Chapter 6
Assessment of Vulnerability, Risk, and Adaptation of MENA Region to SLR by Remote Sensing and GIS

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Abstract An assessment of sea-level rise to the vulnerability of impacts, based on the UNFCCC national communications carried out by satellites for the countries: Egypt, Libya, Saudi Arabia, Jordan, Tunisia Algeria, and Morocco is carried out to illustrate conditions after 30 years from now, based on comparison of scenarios We will introduce some outlines of research based on vulnerability measurements and mapping, and resilience. The measurements of the vulnerability of each country are determined by the changes in temperature, precipitation, socioeconomic parameters, and increase of hazards due to climate changes that occur. The risk associated with climatic changes is also discussed, and ground-based adaptation needed are explored for each country. Development of institutional capabilities for ICZM and upgrading awareness are highly recommended for adaptation in the long run. Periodic nourishment of Alexandria and Rosetta beaches, detached breakwaters for Alexandria, Port-Said, and dune fixation are the recommended for no regrets management policy. A program for raising resilience and awareness is necessary for all.

6.1 Origin and Causes of Climate Change

The Earth's climate has changed in the past for a variety of reasons and several times, for example changing the relationship between land and water (continents and oceans) and changing the intensity of radiation or solar energy, and change in Earth orbit and volcanic eruptions. For example, average global temperatures were higher than today, where water was estimated to be above its current level by several milli- meters (IPCC, 2012). Temperatures also dropped by about 5 Celsius Degrees in the ice ages, which were about 100,000 years old.

Scientists estimated that about 20,000 years ago, the sea level was about 120 meters below its current level because the water was trapped in polar ice sheets. The last 8000 years, which include most of the recorded human history, have been

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relatively stable enabling stability, supporting agriculture, and forming human settlements as a result leading to population growth.

6.1.1 Natural Causes

Throughout Earth's history, the climate has changed globally and locally in nearly all periods. Climate change has many natural causes such as solar activity, ocean currents, volcanic eruptions, meteorites, eccentricity, and tectonic movements among others.

6.1.2 Solar Activity

The change in solar radiation was the main driver of climate change over geological time, but its role in the current climate change on Earth is very small and unnoticeable (Hegerl & Zwiers, 2007). Since 1978, solar radiation has been measured by satellites with high accuracy, these measurements indicate that total solar radiation fluctuates every 11 years in the so-called solar cycle, but it has not increased since 1978, which compatible with the argument of Hegerl, 2007. However, estimations indicate that solar radiation and volcanic activity had a very weak effect in the three decades following 1978 and that these solar and volcanic activities could explain only the periods of warmth and cold that occurred between 1000 and 1900 (Hegerl & Zwiers, 2007). There is no doubt that the only logical relationship to solar activity is that of weather, not climate, as changes in solar radiation and sunspots can make the winter cooler, or warmer, with very small changes in global averages.

6.1.3 Ocean Currents

The oceans, which cover about 71% of the Earth's planet, absorb about twice the amount of solar radiation from the Earth's atmosphere and surface. The oceans are a key component of the climate system, they have a more active and dynamic role in determining the climate system through interacting with continents by carrying vast amounts of heat and redistribute it to the surrounding landmasses (Rahmstorf et al., 2018). Evaporation in the ocean waters increases air humidity, forming rain and storms that then move to large areas of the earth.

Therefore, it was argued that the oceans play an important role in the distribution of unequal solar radiation on the Earth's surface by global climate currents. Without currents, regional temperatures will be more extreme and very hot at the equator and very cold at the poles (Rahmstorf et al., 2018).

6.1.4 Volcanic Eruptions

Volcanic eruptions can affect climate patterns for years due to the flow of certain gases from volcanoes and ash staying in the atmosphere for a relatively long time. The largest portion of gases released into the atmosphere is water vapor. Other gases include carbon dioxide (CO_2), sulfur dioxide (SO_2), hydrochloric acid (HCl), hydrogen fluoride (HF), hydrogen sulfide (H_2S), carbon monoxide (CO), hydrogen gas (H2), NH3, and methane (CH4) (Lockwood et al., 2011).

Sulfuric acid is one of the most important gases; it can remain in the atmosphere for up to 3 or 4 years in the stratosphere. Large explosions can affect the radiation balance of the Earth because volcanic clouds absorb ground radiation, dispersing a large amount of incoming solar radiation, the so-called "radiative effect" that can last from 2 to 3 years after volcanic eruptions.

