverty incidence by region (Percent).

Regions	1995/96	1999/00
Metropolitan	13.1	5.1
Lower Egypt Urban	8.3	6.2
Lower Egypt Rural	21.5	11.8
Upper Egypt Urban	10.8	19.3
Upper Egypt Rural	29.3	34.2
Frontier Urban	5.6	3.7
Frontier Rural	13.8	18.3
All Egypt	19.4	16.7

Land resources stress

Egypt with its lands extending over one million square kilometers, under arid and hyper arid climatic conditions is endowed with varied agro-ecological zones with specific attributes of resource base, climatic features , terrain and geomorphic characteristics, land use patterns and socio-economic. Ten land regions were distinguished (Table 4): Nile Valley and Delta (Vertisols, Fluvisols), Nile Fringes (Arenosols, Regosols), Northwest Coast (Calcisols, Leptosols), Sinai (Arenosols, Calcisols), Desert (Abdel-Kader & Bahnassy (2001).

TABLE 4. Land regions of Nile valley, delta and fringes (Abdel-Kader & Bahnassy, 2001).

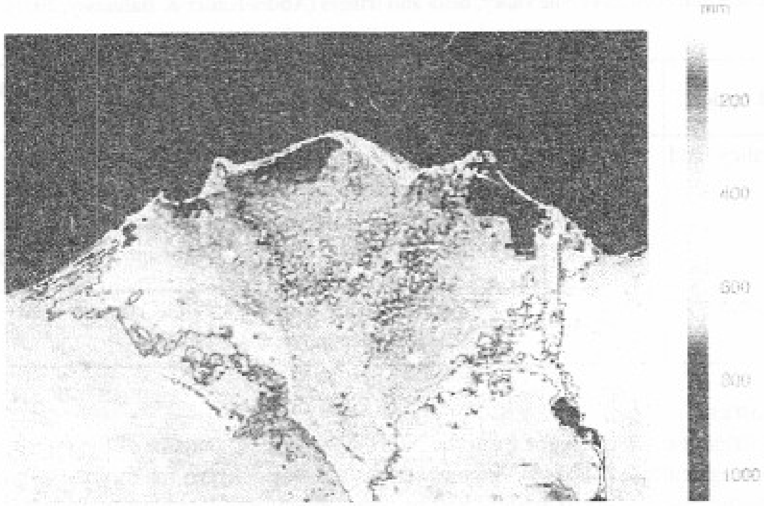
Land region	Area (km^2)	Area (%)	WRB classification	Land degradation type
Nile valley and Delta	30943.15	3.13	Eutric Vertisols, Eutric Fluvisol, Salic Vertisols, Salic Fluvisols, Calcaric Arenosol	Salinization, Waterlogging, Urbanization, Shoreline Erosion, Soil Pollution
Nile fringes	17020.54	1.72	Haplic Arenosol, Calcaric Regosol, Haplic Arenosol	Soil Crusting, Water erosion

Water Stress

All irrigation water comes from the Nile. More than 80 percent of the Nile water is used in agriculture (Table 5). Saving water is a major concern for Egypt. Per capita water resources are approximately 950 m^3/year, which will decrease to 560 m^3/year by 2025. New resources must be developed and irrigation development must continue (Abu-Zeid, 1995). Map 2 shows the total accumulated actual evapotransipration from May 15 unitl September 2002. Water watch (2003). Map 2 showed that the total accumulated actual evapotransipration from May until September 30, 2002 (Waterwatch).

TABLE 5. Water supplies and demands in Egypt (10^9 m^3/yr) (Abu-Zeid, 1995 and Abdel-Shafy & Aly, 2002).

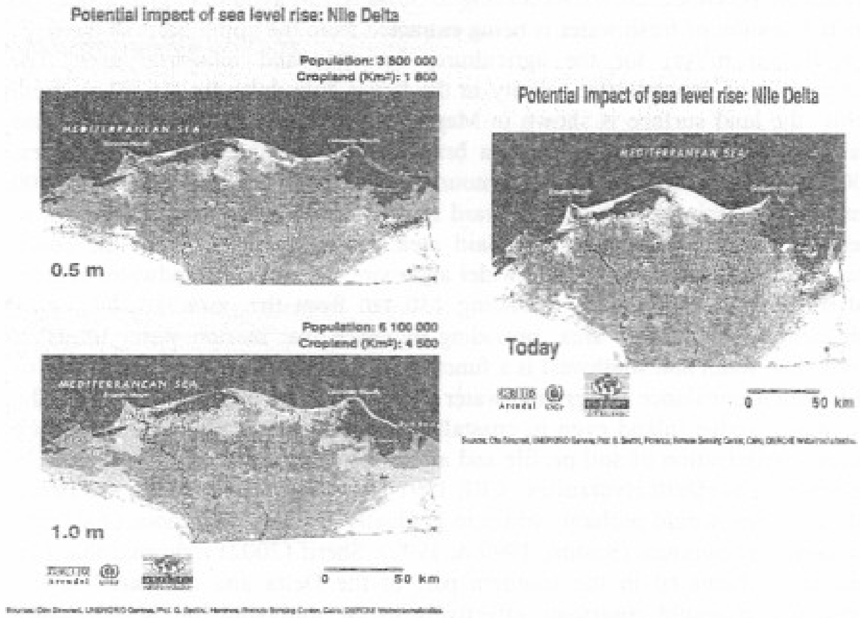
I. Water supplies	1990	2000	2025
Nile water	55.5	57.5	57.5
Groundwater:			
In the Delta and New Valley	2.6	5.1	6.3
In the desert	0.5		
Reuse of agricultural drainage water	4.7	7.0	8.0
Treated sewage water	0.2	1.1	2.4
Management and saving wasted water	-	1.0	-
Total	**63.5**	**71.7**	**74.2**
II. Water demands			
Agriculture	49.7	59.9	61.5
Households	3.1	3.1	5.1
Industry	4.6	6.1	8.6
Navigation	1.8	0.3	0.4
Total	**59.2**	**69.4**	**75.6**



Map 2. Total accumulated actual evapotransipration from May 15 until September 30 (2002), Waterwatch (2003).

