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Risk Assessment of Sea Level Rise and Adaptation Options on Abu Qir Region

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Declaration

I declare that no part of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other University or other Institution of learning.

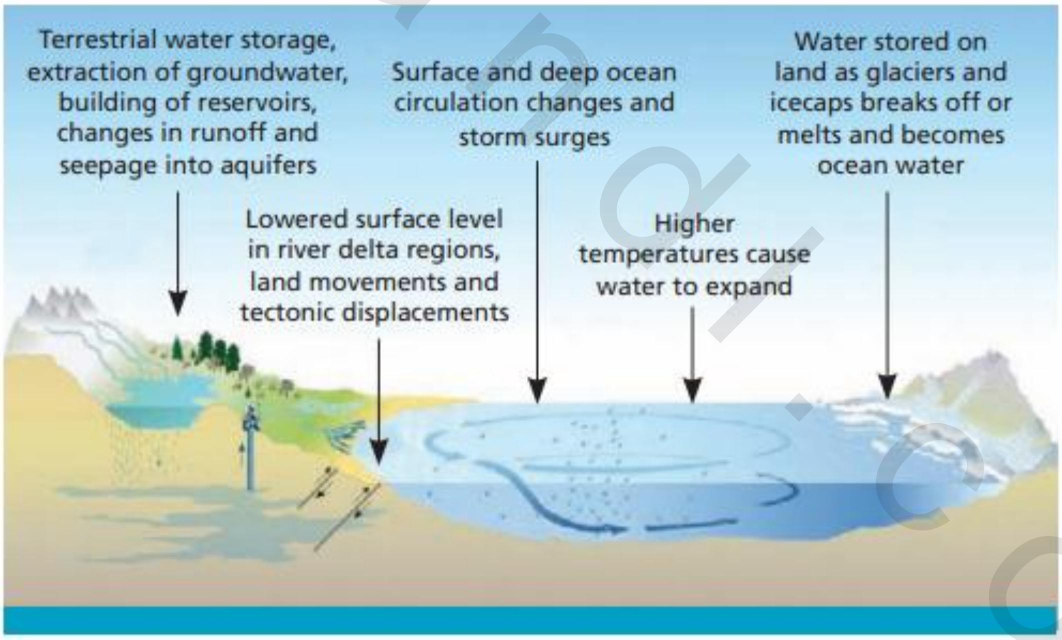
Mostafa Amer Khamis

CHAPTER I

INTRODUCTION

I.1. Background

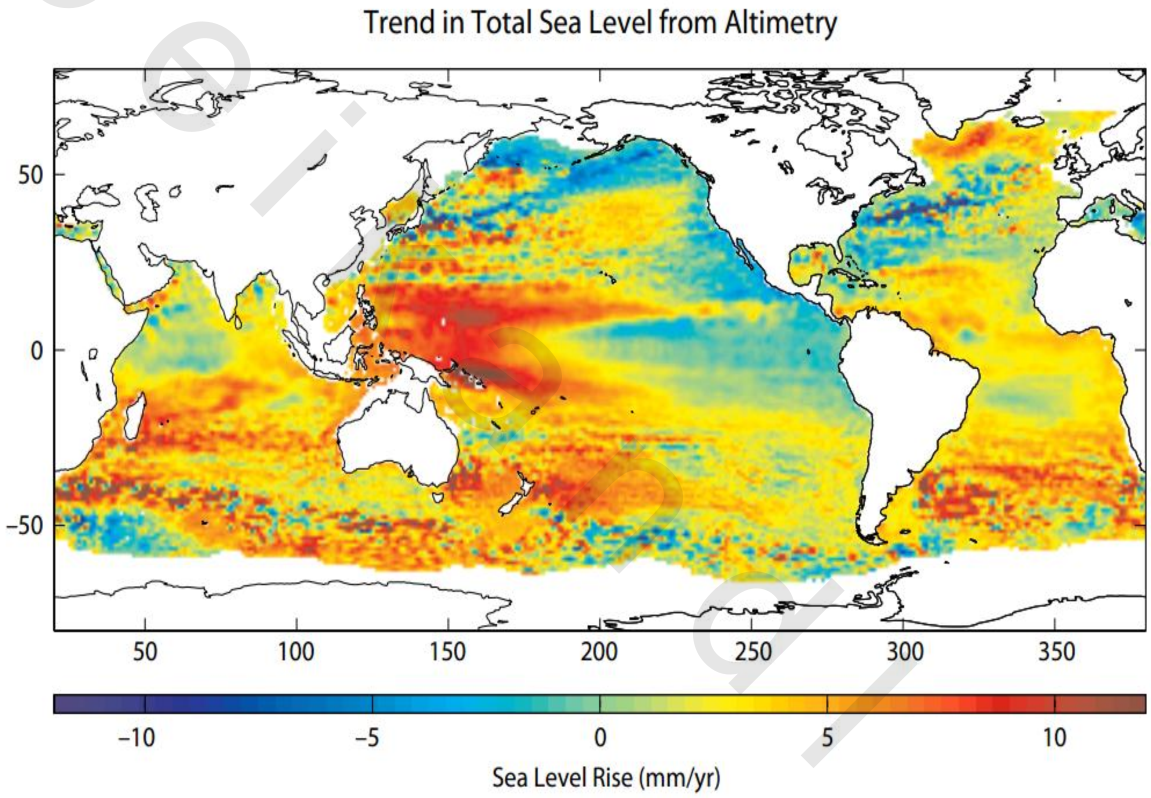
Climate change is a long-term shift in the statistics of the weather (including its averages). The last decade of the 20th Century and the beginning of the 21st have been the warmest period in the entire global instrumental temperature record, starting in the mid-19th century. It is well recognized that climate changes have already caused increases in average global temperatures and is expected to continue rising temperatures. As a result of continued temperature rising, it is expected to give rise to many important phenomena including sea level rise (SLR) and increase of frequency and severity of extreme events. Extreme events include heat waves, marine storm surges and flash floods (IPCC, 2007)[1].



