Adaptation to the Impacts of Sea Level Rise in Egypt

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Adaptation to the impacts of sea level rise in Egypt

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ABSTRACT: Assessment of the vulnerability of and expected socioeconomic losses over the Nile Delta coast due to the impact of sea level rise (SLR) was carried out in detail. Impacts of SLR on the Governorates of Alexandria and Port Said, in particular, were evaluated quantitatively. Options and costs of adaptation were analyzed and presented. Multi-criteria and decision matrix approaches based on questionnaire surveys were carried out to identify priorities in the 2 case studies. Results indicate that there are very limited possibilities of changing jobs for vulnerable stakeholders; cost is the main barrier of implementation; the majority of stakeholders recommend protection actions; and beach nourishment with limited hard structures (groins and breakwaters) is the best immediate option for adaptation, while the ICZM approach is the best available strategic option.

KEY WORDS: Vulnerability · Alexandria · Port Said · Coastal areas · ICZM

1. INTRODUCTION

It is expected that a climate change will take place over the next century in spite of the international effort to reduce greenhouse gas emissions. This change is expected to exacerbate already existing environmental problems in many countries. In particular, coastal areas all over the world are expected to suffer from impacts of sea level rise (SLR), as well as other impacts, in addition to already existing problems of coastal erosion, subsidence, pollution, land use pressures, and deterioration of ecosystems.

In Egypt, the most fertile land of the Nile Delta coast is vulnerable to the impacts of SLR (e.g. Sestini 1989). A detailed vulnerability assessment of the most important cities along the Mediterranean coast—Alexandria, Port Said, and Rosetta—has revealed serious potential impacts of SLR on various socioeconomic sectors of these cities (El Raey et al. 1995, 1997, 1998, 1999).

If this is the case, then an anticipatory adaptation strategy must be developed in spite of the large uncertainty regarding projected climate scenarios. The foundations upon which this strategy is built are the ‘precautionary principle’ and the ‘no regrets policy’. Smith (1997) has illustrated the importance of setting up priorities in spite of uncertainties of climate change. The objective of the present paper is to present the results of a study carried out in the Alexandria and Port Said Governorates to identify, assess, and prioritize options for adaptation to SLR, and to carry out an economic evaluation of the required adaptation measures.

2. ADAPTATION ASSESSMENT METHODOLOGY

The steps followed for implementation of the adaptation strategy follow the guidelines published by Carter et al. (1994). A broad framework for the evaluation of adaptation strategies to cope with climate change can be identified. This comprises the following steps: (1) defining the objectives; (2) specifying the climatic impacts of importance; (3) identifying the adaptation options; (4) examining the constraints; (5) quantifying measures and formulating alternative strategies; (6) weighting objectives and evaluating trade-offs; and (7) recommending adaptation measures.

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The procedure adopted for identifying and assessing adaptation involved 2 stages:

(1) Identify adaptation options and attributes. Identification of adaptation options was carried out by designing and administering a questionnaire based on direct communication with stakeholders in vulnerable areas. The objective was to collect information and to upgrade the awareness of stakeholders. Scientific, engineering, and economic evaluations of the obtained adaptation options were carried out, based on pre-specified criteria. The multi-criteria approach 'Adaptation Simulation Evaluator' (ASE) or TEAM was applied. An adaptation decision matrix approach based on cost effectiveness of adaptation measures was also evaluated.

Identifying evaluation attributes is an important topic that has been discussed by the evaluation team. The following attributes were found to be the most important: expenses, net benefits, environmental impacts, robustness and flexibility, chance of success, feasibility, and fairness. Each adaptation option will be evaluated based on a score of 1 to 10 for each of the above-mentioned attributes.

(2) Evaluate and assess each option. Information on the costs of various operations was taken from previous experience as well as published and unpublished reports. These were used together with economic evaluations, and sometimes through contacts with relevant organizations, to evaluate and assess each option from various points of view.

3. CASE STUDIES

Since it is necessary to have an in-depth understanding of vulnerability for decision-making with regard to adaptation, we consider the results of vulnerability assessments in 2 case studies.

3.1. Vulnerability assessment of Alexandria Governorate

Alexandria is the second largest city in Egypt. It has the largest harbor in the country, and about 40% of Egypt's industrial activities are based there. Its waterfront beach is located along the northwestern border of the Nile Delta coast. It extends for over 63 km and is considered the principal seaside summer resort on the Mediterranean. The resident population exceeds 4.0 million, and more than 1 million local summer visitors enjoy the summer season at Alexandria every year. The city is built on a narrow coastal plain extending from Marakia to the west to Abu Quir to the east and Lake Marioute to the south. Alexandria's coastal plain is composed of a series of shore-parallel carbonate ridges (about 35 m elevation), which are separated by depressions of shallow lagoons and sabkha. Beach erosion, rip currents, pollution, and SLR are the main problems affecting coastal management at Alexandria (El Raey et al. 1995, Frihy et al. 1996).

A multi-band LANDSAT TM image (September 1995) of the city was analyzed to identify and map land use classes. A geographic information system was built in an ARC/INFO environment including layers of city district boundaries, topographic maps, land use classes, population and employment of each district, and archaeological sites (El Raey et al. 1995, 1997).