Gases and dust particles in the atmosphere during the volcano affect the climate, where most of the particles emitted by volcanoes cool the planet by blocking incoming solar radiation. The cooling effect can last for months to years depending on the characteristics of the explosion. Volcanoes have also caused global warming over millions of years during times in the history of the Earth where massive amounts of volcanoes occurred, leading to the release of greenhouse gases into the atmosphere (Lockwood et al., 2011). Although volcanoes are located only in specific places on Earth, their impact is global because of atmospheric circulation patterns. The volcano releases particles of dust, ash, sulfur dioxide, and greenhouse gases such as water vapor and carbon dioxide, these dust and ash particles are small and light so they can stay in the stratosphere for several months preventing sunlight and causing cooling on large areas of the earth.

For greenhouse gases, volcanoes are known to release greenhouse gases such as water vapor and carbon dioxide. However, these amounts, which are emitted into the atmosphere from volcanic eruptions, do not considerably change the global quantities of these gases in the atmosphere. However, there have been some times in the history of the Earth where intense volcanic eruptions have increased the amount of carbon dioxide in the atmosphere significantly, causing global warming.

Monsoon systems interact sensitively with radiation disturbances such as volcanic eruptions and summer monsoon winds mainly driven by stronger heating of subtropical land masses compared to the surrounding oceans. The land blocks react more rapidly with volcanic cooling, leading to a slowdown in monsoons. Understanding monsoons is also very important for future climate. The response of monsoon systems to changes in greenhouse gases, aerosols, spin-off, ice cover, and other factors is not well known.

6.1.5 Meteorites

The effects of many large meteorites are observed in geological records of the Earth, and depending on their size can have significant impacts on the larger climate of the volcanoes. One example of the great influence of meteorites is the Yucatan peninsula in Mexico called the Chicxulub crater, which is believed to have been formed 65 million years ago. The diameter of the crater is more than 180 km. It is believed that the meteorite that caused the crater was at least 10 km in diameter. Many scientists have attributed the extinction of dinosaurs to such an event, causing debris to be thrown into the atmosphere, preventing sunlight from reaching the Earth's surface. All plants and animals are believed to have been affected by an action like this. The rich layer of Iridium sediments found in the geological record throughout the world is strong evidence for this reason (National Research Council, 2012).

6.1.6 Eccentricity

Eccentricity is the change in the shape of the earth's orbit around the sun. There is about a 3% difference between the time when we are closer to the sun and the time when we are farther from the sun. The tilt angle of the Earth's axis varies slowly so that it takes about 41,000 years to shift between 22.1 degrees to 24.5 degrees and back again. This is lower than the current angle we are at right now 23.45 degrees, which means less seasonal differences between the north and south hemispheres, while the larger angle means more seasonal variations, for example, warmer summers and colder winter. Current researches show that Earth's tendency is currently declining and will reach its lowest values around the world within 10,000 years. This trend will tend to make the winter warmer and the summer cooler (IPCC, 2012).

6.1.7 Tectonic Movements

The continental land plates move all the time. As they were at one time combined in only one continent, and broke apart and formed the continents and oceans among them. As continents move, climatic types change accordingly, as ocean currents are expected to shift warm bodies to cooler regions and so on.

Panel movements determine the shapes and sizes of continents and ocean basins that have a significant impact on the climate. When all continents join only one continent, as it was 225 million years ago, most of the Earth's surface is far from the oceans and dominated by the continental climate. But when continents are as separate as today, ocean currents are more able to distribute heat because of proximity to oceans, leading to a less extreme global and regional climate.

The movement of plate tectonics also causes geological activity that in turn affects the climate like volcanoes that was mentioned above.

6.1.8 Human Causes

Natural sources of carbon dioxide are estimated to be more than 20 times like humans, but over long periods up to several years, nature can rebalance them too much through their natural banks, for example through photosynthesis by plants or marine plankton. Because of this natural equilibrium, the level of carbon dioxide remains between 260 and 280 ppm, as was the case in the 10,000 years that mediated the period from the end of the last ice age and the beginning of the industrial age.

Global warming caused by human activities has played a significant role in many physical and biological systems, such as sea-level rise, which is expected to increase in the future, as well as increased frequency and intensity of some extreme weather events and loss of biological diversity in agricultural production. Many studies refer to the issue of global warming to human activities due to increased concentrations of greenhouse gases in the atmosphere, especially carbon dioxide, which is the largest contributor. Several studies have shown that there is a direct relationship between measured anthropogenic emissions of greenhouse gases, high greenhouse gases in the atmosphere, and high temperatures. The results also indicate that the rates of increase in each of them are unprecedented.