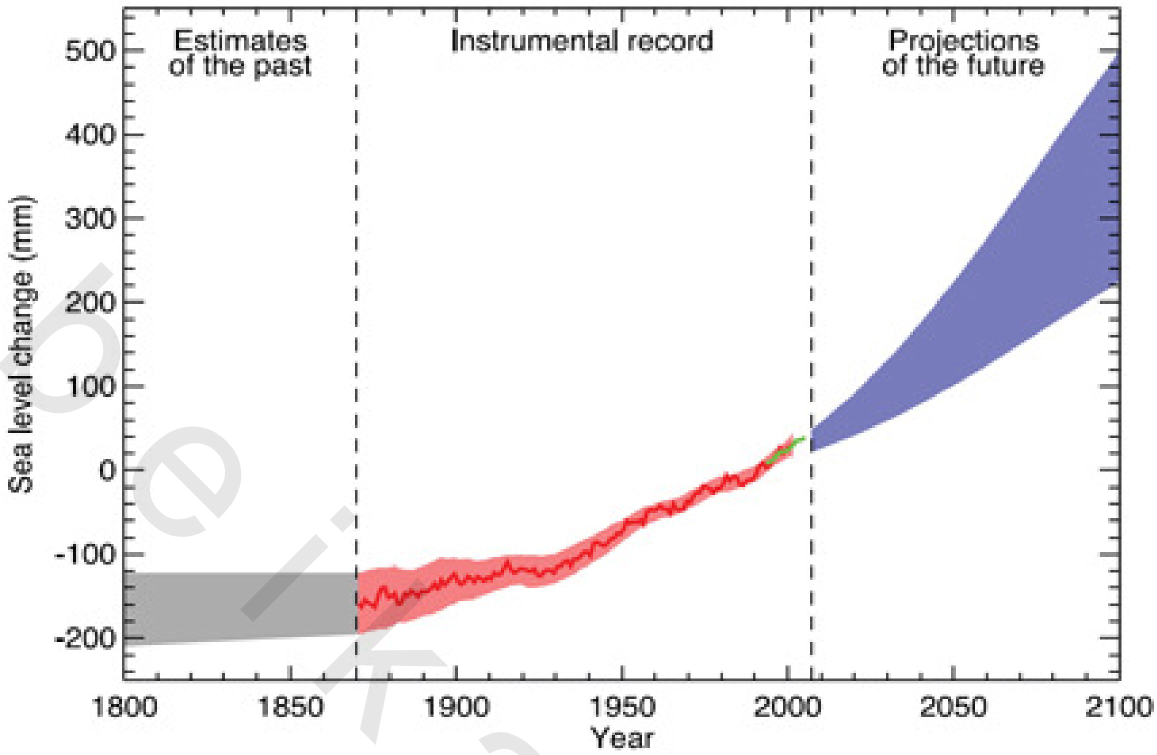
(Figure I -1) What causes the sea level to change (Source: IPCC, 2001) [2].

It is predicted that, with global warming, average sea levels may rise by between 7 and 36 cm by the 2050s, by between 9 and 69 cm by the 2080s and 30–80 cm by 2100 as indicated in Figure (1-3). Increases in coastal flooding that accompany historic sea level rise illustrate how rising ocean levels are likely to exacerbate storm impacts

(IPCC, 2007)[1].The major components of average global sea-level rise scenarios are thermal expansion, glaciers and small ice caps, the Greenland and Antarctic ice sheets, and surface and groundwater storage (Warrick et al., 1996)[3]..Changes in ocean volume can be caused either by thermal expansion from a net gain or loss of heat by the ocean or by a net exchange of freshwater between the ocean and the continents (including the ice sheets in Greenland and Antarctica, as well as mountain glaciers (Gille, 2004)[4]



(Figure I -2) The regional change in sea level based on the 17-year trend from 1993 through 2009 from radar altimeter data from several (Josh, 2010)[5]



(Figure I -3): Past, present and predicted sea level trends (IPCC, 2007) [1]