Scenarios of 0.2, 0.5, and 1.0 m SLR over the next century were assumed, taking current land subsidence (2.5 mm yr^{-1}) into consideration. Percentage population and land use areas at risk for each scenario were identified and quantified. Table 1 shows results of the risk of inundation due to each scenario 'if no action is taken', over the coastal strip of the waterfront (about 63 km). The first column (SL = 0.0 m) represents the percentage of each sector currently located at an elevation below sea level. These sectors are currently protected from inundation, either naturally or by hard structures. If sea level rises by 0.25 m, the second column of the table shows the percentages of these sectors that will be inundated. In this case, inundation will affect areas above sea level in all sectors since there is no protection; this is also the case for the other amounts of SLR. These results were used to assess potential losses of employment for each sector.

Analysis of the results indicate that, if no action is taken, an area representing the difference between SLR = 0.5 m and SL = 0.0 m will at least be lost due to a SLR of 0.5 m. This amounts to 45% of the beaches, 13% of the residential area, 12% of the industrial area,

Table 1. Percentages of the population and the areas of different land use currently existing below sea level (SL = 0.0 m) and percentages that will be affected under different sea level rise (SLR) scenarios for the city of Alexandria (El Raey et al. 1999)

Sector	SL = 0.0 m	SLR (m)		
		0.25	0.5	1.0
Population	45	60	67	76
Beaches	1.3	11	47.8	64
Residential	26.2	27.5	39.3	52
Industrial	53.9	56.1	65.9	72.2
Services	45.1	55.2	75.9	82.2
Tourism	28	31	49	62
Restricted area	20	21	25	27
Urban	38	44	56	67
Vegetation	55	59	63	75
Wetland	47	49	58	98
Bare soil	15	24	29	31

Table 2. Area loss, population displaced and loss of employment in each sector due to different SLR scenarios in Alexandria Governorate, assuming a scenario of 1 m SLR by 2100 (El Raey et al. 1997)

	SLR (cm)		
	18 (2010)	30 (2025)	50 (2050)
Area loss (km^2)	11.4	19.0	31.7
Population displaced (×1000)	252	545	1512
Loss of employment			
Agriculture	1370	3205	8812
Tourism	5737	12323	33919
Industry	24400	54936	151200
Total loss of employment	32507	70465	195443

30% of the services, 21% of tourism, and 14% of the bare soil. At least 1.5 million people in addition to their dependants will have to abandon their homeland, 195000 jobs will be lost, and an economic loss of over US $35.0 billion is expected over the next century. The analysis shown in Table 2 indicates that the most severely affected employment sector will be industry, followed by tourism and agriculture. A detailed assessment of the impact on each district of the city has also been recently carried out (El Raey et al. 1995, 1999).

3.2. Vulnerability assessment of Port Said Governorate

Port Said Governorate is located in the northeastern part of the Nile Delta (30° 50’ N to 31° 00’ N, 32° 00’ E to 32° 30’ E). The Governorate has a total area of about 1351 km^2 and is divided into 5 districts: El Shark, El Monakh, El Arab, El Dawahi, and Port Fouad. The population of Port Said Governorate is about 0.5 million, the average population density is 391 persons km^{-2}, and the rate of population growth is 1.45%. The actual cultivated land in Port Said Governorate is about 483 km^2. This area supports about 2.38% of Egypt’s agricultural activities. The total reclaimed area for agriculture is about 567 km^2. The main income of this Governorate depends on revenue from the Suez Canal, tourism, free trade zones and industrial activities. The industrial activities include food canning, cloth making, carpet weaving, and the leather industry (IDSC 1995). The city assumes strategic importance because of its location on the inlet/outlet of the Suez Canal and because it is the largest economic center close to Sinai on the Mediterranean.

The coastal zone of Port Said area is socioeconomically important to most of the population in this area. Tourism is primarily oriented toward swimming and sunbathing. Therefore, the coast, its slope, and the quality of beach and sea are of prime importance to this industry. Most tourist facilities such as hotels and youth camps are located within 200 to 300 m of the coast. There are also important archaeological sites along the northern part of the Suez Canal.

Many environmental problems exist in the coastal zone of Port Said. Of particular importance are problems of beach erosion, pollution, subsidence, and SLR. These are detailed in the following sections.

3.2.1. Beach erosion

The projections of the Nile Delta, Rosetta and Damietta are currently undergoing extensive change from both natural and anthropogenic pressures. The highest rate of erosion occurs along the outer margins of these projections. This erosion is a result of the combined effects of cut-off of River Nile sediment discharge by the Aswan High Dam and prevailing coastal processes.

Erosion along the tip of the Damietta projection has adversely affected homes and condominiums to the east at Ras El Bar, and it has destroyed the old coastal road from Damietta to Port Said and the lighthouse west of the river (Frihy et al. 1996). However, a number of protective structures have been constructed along this projection to reduce shoaling in the river entrance. These structures are described in detail by Fanos et al. (1995). SLR is expected to enhance rates of erosion.

3.2.2. Pollution problems

The western and southern sectors of Lake Manzala are supplied by drainage water from 7 main sources. Water from these drains enriches the lake with nutrients, including phosphate, nitrate, and silicate. In addition, some of these drains discharge considerable amounts of sewage and industrial wastes directly into the lake. The Ginka subbasin in the southeast sector of the lake is identified as a ‘black spot’. SLR is expected to enhance diffusion in the coastal area and magnify the adverse effects of this pollution.

