Coastal Zones and Climate Change

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Impacts and Implications of Climate Change for the Coastal Zones of Egypt

Mohamed El Raey

Egypt is considered one of the countries most vulnerable to the potential impacts of climate change. High population density, high population growth, and the rapid spread of unplanned urbanization place considerable pressures on the country's land and water resources. Egypt already suffers from low technical capacity and low community resilience to cope with extreme weather events. Global warming is expected to further exacerbate water shortages in Egypt's arid to semiarid environment and lead to a rise in both heat waves and the severity and frequency of sand and dust storms.

Climate change will affect all sectors of development in Egypt, but particularly water supplies, coastal and agricultural resources, tourism, and public health. Downscaled General Circulation Models differ as to the projected increase or decrease of the Nile water budget, but the Nile's flow is known to be particularly sensitive to changes in temperature and precipitation in the upstream catchment regions that feed the river. The Nile Delta region is also highly vulnerable to inundation and saltwater intrusion from expected sea level rise.

Tourism and agriculture are sensitive to changes in temperature and the frequency of extreme events and heat waves. Both sectors contribute significantly to Egypt's economy. Tourism currently represents 11.3 percent of Egypt's GDP, 40 percent of total noncommodity exports, and 19.3 percent of foreign currency revenues. Even though Egypt does not produce enough food to feed its population, the agricultural sector in Egypt accounts for about 14.8 percent of GDP and about 30 percent of commodity exports, which makes it a major revenue generator. Of Egypt's overall labor force, 35 percent work in the agricultural sector, mostly in the Nile Delta region.[1]

This paper describes prevailing conditions in the coastal zones of Egypt and details the contributions of these regions to the national economy. It surveys coastal vulnerabilities to the potential impacts of climate change and assesses the risks to Egypt's economic and social well-being. Finally, it considers mitigation measures in progress and discusses the institutional systems necessary for the government and the private sector to respond proactively to the looming adaptation challenge.

The Coastal Zone of Egypt: Resources and Problems

Egyptian coasts extend over 3,500 kilometers, with one-third of this distance running along the Mediterranean Sea from Rafeh Town in the east to Salloum Town in the west, and two-thirds along the Red Sea and the coasts of the Sinai Peninsula. An estimated 53 percent of Egypt's population lives within 100 kilometers of the coast. Egypt's territorial area and claimed Exclusive Economic Zone represent about 9 percent of that of the Middle East and North Africa. In addition, Egypt has a large number of inland lakes, the largest of which are the freshwater Lake Nasser and the saline Lake Qarun in Fayyoum. The coastal zone is home to several highly populated economic centers, such as the cities of Alexandria, Damietta, Hurghada, Port Said, Suez, and Sharm El Sheikh. Many industrial activities, including petroleum and chemical production, and important tourism centers are located along the coasts. Trading and transportation networks and a large number of harbors are also found on the coasts. The coastal zone is an important source for fisheries, providing income and food security. Egypt's overall annual production of fish, according to 2004 statistics, is about 875,990 tons, of which 116,560 tons (13.3 percent of the overall production) are from the coastal waters.[2]

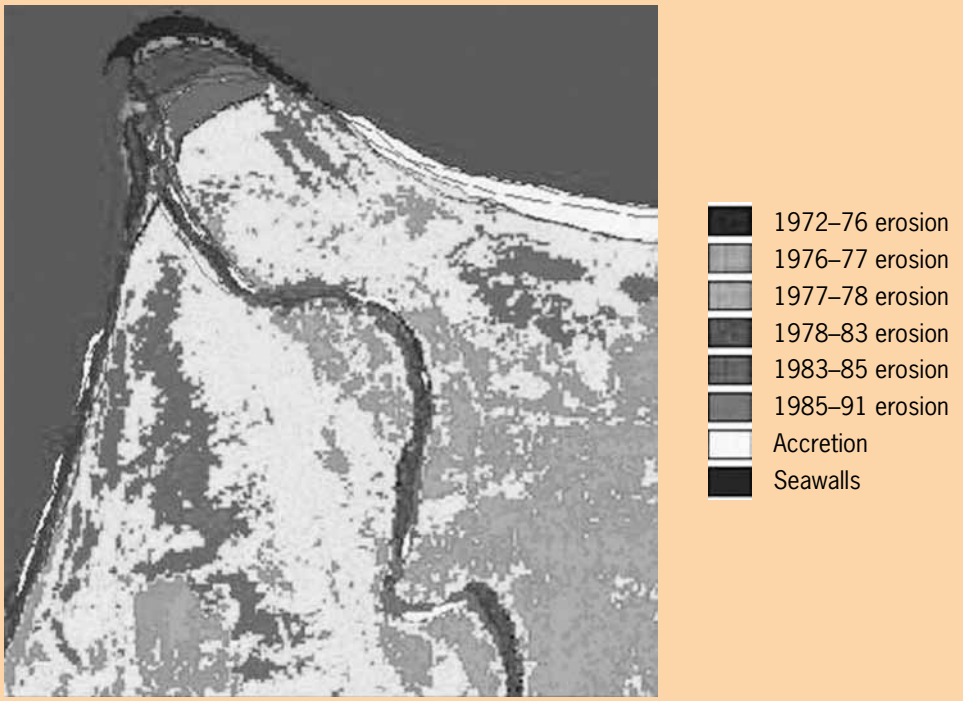
The Mediterranean Coastal Zone

The Mediterranean coastal shoreline of Egypt includes five large lakes, which constitute about 25 percent of the total wetlands in the Mediterranean region. This coastal zone has a large number of economic and industrial centers, as well as important beaches and tourist resorts. Precipitation along the Mediterranean coast varies between 130 and 170 millimeters yearly and decreases gradually to the south. The tidal range is about 30 to 40 centimeters.[3]

The Mediterranean coastal zone suffers from a high rate of population growth, land subsidence in the Delta region, excessive erosion rates (figure 1), saltwater intrusion, soil salinization, land use interference, ecosystem pollution and degradation, and lack of appropriate institutional management systems.