Sea level rise (SLR)

Like many delta systems, the coastal zone of the Nile delta has been designated as a vulnerable zone to a rising sea level as a consequence of expected climate changes combined with geological and human factors. Large areas of the governorates of Alexandria, Behaira, Kafr El-Shiekh, Port Said, Damietta and Suez, are particularly vulnerable to sea level rise. Other vulnerable areas include Lake Bardawil, coast of Obeyedh near Matruh and the coasts of the Bitter lakes. Many other areas on the Red Sea are also vulnerable. (El-Raey, 1996). In view of the understanding of these factors, a degree of vulnerability analysis has been carried out to better locate which sectors need to be assessed and adapted to possible sea level rise (SLR) for the Nile delta-Alexandria region of Egypt. Results reveal that not all of the coastal zones of the Nile delta are vulnerable to accelerated sea-level rise at the same level. Based on multiple criteria the Nile delta-Alexandria coast can be categorized into vulnerable (30%), invulnerable (55%) and artificially protected coastal stretches (15%), Frihy (2003). This case study of a vulnerability assessment of Nile delta is based on assumed scenarios of sea level rise of 0.5m and 1.0m by the end of the 21st century. Remote sensing and GIS techniques are used to assess vulnerability and identify sectors likely to be most seriously impacted (El-Raey, 1996). A general survey of the potential effects of climate change on the costal zone of Egypt. Map 3 showed that the potential impact of sea level rise: Nile delta of today and predicated (0.5 and 1.0 m) of affected areas. UNEP/GRID Arendal (2000) & Sida (2001).

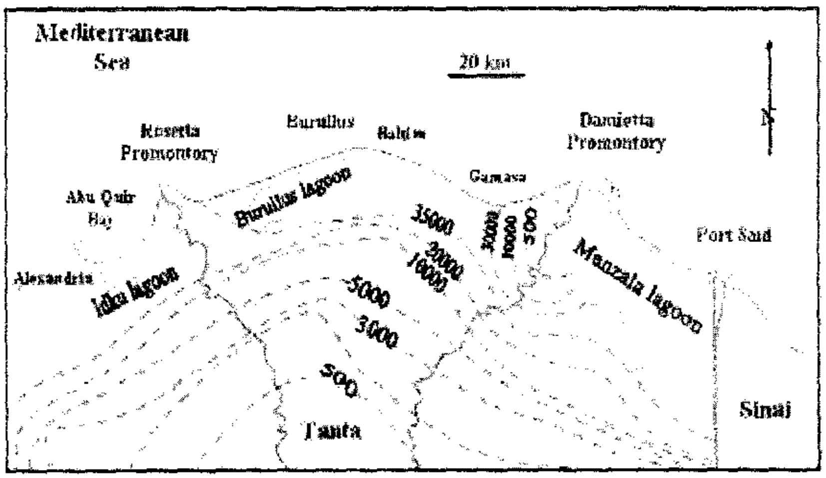


Map 3. The Current and predicated areas affected by the rising sea-level of Nile Delta.

Pressures indicators

Sea-water intrusion

Seawater intrusion phenomena are of main concern in all coastal aquifers around the globe. The problem is more severe in arid and semiarid regions where the groundwater constitutes the main freshwater resource. The Nile Delta aquifer is severely subject to the problem of saltwater intrusion from the Mediterranean Sea causing serious environmental impacts. A limited number of models have been applied to study the saltwater intrusion into the Nile delta aquifer. Attia & Madiha (1988) indicated that: (i) the thickness of the Nile delta aquifer in direct contact with the Mediterranean Sea is about 680 in, (ii) the distance of seawater intrusion, at the bottom of the aquifer, is 67 km, (iii) the inland extent of the dispersion zone (between the isochlore-lines 1000 and 35000 ppm) is 43 km, and (iv) the northern limit of the region where upward flux of brackish groundwater occurs through the semi-previous layer is at 22 km from the sea. In addition, the most serious effect of subsidence/ rise of RSL could be the incursion of the sea onto the low-lying, vulnerable outer margin of deltas (Stanley,1997). Hefny & Shata (1995) have indicated that the Nilotic aquifer system in the northern Nile delta to Tanta has a thickness of about 1000 m, overlying the thick Pliocene clay. The aquifer increases in thickness from about 250 in the south to about 900 m at the coast. The recharge of the aquifer is mostly from the Nile and irrigation canals (the contribution of rainfall is minimal). Hydrogeological studies have recorded distinct distribution of fresh, brackish and saline waters that under lie the delta plain (Gaamea, 2000). According to Shata & El-Fayoumi (1970) a safe and limited amount of fresh water is being extracted from the upper parts of the delta (1.6 billion m^3/yr) for the agriculture, domestic and industrial uses. The distribution of groundwater salinity in the lower Nile delta for the 50 m depth below the land surface is shown in Map 4, which shows a large belt of saline water near the coast followed by a brackish groundwater to south (Gaamea, 2000). This map reveals that iso-contours of saline water from <35000 to <700 ppm is progressively shifted southward starting from Alexandria in the west to the east at Manzala lagoon-Port Said area, extending 50 m from the coast. Stanley (1997) has attributed the wider and more extensive groundwater salinity pattern in Manzala lagoon, extending 130 km from the coast, to the higher subsidence rates in this area, providing evidence that marine water intrusion toward the south and southwest is a function of subsidence. In theory, a rising of RSL would unbalance the ground water salinity pattern; probably will shift the salt water wedge inland even in coastally protected areas and this in turn may increase salinization of soil profile and affect the agriculture land use system in the lower delta (Delft Hydraulics / CRI, 1991). The lagoon ecosystem, and hence fish resources, would probably adjust to gradually changed conditions of salinity and water temperature (Sestini, 1990 & 1992). Sherif (2002) indicated that rice cultivation increased in the southern part of the Delta and decreased in the northern part would contribute effectively to the mitigation of the sea water intrusion. This will help mitigate the seawater intrusion on long term. Map 4 showed that Distribution of groundwater salinity in ppm in the lower Nile delta for 50 m depth, showing incursion of saline water into the northeastern part and brackish water in the north western part including Alexandria (Gaamea, 2000).



