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CASE STUDY

Assessment of Top-down Adaptation Measures to Sea Level Rise Risk in Kafr Elsheikh Governorate, Egypt

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Abstract

Egypt is considered one of the top five countries expected to be most impacted with a 1 m sea level rise (SLR) by the year 2100. This paper discusses top-down adaptation measures and efforts to protect Kafr Elsheikh Governorate from SLR risk, by reviewing several national environmental plans and frameworks. It reviews how the national adaptation plans are implemented on a local level and the overlaps and gaps between them. It shows many adaptation measures conducted in the area, most of them are to face beach erosion and inundation. It has been noted that there are no studies or governmental efforts to protect the southern edge of Burullus Lake which consists of wetlands and fishing villages. Thus, further research is needed for vulnerability assessment on the lake's southern shores, which helps in the decision-making of adaptation measures in the area. Also, more laws should be implemented for high-risk areas, regarding SLR.

Keywords: Adaptation, Kafr Elsheikh, Sea level rise, Top-down measures

1. Introduction

Sea level rise (SLR) is one of the many effects global warming has on the environment. North African shores are extremely vulnerable to SLR due to their geomorphology and topography, which consists mostly of sandy beaches and lagoons that are almost flat and close to sea levels. By the year 2100, Egypt is expected to be among the most five countries affected by 1 m of SLR. There are different research predicting the risk of SLR on Egypt's shores, some of those predictions are optimistic (B1) and some of them are not (A1F1) (Intergovernmental panel on climate change (IPCC) most optimistic and pessimistic scenarios). Regardless of the uncertainty level of these scenarios, it is agreed that climate change and associated SLR will have numerous impacts on the environment including increased coastal erosion; inundation; heightened flooding because of storm surges; rising water levels; salinization of groundwater and estuaries (The Intergovernmental Panel on Climate Change, 1997). In 2007, IPCC determined that the Nile Delta is one of the world's most vulnerable regions to SLR, extreme weather conditions, and other factors worsened by climate change, as a result of its low-lying topography and geomorphology.

The Nile Delta has a significant economic importance, as it contributes to 20% of Egypt's Gross Domestic Production (GDP), through agriculture, industry, and fisheries, more than half of Egypt's economic activity takes place in this region (Enhancing Climate Change Adaptation in the North Coast of Egypt, n.d.). The study will take Kafr Elsheikh Governorate as a case study, assessing its situation regarding SLR top-down adaptation measures, to discuss how national adaptation plans are implemented on the local level. To the authors' knowledge, no work has been published discussing adaptation measures for SLR risk in Kafr Elsheikh Governorate. Kafr Elsheikh Governorate is located between the two branches of the Nile River and extends along the Mediterranean coast for 100 km, with an area of 3466.7 km^2. It contains Burullus Lake which is the second largest natural lake in Egypt. The lake is connected to the Mediterranean Sea

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through an inlet called Boghaz, which is a 1.10–2.40 m wide opening located in Burj El Burullus city (Abdel-Fattah et al., 2018).

2. Motivation of the study

Developing the concepts of urban resilience has become a key thought underpinning sustainability studies during the last decades. This rapidly emerging area of interest urged the author to study the impacts of urban resilience within complex urban contexts. Egypt's Delta is considered one of the urban agglomerations suffering a complex set of challenges concerning the development of both its socio-urban and ecological environments. This accumulation is a result of rapid urbanization, besides the effects of climatic change. Trailing this complex reality, adopting urban resilience approaches is becoming a necessity to cope with the vulnerability of the area, which is affected by continuous urban and ecological mutations. The research aims to investigate the potential of practicing urban resilience approaches through contextual applications, and discuss urban resilience tools. Thus, it aims to promote the administrative response capacities towards the topic, vulnerability assessment, generic urban planning strategies, and chronological understanding of urban resilience and adaptation. Moreover, the research explores the leadership of government to get the best strategies for urban challenges they face. The author aims to explore possible preparedness plans to act against possible SLR risks in Delta Egypt; exploiting opportunities for transformation and development; and achieving a city resilience framework (CRF) for Kafr Elsheikh Governorate.

3. The problem of SLR in Egypt

There are two main causes for SLR, added water from melted ice sheets in the north and south poles, and seawater expansion due to higher temperatures. An increase in SLR could potentially cause increased erosion at Egypt's Low Elevation Coastal Zone (LECZ), where 15% of Egypt's GDP takes place (Adaptation to Climate Change in the Nile Delta, 2008). As a result, the northern lakes may merge with the Mediterranean Sea, causing major altercations in the environmental aspects of marine life and the natural and chemical characteristics of the lakes. Increasing groundwater salinity may result in salinizing nearby agricultural land if the shoreline recedes into agricultural land (Egypt's National Strategy for Adaptation, 2011).

'The value of property in the Nile River Delta threatened by SLR could be seven to 16 billion Egyptian pounds' according to the report entitled *Potential Impacts of Climate Change on the Egyptian Economy* (Maged, 2019). Approximately 2000 km^2 of land could be inundated by 1 m of SLR in coastal areas. It should be expected that there will be considerable erosion, resulting in ~100 km^2 of land loss (The Intergovernmental Panel on Climate Change, 1997).

4. Why adaptation?

In facing climate change risks, both mitigation and adaptation measures are needed. While adaptation costs can be reduced, if greenhouse gas (GHG) emissions are mitigated early, there will continue to be some level of global warming and its related effects will continue to some extent.