The Mediterranean coastal zone is the site of Egypt's second largest city, Alexandria, which is the country's main harbor. Located on the western side of the Nile Delta, the city sits partly on low-elevation land. Alexandria is home to about 40 percent of the country's industrial capacity, in addition to being a prominent summer resort. Other large cities in the northern low-lying Delta region include Rosetta and Damietta. Port Said is an important regional trading center on the Suez Canal to the eastern side of the delta. The coastal zone of the Nile Delta also has many small towns and villages with major populations of fishermen.

Figure 1: Overlaid Satellite Imagery of the Rosetta Promontory, Northwestern Nile Delta Coast, over 40 Years, Indicating Successive Erosion



Source: M. El Raey, S. M. Nasr, M. M. El Hattab, and O. E. Frihy, "Change Detection of Rosetta Promontory Over the Last Forty Years," *International Journal of Remote Sensing* 16, no. 5 (1995).

Note: Depicts Landsat MSS data for 1972, 1976, 1977, 1978, 1983, 1985, and 1991.

The Red Sea Coastal Zone

The coastal zone of the Red Sea on the Egyptian side is generally narrow because a mountain chain runs relatively close to the shoreline. The coast is composed of a large number of embayments, small gulfs, and small beaches. Fragmented and extended coral reef communities, with their rich marine life, extend over large areas of the coast. The tidal range varies between 110 and 130 centimeters.

The population is concentrated in a number of cities along the coast and a few scattered villages in between them. In the north, the Suez Canal connects the Red Sea with the Mediterranean, providing a vital international waterway and important source of income to Egypt. Farther south, the area has a large number of well-known diving sites because of its rich and highly diversified coral and mangrove communities. Major resort cities such as Dhahab, Hurghada, Nuweiba, and Sharm on the Red Sea employ a significant portion of the local population. Indeed, tourism along the coastal zone of Sinai and eastern Egypt on the

Red Sea accounts for a substantial part of Egypt's GNP and represents about 90 percent of the country's total income from tourism.[4]

The Red Sea coast has very limited freshwater resources as a result of its geographical location in the arid subtropical zone. The region also suffers from increasing habitat loss due to growing unplanned urbanization, pollution, coastal land filling, flash flooding, and the negative effects of tourism. The impacts of climate change on the Red Sea's world-famous coral communities include coral bleaching from rising seawater temperatures, loss of habitats, and loss of biodiversity, which can be expected to cause declines in tourism.[5] Egypt's lack of institutional capabilities to monitor and control these pressures will further exacerbate the impacts.

The Nile Delta Coastal Zone

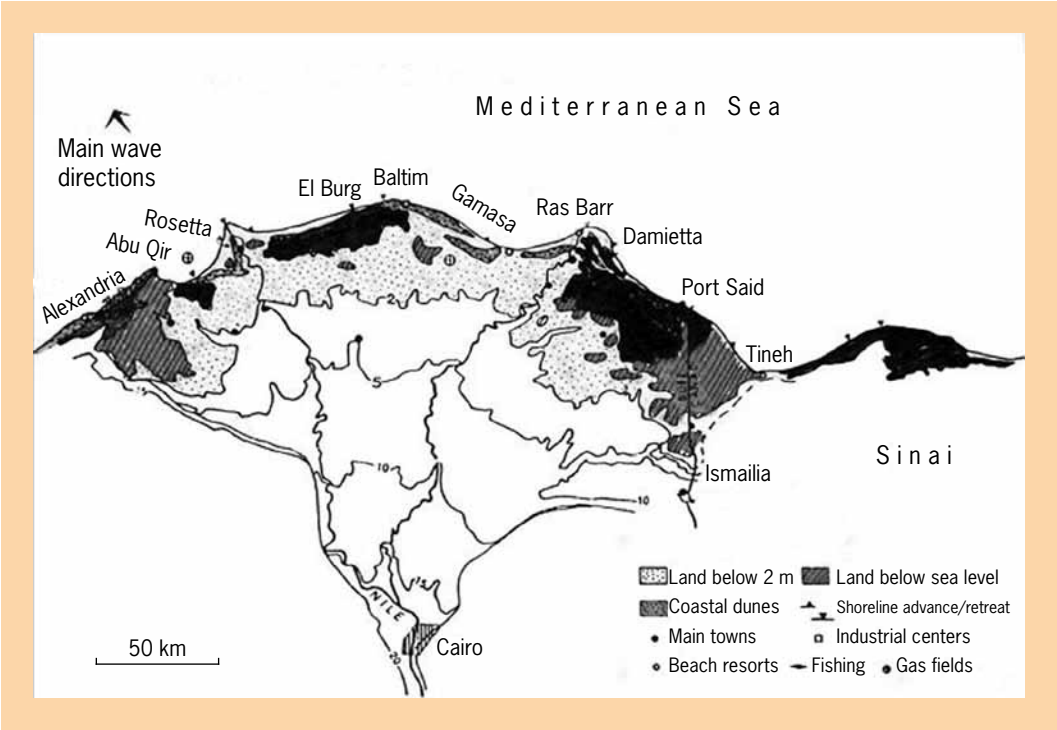
The Nile Delta region in the Mediterranean coastal zone represents the major industrial, agricultural, and economic resource of the country. It is home to over 50 percent of Egypt's population of 80 million and to about 70 percent of the nation's industrial and commercial activities.[6] The region is characterized by relatively low land elevation, which leaves it severely exposed to rising sea levels. In addition, it suffers from local land subsidence, compounding the effects of rising seas. Some estimates indicate that the northern delta region is subsiding at a rate that varies from about 2 millimeters annually at Alexandria to about 2.5 millimeters annually at Port Said.[7]

The Nile Delta shoreline extends from Alexandria in the west to Port Said in the east, with a total length of about 240 kilometers. This zone consists of sandy and silty shores of greatly varying lateral configurations, depending on where the old branches of the Nile have had their outlets. The coastline has two promontories, Rosetta and Damietta, and three brackish lakes—Idku, Burullus, and Manzala—are connected to the sea. There are five harbors located on the coast: Idku, New Burullus, and El Gamil are for fishing; and Damietta and Port Said are commercial ports.