Map 4. Distribution of groundwater salinity in ppm in the lower Nile delta for 50 m depth, showing incursion of saline water into the northeastern part and brackish water in the north western part including Alexandria (Gaamea, 2000).

Urban encroachment

Desertification process as urbanization intrusion on the highly fertile agricultural land is among the up-to-date difficulties facing agriculture in Egypt. Khalil *et al.* (1999) studied that urban growth trend in El-Mahalla El-Kobera, Gharbiya governorate. Data indicate that urbanization growth rate is increasing with elapse of time and figured out to 10.3 and 32.65% yearly, in the period 1950-1987 and 1987-1995. However, the overall mean loss in agricultural land amounted to 0.34-0.46 5% yearly in the first and second period of detection respectively. Fahim *et al.* (1999) studied that urban growth trend in Tanta, Gharbiya Governorate. Data showed that urbanization growth rate in the period 1950-1987 9.2 % year was magnified, however, in the period 1987-1995 to score of 18.8% year, twice as high as that the previous decade. Unfortunately, a yearly decrease in the agricultural land was detected, which figured out to 0.44-0.48% / year for both period 1950-1987 and 1987-1995, respectively, with reference to agricultural land and urban areas acreages in 1950.

Recent surveys from 1992-1995 showed urban encroachment to have covered around 20,000 feddans of fertile areas. In ten years ago, urbanization removed almost 8,313 ha from agricultural production in the western Desert representing a 10.3% increase in the urban land use during this period. It is estimated that urban encroachment and soil scrapping may have caused the desertification of 20,000 feddans yearly. Lenney *et al.* (1996) indicated that the amount of land lost to urbanization, defined as the encroachment of an existing urban settlement onto previously productive agricultural lands, is less than anticipated. Only 0.4% of productive agricultural lands were converted to new urban use between 1984 and 1990. Also, they showed that the urbanization sites are defined using satellite images analysis; only 47.06% of these sites were correctly identified on the ground and merely 37.22% of urbanization features on the ground can be expected to be correctly identified.

Soil scrapping

Serious adverse and irreversible desertification process used to continually sizable areas of highly fertile areas into urbane residential areas or scrapping the top 1.0-2.0 meters of the soil for the manufacturing of red bricks. (Hegazi *et al.*, 2002).

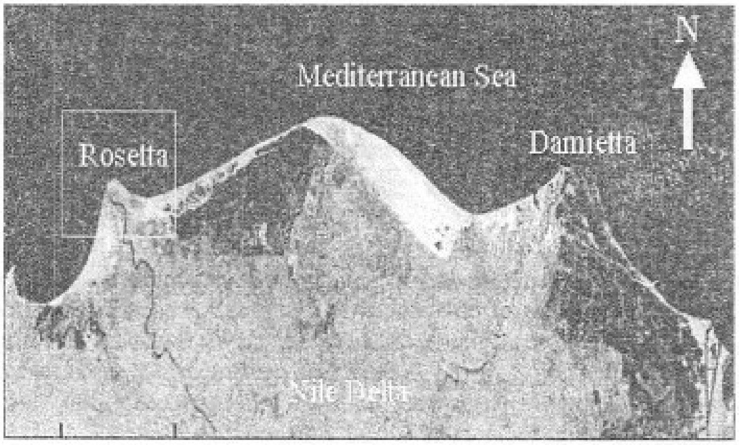
Water quality

Drainage water from agricultural land collects residues of applied fertilizers and related agro-chemicals. Some drains also receive sewage as well as industrial waste from the villages and cities in the Delta. In areas of Greater Cairo and Alexandria, where drains would contain raw sewerage and/or industrial liquid waste, the poor quality of the water could negatively impact on livestock and crops production in the Delta (The World Bank, 2002).

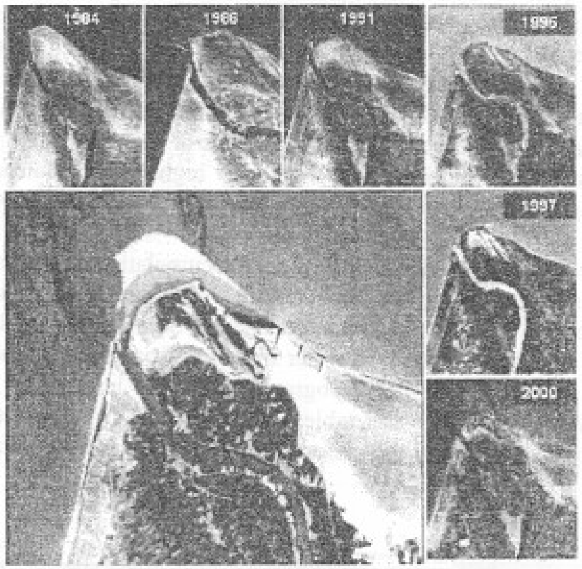
State indicators

Shoreline erosion

The erosion rates of shorelines of the Nile Delta have been enhanced in the last two decades. Satellite imagery estimated the areas lost to the sea to be several thousand feddans. This was attributed to the lack and change of sediment load of Nile water discharge to the Mediterranean Sea at the end of Demiatta and Rashid Nile marine branches (Map 5). Other investigations warn of the impacts of climatic change on the coastal areas of fertile valley. These could present more serious and adverse impacts than the present erosion rate of shorelines. Remote sensing has been used to detect shoreline changes along Rosetta promontory of the Nile Delta over the last two decades. The study focuses on using the geo-information technology for updating changes over the delta coast, in particular active stretches of the coastal area, by comparing existing configurations with ancillary surveys and studies, describing various changes, and attempting to establish existing and future classifications of different coastal activities. Multi-dates satellite data for the years, 1984, 1986, 1991, 1995, 1997 and 2000 were used. Results of the study showed that the rate of changes is 118.6 m/y (Map 6) (Ahmed, 2000). Other published results determined a rate between 18 m/y as a minimum shift and 230 m/y as a maximum shoreline change at Rosetta promontory over the last century. All studies revealed that this severe erosion is due to coastal processes, sediment deficiency and sea level rise or/and delta subsidence. Coastal instability at Rosetta promontory has almost continued during the last century. Severe erosion was determined along other cells over the delta coast. Many development projects are constructed and planned during the last five decades, without taking in consideration this kind of problems.