SLR risk needs more adaptation to face what cannot be avoided, regardless of the scale of mitigation undertaken at least over the next two to three decades (Prasad et al., 2009). A vital aspect of adaptation measures is their dynamic nature, which is always subject to updates based on newly acquired knowledge, technological advancements, and future predictions. It is important to know that the notion of adaptation is more than simply implementing the right technologies or practices. Coherent intersectoral strategies are necessary (Proposed Climate Change Adaptation Strategy, 2013).

There are effective adaptation measures, some of them have low cost and some have a high benefit-to-cost ratio. An evaluation of each measure's cost and benefit needs to be studied for each urban region.

5. Egypt's plans and frameworks to adapt to SLR (top-down approach)

Before reviewing national risk management plans, we must shed light on the Egyptian planning system. Egypt has a centralized government, which means that plans are done on a national level (coordinated horizontally between different ministries, committees, institutions, and agencies), and then they travel vertically to different governorates, districts, and municipalities to be implemented. Most of the time the place of implementation (governorate/district/municipality) does not contribute to the national planning process or decision-making. They are merely responsible for implementing the plans coming from above. This is the reason why the national plans are more general in nature, to be able to

cover different contexts and places. They act merely as a guideline. For adaptation measures, projects are conducted for specific areas based on extensive studies. As illustrated in (Fig. 1), these projects are under the authority of a ministry or committee (depending on the case) where vertical coordination takes place, between project, governorate, district, and municipality personnel (Faludi, 2000).

In 1982, the *Egyptian Environmental Affairs Agency* (EEAA) was founded to promote and coordinate governmental efforts, that are related to environmental protection (Proposed Climate Change Adaptation Strategy, 2013). Since then, there have been many efforts on the national level that try to adapt and mitigate different environmental risks, including the risk of SLR:

(1) In 1996, ICZM's national committee prepared the first document at the national level called *The National Integrated Coastal Zone Management (ICZM) Plan Framework.* It emphasized the importance of the coastal zone and outlined its challenges.
(2) In 2001, EEAA prepared the *National Environmental Action Plan* (NEAP) 2002–2017 employing a participatory and consultative planning modality. A total of six key issues were identified (water, air, land, waste, global environmental issues, and supportive measures). NEAP manages national marine and coastal zones, including actions for prevention and correction.
(3) EEAA prepared a *National Strategy for ICZM* as a part of the Priority Actions Program Regional Activity Centre (PAP/RAC) of the Mediterranean Action Plan (MAP) in 2009. This strategy elaborated on the challenges that face the country and the impact they have (erosion, seawater intrusion, and flooding). As a result, the strategy proposed three strategic objectives:
   (a) Improved coordination of ICZM policy.
   (b) Planning for sustainable coastal resource use.
   (c) Creating awareness among stakeholders. (Enhancing Climate Change Adaptation in the North Coast of Egypt, n.d.).
(4) The *Adaptation to Climate Change in the Nile Delta 2009–2014* through ICZM objective is to incorporate SLR risk management into Egypt's LECZ management plan. A key objective of the project is to integrate risk management of coastal settlement in LECZ of Egypt and implement innovative and environmentally friendly adaptation measures that strengthen Nile Delta resilience. Additionally, it includes a framework for assessing and monitoring adaptation efforts. Among the adaptation policies are the coastal risk reduction options, which include:
   (a) Upgrading protection.
   (b) Managing subsidence.
   (c) Land use planning, carefully locating new development locations away from the floodplain.

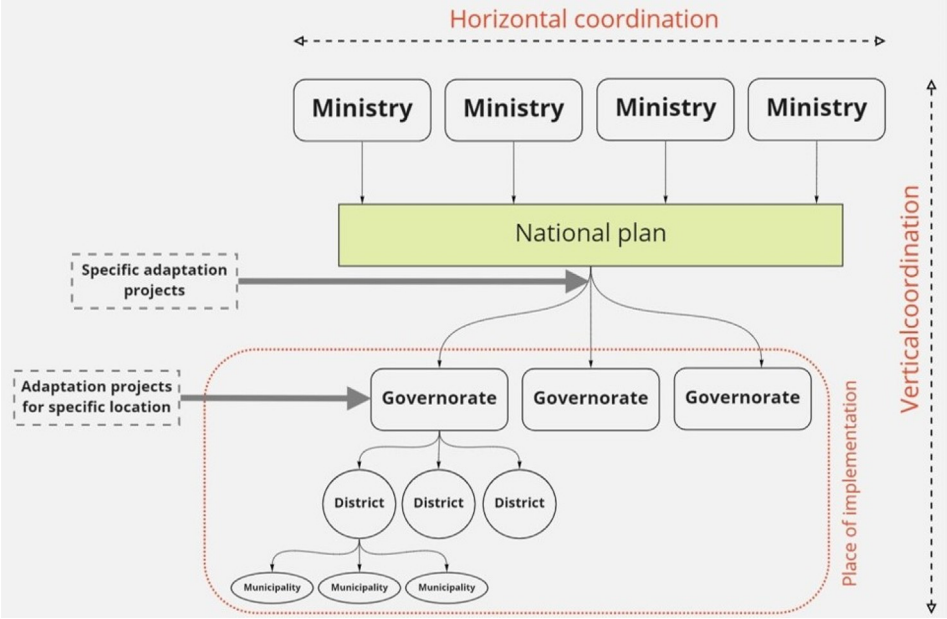

Fig. 1. Coordination between different governmental stakeholders in adaptation to sea level rise. Ref: Author.

(d) Selective relocation away from vulnerable, existing city areas (worst case scenario) (Adaptation to Climate Change in the Nile Delta, 2008).