These phenomena usually are modeled separately. Using GCM output, the thermal component of sea-level rise has been estimated by (Bryan, 1996)[6](Sokolov et al.,1998)[7], and (Jackett et al.,2000)[8]. Contributions from glaciers and ice sheets usually are estimated via mass-balance methods that use coupled atmosphere-ocean and atmosphere-ice relationships. Such studies include: for glaciers and the Greenland ice sheet, (Gregory and Orleans,1998)[9].;for Greenland only, (Van de Wall et al., 1997)[10]for the Antarctic ice sheet, (Smith et al. (1998)[11]and for Greenland and Antarctica, Ohmura et al. (1996)[12]. and Thompson (1997)[13].Simple models that integrate these separate components through their relationship with climate, such as the upwelling diffusion-energy balance model (Wigley ,1995)[14]. can be used to project a range of total sea-level rise. (De Wolde et al. 1997)[15]. used a two-dimensional model to project a smaller range than in the major differences were related to different model assumptions. (Sokolov 1998)[7].used a two-dimensional model to achieve a larger range. These phenomena are additive because it is impossible to provide projections of all of these phenomena with any confidence, many assessments of coastal impacts simply add projections of global average sea level to baseline records of short-term variability (Ali, 1996)[16].According to the

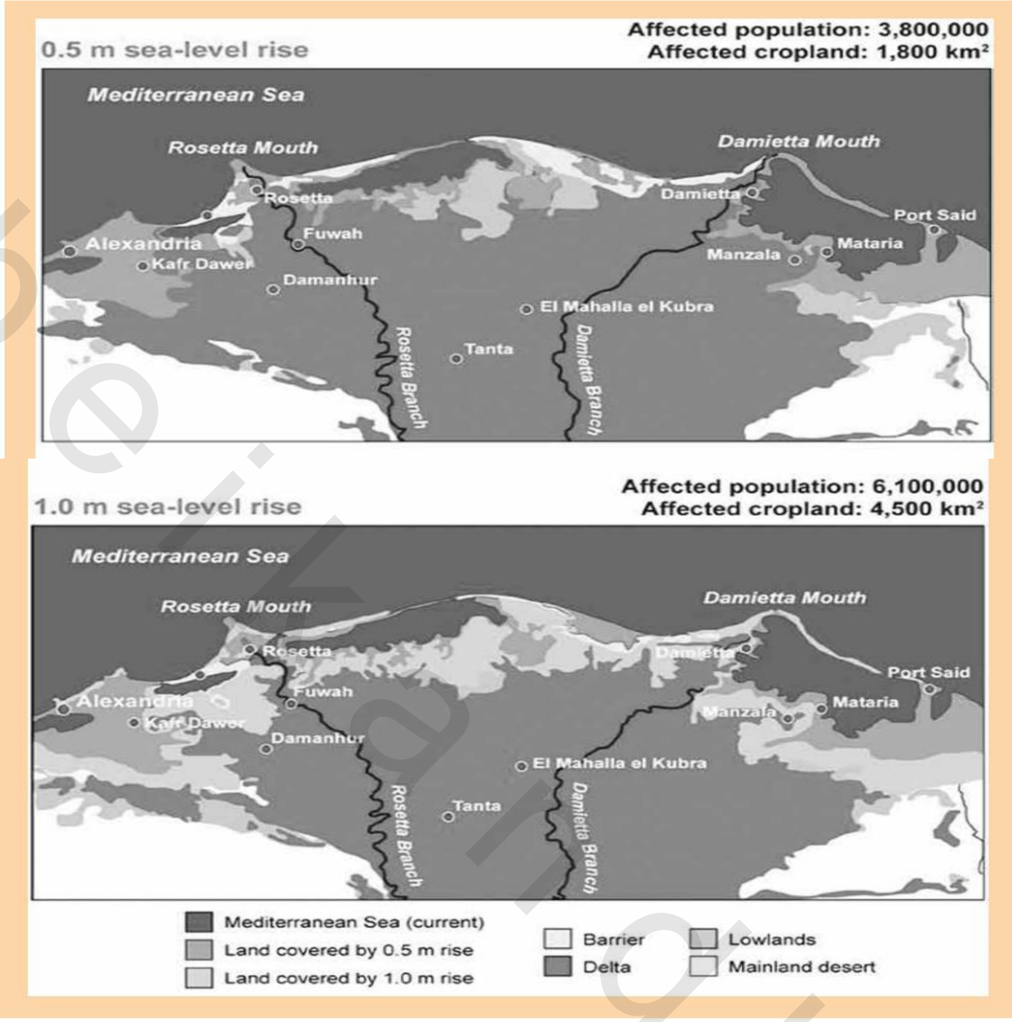
Inter-governmental Panel of Climate Change IPCC reports, the mean annual global surface temperature will increase by 1 to 3.5°C by the year 2100, Furthermore, recent measurements indicate that sea-level rise is occurring at a rate of about 1 to 2 millimeters per year, or about 100 millimeters in the last century (McCarthy et.al, 2007)[17].The majority of this change will occur due to the expansion of the warmer ocean water (Roaf, et al., 2005)[18].According to (IPCC,2001)[2] reports, scientists predict the Mediterranean will rise by a range of 30 centimeters to one meter by the end of the century but still a one-meter rise in the level will possibly submerge important parts of Alexandria (El Raey , 2010)[19].