Map 5. Rosetta promontory along the Nile Delta coastal zone of Egypt.



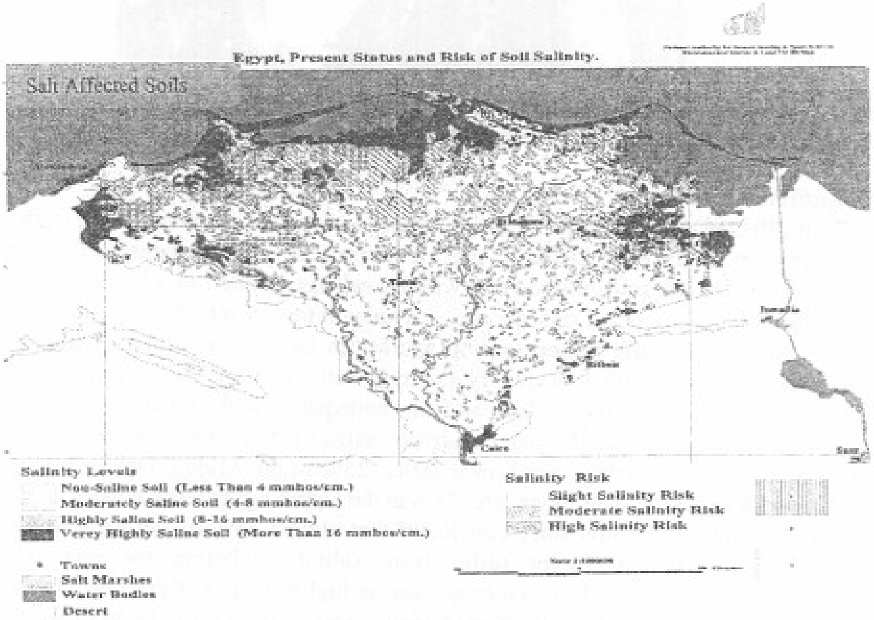
Map 6. Shoreline detection changes of Rosetta coastal zone using multi-date satellite images along the Nile delta coast.

Salt-affected soils

Salt-affected soils, in spite of their scattered occurrence, mainly exist in the northern part of the Nile Delta. in the Mediterranean coastal plains and lower Delta, excessive rates of groundwater withdrawal has resulted in a large drop in the water table and, as a Consequence, seawater intruded into the aquifers (El-Bably, 2002). The main reason for soil salinity in these areas include seawater intrusion, irrigation with low quality (saline) water as they are located at the downstream regions of the system, and an inadequate field drainage. An early soil survey indicated that the percentages of salt-affected soils relative to total cultivated lands was 60% in the Lower Delta, 25% in the Middle Delta, 20% in the Upper Delta and Middle Egypt, and 25% in the Upper Egypt (Aboukhaled *et al.*, 1975). A rather recent inventory concluded that almost 35% of the agricultural lands (ca. 1 Mha) in Egypt suffer from salinity, wherein the electrical conductivity of the extra from saturated soil is higher than 4 dS/in (El- Bably, 2002). The majority of the salt affected lands exist in the Lower Delta. Indeed, the current situation is serious and threatens riot only the agricultural sustainability, but also the whole ecological system.

In general, the causes of soil salinization in the Nile include a high water table, resulting from either over-irrigation or insufficient drainage system, irrigation with salty drainage and groundwaters, accumulation of surface runoffs in low-lying areas, lateral movement of subsurface water from up slope to down-slope irrigated lands, and overuse of salt-generating agrochemical (Kotb *et al.*, 2000). The soils of the southern part of the Delta are generally non-saline, as the electric conductivity of their saturation extracts is below 4 dS m^{-1}. The salinity problem becomes more severe when approaching the Mediterranean coast and around the north lakes where soils are extremely saline. The total soluble salts in general increase with depth, due to the effect of the ground water (Abdel-Aal, 1971). Soluble magnesium exceeds soluble calcium at this site due to contamination from the seawater. Sulphates are relatively higher near Manzala Lake due to secondary gypsum formation usually found in Sirw area (Abdel-Aal, 1971).

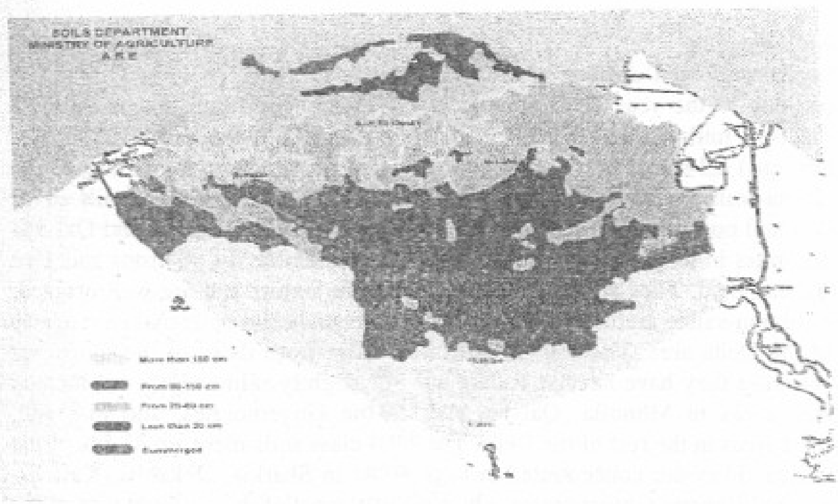
However, in soils of the south, salt accumulation has occurred from the irrigation system during the last century, since no action was taken for the construction of an adequate drainage system. Saline soils in the northern part have been affected by brackish water intrusion from the sea, the northern lakes and tidal marches. The flat topography and low land have accelerated this process by bringing the water table close to the soil's surface (El-Nahal *et al.*, 1977). Map 7 showed that the present statutes and risk of soil salinity in Egypt.