3.2.3. Subsidence and SLR

The eastern part of Lake Manzala (Port Said and the northern part of the Suez Canal) appears to subside at a rate of 4.5 mm yr^{-1} (e.g. Stanley & Warne 1993), faster than any other region along the Nile Delta coast. SLR is expected to cause a landward shift of the salt wedge and to increase the rate of saline seepage to the topsoil of the delta. This may have a serious impact on agriculture and drainage conditions, and potentially on available groundwater resources in the upper Nile

Delta. In addition, the salinity in Lake Manzala may increase because of a stronger influence of tidal flows penetrating the lake. Changes in the salinity conditions of Lake Manzala may lead to impacts on lake ecology and fisheries. Accelerated SLR will enhance the increase in salinity. Combined with the notion that it is unlikely that the lake will expand inland (as protection measures will be taken), this leads to the general prediction that shallow wetland areas will decrease and that the reed beds will become less abundant (due to higher salinity).

3.2.4. Socioeconomic impacts

The most serious impact of SLR on Port Said Governorate would be the threat to recreational beach communities as well as to other activities in the coastal zone. Based on the adopted local SLR scenarios of 0.50, 0.75 and 1.25 m, losses of land area, urban areas, industrial areas, vegetation areas, population, and employment were estimated. Estimates of losses were carried out by overlying Bruun's horizontal retreat distances over land use areas obtained from satellite images and ground surveys (El Raey et al. 1998). Results indicate that beach areas (hence tourism) are most severely affected, followed by urban areas. The agriculture sector is the least affected sector. Percentages as well as expected economic losses for each case are shown in Table 3, in which the estimates used for an area of 1 km^2 are about US $100 million for beach and agricultural areas and US $500 million for industrial areas.

Even though the affected beach areas are large, the percentage losses in industrial areas, transportation network, and urban areas are the most serious. It is estimated that the economic loss is over US $2.0 billion for a 0.5 m SLR and may exceed US $4.4 billion for a 1.0 m SLR. About 28 000 to 70 000 people are expected to be displaced, and at least 6700 to 16 700 jobs are expected to be lost for the scenarios adopted. The socioeconomic impacts of excessive beach erosion are dramatic. Industry plays an important role for employment income in Port Said Governorate, due to the existence of the Suez Canal. SLR will affect this sector; its loss is about 12.5 % in the case of a 0.50 m SLR.

4. COASTAL PROTECTION ACTIVITIES AND CONSIDERATIONS

To develop an adaptation strategy, the current activities and policy of coastal protection should be quantified. A review of the coastal protection activities in progress, as well as of the durability of structures, design, and costs of implementation along the Nile Delta coast, are presented in this section.

4.1. Recent coastal protection activities

Fanos et al. (1995) presented a review for all the protection works along the Nile Delta coast, which can be summarized as follows:

(1) West of Alexandria. The new drain at the western Nobariya drain outlet is about 20 km to the west of Alexandria. Two jetties of 65 m length were constructed in 1986 to protect the exit from siltation, and they are functioning effectively.

(2) Eastern harbor of Alexandria. A 180 m extension of the existing west breakwater would narrow the gap between the west and central breakwaters from its existing 300 m width to 100 m (Tetratech 1986). This decrease in gap width would reduce wave heights along the critical area of the Corniche.

(3) Alexandria beaches. Five beaches, El Shatby, Stanley, Sidi Bishr, El Asafra, and El Mandra, were nourished by medium to coarse sand transported from the desert near Cairo.

(4) Abu Quir Bay. The Abu Quir Sea wall was built in 1780 and has been maintained by placement of additional large concrete blocks. This wall was modified and reinforced in 1980 by constructing a sloping face (2:1) and placing 0.5 ton modified cubes as a layer of protection.

Table 3. Physical (km^2) and socioeconomic losses due to a SLR of 0.50 m in Port Said Governorate (El Raey et al. 1998)

	El Shark	El Arab	El Monakh	El Dawahi	Port Fouad	Total	Percent	Million US $
Beach area	0.426	0.377	7.419	–	13.039	21.26	1.6	2126
Urban area	0.034	0.044	0.339	–	0.046	0.46	7.8	92
Industry area	0.015	0.002	0.018	–	0.016	0.05	12.5	25
Agricultural area	0.000	0.000	0.000	–	0.000	0.00	0.0	0.0
Aquacultural area	0.000	0.000	0.000	–	0.024	0.024	0.12	2.4
Municipal services	0	0	0	–	0	0	0	0
Transport network (km)	10	7	3	–	3	23	11.7	4.6
Population	3968	16699	6503	–	1021	28191	5.3	–
Employment	953	4000	1558	–	248	6759	5.3	–

(5) West of El Gamil regulator and inform of El Fardos village. In 1994, construction of 4 detached breakwaters was begun in the area to protect it from erosion. Each breakwater is 250 m long and is constructed from a barge-mounted plant at a water depth of 4 m. The cost of these 4 breakwaters is US $3.5 million (Delft Hydraulics 1991). These are still under construction.

(6) El Gamil outlet. Two jetties of 225 and 200 m length on the western and eastern sides of El Gamil outlet, respectively, were constructed to protect this outlet from siltation and migration. The cost of these 2 jetties was US $0.75 million (Delft Hydraulics 1991).