There is a direct correlation between population growth, high greenhouse gases, and temperature. Computer simulations indicate that man-made greenhouse gas emissions alone are sufficient to cause the observed rise in temperature of the atmosphere and other terrestrial systems (oceans, continents, and ice).

There is no natural cause that can account for the current rapid rise in temperature and carbon dioxide, which is about 20,000 more than normal, due to human factors.

6.1.9 Land Use Changes

When people change the way they use the land, they inadvertently change the climate. The most obvious example is the effect of urban heat island, a phenomenon that makes urban areas hotter than the surrounding rural areas during the day, and especially during the night. The change of green areas or forests to farms or urban areas is also a significant change in the water balance (transpiration) and heat as well as the amount of absolute carbon dioxide.

6.1.10 Transportation

The transport sector includes the movement of people and goods by cars, trucks, trains, ships, aircraft, and other vehicles, to arr the majority of greenhouse gas emissions, particularly carbon dioxide, are derived from the combustion of oil-based products such as gasoline. Some relatively small quantities are also emitted from this sector, such as methane and nitrous oxide during fuel combustion. Besides, a small number of hydro-fluorocarbons (HFCs) emitted from air conditioners used in cars as well as refrigerated transport or refrigerators are included.

Global tourism is closely related to climate change as was confirmed by The United Nations; it is one of the major contributors to the increase in concentrations of greenhouse gases in the atmosphere. It also represents about 50% of traffic movements in the world. The rapid expansion of air traffic contributes about 2.5% of the production of carbon dioxide, and the tourism rate is expected to increase from 564 million in 1996 to 1.6 billion by 2020, adding much to the problem unless steps to reduce emissions from international travelers and to increase the transportation and welfare they need (Becken, 2007).

6.1.11 Industry

The industrial sector produces commodities and raw materials that we use in our daily lives. Greenhouse gases emitted from industrial production are divided into two categories: direct emissions produced during the industry itself, and other indirect emissions produced off-site.

Direct emissions are generated from fuel combustion methods to generate electricity through chemical reactions and leakage from the same processes as well as industrial equipment. Most direct emissions come from fossil fuel consumption for power generation. As well as the leaks of natural gas and oil systems and the use of fuel in production processes and chemical reactions during the production of chemicals, iron, steel, and cement. Indirect emissions are generated by the burning of fossil fuels in power plants to generate electricity, which is used by the industrial plant to operate industrial buildings and machinery.

6.1.12 The Construction Sectors

The construction sector is one of the largest energy-consuming sectors with an estimated 30% to 40% of total GHG emissions. Energy consumption in this sector has increased over the past years due to the large increase in new buildings.

The developed countries differ from the developing countries in this sector, where in the first they plan well before the construction of any more buildings while in the second the construction is random, which affects the rest of the other sectors as in the drainage, water, electricity and other important sectors, those buildings cause consuming more energy.

6.1.13 Energy Supply

The energy supply sector is the largest contributor to global greenhouse gas emissions, with energy contributing relatively little to greenhouse gas emissions, especially in developed countries. They include, in large part, the electricity sector through generation, transmission, and distribution of electricity. Carbon dioxide (CO_2) accounts for the vast majority of greenhouse gas emissions from this sector, but small amounts of methane and nitrous oxide are also emitted.

To sum up, as was described the increase in human activities has led to an increase in greenhouse gases in the atmosphere (especially carbon dioxide), causing the recently observed global warming. If greenhouse gases continue to grow at the same speed, it is expected that temperatures will rise very dramatically on the Earth's surface it could reach around 4 °C above mid-nineteenth century temperatures. It does not mean that if the emissions are reduced quickly enough the heat will stop rising but there is a chance that it does not exceed 2 °C, which may reduce the destructive effects and makes the ability to adapt better.

It was observed that the concentration of carbon dioxide increased from 280 ppm before 1800 to 396 ppm in 2013 and this was known through many measurements by scientists (Trofimenko, 2011). Scientists have pointed out that for thousands of years and until about 200 years ago, the carbon cycle was in a fairly stable equilibrium. Since the nineteenth century, anthropogenic emissions of carbon dioxide from burning fossil fuels, manufacturing, and deforestation have affected this equilibrium.

Over the past two centuries, the increase in the burning of fossil fuels has been closely linked to global growth in energy use and economic activity. It has also increased significantly from 2000 to 2010 (NASA and GISS, 2013).