Alexandria and Port Said are the main economic centers of the coastal zone. These cities are vulnerable to sea level rise as a result of the low elevation of adjacent land. Figure 2 illustrates the topography of the delta, showing that a large portion already lies below sea level. The Mohamed Ali Seawall, built in 1830, protects the lowland area southeast of Alexandria against inundation by water from Abu Qir Bay, and narrow strips of elevated land protect the southern area of Port Said. Many smaller towns and villages on the northern coast are also vulnerable to sea level rise and saltwater intrusion.

Like other deltaic regions worldwide, the Nile Delta is subject to shoreline changes resulting from erosion and accretion, subsidence, and sea level rise resulting from climate change. Since early studies by Sestini, various analyses have evaluated the impacts of

Figure 2: Topography of the Nile Delta Region



Source: M. El Raey, A. Nasser Hassan, R. J. Nicholls, and A. C. de la Vega-Leinert, eds., *Proceedings of SURVAS Expert Workshop on African Vulnerability and Adaptation to Impacts of Accelerated Sea-Level Rise (ASLR)*, Cairo, November 5–8, 2000.

climate change on the Nile Delta using various sea level rise scenarios (figure 3), concluding that a large percentage of the Nile Delta is directly vulnerable to inundation and saltwater intrusion that could drive millions from their homes.[8]

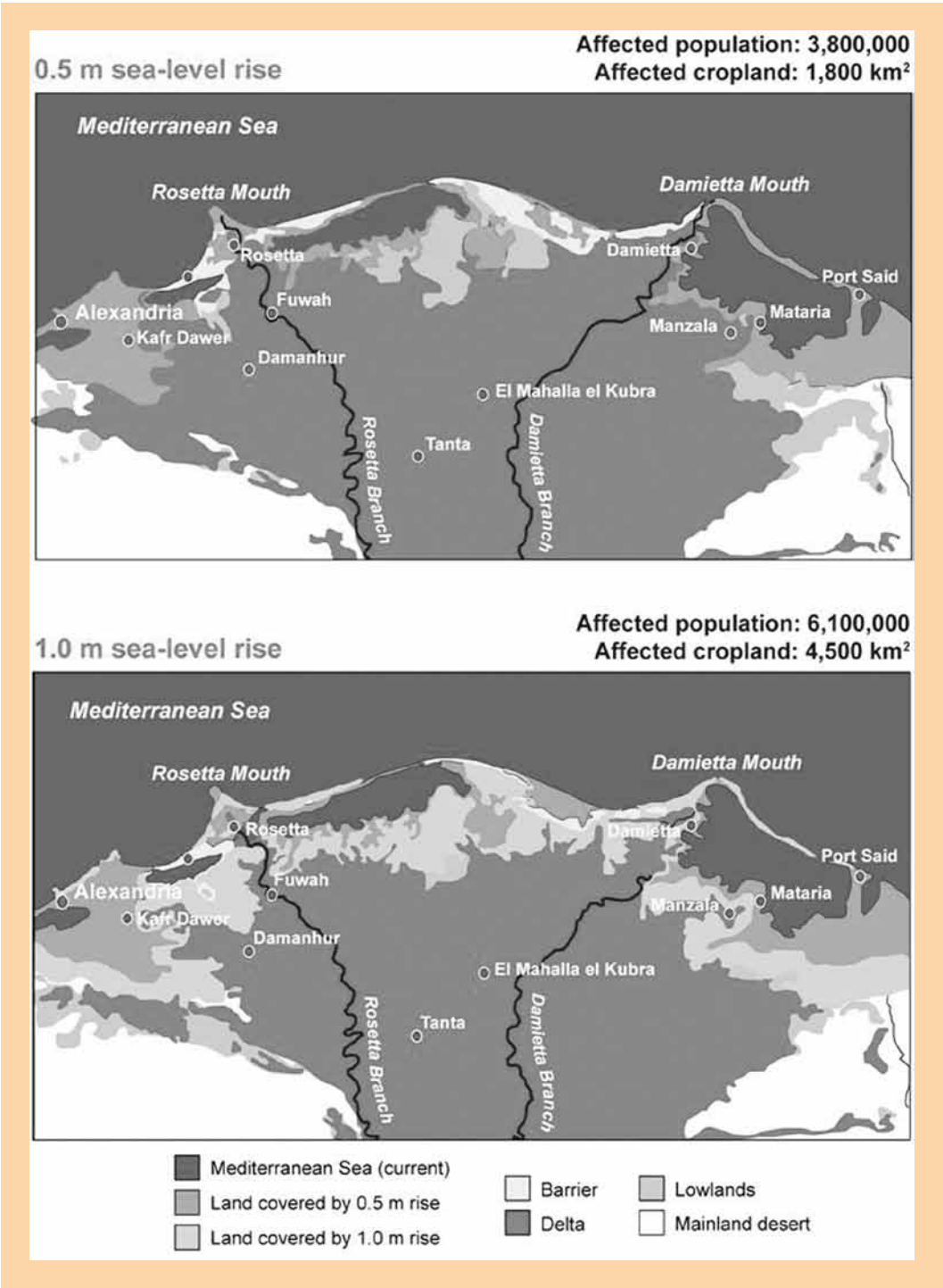
Consequences of Climate Change for Coastal Areas

Climate change will have serious repercussions for all sectors of development in the country. The most important general consequences include impacts on the water resources of the Nile River, agricultural productivity, and coastal resources and tourism.