(5) The government's achievement at the strategic level with the engagement of relevant stakeholders is *Egypt's National Strategy for Adaptation to Climate Change and Disaster Risk Reduction*, which was developed as a framework for adaptation policy. By using the Decision Support Centre (DSC), the National Committee in Egypt is affiliated with the Scientific Advisory Committee, which is comprised of government and scientific experts. The committee launched the National Strategy in 2011. As part of the UNFCCC, the first and second communications reports were utilized in the development of the strategy. Global warming and ecosystem vulnerability were discussed in the reports along with proposed adaptations and disaster reduction measures. Climate change-related risks and disasters are tackled by the strategy to increase Egyptian communities' resilience. The five-year strategy updates any changes that may occur until the end of the century. The framework presents five elements to be fulfilled for adapting to SLR: studies, rules, structural and architectural interventions, rehabilitation of installments, and reinforcing natural protection (Egypt's National Strategy for Adaptation, 2011). This strategy will be used later in this research.

(6) In 2013, the Egyptian Ministry of Water Resources and Irrigation drafted a *Climate Change Adaptation Strategy*. It introduced an adaptation strategy for Egyptian water sectors under constantly changing climatic conditions that influence 4 main risks:

(a) Drought and water scarcity (high risk).
(b) Increased floods (low risk).
(c) High water consumption (high risk).
(d) SLR (high risk).

The strategy features general and specific adaptation measures and policies, to tackle the previously mentioned 4 major risks and their consequences. The strategy also aims to integrate adaptation to climate change into national development plans, including policy-making, financing, implementation, and monitoring at national, sectoral, and subnational levels (Proposed Climate Change Adaptation Strategy, 2013) Table 1.

An expert interview was conducted on 12/12/2021 with Prof. Mohamed Ahmed Ali (Project Manager)

Table 1. Reviewed National plans for adaptation to sea level rise risk. Ref: Author.

Ministry	Framework/Plan	Year	Task
National committee of Integrated Coastal Zone Management	The National Integrated Coastal Zone Management Plan Framework	1996	First comprehensive document prepared by the national committee of ICZM
Egyptian Environmental Affairs Agency (EEAA)	National Environmental Action Plan 2002–2017	2001	Employing a participatory and consultative planning modality. Six main issues were highlighted (Water, Air, Land, Waste, Global Environmental Issues, Supportive Measures). The NEAP includes a program for managing national marine and coastal zones
Ministry of Water Resources & Irrigation, Coastal Research Institute, the Egyptian Shore Protection Authority	Adaptation to Climate Change in the Nile Delta through Integrated Coastal Zone Management 2009–2014	2008	To integrate the management of SLR risks into the development of Egypt's Low Elevation Coastal Zone (LECZ) in the Nile Delta
Egyptian Environmental Affairs Agency (EEAA)	National Strategy for Integrated Coastal Zone Management (ICZM).	2009	Prepared in cooperation with the Priority Actions Program Regional Activity Centre (PAP/RAC) of the Mediterranean Action Plan (MAP). The strategy presented major challenges facing the country and the impact of climate change (erosion, seawater intrusion, flooding)
Panel of experts from different ministries and sectors	Egypt's National Strategy for Adaptation to Climate Change and Disaster Risk Reduction	2011	A framework for adaptation policy
Ministry of Water Resources & Irrigation	Proposed Climate Change Adaptation Strategy for the Ministry of Water Resources and Irrigation in Egypt	2013	Presented an adaptation strategy for the water sector in Egypt under the foreseen changes affecting water resources management and climatic conditions

and Prof. Taher Osman, (Project Officer) from 'Enhancing Climate Change Adaptation in the North Coast and Nile Delta Project'. The project is funded by the Green Climate Fund, which is affiliated with the *United Nations Development Program* (UNDP, n.d.). The project aims to adapt to SLR in 5 Egyptian governorates and under the authority of the Ministry of Water Resources and Irrigation. It includes both physical structures and capacity-building measures. The experts gave their insight and expertise about the project in different governorates and how the vertical coordination between different governmental stakeholders takes place. Prof. Taher stated that working with governorate personnel was supportive, but they had issues with participation from the municipality and the local community. He refers that to the lack of trust on the local level in governmental personnel, especially in rural areas like Kafr Elsheikh Governate, where the community is used to being secluded for centuries, and they do not welcome development projects as easily as other locations. When asked Prof. Mohamed Ahmed Ali about which national plan the project follows, and where an adaptation project fits in the national plans, his answer was that the project is now planning an ICZM to overcome the shortcomings of the previous plans. Some of those shortcomings were:

(1) Not covering the funding.
(2) Covering the funding for only the time of constructing the project and skipping the follow-ups which affected the quality of some projects.
(3) Not clearing up the coordination between different stakeholders.
(4) According to him, there is a new national plan for coastal zones in the making. That is why the author could not find a direct link between different adaptation measures or projects and national adaptation plans, which is a sign of governmental decision fragmentation.

6. Case study: Kafr Elsheikh Governorate

Kafr Elsheikh Governorate lies in the north of the Nile Delta, Egypt, between the two branches of the Nile River on an extension of 100 km on the Mediterranean coast, with an area of 3466.7 km^2. There are ten municipalities in the governorate, five of them have shores on Burullus Lake (the second largest natural lake in Egypt), or the Mediterranean Sea (Fig. 4). An inlet (Boghaz) connects the lake to the Mediterranean Sea. The inlet is an opening between 1.10 m and 2.40 m wide in Burj El Burullus city. The lake was specified as a reservoir area and as a Ramsar site (No. 408), managed by EEAA in 1990. It is also a spot for migratory birds and is surrounded by agricultural land. As such, the lake is valued for its plant diversity and ecosystem services (Proposed Climate Change Adaptation Strategy, 2013). The lake is surrounded by a population of 1 million people, and 185 000 inhabitants make use of it daily, as proposed by social studies. (Enhancing Climate Change Adaptation in the North Coast of Egypt, n.d.).