(7) Highway near El Gamil airport. A small bituminous dike, about 4 km in length, was constructed to protect the low parts of the coastal road near the airport from flooding. The cost was US $1.0 million (Delft Hydraulics 1991).

4.2. The lifetime of a structure

Generally, a structure is designed and built according to the relevant conditions and general design criteria deemed applicable, including anticipated changes in conditions. The latter may arise from natural trends or human intervention. The structure may be given some extra strength, or measures may be taken to facilitate future adaptation.

In general, shore protection structures in many instances are designed for a lifetime of 50 to 100 yr, depending on their function, type, and importance, and on the stability of the coast (Delft Hydraulics 1991). Parts of a structure may have a shorter lifetime; they will have to be replaced or reconditioned at certain intervals within the lifetime of the whole structure. Reasons for adaptation of a structure in the course of its lifetime may be any of the following: (1) changes of external physical conditions such as SLR, subsidence, erosion, and related changes of currents and waves; (2) deterioration of the structure; (3) socioeconomic developments requiring a higher safety criterion; and (4) technological advances.

Table 4. Costs of recent coastal engineering works (Tetratech 1986)

Beach nourishment project	Quantity (m^3)	Cost (US $)	Unit price (US $ m^{-3})
Stanley	40 135	340 000	8.47
El Chatby	150 000	1 080 000	7.20
Sidi Bishr	33 319	696 000	20.89
Asafra	85 575	620 000	7.25
Mandara	104 783	580 000	5.54
Abu Quir	34 455	240 000	6.97
Abu Quir sea wall	4500 m	10 000 000	2200 m^{-1}

4.3. Length of the structure

The length of a sea defense structure is generally determined by the size of the area to be protected and by the expected threat of the sea. Socioeconomic and geomorphological developments may lead to increased length.

4.4. Impact of SLR on the structure

A rise of sea level relative to the crest level of a structure may consist of the following components: (1) compaction of the structure itself and of the local bed; (2) general subsidence of the subsoil in the area; (3) natural SLR; and (4) extra SLR as a consequence of the increased greenhouse effect.

Primary effects of relative SLR may be a deepening of the water in front of a structure, greater wave heights inducing more severe wave attack, and more wave run-up. Feedback mechanisms due to shoreline protection structures will also affect the longshore transport system. A practical point is that design and construction must start well in advance of the expected SLR to ensure that an adaptation measure is completed in time; in such a case, safety would never fall below the adopted criteria (Delft Hydraulics 1991).

4.5. Cost of coastal protection

The actual costs of the basic 'beach nourishment' against SLR along the Alexandria coast are given in Table 4 according to the experience of the Shore Protection Authority (SPA) and Coastal Research Institute (CRI) (Tetratech 1986). Based on earlier experience, a 10 % increase in costs over the latest published data is expected for the 1990s.

5. ADAPTATION STUDIES

5.1. Evaluation methods

Evaluating adaptation strategies is an increasingly urgent task for the economic sectors of vulnerable regions such as Alexandria and Port Said. A multi-criteria approach may be more effective for anticipatory adaptation evaluation than single-measurement approaches such as cost-benefit analysis and multi-attribute utility analysis. This judgment is based on a belief that social decisions regarding climate change impacts are better considered in the context of a range of attributes that often go beyond those of cost-benefit analysis in its pure form (Smith & Chu 1994).

The 2 methods used here to evaluate the selected measures (decision matrix and ASE) were tested for specific localities in the course of the training and familiarity procedures. The decision matrix analyzes cost-effectiveness of adaptation measures by comparing costs of adaptation measures with benefits measured in a common measurement, but not necessarily dollars. Such measurements can be added up across the different policy objectives (weighted based on relative importance) and compared to costs to determine cost-effectiveness (e.g. cost per point on the ordinal scale) and rank measures.

The ASE multi-criteria approach for assessing strategies of anticipatory adaptation to climate change, developed by US Environmental Protection Agency, was also adopted. ASE uses a question and answer format to guide users through the process of structuring and performing a multi-criteria comparison of strategies. No default assumptions or values are present in the system. Therefore, the comparison is intentionally kept at a simple enough level that specific underlying models are not needed unless the user desires. ASE includes databases of site types, climate change forecasts based on several general circulation models (GCMs), potential vulnerabilities, and associated adaptation options. Elements from these databases are provided to users in the form of guidance and suggestions to consider in the process of structuring an analysis. ASE guides the analyst through 5 analysis steps: (1) characterize technical and policy objectives and situation and identify critical vulnerabilities to climate change; (2) select or design adaptation strategies; (3) select or design evaluation attributes; (4) score strategies for each attribute (along relative or absolute scales); and (5) analyze the results using visual displays (changing priorities, sensitivity analysis, and so forth).

5.2. Options

Before we carried out the evaluation of adaptation measures, we identified the most important options for adaptation in the vulnerable areas based on experts' discussions. These are considered below in detail.