Sea Level Rise

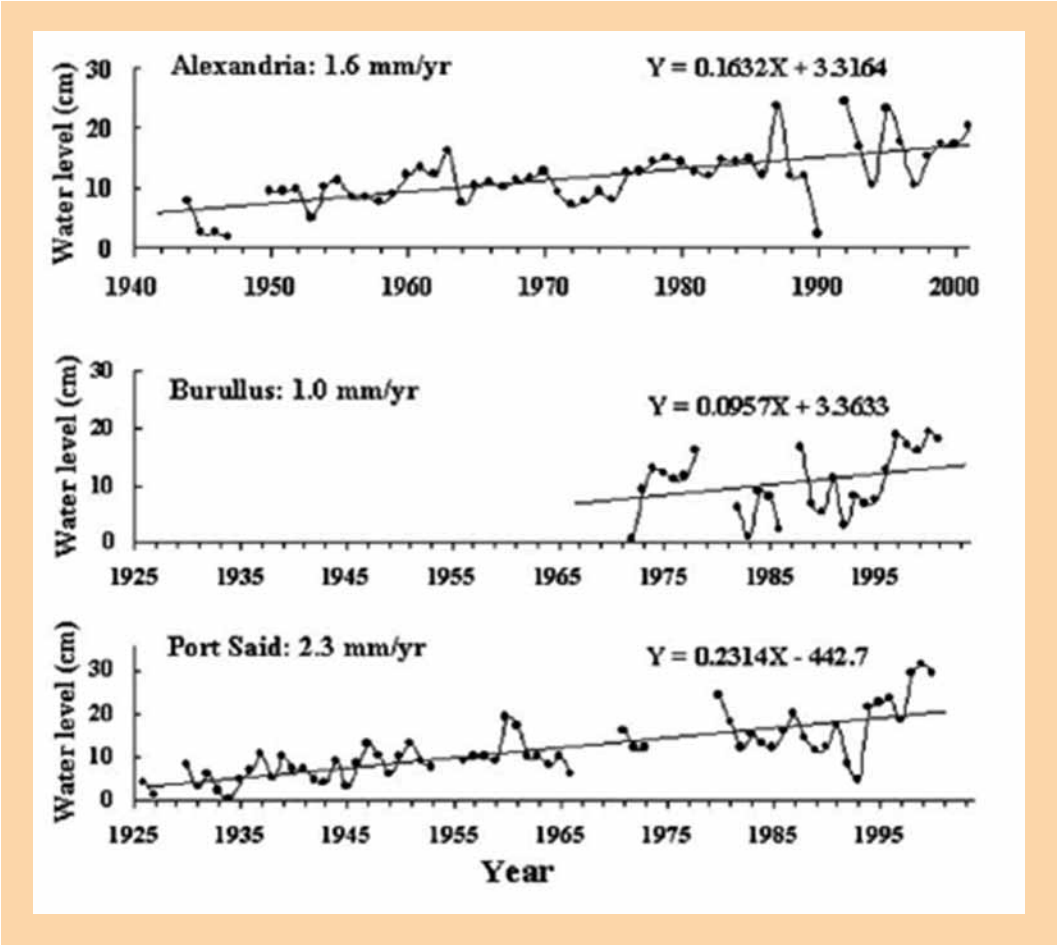
Results from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report indicate that a global sea level rise of 18 to 59 centimeters is expected by the end of this century.[9] In Egypt, local land subsidence in the Nile Delta would exacerbate the impacts of rising seas. Figure 4 represents the observed time variation of sea level and indicates the rates of land subsidence of the Nile Delta calculated by one study.

Figure 3: Expected Impacts of Sea Level Rise for Two Scenarios on the Nile Delta Region



Source: D. M. FitzGerald, M. S. Fenster, B. A. Argow, and I. V. Buynevich, "Coastal Impacts Due to Sea-Level Rise," *Annual Review of Earth and Planetary Sciences* 36 (2008).

Figure 4: Land Subsidence Rates as Estimated at Alexandria, Burullus, and Port Said



Source: O. Frihy, "The Nile Delta-Alexandria Coast: Vulnerability to Sea-Level Rise, Consequences and Adaptation," *Mitigation and Adaptation Strategies for Global Change* 8, no. 2 (2003).

The study area includes the entire coastal zone of the Nile Delta between Alexandria and Port Said. The inland boundary of the study area extends from the shoreline to the contour line of 3 meters above mean sea level. Tide gauge measurements at Alexandria, Burullus, and Port Said have been collected and statistically analyzed to estimate land subsidence over the last three decades at each of these regions. Results indicate that sea level rise varies from one region to another because of the difference in the land subsidence effect. Observed measures reveal that land subsidence is at least 1.6 millimeters per year at Alexandria and 1.0 millimeter per year at Burullus, while at Port Said the value is 2.3 millimeters per year.[10] These local estimates should be added to the IPCC global estimates over the current century to obtain final estimates of sea level rise.

The potential impacts of sea level rise will affect many sectors of development, including tourism, cultural and natural heritage, agricultural quality and productivity, freshwater availability, public health, and socioeconomic welfare.

Increased Soil Salinity from Saltwater Intrusion

Sea level rise is expected to exacerbate intrusion of saline water into the fresh groundwater aquifers in the coastal zone. Increasing temperature is also expected to enhance soil evaporation, hence increasing soil salinity. One early soil survey indicated that the amount of salt-affected soil relative to total cultivated land was 60 percent in the Lower Delta, 25 percent in the Middle Delta, 20 percent in the Upper Delta and Middle Egypt, and 25 percent in Upper Egypt.[11] A later survey concluded that almost 35 percent of the agricultural lands in Egypt suffer from salinity.[12] The current situation threatens not only agricultural sustainability but the entire ecological system as well.[13]