I.2 Climate change on the coastal zone of Egypt

Egypt's coastal zone of the Nile delta has been defined as a vulnerable zone as a consequence of SLR combined with geological and human factors. Egypt is considered one of the country's 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 (El Raey ., 2010)[19].Alexandria is the second largest city of Egypt with a population of over 4 million people. It hosts over 45% of the Egyptian industry and two major harbors of Egypt. Geographically, Alexandria is located approximately at 30°50' to 31°40' north and 29°40' to 32°35′ east. The city has a waterfront that extends for 60 km from Abu –Qir Bay in the east to Hammam in the west and it is most vulnerable to SLR (Khatriet al., 2007) [20].Abu Qir westwards in a relatively narrow strip between the Mediterranean Sea and Lake Maryut for a length of 55 kilometers, in addition to 65kilometers western devoted for industrial and tourism activities. According to that description it is easy to configure the vulnerability of Abu Qir region to the sea level rise phenomena.

1.3 Sea-Level Rise and Its Impact on Coastal Zones

The Mediterranean coastal zone suffers from a high rate of population growth, land subsidence in the Delta region, excessive erosion rates, saltwater intrusion, soil Stalinization, land use interference, ecosystem pollution and degradation, and lack of appropriate institutional management systems. the Nile Delta is subject to shoreline changes resulting from erosion and accretion, subsidence, and sea level rise resulting from climate change(El Raey ., 2010)[19].



(Figure I -4) Coastal Impacts Due to Sea-Level Rise (FitzGerald, 2008) [21]

I.3.1 Sea Level Rise in Egypt

Sea level changes are caused by several natural phenomenon; the three primary Contributing ones are: ocean thermal expansion, glacial melt from Greenland and Antarctica - in addition to a smaller contribution from other ice sheets- and change in terrestrial storage. Among those, ocean thermal expansion has been expected to be the dominating factor behind the rise in sea level. However, new data on rates of delectation in Greenland and Antarctica suggest greater significance for glacial melt, and a possible revision of the upper bound estimate for sea level rise (SLR) in this century (El Sharkawy et al., 2009)[22].Global-mean sea-level change is one of the more certain impacts of human-induced global warming and one which is expected to continue for centuries due to the time scales associated with climate processes and feedbacks even if greenhouse gas (GHG) emissions concentrations were to be stabilized (Meehl et al., 2010)[23].Some potential impacts of a change in sea level have already been assessed locally, nationally, regionally and globally (e.g. Bijlsma et al., 1996)[24]and(Mclean et al., 2001)[25].Sea level rise (SLR) due to climate change is a serious global threat: The scientific evidence is now overwhelming. Continued growth of greenhouse gas emissions and associated global warming could well promote SLR of 1m-3m in this century, and unexpectedly rapid breakup of the Greenland and West Antarctic ice sheets might produce a 5m SLR. (Dasgupta, et al., 2007)[26].In 2007 the New York State created the sea level rise task force and charged it with preparing a report that addresses these issues, including recommendations for an action plan to protect coastal communities and natural resources from rising sea levels (Chandler,2011)[27].Results from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5,2014)indicate that a global mean sea level rise will rising by the end of this century. In Egypt local land subsidence in the Nile Delta would exacerbate the impacts of rising seas. (Figure1-5) represents the observed time variation of sea level and indicates the rates of land subsidence of the Nile Delta calculated by one study. (ElRaey, 2010)[19].

(Figure I-5) Image of storm wave in Alexandria 10 / 12 / 2010

I.3.2 Sensitivity and Adaptive Capacity

Bijlsma et al. (1996)[24]and IPCC (2001)[2] identify the areas of greatest sensitivity to accelerated sea-level rise. These areas comprised low-elevation coral atolls and reef islands, as well as low-lying deltaic, coastal plain, and barrier coasts, including sandy beaches, coastal wetlands, estuaries, and lagoons. It is important to recognize that vulnerable coastal types in many parts of the world already are experiencing relative sea level rise, from a combination of subsidence and the global component of sea-level rise identified to date. Submergence rates of 2.5 mm yr-1 or more are not uncommon, and higher rates apply locally, such as in parts of China (Ren, 1994)[29].the United States (Dean, 1990)[30].Canada(Shaw et al., 1998)[31].and Argentina (Codignotto, 1997)[32]. Although this sea-level rise implies enhanced vulnerability, it also provides a basis for assessing coastal response to various rates of relative sea-level rise, where similar coastal types, boundary conditions, and system properties can be identified.

A.Exposure

Exposure generally refers to the state and change in external stresses that a system is exposed to. In the context of climate change, these are normally specific climate and other biophysical variables (including their variability and frequency of extremes). The location of people and assets can also be regarded as exposure(IPCC, 2007)[1].(Preston and Smith, 2009)[33].

B. Sensitivity

It is the degree to which a system is affected, either adversely or beneficially, by climate change. The effect may be direct, for example: change in crop yield due to temperature variability, or indirect as the damages caused by an increase of the frequency of coastal flooding due to sea level rise.(IPCC, 2007)[1].