5.2.1. Beach nourishment and groins

Beach nourishment includes depositing sand onto the open beach as well as beach scraping, building artificial dunes as storm buffers and beach sand reservoirs, and laying pipes underneath the beach to suck in the water and trap sand. Groins, which are hard structures perpendicular to the coastline, are used with beach nourishment to trap sand. The expense of this option is very low compared to other options. The net benefit (direct and indirect) of this option is good because it forms new beaches for tourism and creates employment. The environmental impact of this option is fair, particularly for the beach. It is good for fishing due to the migration of fish to offshore areas. The flexibility (success in the long term) of this option is good with regard to SLR. The chance of success is judged to be good. This option needs periodic nourishment. The public acceptance (feasibility) of this option is excellent, and the expected environmental impact (fairness) along other coastal areas is excellent, as long as the nourishment is carried out periodically for vulnerable beaches. This option has no effect on fishermen, and it may increase fishing because sand material could constitute a new source of nutrients for fish. Beach nourishment has no adverse effects on farmers, and it protects their land from flooding and saltwater intrusion. Also, this strategy has no adverse effects on the industrial workers, and it protects the factories and workers from flooding. The best advantage of this strategy is the retainment of the beach for tourism, the protection of hotels, and an increase of jobs in the tourism sector.

5.2.2. Breakwaters

Breakwaters are hard structures used to reduce the wave energy reaching the shoreline. They can be set up offshore as submerged breakwaters or as riprap along the shore to absorb wave energy. This strategy is relatively very expensive. The net benefit of this option is only along the coastline, not on the social community or ecosystem. The environmental impact of this strategy is fair, but it is considered to be the best available tool for protection of lowland areas. The flexibility is good and so is the chance of success. The feasibility of implementation of this strategy is good. People staying in the coastal area need to protect themselves from coastal erosion. This strategy affects fishing processes, so the fishermen need new tools and modern motor boats for fishing offshore. Breakwaters and dikes are good tools for protecting cultivated land as well as all the infrastructure that is located in the coastal areas; therefore, the farmers, industrial workers and employment in the tourism sector are not affected by this option.

5.2.3. Legal development regulation

Legal development regulation involves the taking of legal or regulatory actions to restrict development or prohibit redevelopment of a hazard-prone area—for example, adopting erosion-based setback regulations, restricting post-storm reconstruction, or changing the tax structure to discourage development. In our case this strategy involves large expenses, has good net benefits, and is excellent in regard to the environmental impact. But, in Egypt, it is not effective. Regulations are not actively enforced, particularly in prone areas. In any developing country, the rules are enforced when the public agrees they have some public benefit. This option is fair for feasibility and fairness. The chance of success for this strategy is bad if socioeconomic considerations are taken into account. This option has no effect on the fishermen, farmers, and industrial workers, but may affect the businessmen. An institutional capability for monitoring and assessment, such as a remote sensing system, is necessary for the implementation of this option.

5.2.4. Integrated coastal zone management (ICZM)

Coastal areas are experiencing rapid population growth. This growth comes at the expense of natural environments; it increases pollution and often requires protection against erosion or coastal flooding during storm surges. Accelerated SLR is another stress on the natural and human ecosystem which should be taken into account within the planning framework. Redirecting growth away from sensitive lands and toward less vulnerable areas is one option to reduce the risks associated with SLR and also to reduce vulnerability to other problems of the coastal zone.

ICZM represents the best possible use of resources under multi-criteria analysis. It requires the availability of a geographic database, a monitoring system such as remote sensing, and a decision support system, the availability of which requires advanced training and investment. The objectives of ICZM are to: (1) develop public awareness, build capacity, foster cooperation and implement issue-driven action plans; (2) provide local and national benefits and improve the quality of life; (3) optimize use of natural resources by integrating horizontal and vertical institutions in decision-making and development; and (4) minimize degradation of natural systems and simulate sustainable development.

ICZM embraces the general principles of environmental management adopted by UNCED's (United Nations Committee for Economic Development) Agenda 21 program: the precautionary principle, use of proper resource accounting, principle of transboundary responsibility, and principle of intergenerational equity.

5.2.5. Land use change

The option to change land use in the vulnerable area is still an open one. The objective is to change to a less vulnerable land use or to another land use to better utilize the lowland, such as aquaculture. A slight or moderate SLR may be quite beneficial for development of aquaculture on the coastal areas (Ibrahim 1997).

5.2.6. No action

This option means nothing is done to address the problem. Expenses of this option are nothing, and the net benefit is fair. The environmental impact and feasibility are also fair. This option will have bad effects in the future due to flooding of cultivated land, waterlogging, and damage for hotels, factories, and infrastructure facilities. Fishermen, farmers, industrial workers, and businessmen will be affected. This option is different from the 'business as usual' option, as the latter involves continuation of the protection work in progress.

5.3. Alexandria Governorate case study

Fig. 1 is a satellite image of Alexandria.

5.3.1. Identification of stakeholders

The assessment of vulnerability to SLR for the Alexandria area identified stakeholders to be fishermen, industry workers, businessmen, farmers, and others.

5.3.2. Public perception and awareness

A questionnaire was prepared and administered by direct person-to-person interviews with a random sample of 100 persons representing the main stakeholders of Alexandria Governorate. Although this sample is not statistically significant, it is considered good enough to give qualitative indications of major directions. The questionnaire was supplemented by an explanation in Arabic of the problem in order to upgrade awareness of the vulnerable groups.