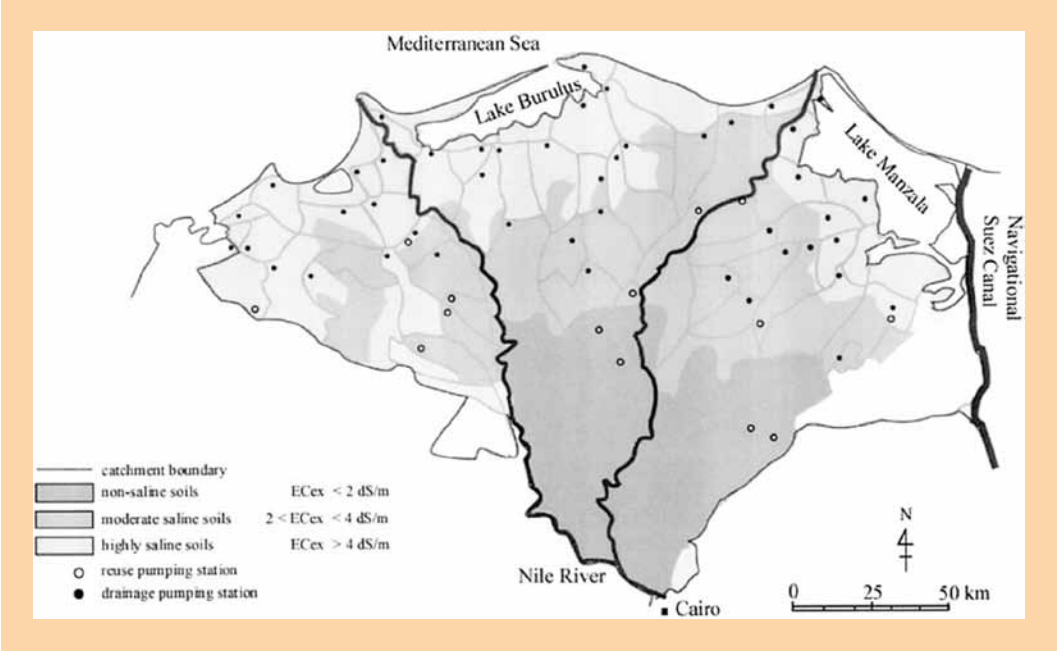
The majority of the salt-affected lands are in the Lower Nile, in the northern part of the delta, especially in low areas to the southeast of Alexandria. In the Mediterranean coastal plains and lower delta, excessive rates of groundwater withdrawal have resulted in a large drop in the water table. Consequently, seawater has intruded into the aquifers. The main reasons for soil salinity in these areas include seawater intrusion, irrigation with low-quality (saline) water, and inadequate field drainage. Figure 5 presents a classification of salt-affected soils in the Nile Delta.

Saltwater intrusion and its potential impacts on groundwater quality in the Nile Delta cannot be overlooked, especially in lowland areas along the Mediterranean coast. In addition to waterlogging and water-bogging problems, it is expected that increasing soil salinization will lead to deterioration of crop quality and lower productivity, which will have significant socioeconomic consequences and serious implications for food security and public health.

Extreme Events: Droughts, Heat Waves, and Storm Surges

The Middle East and North African countries are subject to a number of extreme events that recur more or less on seasonal cycles. Egypt is no exception. Sandstorms and flash floods occur regularly across Egypt. In recent years, severe sandstorms, dense haze, and flooding have occurred with increased severity and frequency.[14] They have had negative socioeconomic impacts on almost all sectors, including agricultural productivity, livestock, public health, the environment, and tourism. The causes of these events are linked to anomalies in global surface temperature, jet stream location and strength, and the location of the Intertropical Convergence Zone (ITCZ). Most of these anomalies are affected by global warming, and the increase in sandstorms, haze, thunderstorms, and flash flooding phenomena in Egypt is taken as an indicator of climatic changes.[15]

Figure 5: Soil Salinity Distribution over the Nile Delta



Source: T. H. S. Kotb, T. Watanabe, Y. Ogino, and K. Tanji, "Soil Salinization in the Nile Delta and Related Policy Issues in Egypt," *Agricultural Water Management* 43, no. 2 (2000).

Flooding and Storms

Flash floods are common in some areas of the coastal zone of Egypt, especially on the Red Sea and Sinai coasts. Flooding events normally prevail when rainfall intensity exceeds 1 millimeter per minute and the duration exceeds 10 minutes. In Port Said on the eastern coast, thunderstorm days rose from 0 to 18 to 41 days in the last 10 years. The increased number of thunderstorm days during the past decade compared with the two previous decades could be an indicator of the extensive northward intrusion of the southerly warm air, or the wide northward oscillations of the ITCZ influenced by global warming.[16]

The Mediterranean coast of Egypt experienced a successive increase in the amount of annual rainfall during the last three decades. The mean trend over the area is 0.76 millimeters per year. Rainfall has increased over the western coast of Egypt by up to 3 millimeters per year. The changes in the general circulation of the atmosphere and effects of some incidents, such as the North Atlantic Oscillation phenomenon, seem responsible for this change. Increased intensity and frequency of marine storms will necessarily increase the risks of transportation accidents and health risks in the coastal zone.[17]

Dust Storms

Saharan dust and heat waves are known to have serious effects on agricultural productivity, materials lifetime, and public health. Egypt is subject to severe sandstorms (Khamasin), which persist over a period of about 50 days during the months of March and April, afflicting coastal areas of North Africa (figure 6). Observed increases in the rates and frequencies of dust storms and temperature inversions over the Nile Delta region have resulted in the well-known "black cloud" phenomenon over coastal and noncoastal cities in September and October of each of the past 10 years (figure 7).

Figure 6: Trajectory of Khamasin Sandstorms along the North African Coast

Source: A. M. Abed, M. Al Kuisia, and H. A. Khaira, "Characterization of the Khamaseen (Spring) Dust in Jordan," *Atmospheric Environment* 43, no. 18 (2009).