The lake has been undergoing a national rehabilitation project since 2018 to enhance its water quality and fish production, by improving water exchange between the Mediterranean Sea and the lake, which happens through the inlet. A permanent dredging operation was implemented at the inlet location (to level 5.0 m), with an average dredging volume of 750 000 m^3. Located on the northern edge of the lake is a narrow barrier (width 0.4–5.5 km) with an average elevation of 1.5 m above sea level. Burj El Burullus city lies on its eastern border and low coastal plains run along its western side (Fakl, 2022). The lake's protective sand belt endured weakening since the construction of the Aswan Dam in 1964, by reduced sediment flows. SLR would demolish the sand belt even more, leading to the lake's water quality being altered significantly. Also,

Table 2. Effect of sea level rise on Kafr Elsheikh Governorate (Hassaan, 2013).

	Affected % of total inundation area		Impact
	B1	A1F1	
Wetland	72.13%	67.13%	Adverse impacts on biodiversity and fish production as a result of increased salinity of water.
Cultivated land	18.22%	22.81%	Lead to significant loss in jobs and food production.
Roads	11.6%	14.0%	More than 92% of these roads are unpaved roads. So, the actual harm from inundation of these roads would be in terms of lower accessibility and mobility of population.
Irrigation networks	11.11%	13.44%	

salted groundwater, agriculture, and fishing activities will be compromised, and with it the livelihood of millions of people.

Hassaan (2013) calculates that approximately 24.50% of the total area of Kafr Elsheikh Governorate would be at risk of flooding under B1 and A1FI, respectively (Table 2). At the district level, five of the ten districts in Kafr Elsheikh Governorate are vulnerable to inundation due to SLR (43.63%–47.31% of the district's total area). As a result, they will be vulnerable to various levels of inundation. He classifies vulnerability levels into three main categories, by the year 2100:

(1) Highly vulnerable districts (over half of their total land area is vulnerable): Metobas and Sedi Salim Districts. These are located on the western edge of the governorate.
(2) Moderately vulnerable districts (between 25 and 50% are vulnerable areas): El Hamul and El Riyad Districts.
(3) Less vulnerable districts (less than 25% are vulnerable areas): El Burullus District (Hassaan, 2013).

The next part represents an assessment of top-down adaptation measures done in Kafr Elsheikh Governorate to protect its shores from SLR. The author used *Egypt's 2011 National Strategy for Adaptation to Climate Change and Disaster Risk Reduction* to assess the current situation in Kafr Elsheikh's Governorate. The chosen framework is the most comprehensive plan, covering not only physical structures but also soft measures (studies & rules) (Fig. 2).

7. Studies

The studies are a detailed evaluation of the effectiveness of the proposed adaptation measures including methodological assessment, usually conducted before constructing or modifying shore protection structures (Egypt's National Strategy for Adaptation, 2011).

7.1. Alexandria research centre for adaptation (ARCA)

As part of research to adapt to climate change, ARCA was established in 2011, International Development Research Centre (Ontario–Canada). Research at ARCA on adaptation to climate change is multidisciplinary and policy-driven. By working with policymakers, it develops a research agenda relevant to policy and supports this agenda with small grants (Proposed Climate Change Adaptation Strategy, 2013). One example of the work the center has published is 'Assessment of Policy–Research Interaction on Climate Change Adaptation Action: Inundation by SLR in the Nile Delta' (Abdrabo and Hassaan, 2020). The authors overview the interaction between policy and research, on which they develop a framework. This is followed by a discussion about the research-generated knowledge and the role this knowledge can play in Egypt to develop adaptation strategies.

Among the projects funded by ARCA is one titled 'Assessment of vulnerability and adaptation to SLR for the Egyptian coastal lakes'. It evaluates the impact of future climatic change on hydrodynamic and water quality characteristics of Egyptian coastal lakes (Abdel-Fattah et al., 2018). Also, there is a lot of research done individually by researchers from different specialties in this regard which can be made use of. For example, Abd-Elhamid and colleagues in their research investigated the feasibility of using a diaphragm wall (DW) to protect Egypt's northern shores from SLR and investigated the environmental and social economic impacts (Fig. 3). Based on the results, the cost of building DW along the coast will cost ~1% of the loss estimate from SLR by 2100 (Abd-Elhamid et al., 2016). Using a Geographical Information System (GIS) (Hassaan, 2013), identified the areas in Kafr Elsheikh Governorate that have high vulnerability rates to flooding under B1 (IPCC's most optimistic scenario) and A1F1 (IPCC's most pessimistic scenario) (Hassaan, 2013).

7.2. Rules

Due to Egypt's centralized government system, its environmental law covers all governorates. This part of the assessment presents Egyptian laws with no specification to Kafr Elsheikh Governorate. Several measures have been implemented by the Egyptian government to combat the threats to coastal areas. For example:

(1) Add rules to cover climate change impacts on coastal development:
(a) Prime Ministerial Decree no. 1599/2006

To protect the Egyptian coastline, the *Egyptian General Authority for the Protection of Shores*, working together with EEAA prohibits the construction of any facility on the shorelines without its approval. Any activity/construction that could have an impact on the shorelines must be licensed (seawalls and offshore breakwaters, headlands, ports, marines).