Table 5 summarizes the answers to the questionnaire by the various stakeholder groups. The most important observations are: (1) Strong feeling among almost all stakeholders of the need to protect the area. (2) Strong feeling among most stakeholders that cost is the main barrier. (3) Weak tendency among all stakeholders to change jobs in response to the effects of climate

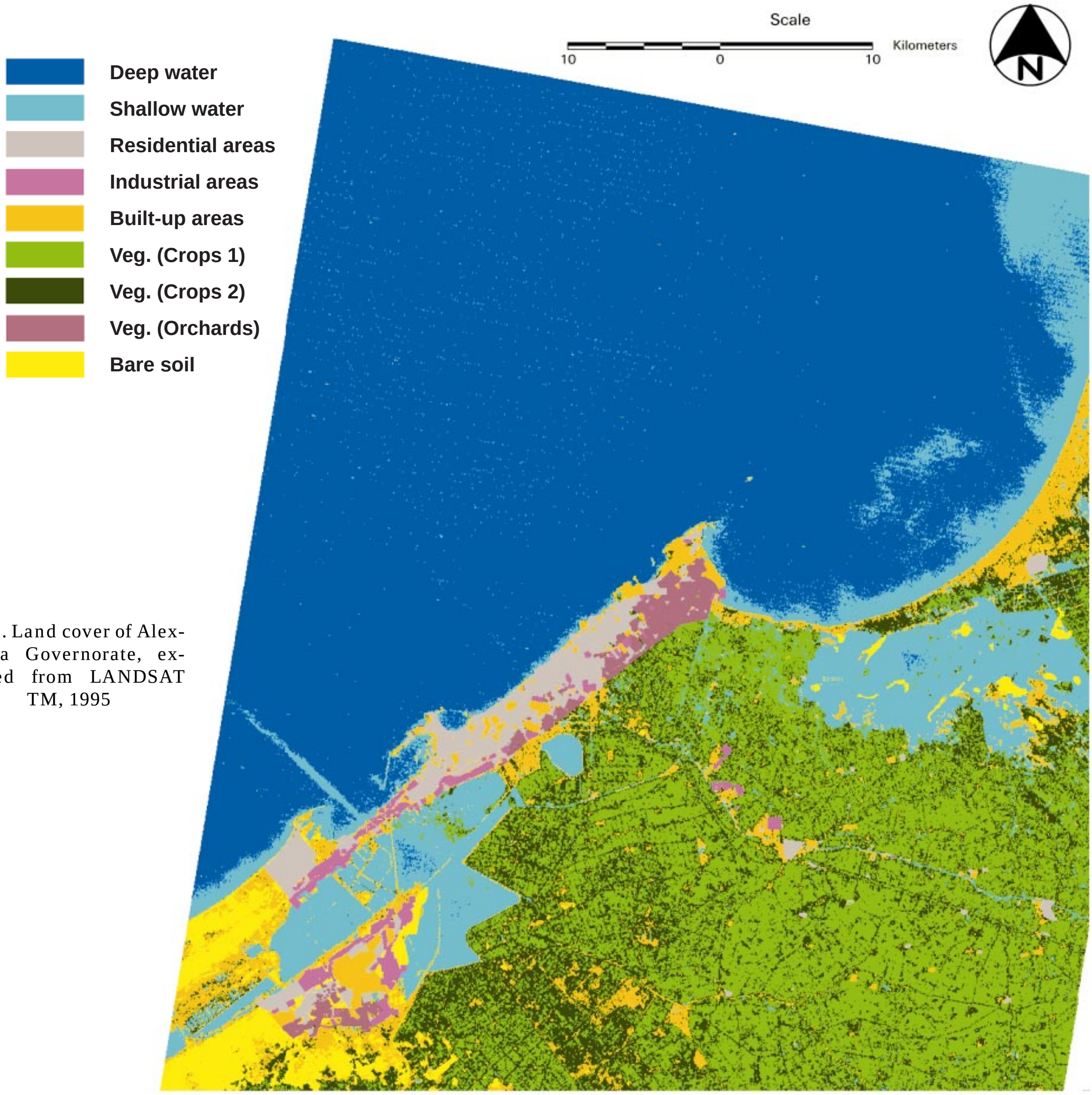

Fig. 1. Land cover of Alexandria Governorate, extracted from LANDSAT TM, 1995

Table 5. Opinions of the stakeholders in Alexandria Governorate on barriers to implementation, response, and suggested action (values are percentages)

		Fishermen	Farmers	Industrial laborers	Businessmen	Tourism
Barriers to implementation	Administration	3	60	11	29	57
	Time	15	7	4	5	7
	Cost	62	13	71	42	29
	Don't know	20	20	14	24	7
Response	No response	8	13	0	8	0
	Take action	92	87	100	92	100
Action	Protect	50	60	50	71	–
	Emigrate	40	13	21	17	64
	Change job	–	–	21	4	7
	Don't care	10	27	8	8	29