Figure 7: Saharan Dust over the Eastern Mediterranean

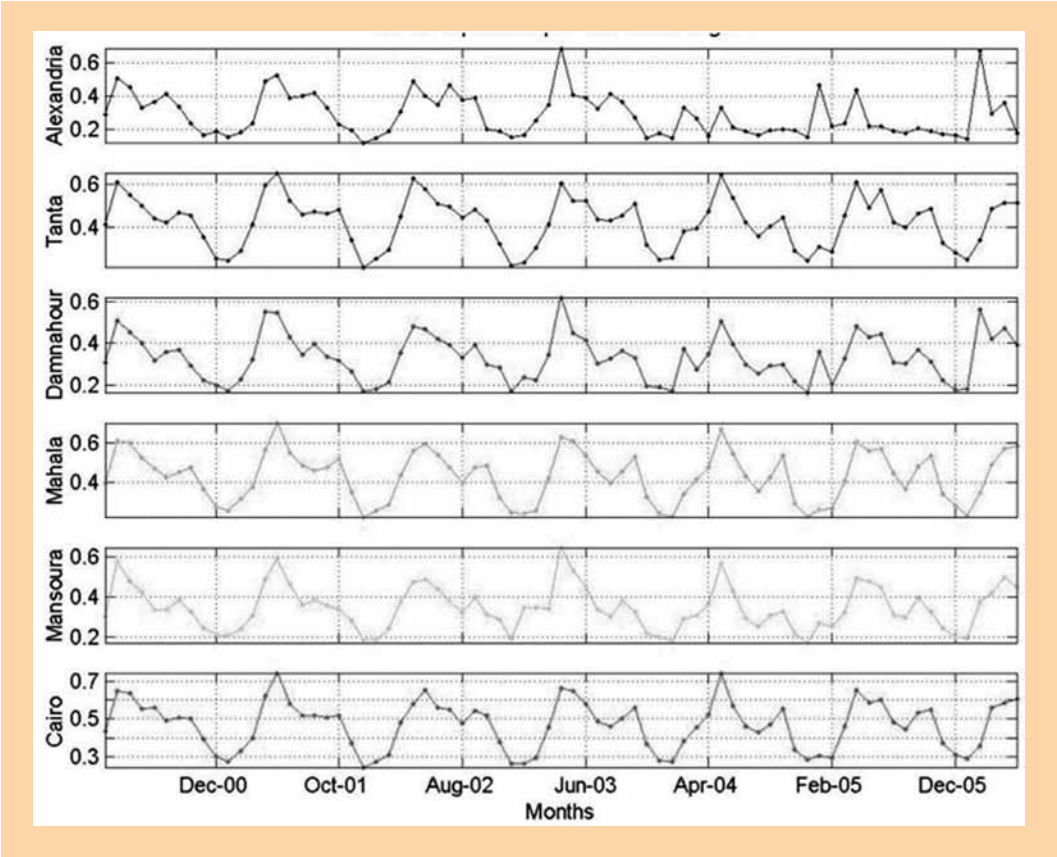
Source: Jeff Schmaltz, MODIS Rapid Response Team, National Aeronautics and Space Administration/Goddard Space Flight Center (2003).

Figure 8 presents a time series of the aerosol optical depth of the atmosphere as observed by MODIS satellite from 2000 to 2005 over cities in the Nile Delta region. In addition to the high peak of April due to the Khamasin of each year, a buildup of a smaller peak in September and October of each year is also observed. This has been attributed to temperature inversions which now prevail over the region.

Change of Acidity and Circulation Patterns in Coastal Waters

It is expected that increased water temperature, evaporation, and increasing levels of carbon dioxide absorbed into the sea will lead to changes in ocean acidity and the distribution of water salinity—changes likely to affect marine life and coral reefs. It is also expected that the coastal circulation patterns will change because of changes in temperatures, wind speed, and currents in the coastal zone. Altered coastal circulation

Figure 8: Aerosol Depth Variation as Observed by MODIS Satellite over Cairo and the Nile Delta Coastal Cities



Source: H. El Askary and M. El Raey, in preparation.

patterns will likely cause changes in fisheries catch, coastal recreation areas, and coastal navigation.

Potential Socioeconomic Risks of Climate Impacts

Tourism

Tourism is an important resource in Egypt. Coastal and marine ecosystems are the *raison d'être* for recreational tourism in the Red Sea and Sinai Peninsula resorts. In addition to international tourism, the coastal cities of Alexandria, Bulteem, Gamasa, Port Said, and Ras El Bar are popular destinations for local tourists, and many middle- and low-income Egyptians spend their summers in these towns.

The impact of climate change on coastal tourism is considered serious. Sea level rise threatens the infrastructure on which coastal tourism depends. Global warming also risks

diminishing the aesthetic quality of the marine environment that attracts vacationers. Bleaching could destroy the coral reefs that draw visitors for diving and snorkeling. Tourism development itself often damages these already fragile ecosystems, overwhelming their limited carrying capacities and abilities to regenerate.

Coral Reefs

Coral reefs have great environmental and economic value. They provide several ecosystem services, among them protecting the coastline, encouraging biodiversity, and providing fish breeding grounds and habitat. In this latter role, corals reefs support both large-scale commercial fisheries and smaller-scale artisanal fishing. They also provide tourists with opportunities for diving, snorkeling, and recreational fishing. In Egypt, coral reefs extend along most of the southern part of Sinai, particularly at Ras El Tor and the area between Ras Nasrani to Ras Mohammed. In the Red Sea, there are important reefs around Hurghada and near Gebal Elba, at Egypt's extreme southern border.

Human activities along these coastlines are highly varied, with some areas of intensive use at risk for considerable reef degradation. Some remote reefs remain relatively inaccessible and largely unharmed by humans. Egypt currently has five marine protected areas, established around the Sinai Peninsula and Red Sea coasts at sites where recreational scuba diving is common and the threat from anchor and flipper damage is high. Seven additional areas, including coral reefs, have been proposed to the government for protection status.

Coral reefs are among the most vulnerable ecosystems to climate change. Corals are especially sensitive to elevated sea surface temperatures. When physiologically stressed, corals may lose much symbiotic algae, which supply nutrients and colors. In this stage, corals appear white and are considered "bleached." Corals can recover from short-term bleaching, but prolonged bleaching can cause irreversible damage and subsequent mortality.

Monuments and Cultural Heritage

Cultural tourism in Egypt depends on the beauty and preservation of ancient monuments and historic sites. Climate changes may affect these cultural treasures in sometimes subtle ways. The most fragile elements of the country's heritage are the wall paintings in ancient tombs and temples. Strong shifts in temperature and in the moisture content of the air—the result in part of climate change—may degrade the paintings' stability over time. More dramatically, climate change affects the Nile and the water cycle. This in turn may affect cruising activities on the river, and rising groundwater tables and storm surges may damage cultural sites in coastal areas.