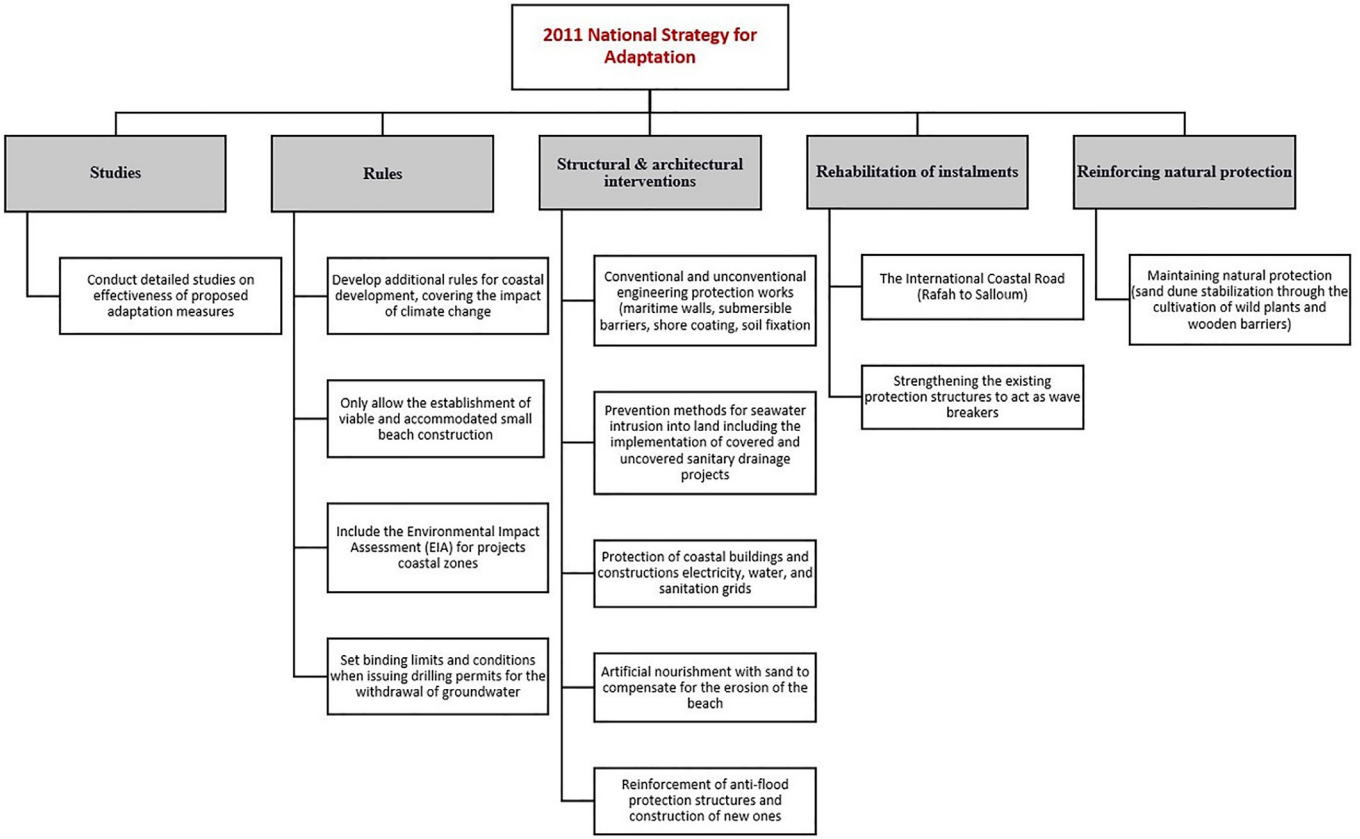

Fig. 2. Egypt's 2011 framework for adaptation to climate change and disaster risk reduction (Egypt's national strategy for adaptation, 2011).

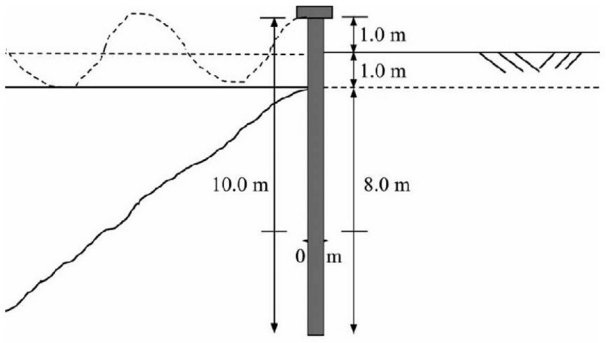

Fig. 3. Suggested schematic diagram for the designed diaphragm wall (Abd-Elhamid et al., 2016).

(2) Allow only the development of small, viable, and accommodating beach developments:

(a) Environment Law No. 4/1994 amended by Law No. 9/2009

Setback lines from the coast are included in the law, as it states, *'It shall be prohibited to issue permits for the construction of any installations on the seashores of the Arab Republic of Egypt up to a distance of two hundred meters inwards from the shoreline, except after obtaining the approval of the Shores Protection Authority and EEAA approval (Article 59)'*. (Egypt Third National Communication, 2016).

(b) Ministerial Decree No. 447/1988

The decree states that rates and standards must be adhered for the purpose of setting up tourist projects on Egyptian northern shores (Enhancing Climate Change Adaptation in the North Coast of Egypt, n.d.).

(3) Include *Environmental Impact Assessment* (EIA) for coastal development projects, with a section devoted specifically to impacts on climate change:

(a) The Law for the Environment (Law No 4 for the year 1994)

As well as requiring EIA for any new project, this law allows coastal erosion prevention structures to be built. It establishes environmental monitoring networks, manages and supervises natural preserves, and sets up a Coastal Zone Management Committee (CZMC) to manage and coordinate with the relevant agencies (Adaptation to Climate Change in the Nile Delta, 2008).