Map 7. Present statutes and risk of soil salinity in Nile Delta.

Waterlogged soils

The water-table was deeper than 150 cm in the majority of the southern part, and was shallower in the northern part near the coastal lakes; reaching less than 20 cm from the soil surface and in some areas the soil was submerged under water (Map 8), (El-Bably, 2000). In all cases, however, the subsoil in the northern areas was quite wet and showing evidence of poor-aeration. The presence of reduced iron manganese concentration and colour mottling at different depths of the subsoil indicates poor drainage and anaerobic conditions. However, the depth of the groundwater reflects only the situation at the sampling time and does not represent seasonal variations. In some areas, the measurement of groundwater depth as well as other soil survey investigations was carried out during high groundwater seasons. These records are considered as descriptive and could be used to give indication of the range in which the groundwater in a certain area lies (El-Nahal *et al.,* 1977). Shallow water table in the southern part of the Delta was found in areas subjected to water seepage from in canals where drainage was lacking or proved to be inadequate. Ground water table was deep in areas where no seepage occurred or where drainage system was constructed. Khater *et al.* (1997) and Zein *et al.* (2000) found that values of electric conductivity and sodium adsorption ratio (SAR) for ground water table varied from one location to another. Regarding the range of drainage rates in tile Nile Delta, the general conclusion is that apart from a few and small catchments in the Middle and South Delta, tile majority of the areas with high drainage rates (5.22-10.68 mm day^{-1}) lies along tile coastal plain. These areas are considered the last sites for water recycling before tile final disposal into the Mediterranean Sea and Terminal Lakes. The average drainage rate in Egypt is assumed to be 1 mm day^{-1} for the design of subsurface drainage system according to tile above-mentioned conditions. Normally, tile assumed drainage rate is adequate for properly operating systems as in the case of tile South Delta. In contrast, the high drainage rates in the North Delta cause an inadequate drainage system and result in high water tables. Moreover, the North Delta catchments may become water-logged by the intruding sea water.



Map 8. Depth of water table level in Nile Delta.

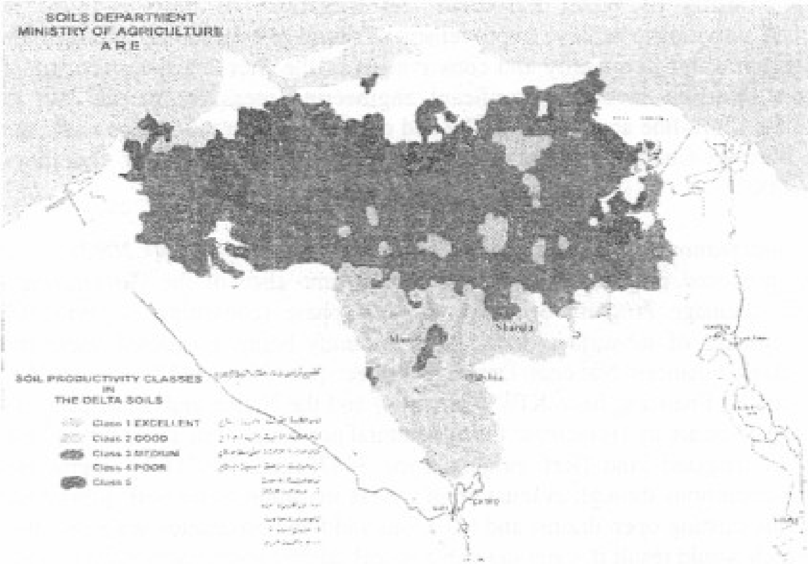
Soil and water pollution

The consumption of chemical fertilizer increased sharply. The overuse of fertilizers continued through the nineties coupled with more intensive use of pesticides and other chemical fertilizers seeking ever increased productivity especially after the liberization of prices of agriculture products. The use of pesticides increased in Egypt from 2143 tons in fifties up to 11700 tons in 1990. The overuse of chemical fertilizers and the residues of applied pesticides were sources of pollution of soil and water resources. Other sources of pollution are the dumping of industrial wastes water in the irrigation canals. Such source of pollution was enhanced considerably after rapid expansion of textile, chemical, automotives, leather…..etc industries in the sixties, seventies and eighties. The seepage of some sewage water with low treatment levels was another source of pollution especially towards the end of irrigation canals draining in the lakes in the far north regions of the Nile Delta where pollutants were accumulated with high concentrations causing adverse chemical and biological impacts. The long standing traditions of rotational use of fertilizers in old fertile delta soils was altered after the construction of the High Dam under the wrong impression that the lack of sediments load in the Nile water due to the construction of the High Dam will lower the fertility of the Nile Delta soils. This wrong impression led to the extensive use of chemical fertilizers, pesticides and agrochemicals amendments. The extensive use of nitrogenous fertilizers led to excessive leaching of nitrates to excessive leaching of nitrates to the water table and further to the groundwater resources. The produced food products could be contaminated with pesticide residues and rejected as export commodities. Health and environmental hazards are serious threats to the humans, animals, flora and fauna with adverse effects extending to the main areas where drainage water is discharges (Hegazi, 2002).