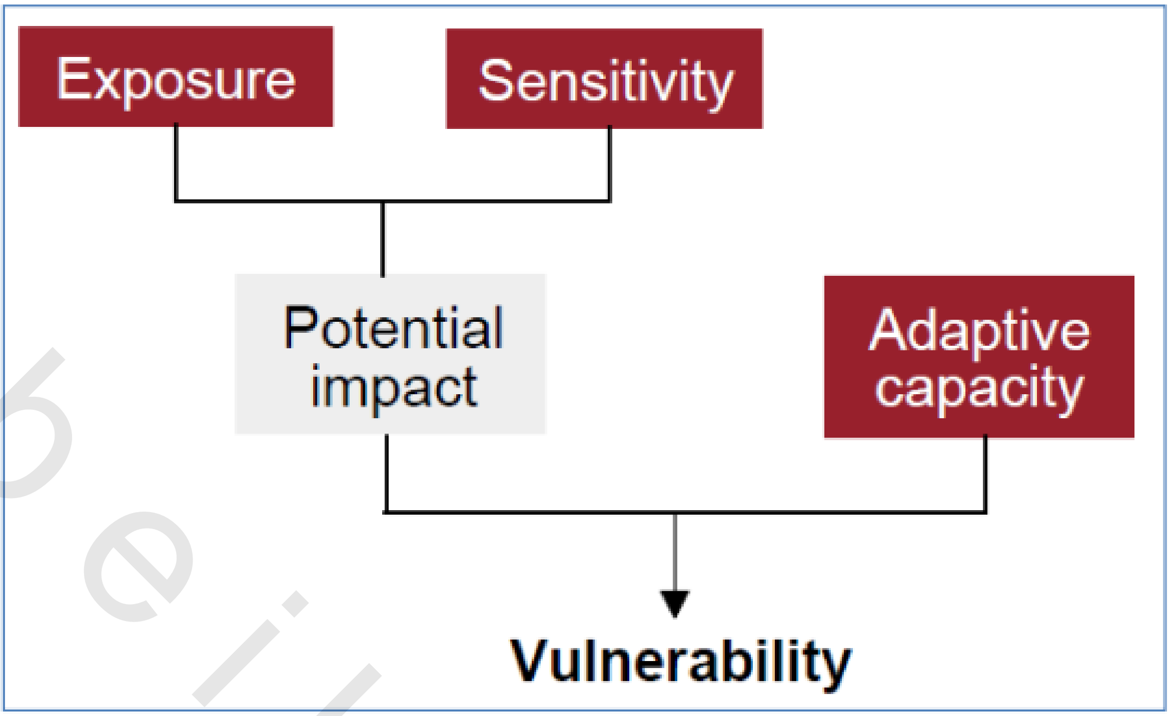
C. Adaptive capacity

It is the ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences(IPCC, 2007)[1]And (Smit and Pilifosova, 2003)[34].

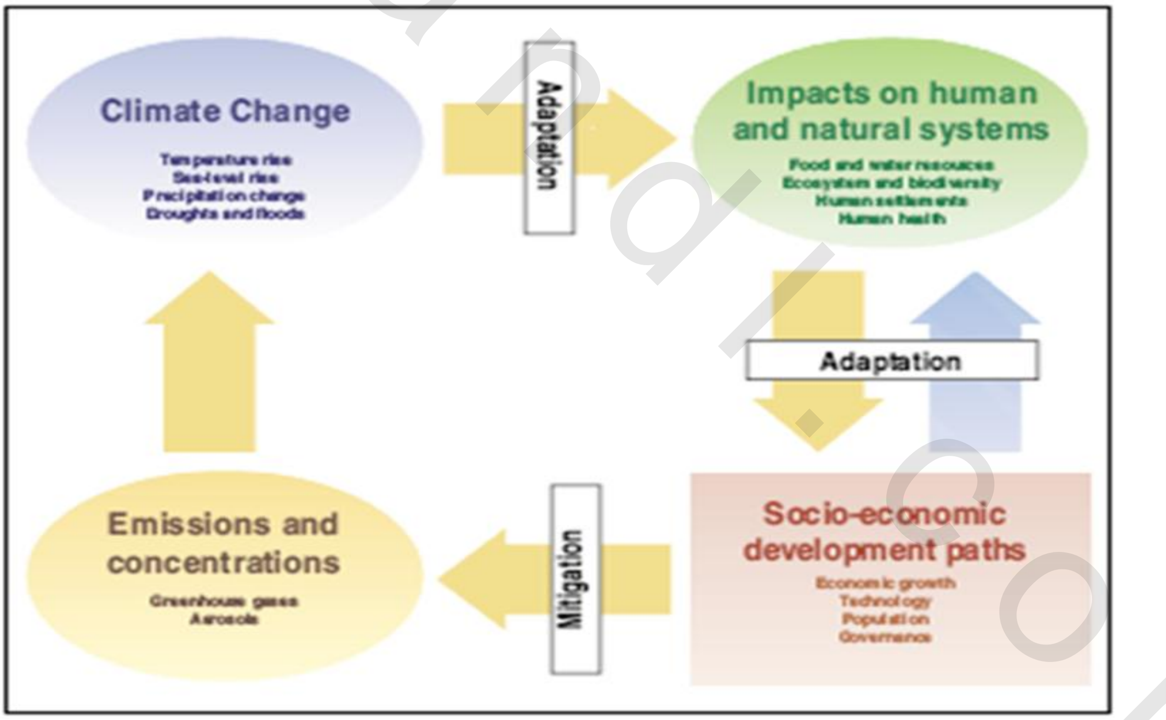
Adaptive capacity includes:

- coping capacity (the ability to accept the impacts and recover back to the system state before the impact, but does not change the system's exposure or sensitivity to reduce future impacts)
- The ability to adapt (the change in a system's exposure or sensitivity to reduce future impacts).