On the local level the development plan for Kafr Elsheikh Governorate year 2032 states that: Kafr Elsheikh Governorate's northern coast is divided into three main planning sectors, subdivided into six sectors (Fig. 4), as follows:

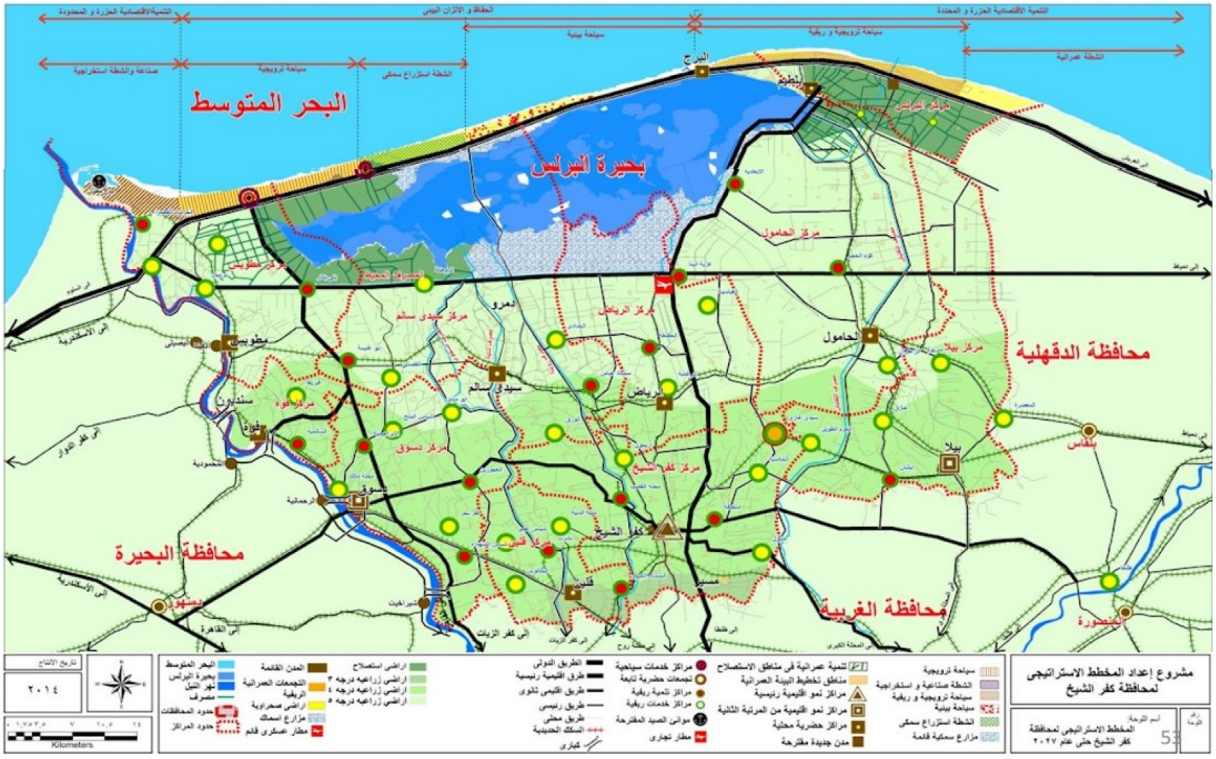

Fig. 4. Development plan for Kafr Elsheikh Governorate year 2032. (Strategic plan for land use on the northern coast of Delta Egypt, n.d.).

(1) The Rashid sector is at the western edge of Lake Burullus (divided into three sectors), where the economic development is cautious, limited, and linked to the industry and extractive activities of the industrial zone in Metobas city.
(2) Lake Burullus area is characterized by environmental homogeneity according to the natural determinants and is suggested to be under a policy of conservation and environmental balance. It is divided into two sectors.
(3) The Baltim sector starts from the lake inlet at Burj El Burullus city in the west and reaches the governorate borders in the east. (Strategic plan for land use on the northern coast of Delta Egypt, n.d.).

7.3. Structural and architectural interventions

This part deals with conventional and unconventional engineering protection works, for example: compensating for beach erosion with artificial nourishment and solid protection measures such as stone heads. While the next two projects were executed before the 2011 plan, they are mentioned here because they are adaptation measures in the study area, and they comply with plan parameters (Egypt's National Strategy for Adaptation, 2011).

7.3.1. Burj El Burullus adaptation measures (erosion)

Among the various protection projects executed by the Shore Protection Authority (SPA) are the construction of dolos revetments, basalt wall, sea wall, and groins on Burj El Burullus shores, to reduce erosion and control shoreline changes (Fig. 5). In 1947 the 6 km seawall was constructed along the coast of Burj El Burullus, and in 1975 a basalt rock wall (~1 km) was constructed. In a surf zone that is active, the government has built 17 detached breakwaters, to reduce erosion rates parallel to the beach. As a result of the eroding coast, west of Kitchener drain, nine groins were established in 2004, which were made of concrete (blocks, dolos), limestone, and basalt mounds. Study results indicate high erosion rates in two zones (B and part of D) where protection structures were ineffective and could not counter erosion. Therefore, it is essential to carefully select the protective structures for affected zones with a continual evaluation of their effectiveness (Elkafrawy et al., 2021).