Impact indicators

Land productivity decline

Projections to the year 2000 now show a potential food gap that is only 17 percent (4.5 million tons) of the food gap projected in the early 1980's (26 million tons). El-Nahal *et al.* (1977) showed that the productivity classes of the Nile Delta soils as shown in Map 9 (El-Bably, 2002). The first class soils cover only a small portion of the Nile Delta, about 4% mainly in Menofia and Qalybia Governorates in the southern part. These soils are suitable for all crops and give the highest yield. They are deep soil with medium texture and are well drained. They are non-saline and free of alkalinity. The second class soils make up nearly 5% of the Delta area. The soils of this class differ from those of the first class only because they have heavier texture and are slightly saline. They are located in large areas in Monofia, Qalybia and Garbia Governorates, and in small, scattered areas in the rest of the Delta. The third class soils make up 33.5% of the Delta area. They are concentrated in large areas in Sharkia, Dekahlia, Kafr El-Sheikh, and Beheira Governorates, which occupy most of the northern part of the Delta. The fourth class soils make up 7.8% of the Delta area. They are concentrated mainly in the newly reclaimed soils along the desert fringe, south of the northern lakes and along the sea coast. The fifth class soils (flooded land) make up 22.5% and the sixth classes (public utilities) make up 7.4% of the Delta area. Generally, the high salt content, high water table and the heavy or coarse texture are the main factors that restrict the productivity of the third and the fourth class soils (Map 9).



Map 9. Soil productivity classes in the Nile Delta soils.

Response indicators

Legislations

Legislations were passed in the years 1983 and again in 1985 imposing serious penalties for scrapping of the top soil material for manufacturing ores brick. Urban encroachments on fertile lands are prohibited and city limits were marked. (Law 4, 1994).

Land improvement and conservation

In 1971, the Ministry of Agriculture and Land Reclamation established the Executive Authority for Land Improvement Projects (EALIP) which has the overall responsibility of all types of land improvement in Egypt. It plays a central role to implement the strategy of the government for better utilization, conservation and restoration of land productivity. EALIP has been implementing a land improvement programme covering the entire irrigated lands of Egypt. It has a yearly plan to improve 1 500 000 feddans all over the country. The application for improving programme includes gypsum application for improving the productivity of sodic soils, subsoiling to improve soil physical properties, break up hard pans, soil compaction and all indurate layers within the root zone, land leveling and reshaping for better water management and improvement of the drainage and canal system for salinity and waterlogging control.(Gomaa,2002 and Gehad, 2003).

Shoreline protection

The Ministry of Water Resources and Irrigation has been involved in continued activities to achieve improvement of drainage conditions, conservation of irrigation water in quantity and conservation of the shorelines. Combating of seawater intrusion involved significant engineering measures carried out to protect the shore-line areas of the Delta and certain important locations along the North-Western Coastal areas at Rashid, Balteem, and Ras- El-Bar shorelines (Frihy, 2003).

The Second National Drainage Project 2001-2007 (The World Bank 2002)

The proposed project would be the second time slice of the Government's National Drainage Program of which the first phase (consisting of about 0.7 million feddans of subsurface drainage) is currently being completed under the World Bank-Financed National Drainage Project (Ln. No. 3417/Cr. No. 2313-EGT) with co financing from KfW (Germany) and the Netherlands. The project's main objectives are to: (i) increase the agricultural productivity of about 0.8 million feddan of irrigated land (Ref. project maps 30870 and 30871) by improving drainage conditions through evacuation of excess irrigation water with subsurface drains into existing open drains; and (ii) avoid yield and production losses on this land, which would result if water logging and soil salinity problems were to persist. Other project objectives include building capacity in the Egyptian Public Authority for Drainage Projects (EPADP) through institutional support, technical assistance and training activities provided under bilateral donors' assistance. In addition, the project would assist in identifying and addressing the environmental issues resulting from the discharge of untreated raw industrial and domestic waste into a few open drains in the project areas.

Investment in land and water resources / Commitment to International Convention

A Scientific Committee was established to be affiliated to the National Coordinating Committee for Combating Desertification (NCCCD). The Scientific Committee is headed by the president of the Desert Research Centre who is the National Focal Point for UNCCD. The other members of the Scientific Committee are high level experts from varied institutions of previous and recognized expertise in the fields of combating desertification. The Scientific Committee is entrusted with the following (Hegazi *et al.*, 2002) :

(a) Survey, compile and analyze previous and ongoing activities to combat desertification
(b) Assessment and monitoring of processes of desertification
(c) Coordination of activities with the various stakeholders.
(d) Follow up on the implementation of commitments of Egypt towards the implementation of UNCCD .

(e) Follow up on implementation of the NAP and assessment of the impacts of its activities. Since the inception of NCCCD and its affiliated Scientific Committee in July 2001 concerted activities were conducted to expedite the formulation and endorsement of NAP of Egypt.

Summary and Conclusion

General conclusion

The coastal zone of Nile Delta suffers from a number of serious problems, including a high rate of population growth, land subsidence, excessive erosion rates, water logging, salt water intrusion, soil salination, land use interference ecosystem pollution and degradation, urbanization on fertile soils and lack of appropriate institutional management systems. Realizing the importance of this zone, the Egyptian government has already taken steps towards reducing the impact of these problems. These indicators evaluated throughout DPSIR approach.

Specific conclusion

1. The coastal zone of Egypt is seriously vulnerable to the effects of sea level rise and changes in weather patterns from both the physical and the socio-economic points of view. Large areas of the governorates of Alexandria, Behaira, Kafr El-Shiekh, Port Said, Damietta and Suez, are particularly vulnerable to sea level rise.
2. The impacts of accelerated sea level rise (ASLR) through direct inundation, salt water intrusion, deterioration of ecological systems and associated socio-economic consequences, have been addressed.
3. The techniques and methodologies for vulnerability assessment of Egypt's coastal zones are reasonably well identified (*e.g* remote sensing and GIS). Although a quantitative pilot study has been carried out for one or more of the vulnerable areas (*e.g.* Alexandria Governorate, Port Said,.....), current data on land use and elevation are needed before reaching a final overall assessment of the potential impacts of climate change on the coastal zones of the country.
4. Irreversible desertification process used to continually sizable areas of highly fertile areas into urbane residential areas.
5. A program based on a strategic policy for costal protection and adaptation already implemented.