Both coping capacity and ability to adapt can change over time for a number of reasons, for example socio-economic change in a given area (Adger, 2006)[35], (Yohe and Tol, 2002)[36],(Turner II, et al., 2003)[37](Eriksen and Kelly, 2007)[38].



(Figure 1-6): Vulnerability and its components (Allen Consulting, 2005) [39].



(Figure1-7) Steps to climate change vulnerability assessment as proposed by (IPCC 2007)[1].

I.3.3Vulnerability

Vulnerability can be defined as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (Elsharkawy et al., 2009) [22].Vulnerability to climate change is considered to be high in developing countries due to social, economic, and environmental conditions that amplify susceptibility to negative impacts and contribute to low capacity to cope with and adapt to climate hazards. Moreover, projected impacts of climate change generally are more adverse for lower latitudes, where most developing countries are located, than for higher latitudes. Because of the high level of vulnerability, there is an urgent need in the developing world to understand the threats from climate change, formulate policies that will lessen the risks and to take action (Frihy et al, 2012)[41].

I .4 Literature review

Climate change impacts danger is greatest, where natural systems are severely degraded and human systems are failing and therefore incapable of effective response, specifically in deprived nations. Moreover, land degradation and desertification may also be exacerbated in these areas, posing additional threats to human well-being and development, added by intensified human pressures on lands and poor management. The livelihoods and food security of the rural poor are threatened by climate change with all its impacts, and the vulnerability to adverse health impacts is greater where health care systems are weak and programs for disease surveillance and prevention are lacking. In addition to multiple factors converging to make the people inhabiting coastal zones and small islands highly endangered from the causes of SLR (Leary, et al., 2007)[42]. The coastal zones of Africa contain high populations, significant economic activity and important ecosystems. These are at risk from future sea level rise and storm surge. With a large and growing population in coastal zones and a low adaptive capacity, many African countries are highly vulnerable. The climates of Africa are both varied and varying; varied, because they range from humid equatorial regimes, through seasonally-arid tropical regimes, to sub-tropical Mediterranean-type climates, and varying because all these climates exhibit differing degrees of temporal variability, particularly with regard to rainfall (Hulme, 2001) [110].

About the extreme weather events, there are some evidences (IPCC, 2007a) [1].that in many African countries, natural disasters involve too much or too little rain: the Sahel witnessed a series of devastating drought years between the 1960s and 1990s, while more recently, Mozambique (2000 and 2001) and Ethiopia (2006) have experienced severe flooding, to name only a few examples.

The sea-level rise witnessed in the twentieth century was for the first time observed to be driven primarily by human-induced warming. An increase of melt water into the world's oceans and a thermal expansion caused by warming sea temperatures both contributed to the rise, which since 1993 has averaged three millimeters per year (WBGU, 2007)[112].Without action on greenhouse gas emissions, and barring any non-linear events, a global rise of between 0.2m and 0.6m can be expected by 2100 across all IPCC scenarios.

Rising sea levels will carry with them significant implications for coastal settlements and populations, and are likely to increase the socio-economic and physical vulnerability of many of Africa's coastal cities. Those most susceptible to sea level rise are poor populations living along the coast in areas potentially vulnerable to flooding (Boko et al., 2007) [111].

There are three factors that make Africa particularly vulnerable to the impacts of climate change (WBGU, 2007) [112]. The first is Africa's position on the globe; Africa already has a warm climate and is exposed to inconsistent rains with large areas characterized by poor soils or floodplains. Second is the fact that many of Africa's economies are dependent on sectors that are susceptible to climate fluctuations, such as agriculture, fisheries, forestry and tourism. Agriculture represents on average between 20 to 30 percent of GDP in sub-Saharan Africa and makes up 55 percent of the total value of African exports. Meanwhile, depending on the country, between 60 and 90 percent of the total labor force in sub-Saharan Africa is employed in agriculture. Third is the socio-economic context: the lack of good governance; persistent and widespread poverty; poor economic and social infrastructure; conflicts; and limited human, institutional and financial capacities means that as a continent, Africa is least able to adapt to the effects of climate change.

Climate change and its impacts will affect a growing number of people, and migration hotspots around Africa are likely to increase. Climate change will cause population movements by making certain parts of the world much less viable places to live: by causing food and water supplies to become more unreliable; undermining livelihoods; through sea-level rise and flooding that reduces available land; and by increasing the frequency and destructive power of storms (Brown, 2008 b) [113].. This may force large numbers of people to leave their homes and communities.

Many of the world's major cities are built in low-lying coastal regions. Impacts of SLR include inundation of these areas, coastal erosion and saltwater intrusion into aquifers, loss of coastal wetlands and mangrove areas and impacts on biodiversity (Church et al. 2008) [43].

All countries of North Africa are presently experiencing changing in water resource stress, Agriculture, Migration, Natural Disasters, Tourism and Energy as a result of climate change.(NIC, 2009)[44].

An assessment of vulnerability and adaptation of coastal zones to sea-level rise in Morocco was conducted. Results indicated that 10% and 24% of the area will be at risk of flooding, respectively for minimum (4 m) and maximum (11 m) inundation levels (Snoussi et al., 2009)[45].