7.3.2. Baltim shore-parallel breakwater systems

There are nine detached breakwaters in Baltim Beach, each of which was constructed between 1993 and 2002 and fronts a shoreline of ~6.5 km in length. The breakwaters are constructed between 3 and 4 m deep, in an active surf zone (Fig. 6). They are located 220 m from the shoreline and parallel to it. Each breakwater stretches between 250 and 350 m long. They are spaced between 320 and 400 apart. Armored with dolos units weighing 4–7 tons, they stand 2.5 m above sea level (Frihy et al., 2003).

7.4. Rehabilitation of installments

The use of manufactured structures, which were not originally designed for coastal protection, can reduce coastal flooding resulting from SLR. A prominent example is International Costa Road (ICR), which runs parallel to the coastline across the northern part of Kafr Elsheikh Governorate. Since the road is located 2 m high in most sections (Fig. 7),

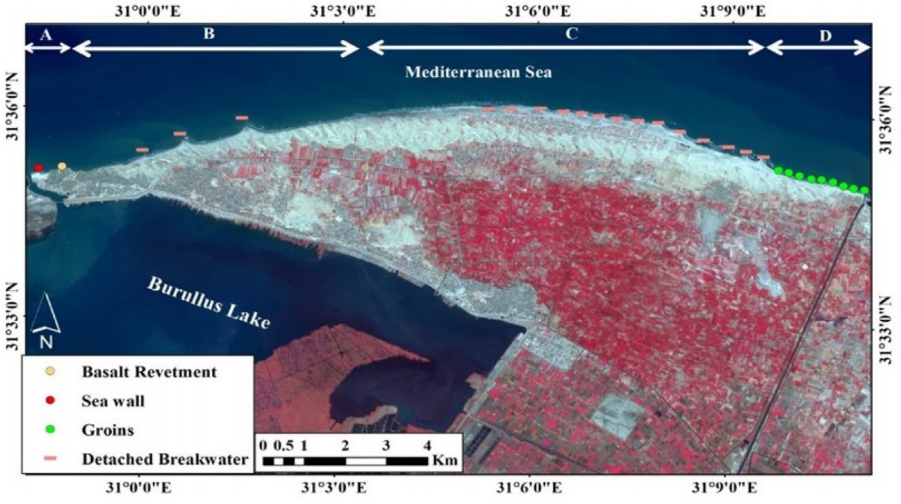

Fig. 5. Burj El Burullus adaptation measures (Elkafrawy et al., 2021).

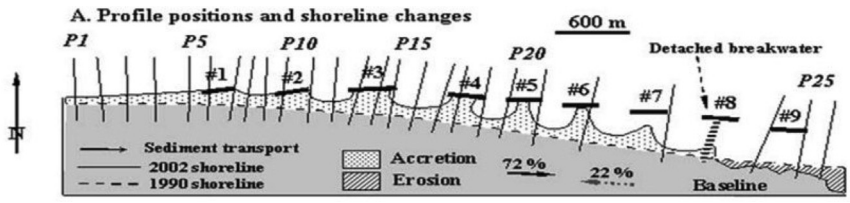

Fig. 6. Baltim shore-parallel breakwater system (Frihy et al., 2003).

Fig. 7. The international coastal road 2 m above sea level (Hereher, 2010).

strengthening its northern banks could prevent flooding in areas south of it (Hassaan, 2013).

7.5. Reinforcing natural protection

The following part discusses maintaining natural protection, by cultivating wild plants and constructing wooden barriers to stabilize sand dune slopes, like the UNDP project 2018–2025 in Egypt, when EEAA, CoRI, and SPA, under the UNDP (n.d.), submitted the project for consideration to the Green Climate Fund [GCF]. The project utilizes existing dredge material (made by local women) from ongoing long-term operations, aiming to minimize the impact of coastal flooding caused by SLR along 5 vulnerable hotspots in Egypt's Nile Delta, one of them is Kafr Elsheikh (Fig. 8). The Ministry of Water Resources and Irrigation is supervising the project, which will cost 31.4 million US$ over a 7-year period. They convert flood-prone areas to low-risk areas by replicating natural coastal features such as sand dunes (The Intergovernmental Panel on Climate Change, 1997).

8. Discussion

Since the 1990's the Egyptian Government has taken many steps to tackle climate change and its effect on agricultural and urban areas. Since then, many governmental plans, strategies, and frameworks have been conducted to address different climate change risks, including SLR. It is noted that there are a lot of intersections and overlapping between the frameworks, which is in line with what

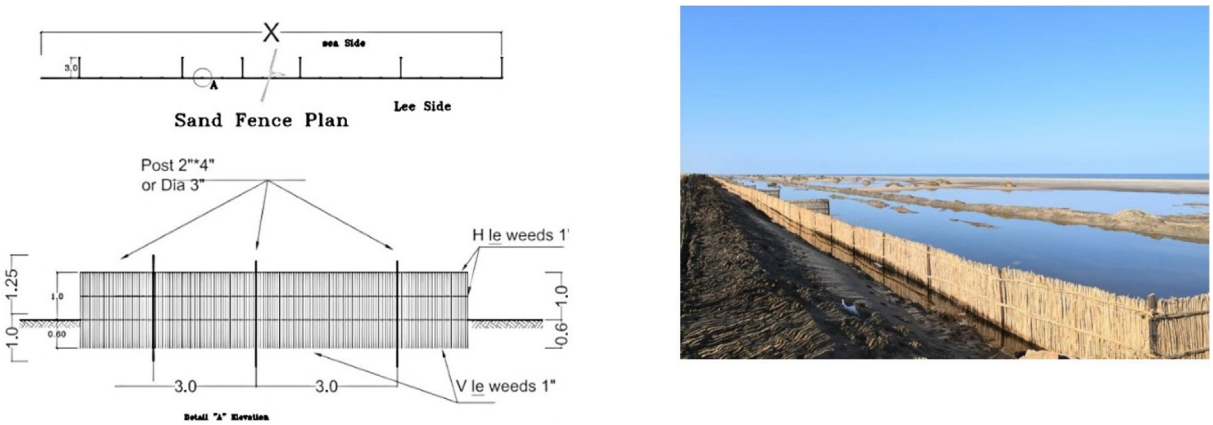

Fig. 8. United nations development program adaptation project in Kafr Elsheikh using dredge material from the area (The Intergovernmental Panel on Climate Change, 1997).