References

Al Askary, M.A. and Frihy, O.E. (1986) Depositional phases Rosetta and Damietta promontories on the Nile Delta coast. *J.of Africa Earth Sciences* **5**, 627.

Aboukhaled, A.; Arar, A.M.; Balba, A.M.; Bishary, B.G.; Kadry, L.T.; Rutema, P.E. and Taher, A. (1975) Research on crop water use, salt affected soils and drainage in the Arab Republic of Egypt, Food and Agriculture Organization of United Nations, Near East Regional Office, Cairo, Egypt pp. 62-79.

Abdel-Aal, R.M. (1971) Effect of ground water and parent material on different soil characteristics in the north east Nile Delta. *Ph.D. Thesis,* Cairo Univ., Egypt.

Abdel-Kader, F.H. (2003) Land degradation and conservation measures in Egypt Medcoast Land Project, Workshope1: Ecosystem-based assessment of soil degradation to facilitate land users and land owners prompt action. Adana. Turkey, 2-7 (2003).

Abdel-Kader, F.H. (2004) Data sets and models for assessing key land degradation indicators in dry land of Egypt. Seminar..... National Authority for Remote Sensing and Space Sciences (NARSS) February 24^{th} , 2004, Cairo.

Abdel-Kader, F.H. and Bahnassy, M. (2001) Digital soil map of Egypt at scale 1:1000.000. In: First meeting on Work progress of the eastern Mediterranean Soil mapping at 1:1 million scale. Lebanese National Council for Scientific Research, Beirut, 15-18 January (2001).

Abdel-Shafy, H. I. and Aly, R. O. (2002) Water Issue in Egypt: Resources, Pollution and Protection Endeavors. CEJOEM, Vol.8. No. 1. pp. 3–21.

Abu-Zeid, M. (1995) Major policies and programs for irrigation drainage and water resources development in Egypt, Options Méditerranéennes, Sér. B / n°9, 1995 - Egyptian Agriculture Profile.

Attia, Fatma A.R. and Madiha, Mustafa (1998) Seawater intrusion in Egypt and groundwater development. Chapter 12. Water Reports 11. Seawater Intrusion in Coastal Aquifers, Guidelines for study, monitoring and control. FAO (1992).

Ahmed, M.H. (2000) Long-term changes along the Nile Delta coast: Rosetta promontory A case study Egypt. *J. Remate sensing & Space Sci.* **3**, 125.

CAMPAS (2001) Central Agency for Pubic Mobilization and Statistics. Statistical Year Book, Cairo, Arab Republic of Egypt.

Coertelliery, V. and Stanley, D.J. (1987) Late quaternary stratigraphy and paleography of the eastern Nile Delta, Egypt. *Marine Geology* **27,** 257.

Delft Hydraulics / CRI. (1991) Implication of relative sea-level rise on the development of the lower Nile Delta, Egypt, Pilot study for a quantitative approach, Final Report, p. 300.

El-Bably, A.Z. (2002) Advanced and integrated approaches for crop tolerance to poor quality irrigation water in Egypt: 7^{th} *International Meeting* on soils with Mediterranean type of climate. Bari: CIHEAM, 361-378.

El-Nahal, R.M.; Abd El-Aal, A.A. and Abd El-Wahed, A.A. (1977) Soil Studies on the Nile Delta. Egypt. *J. Soil Sci.* **17** (1), 55.

El-Raey, M. (1996) Impact of climate change on Egypt. Coastal Zone Development and Climate Change. The GAIA Project .

Farid, M.S. (1985) Management of ground system in the Nile Delta. *Ph.D. Thesis,* Faculty of Engineering, Cairo University, Cairo, Egypt.

Fahim,H.M.; Khalil, K.I.; Hawela, F.; Zaki, H.K. and El-Mowelhi, N. (1999) Multitemporal detection of urbanization growth II. urban encroachment detection in Tanta, Gharbiya Governorate. Egypt. *J. Soil Sci.* **39**, (2), 145.

Frihy, O.E. (2003) The Nile Delta-Alexandria coast: vulnerability to sea-level rise, consequences and adaptation. *Mitigation and Adaptation Strategies for Global Change.* **8**, (2), 115.

Gaamea, O.M. (2000) Behavior of the Transition Zone in the Nile Delta Aquifer under Different Pumping Schemes, *Ph.D. Thesis,* Dissertation, p. 180 Cairo University. Cairo, Egypt.

Gomaa, M. (2002) Land and water resources information system in Egypt. Workshop: Land Resources Information Systems in the Near East. Cairo, 3-7 September 2001, FAO, Rome.

Gehad, A. (2003) Deteriorated soils in Egypt: Management and Rehabilitation Executive Authority for Land Improvement Projects, EALIP – Egypt.

Hammad, H.Y.; Mobarek I.; Khafagy, A.A. and Sidky, S. (1979) A short nate on the sediment regime of the river Nile. Bulletin, Institute of Oceanography and Fisheries. 7, 314 Alexandria, A.R.E.

Hefny, K. and Shata, A. (1995) Strategy for planning and management of groundwater in the Nile Valley and Delta in Egypt, Strategy Research Program, Working paper, pp. 1–31.

Hegazi, M.; El Bagouri, I. H.; Kassas, M. A. (2002) Arab Republic of Egypt, National Action Plan for Combating Desertification. www.unccd.int

Khater, A.A.; A. Al-Sharif, and Abdellah, A.A. (1997) Potential effect of ground water table on some pedogenic formations in the soils of Kafr El-Sheikh Govemirate, Egypt. *Menofiya J. Agric. Res.* **22** (1), 213.