Public Health

Global climate change is expected to have multiple adverse impacts on human health.[18] More intense and frequent heat waves, for example, are projected to increase the rates of heat stress mortality, particularly for vulnerable populations such as children, the elderly, the infirm, and the poor. Global warming is also expected to alter the prevalence of certain disease vectors. Thus, in coastal regions, waterlogged areas in the lowlands could provide increasing breeding grounds for mosquitos carrying malaria. Climate impacts on agriculture will also likely have considerable consequences for population nutrition. Comprehensive studies of these potential risks are still lacking for Egypt, largely due to the dearth of data.

Food Security

With a rapidly growing population and limited arable land, Egypt is expected to continue importing most of its food. Table 1 indicates the self-sufficiency ratios for some major food commodities, showing that the country is a major net importer of all important commodities.

Table 1: Self-Sufficiency Ratios for Some Major Food Commodities in Egypt

Commodity	Ratio
Meat	0.84
Sugar	0.61
Vegetable oils	0.15
Cereals	0.60

Source: Food and Agriculture Organization of the United Nations, Economic and Social Development Department, "WTO Agreement on Agriculture: The Implementation Experience," www.fao.org/docrep/005/Y4632E/y4632e06.htm (accessed March 4, 2010).

Note: Data are for 1985–2000.

Numerous studies have been conducted in the agriculture and food areas. Modeling that examined the potential effects of climate change on three field crops—wheat, maize, and cotton—in three main agro-climatological regions projected productivity declines of 15 to 20 percent for wheat and maize. Only cotton is expected to increase by about 15 to 17 percent. Saltwater intrusion is projected to reduce land productivity generally in the Nile Delta region. Declines in fish catches resulting from ecosystem changes in the northern lakes are also expected.[19]

Suez Canal Revenues

Tariffs and fees generated from ships using the Suez Canal constitute a growing source of national income in Egypt. Revenues from the canal reached $4.6 billion in 2007, or about 3 to 4 percent of national GDP, compared with $2 billion in 2002. With the melting of the ice cap over the Northern Arctic, however, a new and shorter route for shipping between Europe and East Asia could open up (figure 9). Shipping cargo via the Arctic route would cut about 4,450 miles off of the voyage from Rotterdam to Yokohama, Japan, for example, compared to passing through the Suez Canal.[20] This alternative route is expected to cause a loss of not less than 20 percent of annual revenue for the Suez Canal.

Figure 9: Potential Alternative Shipping Routes between Europe and East Asia

Source: Stimson Center 2010.

A Vulnerability Hotspot: Climate Risks in the Nile Delta

Because of its high population density and exposure to both land subsidence and accentuated sea level rise, the Nile Delta is regarded by the IPCC as an extreme hotspot of climate vulnerability.[21] To evaluate the risks to the Delta region, a detailed assessment of potential climate impacts on the coastal cities of Alexandria, Marina, Matruh, Port Said, and Rosetta was conducted using remote sensing techniques, field visits, and geographic information systems (GIS).

In Alexandria, for a scenario involving a sea level rise of 0.5 meters over the next century, about 30 percent of the city would be lost to inundation and saltwater intrusion if no countermeasures were taken. For Rosetta, the damages from sea level rise of 0.5 meters would include $2.9 billion in lost land over the next century and could lead to the elimination of a third of the city's jobs. In Port Said, for sea level rise of 0.5 meters, the lost beach area alone would amount to more than $2 billion.

Alexandria

Alexandria is the second largest city in Egypt after Cairo. It is a major tourist attraction for both Egyptians and foreigners. In order to assess vulnerability to potential impacts of sea level rise, remote sensing techniques were used to produce land use maps. These maps were combined with digital elevation models and GIS data to identify the size and location of

vulnerable lowland areas based on three scenarios for sea level rise of 25 centimeters, 50 centimeters, and 1.0 meter. An estimated 45 percent of the population of Alexandria currently lives on land situated below sea level. Tables 2 and 3 show that a sea level rise of 50 centimeters would inundate two-thirds of the city's population, submerge nearly 32 square kilometers of its land area, and displace more than 1.5 million people.

Table 2: Percentage of the Population and Areas of Various Land Uses Currently Below Sea Level and Under Three Scenarios of Sea Level Rise for Alexandria

Sector	Below sea level (%)	% of areas affected under each scenario		
		0.25 m rise	0.5 m rise	1.0 m rise
Population	45.0	60.0	67.0	76.0
Beaches	1.3	11.0	47.8	64.0
Residential	26.2	27.5	39.3	52.0
Industrial	53.9	56.1	65.9	72.2
Services	45.1	55.2	75.9	82.2
Tourism	28.0	31.0	49.0	62.0
Restricted area	20.0	21.0	25.0	27.0
Urban	38.0	44.0	56.0	67.0
Vegetation	55.0	59.0	63.0	75.0
Wetland	47.0	49.0	58.0	98.0
Bare soil	15.0	24.0	29.0	31.0

Source: S. Agrawala, A. Moehner, M. El Raey, D. Conway, M. van Aalst, and M. Hagenstad, *Development and Climate Change in Egypt, Focus on Coastal Resources and the Nile*, Working Party on Global and Structural Policies (Paris: Organisation for Economic Co-operation and Development, 2004).

Table 3: Area Loss, Population Displaced, and Loss of Employment under Different Sea Level Rise Scenarios in Alexandria

Parameter	Sea level rise scenarios (meters)		
	0.18	0.30	0.50
Area loss (km^2)	11.4	19.0	31.7
Population displaced (thousands)	252.0	545.0	1512.0
Loss of employment (total)	32,507.0	70,465.0	195,443.0
Agriculture	1,370.0	3,205.0	8,812.0
Tourism	5,737.0	12,323.0	23,919.0
Industry	24,400.0	54,936.0	151,200.0

Source: Agrawala et al., op. cit.

Port Said

Port Said lies on the Mediterranean at the entrance of the Suez Canal. Manufacturing, transportation, and the residential sector are at the greatest risk from sea level rise. Agriculture is not affected because it is mainly found in the El Dawahy district, which is beyond the areas touched by sea level rise. If sea level rise reaches 50 centimeters, modeling that extrapolates from present population levels and takes into consideration the statistical distribution of employment over various sectors projects that the city would lose almost 7,000 jobs. Table 4 shows physical and socioeconomic losses for a sea level rise of 0.5 meters in the Governorate of Port Said.