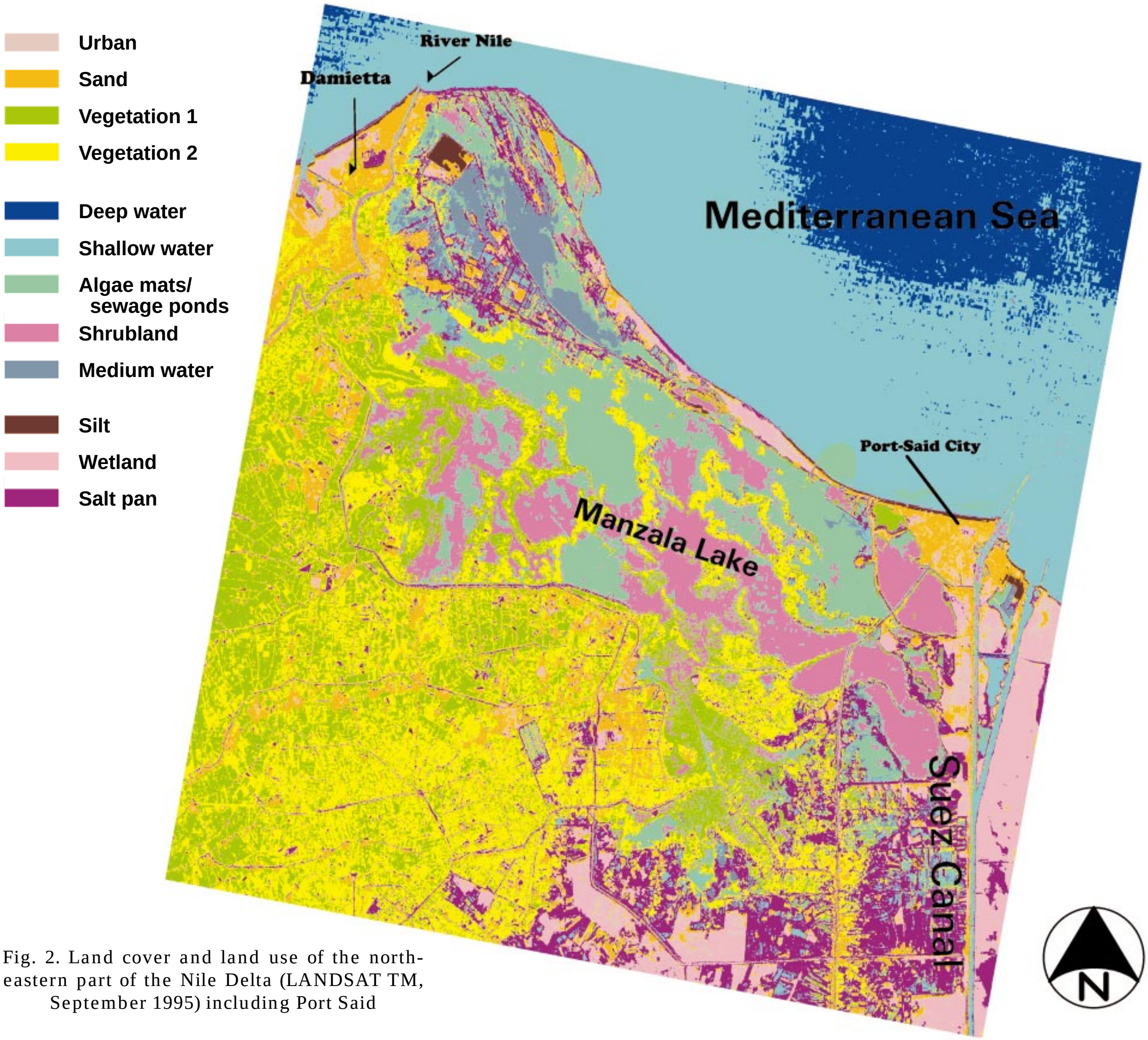

Fig. 2. Land cover and land use of the northeastern part of the Nile Delta (LANDSAT TM, September 1995) including Port Said

change. (4) Wide variation of opinions on barriers, responses, and recommended actions among stakeholders. This may reflect their varied interests in coastal problems and their flexibility in responses. (5) Low percentage of stakeholders who do not know what the barriers are and do not care about solutions.

5.3.3. Decision matrix and ASE

The decision matrix for the case of Alexandria is shown in Table 6. The analysis of the decision matrix indicates that the current policy (hard protection measures on some vulnerable areas) and no action (stopping these activities) options have the lowest scores. Beach nourishment and ICZM have the highest scores; however, ICZM has high-cost measures. The most cost-effective option is land-use change, but it is a relatively high-cost measure. It is recommended that an ICZM approach be adopted since it provides a reasonable trade-off between costs and cost-effectiveness.

Table 7 represents the results obtained from the ASE for the Alexandria case study. A scale of 1 to 10 was chosen for the range from lowest to highest scores, respectively. Analysis of the results of the ASE again indicates the preference for the beach nourishment and groins approach. However, we cannot overlook the benefits of ICZM due to its strategic benefits.

5.4. Port Said Governorate case study

Fig. 2 is a satellite image of Port Said.