An assessment of vulnerability to climate change was conducted in the city of Busan in South Korea based on the conceptual framework provided by the Intergovernmental Panel on Climate Change (IPCC). They developed a methodology of climate change vulnerability assessment in coastal cities and applied it to Busan. Their results indicated that their methodology is easy to use and provides concrete policy implications when setting up adaptation strategies (Kuhn et al., 2011)[46].

Projections of SLR based on a suite of climate change scenarios in the greater New York City were investigated. They expected that sea levels will rise by 18–60 cm by the 2050s and 24–108 cm by the 2080s over late 20th century levels(Gornitz et al., 2002)[47].

The actual costs of the basic 'beach nourishment against SLR along the Alexandria coast are given in Table5.4 according to (El-Raey 2005) [106] and according to the experience of the Shore Protection Authority (SPA) and Coastal Research Institute (CRI) (Tetratech 1986) [107]. Based on earlier experience, a10% increase in costs over the latest published data is expected for the 1990s. According to people opinion in field trip they told me the best protection solutions to storm waves in Abu Qir are:

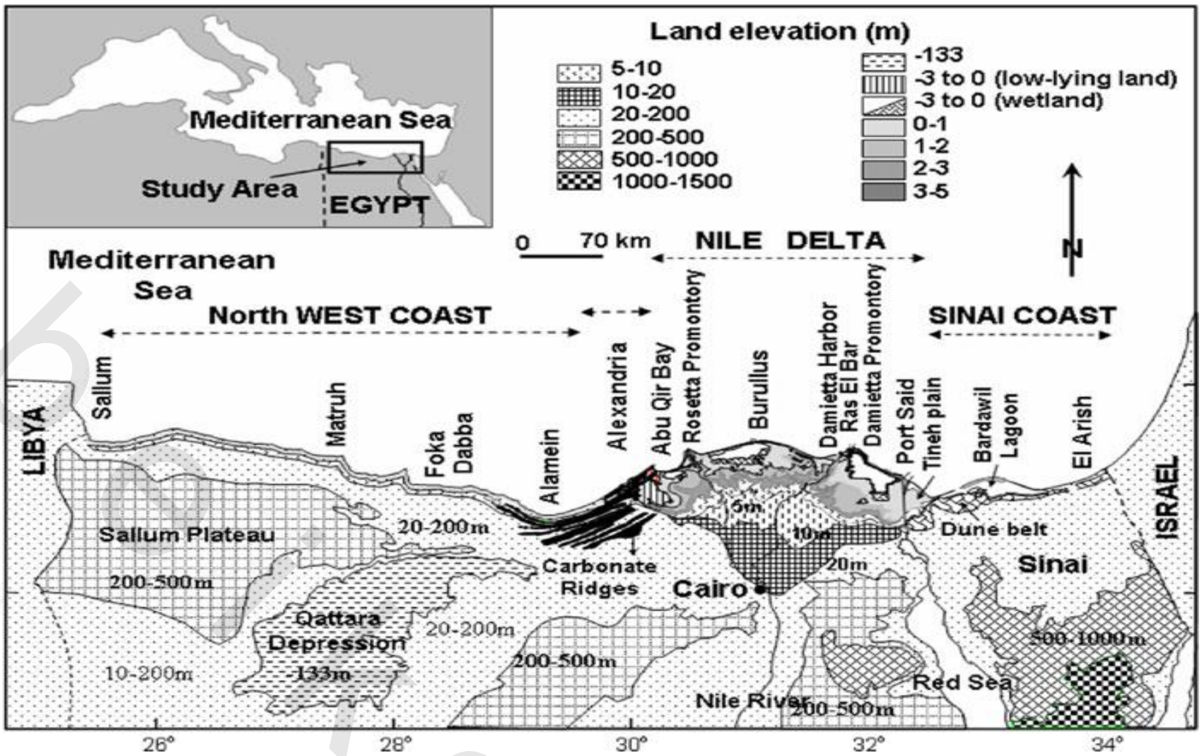
Table (1-1) Costs of recent coastal engineering works as of year 2000 prices

(El Raey, 1999)[109]