Khalil, K.I.; Fahim, M.M.; Zaki, H.K. and El-Mowelhi, N. (1999) Multitemporal detection of urbanization growth I. Urban growth trend in El Mahalla El Kobra, Gharbiya Governorate. *Egypt. J. Soil Sci.* **39** (2), 129.

Kishk, M.A. (1997) Poverty of environment & environment of poverty, *Proceeding of the National Symposium* on Poverty and Environmental Deterioration in Rural Egypt, Minia, Egypt.

Kotb, T.H.S.; Watanabe, T.; Ogino, Y. and Tanji, K. (2000) Soil salinization in the Nile Delta and related policy issues in Egypt. *Agricultural Water Management* **43**, 239.

LADA (2002) http: //www. fao. org/landandwater/agll/lada.

Land Master Plan of Egypt (1986) Arab Republic of Egypt, Ministry of Development, General Authority for Rehabilitation Projects and Agricultural Development, Cairo, Egypt.

Lenney, M.P.; Woodcock, C.E.; Collins, J.B. and Hamdi, H. (1996) The status of agricultural lands in Egypt: The use of multitemporal NDVIF eatures Derived from landsat TM. *Remote Sens. Environ.* **56**, 8-20 (1996).

Metz, H.C. (1991) *"Egypt. A Country Study"*, Library of congress, Washington,, D.C.

Nielsen, E.V. (1977) Share evolution. CRI/UNDP/UNESCO, processes (Academy of Scientific Research and Technology) 15-59.

Said, R. (1981) *The Geological Evolution of the River Nile,* p. 151, New York, Springer Verlag.

Sestini, G. (1990) Impacts of global climate change in the Mediterranean region: Responses and policy options. In: *"Changing Climate and The Coast"*. J.G. Titus (Ed.), Vol. **2**, pp. 115–125,Western Africa,the Americas, the Mediterranean Basin and the Rest of Europe.

Sestini, G. (1992) Implications of climate change for the Nile Delta. In: *"Climate Change and the Mediterranean"*, L. Jeftic; J.D. Milliman and G. Sestini (Ed.), pp. 533–601. Environmental and societalimpacts of climate and sea-level rise in the Mediterranean Sea, London, Edward Arnold.

Sestini, G. (1976) Geomorphology of the Nile Delta. CRI/UNDP/UNESCO, proceedings seminar on the Nile Delta sedimentology(Academy of Scientific Research and Technology, Alexandria), 12-24.

Shata, A. and El-Fayoumi, I. (1970) Remarks on the hydrogeology of the Nile delta. In: *"Hydrology of Deltas"*, Paris, IASH/ UNESCO, Bucharest Symp., I., UNESCO.

Sherif, M. (2002) Assessment Modeling and management of seawater Intrusion in the Nile Delta Aquifer. *J. Hydrol.* **103**,11.

Sida (2001) Sea level Rise in Nile Delta, WWW.Sida.gov.

Stanley, D.J. (1988) Subsidence in the northeastern Nile Delta: rapid rates, possible causes, and consequences, *Science* **240**, 497.

Stanley, D.J. (1997) Mediterranean Deltas: subsidence as a major control of relative sea-level rise, *Bull. Inst. Oceanogr, Monaco* **18**, 35.

Stanley, D.J. and Warne, A.G. (1993) Nile Delta: recent geological evolution and human impacts, *Science* **260**, 628.

Stanley, D.J. and Warne, A.G. (1994) Worldwide initiation of Holocene marine deltas by deceleration of sea-level, *Science* **265**, 228.

UNEP/GRID Arendal (2002) *http:// www.grida.no/* Sea-level Rise in the Nile Delta.

World Bank (2002) Second National Drainage Project . *Report No:* 20443-EGT.

World Bank (2002) Arab Republic of Egypt: Poverty Reduction in Egypt, Diagnosis and Strategy, Report No. 24234-EGT, Volume 2, June.

Waterwatch (2003) *WWW.Waterwatch.nl*

Zein, F.I.O.; Abd-Allah, M.A.A. and El-Yamani, M. S. (2000) Influence of irrigation water quality on some crops, soils and watertable and their content of heavy metal, at the Northern Nile Delta-Egypt. *Egypt. J. Soil Sci.* (in press).

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مؤشرات تدهور الأراضى بدلتا النيل اطار (القوى المحركة – الضغط – الحالة – التأثير – الاستجابة)

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تم استخدام اطار (القوى المحركة – الضغط – الحالة – التأثير – الاستجابة) فى تقييم وتحديد مؤشرات رصد التدهور بدلتا النيل وتنقسم المؤشرات المستخدمة فى دلتا النيل إلى ما يلى:

مؤشرات القوى المحركة: Driving Force Indicators
النمو السكانى – معدلات الفقر – كميات المياه المتاحة – مساحة الأراضى المنزرعة – ارتفاع مستوى سطح البحر.

مؤشرات الضغط: Pressure Indicators
تقدم المياه الجوفية المالحة – الزحف العمرانى على الأراضى الزراعية – التجريف – جودة مياه الرى.

مؤشرات الحالة: State Indicators
النحر المائى للدلتا – ملوحة الأراضى – الغدق – تلوث التربة والمياه.

مؤشرات التأثير: Impact Indicators
تدهور انتاجية الأراضى بما ينعكس على حدوث الفجوة الغذائية السكانية التى لها تأثير على حدوث الفجوة الاقتصادية.

مؤشرات الاستجابة: Response Indicators
- أصدرت الدولة العديد من القوانين أعوام (١٩٨٣ ، ١٩٨٥) – قانون ٤ لسنة ١٩٩٤.
- دور الدولة فى التوسعات الزراعية من خلال اقامة العديد من المشروعات الزراعية فى الأراضى الجديدة.
- دور الدولة فى صيانة الموارد الأرضية والمائية من خلال مخطط الدولة لاستصلاح الأراضى ٢٠١٧.