Table 4: Physical and Socioeconomic Losses Associated with a 0.5-Meter Sea Level Rise in Port Said

Parameter	El Shark	El Arab	El Monakh	Port Fouad	Total	%	Million US$
Beach area (km^2)	0.426	0.377	7.419	13.039	21.26	1.6	2,126
Urban area (km^2)	0.034	0.044	0.339	0.046	0.46	7.8	92
Industrial area (km^2)	0.015	0.002	0.018	0.016	0.05	12.5	25
Aquacultural area (km^2)	0	0	0	0.024	0.024	0.12	2.4
Transport network (km^2)	10	7	3	3	23	11.7	4.6
Affected population	3,968	16,699	6,503	1,021	28,191	5.3	—
Employment loss	953	4,000	1,558	248	6,759	5.3	—

Source: Agrawala et al., op. cit.

Note: No data are available for El Dawahy.

Responses

Institutional Systems

As early as the 1990s, the Egyptian authorities realized the vulnerability of the country's coastal zone to the potential impacts of climate change. In response, the government has established a National Center for Land Use and a National Committee for Integrated Coastal Zone Management, staffed by selected representatives from various ministries and charged with coordinating and implementing integrated planning among relevant agencies.

In its efforts to upgrade environmental laws and regulations, the National Assembly approved an addition (Law 9/2009) to Environmental Law 4/1994, which enforces Integrated Coastal Zone Management. Similarly, to promote scientific research and technical coordination among concerned authorities and to help disseminate policies and measures

for adaptation, a prime ministerial decree established an institutional capability for climate change adaptation at the Information and Decision Support Center, the think tank for Egypt's cabinet.

Policy Strategies and Challenges

The policy strategies implemented so far concern greenhouse emissions reduction measures and projects under the Clean Development Mechanism (CDM). So far, only very limited policies for adaptation have been undertaken in any of the vulnerable sectors.

Clean Development Mechanism

A designated national authority for CDM has been established with a focal point in Egypt. The national authority has been successful in implementing a large number of CDM energy projects, with the objective of reducing greenhouse gas emissions, conserving energy, and enabling the country to participate in the global emissions trading market. In addition to establishing an institutional framework for CDM and creating a pipeline of CDM projects, the national authority has also conducted information and awareness-raising campaigns and strengthened policymaking capabilities and capacities for public-private partnerships.[22]

Adaptation Measures and Options

Developing the necessary adaptation strategies for Egypt will be a complex process. Adaptation opportunities are site-dependent and selecting the most effective measures necessarily entails multicriteria analysis to assess available technology options, maintenance requirements, environmental impacts, and equity and cost issues. The government will need to shape an integrated adaptation framework and supporting policies and processes to protect the vulnerable areas identified in the current study. As a first step, it should activate the National Integrated Coastal Zone Management Committee initiated several years ago and charge it to formulate and implement a strategic integrated coastal zone management plan.

The following adaptation measures are among those now under way or under consideration by Egyptian authorities:

- Protective structures are being constructed by the Shore Protection Authority at many sites along the Mediterranean.
- Natural sand dune systems constitute an important natural protection. Work by NGOs is in progress to upgrade awareness and protect and repair sand dunes.
- As a first line of defense, the Shore Protection Authority is considering protecting and reinforcing the Mohamed Ali Wall that protects lowland areas south of Abu Qir Bay.

- As the second line of defense, Egyptian authorities are considering reinforcing the embankment of the International Coastal Road (the coastal highway running from Libya to Palestine) to protect the northern zone of the delta. The northern side of the international road could be redesigned as a seawall.
- The banks of Al Salam Canal, which runs to the south of Lake Manzala and provides water to Sinai, sit more than 2 meters above the lake's water level. If the northern banks are properly designed and maintained, they could be used for protection.
- Existing wetlands should be preserved or new ones created to serve as buffers in areas vulnerable to sea level rise in low-lying deltas. Lake Manzala and Lake Burullus are two examples of areas suited for such adaptation processes.

International Support for Adaptation

To date, only limited financing has been made available at the regional and international levels to address climate problems. An infusion of international funds is needed to help countries like Egypt with capacity building and technology transfer for coastal adaptation, protection, and management. Particular issues on which international assistance should focus include the following:

- Developing regional circulation models and fostering "home-grown" model-building capacity (as opposed to importing models developed elsewhere) to enable decision makers to better project, assess, and understand prospective climate changes and risks at scales relevant for national policymaking
- Carrying out vulnerability assessment for potential climate impacts, including extreme events and adaptation strategies
- Testing options for environmentally friendly technologies for protection of the Mediterranean coast in general and low elevation areas in the delta in particular
- Developing public awareness programs targeting stakeholders and officials of the coastal governorates about the impacts of climate change on coastal zones
- Establishing proper observation systems, monitoring networks, and geographic databases of key indicators on sea level rise to support decision making
- Building cooperative approaches and integrated institutional structures to coordinate the efforts of all concerned actors and institutions in Egypt

Conclusions and Recommendations

The coastal zone of Egypt is highly exposed to the potential impacts of climate change. In particular, the Nile Delta region is acutely vulnerable to sea level rise and saltwater intrusion. The potential effects include significant socioeconomic implications, which may involve mass population displacement from the delta. It is therefore necessary to consider

accommodating possible environmental migrants elsewhere in the country and developing employment opportunities in safe areas.

Other vulnerable coastal zones include the Mediterranean and Red Sea, which could suffer considerable damage to coral reef communities, shortages of water resources, loss of biodiversity, and loss of natural and cultural heritage. Such consequences would seriously affect coastal tourism and quality of life in this region. Extreme weather events and increasingly frequent and intense dust storms in the coastal region are expected to detrimentally affect economic productivity, public health, and the quality of life, but their full repercussions are not well understood.

The government and the private sector must be proactive in establishing adaptation policies and measures to minimize potential impacts. These should include establishing institutional coastal monitoring capabilities, enforcing laws and regulations, enacting integrated coastal zone management, and raising awareness of climate risks and adaptation responses.

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