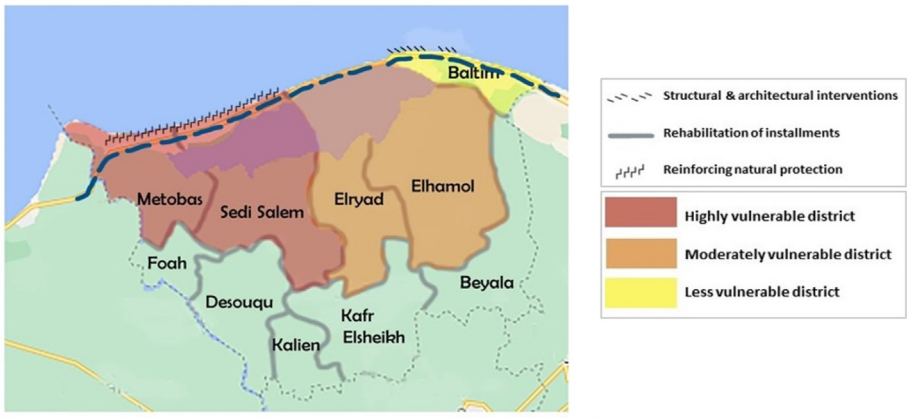

Fig. 9. Location of adaptation measures in relation to the level of vulnerability to sea level rise in Kafr Elsheikh Governorate. Ref: Author.

was mentioned in the UNDP (n.d.) draft. Often, political discontinuity causes this overlap and hinders efforts to reduce climate risk on a long-term basis. As a result of frequent government turnover, skills and capacity are lost and the political will to continue initiatives from previous administrations is diminished.

At the same time there are coordination gaps as the frameworks discuss the entire coast and are not specified for a specific governorate. Every governorate needs to study the applicability of the national framework to its specific contexts and needs. Also, the link between national plans and adaptation projects needs more coordination to make sure the plan is implemented fully. It is also important to build networks between existing research institutes working in climate-relevant fields. Furthermore, after reviewing several national environmental plans and frameworks, it is noted that they mention little community participation and awareness in facing the risks, which calls for future research, especially in rural eras in Kafr Elsheikh, where community trust in development projects is low (as mentioned in the expert interview).

In the light of the presented analysis for Kafr Elsheikh Governorate's SLR adaptation measures, there are a lot of adaptation measures executed in the region most of them are to face beach erosion, but several inundation measures are being implemented now sectors (Fig. 9). It has been noted that there are no studies or governmental efforts to protect the southern edge of the lake, which is mostly wetlands and fishing villages, e.g., Shakhlouba (where one could see the SLR risk with bare eyes) maybe because of the narrow Burullus Lake inlet on the Mediterranean (Fig. 10). By dredging and protecting the shorelines, the inlet has been undergoing a development project since 2018, to improve the much-needed water exchange between the lake and the Mediterranean Sea. Furthermore, a significant amount of fresh water is drawn into the lake from agricultural drains on its southern, eastern, and western sides. Another reason for overlooking small communities and rural areas is addressing the SLR problem only on a national level, where the focus is on higher density and more economy productive areas.

Fig. 10. Shakhlouba Village south Burullus Lake, where sea level rise is visible to the eye. Ref: Author (2021).

9. Conclusion

This study aims to assess Kafr al-Sheikh Governorate's current situation regarding SLR top-down adaptation measures, to see how national adaptation plans are implemented locally. The results can be summarized as follows:

(1) Due to being a centralized country, vertical coordination between different stakeholders is working well with some exceptions in rural areas.
(2) There is room for improvement in horizontal coordination when solving the problem of SLR risk in Egypt between governmental stakeholders. This is shown clearly in the number of adaptation plans conducted by different governmental authorities in a short timeframe. One reason for that could be government turnover in the last ten years which affects coordination and work fluency.
(3) There are many national adaptation plans to solve the problem of SLR, with overlapping and gaps.
(4) The shores of Kafr Elsheikh Governorate are protected from SLR risk except for the southern shores of Burullus Lake.
(5) More laws should be implemented for high-risk areas regarding SLR risk.
(6) There is a need to develop an awareness program among community stakeholders and officials of the coastal governorates regarding the impacts of climate change on coastal zones.
(7) Burullus Lake water level needs to be monitored and documented after the many developing projects it has been undergoing, which calls for future research.
(8) Frameworks for every region and governorate need to be conducted, to work on the context and needs of each place and community.
(9) National frameworks and plans mention little community participation and awareness regarding SLR risk, which calls for future research.
(10) Further research is needed for vulnerability assessment on the southern shores of Burullus Lake, especially in Shakhlouba Village, which helps in the decision-making of adaptation measures in the area.

Author credit statement

As the sole author of this paper, all parts of it was done by me.

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Conflicts of interest

The author declares no potential conflicts of interest with respect to the research, authorship or publication of this article.

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