Table 6. Coastal resource adaptation decision matrix (scale of 1 to 10) for Alexandria Governorate. Values by which the objectives are weighted are given in parentheses. na: not applicable

Measure	Scenario	Weighted objectives: Property protection (3)	Flood avoidance (3)	Coastal development (3)	Wetland preservation (1)	Score	Total score	Cost of measure (million US $)	Cost-effectiveness (cost/incremental unit of benefit)
Current policy	Rise	6	5	4	2	47	95	na	na
	No rise	5	3	7	3	48			
Beach nourishment and groins	Rise	7	6	8	6	69	150	54	0.98
	No rise	9	7	9	6	81			
Breakwaters	Rise	8	8	5	7	70	150	468	8.5
	No rise	9	8	7	8	80			
Legal development regulation	Rise	2	2	3	4	25	101	20	3.3
	No rise	8	8	7	7	76			
ICZM	Rise	8	7	7	7	73	158	550	8.7
	No rise	9	8	9	7	85			
Land use change	Rise	3	2	3	6	30	100	900	180.0
	No rise	8	7	6	7	70			
No action	Rise	3	2	3	2	26	55	2 500	−62.5
	No rise	4	2	3	2	29			

Table 7. Adaptation strategy evaluation matrix (scale of 1 to 10) for Alexandria Governorate

Evaluation attribute	Adaptation strategy options: Beach nourishment and groins	Breakwaters	Legal development regulation	ICZM	Land use change	No action
Expenses (million US $)	54	468	20	550	900	2 500
Net benefits	9	5	9	9	4	2
Environmental impact	7	6	8	9	2	3
Robustness/flexibility	9	8	7	8	4	2
Chance of success	9	8	7	8	5	2
Feasibility	9	9	6	8	6	2
Fairness	4	5	4	2	7	8
Total score	47	41	41	36	28	17

5.4.1. Identification of stakeholders

Stakeholders in Port Said were identified to be fishermen, businessmen, industry workers, and others.

5.4.2. Population perception and options

A random sample of 100 persons was selected for person-to-person discussions and information exchange. The results of analysis of a questionnaire showed that about 86% of the respondents are aware of the problem of SLR. Options for adaptation were explained and discussed based on person-to-person contacts. Almost three-fourths (74%) are not willing to move away from the area for any adaptation measures, 32% think that decision-makers are not serious in protecting the city against SLR, and 50% think that building fish farms is the most proper option for adaptation.

5.4.3. Decision matrix and ASE

The decision matrix was evaluated based on the questionnaire results and costs of construction according to Table 4. The decision matrix for the Port Said Governorate case study is presented in Table 8. Investigation of the results of the decision matrix indicates that the current policy and no action options have very low scores. However, installation of breakwaters and ICZM have the highest scores. Even though the cost is very high, the cost-effectiveness of land-use change is also high. It is recommended that

Table 8. Coastal resource adaptation decision matrix (scale of 1 to 10) for Port Said Governorate. Values by which the objectives are weighted are given in parentheses. na: not applicable

Measure	Scenario	Weighted objectives: Property protection (3)	Flood avoidance (3)	Coastal development (3)	Wetland preservation (1)	Score	Total score	Cost of measure (million US $)	Cost-effectiveness (cost/incremental unit of benefit)
Current policy	Rise	4	2	6	2	38	86	na	na
	No rise	5	3	7	3	48			
Beach nourishment and groins	Rise	7	6	8	6	69	149	81	1.29
	No rise	9	7	9	6	81			
Breakwaters	Rise	8	8	5	7	72	152	702	10.64
	No rise	9	8	7	8	80			
Legal development regulation	Rise	2	2	3	4	27	102	20	1.3
	No rise	8	8	7	7	75			
ICZM	Rise	8	7	7	7	78	162	200	2.63
	No rise	9	8	9	7	84			
Land use change	Rise	3	2	3	5	32	97	684	58.9
	No rise	8	7	6	7	65			
No action	Rise	3	2	3	2	26	55	2000	–62.5
	No rise	4	2	3	2	29			

Table 9. Adaptation strategy evaluation matrix (scale of 1 to 10) for Port Said Governorate

Evaluation attribute	Adaptation strategy options: Beach nourishment and groins	Breakwaters	Legal development regulation	ICZM	Land use change	No action
Expenses (million US $)	81	702	2	200	648	2 000
Net benefits	8	2	9	9	6	2
Environmental impact	7	4	8	9	5	4
Robustness/flexibility	8	6	7	8	6	4
Chance of success	9	8	7	9	5	2
Feasibility	9	9	6	8	6	2
Fairness	9	7	4	7	4	2
Total score	50	36	41	50	32	16

an ICZM approach be followed since its cost of implementation and cost-effectiveness are reasonable.

Table 9 presents the ASE resuts obtained from the analysis. Beach nourishment, legal development regulation, and ICZM have the highest scores.

6. SUMMARY AND CONCLUSIONS

From the decision matrix and ASE analyses of the 2 case studies, we reach the following conclusions:

(1) The current and no action options were found to have very low scores in both analyses. (2) Almost all stakeholders in both case studies find that protection is needed. (3) Based on the study of various considerations of adaptation options, a combination of beach nourishment and hard structures (groins and breakwaters) would be the best option available for short-term protection of most of the coastal areas on the Nile Delta. (4) Even though costs of long-term options of protection may be very high, the losses in the long run are even higher. Hence, a strategic view must be adopted, taking into account such considerations as socioeconomic, awareness, and cultural aspects. (5) ICZM is the best strategic option with regard to availability of financial support. This may involve land use changes to aquaculture in some areas, hard protection in some other areas, and legal regulations in the rest of the areas. This option is the most recommended by the multi-disciplinary study team. However, implementation of this option may not be easy unless financial support is provided and upgrading of awareness is achieved.

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