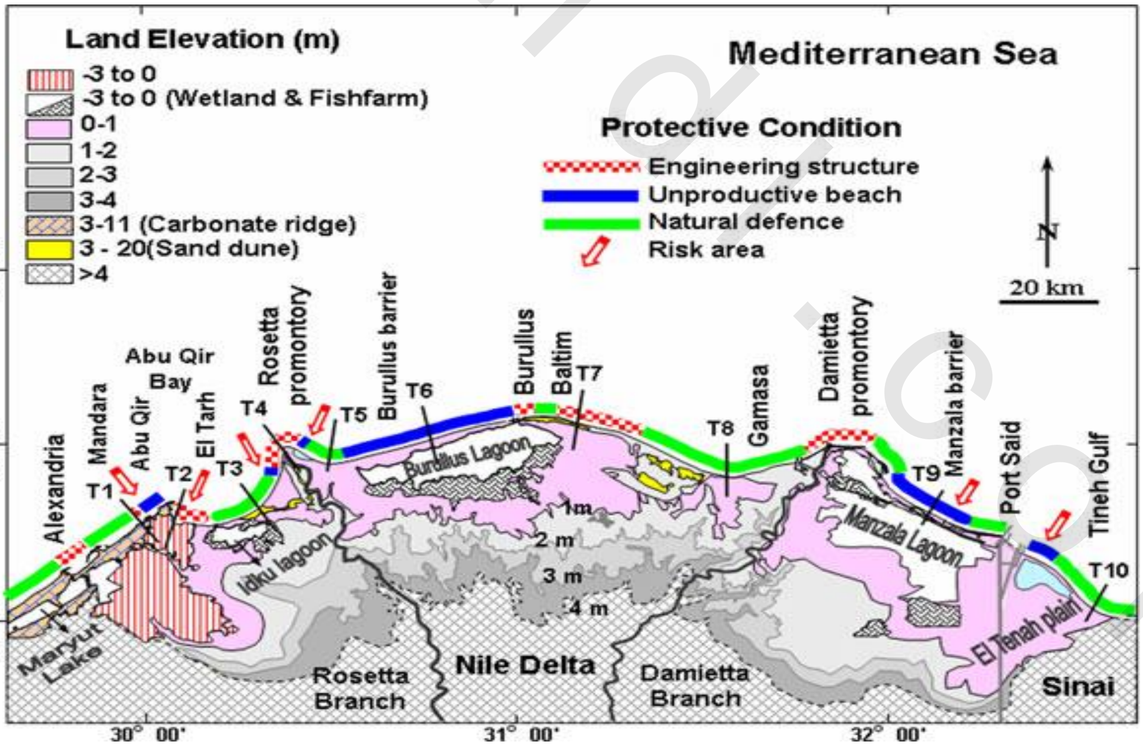
Beach nourishment Cost Project	Quantity M^3	Cost ($ US)
Mandara	١٠٤٧٨٣	580 000
Abu Qir	٣٤٤٥٥	240 000
Abu Qir sea wall	٤٥٠٠	10 000 000

I.5 Vulnerability risk assessment

Vulnerability risk assessment and adaptation to climate change induced sea level rise along the Mediterranean coast of Egypt. In particular, cities such as Alexandria, Port Said, Rosetta, Marina and Matruh have been explored (El Raey et al, 1999,1995). Significant changes in climate and their major impacts as sea-level rise (SLR) are already visible globally. These changes are no longer a distant possibility but a current reality, and have become one of the defining challenges for policymakers, industry, and civil society (Frihy et al., 2012)[41]. The 1,500 km Mediterranean coast of Egypt, is at some places vulnerable (biophysical) to the impact of SLR (inundation and erosion), particularly the lower Nile Delta and low-lying areas in Alexandria. Social vulnerability will be manifested in sectors, such as energy, water resources and irrigation, agriculture, population and health, rural and urban areas, housing and roads, as well as tourism.(Frihy et al. 2012)[41].



(Figure I -8) the Mediterranean coast of Egypt showing the main land elevation and coastal ridges compiled from (Said 1979)[49].



(Figure I -9)The lower coastal plain of the Nile Delta and Alexandria showing land topography (Frihy et al. 2010)

Topographic features discussed in the text, including land elevation relative to mean sea-level, protective state (land topography updated from (Frihy et al. 2010) [50].Climate change could have profound impacts on the Mediterranean coastal region. This would result in considerable loss of wetland, threats to ecosystem, infrastructure and settlements, tourism industry and human health (EEA 2005) [51].Vulnerability analysis focuses both on consequences for the object itself and on primary and secondary consequences for the surrounding environment. It is also concerned with the possibilities of reducing such consequences and of improving the capacity to manage future incidents (Lövkvist et al. 2004)[52].At Alexandria, the shoreline associated with the natural consolidated carbonate ridge67 % of the total coast) is substantially longer compared with those armored by Engineering structures (~20 %) and the unprotected ones (~13 %). Except for the low lying areas mostly vulnerable to wave run-up during storms, such as east of the city at Mandara most of the Alexandria coastal area is being protected from 0.5 to 1.0 m SLR. The engineering hard structures together with their associated accretion have transformed this beach into accretion effective littoral barriers. These structures succeeded in minimizing the damages resulted from Subsequent winter storm surges in 2010 and 2011 (Frihy et al. 2012) [41].

Problem Statement

It is well known now that climate change is affecting so many sectors that in turn affect humans; whether lives or welfare, such as agriculture, fisheries, transportation and so on. One of the big consequences of climate change is its effects on the sea level rise. Because the study area is in a coastal, subsidence and low lying area it faces a doubled problem. This thesis will present in details the real problems that Abu Qir faces and will show these effects on maps besides calculating the areas that could be lost.

I .6 Objectives of the thesis

The major aim of this study is to carry out an accurate detailed assessment of the vulnerability of various sectors in Abu Qir region to the impacts of sea level rise.

The main tasks may be summarized as follows:

1. Collection, analysis and interpretation of available data and indicators on various spatial and administration sectors of the region.

2. Buildup an accurate Digital Elevation Model (DEM) for Abu Qir region.
3. Identify vulnerable areas exposed to Sea inundation.
4. Suggest needed adaptation techniques.