6.1.14 Uncertainty

In the context of climate change risk assessment, uncertainty arises because, although we may already be confident that the climate is changing, we do not know precisely the magnitude of these changes or their associated effects. For example, in some areas, it may not be clear whether rainfall will increase or decrease. It is also an important fact for decision-makers as they are in a very sensitive position but cannot make a large percentage of the exact point or threshold at which the climate will change at a certain level concerning their area of control. Uncertainty is a broad range of possible outcomes and complexity makes it impossible to define a set of probabilities (Rueter, 2013).

6.1.15 Error Versus Uncertainty

It is important not to confuse the terms “Error” and “uncertainty“because they are very different. The error is the difference between the measured value and the real value of the thing being measured. Uncertainty is estimating the doubt about the outcome of the measurement. For example, the error can be corrected by making corrections from calibration. The error that its value is not well known is uncertainty. Uncertainty describes the novelty and accuracy of measurement in any field (Rueter, 2013).

In climate change, there are several uncertainties, such as in the greenhouse gas emissions/concentration scenario, model configuration, and bias and downscaling uncertainty.

The development of a set of global-scale climate change projections for the twenty-first century as a response to increased greenhouse gas emissions is necessary to assess the impacts of global warming from greenhouse gases and to develop appropriate adjustment and mitigation strategies. In the development of these projections, all the causes of climate change that have already been taken into account, both natural and human, must be developed with their uncertainty in mind. Uncertainty is influenced by our incomplete knowledge of these causes and processes and their precise description (Quiggin, 2008).

Over the past decade, research interest has shifted significantly to quantitative assessment and representation of uncertainties in climate change projections for use in impact and risk analysis studies. It is important to note that the term “uncertainty“has a generally negative connotation, which means that uncertainty is associated with our weak knowledge of the problem and should therefore be reduced as much as possible by further research.

6.1.16 Uncertainties in Climate Change Projections

As was mentioned above, the climate could be changed as a result of several causes, both human and natural. Among the major anthropogenic factors are atmospheric greenhouse gases, tropospheric aerosols caused by pollutant emissions, and changes in land use, for example, the greenhouse gases affect the climate by absorbing infrared radiation emitted from the Earth’s surface and aerosol can absorb the dispersion of solar and infrared radiation, as well as the significant impact of land-use change.

The problem lies in the accuracy and validity of future projections as the first step in the series of steps to be followed to produce an appropriate projection of climate change globally and to generate scenarios for GHG emissions and aerosols based on future socio-economic and technological development assumptions, which are difficult to predict in the next century, resulting in different emission paths, making them a high uncertainty. Land-use change is also difficult to predict as human behavior and urbanization are difficult to project, adding to the vulnerability of these models (Giorgi, 2010).

In addition to the main natural effects seen in climate simulations, such as in volcanic eruptions, for example, they can lead to the injection of small particles in the stratosphere, where they can remain for several months to years as mentioned above, causing a change in the amount of solar radiation reaching the Earth.

Considering that natural phenomena such as volcanoes, for example, or the number of sunspots is an unexpected and cannot be project accurately, climate models have a large error rate that makes it difficult to rely on to make critical decisions that lives of communities depend on (Giorgi, 2010).

Since emissions scenarios are the first step in the sources of uncertainty and due to their extreme ambiguity and unpredictability, whether natural or human during the next century or even the next few years, this makes uncertainty unavoidable and will not be eliminated, even with developing a great range of potential social and economic paths in the future. The uncertainty about climate change will remain very high.

This may be why IPCC has developed a series of scenarios that have moved from low to high emission levels, intending to cover the entire range of future developments. IPCC has not linked any probabilities to these scenarios, making them all plausible (Giorgi, 2010).

The next stage is the introduction of these greenhouse gas (GHG) scenarios into the global biological and geochemical models for the corresponding GHG concentration scenarios. These biogeochemical models are affected by uncertainty due to poor knowledge of the biogeochemical cycles and the use of approximate representation. Therefore, until the science of biogeochemical cycles improves, uncertainty in these models will remain unreliable and should be reduced.

Experts are taking greenhouse gas concentration scenarios and introducing them into special systems for producing climate projections for the twenty-first century. In other words, climate projections are a sensory experience of the climate system's response to certain increases in greenhouse gas levels. Future climate predictions do not make any assumptions about the potential for volcanoes or future changes in solar activity, as they are very difficult and maybe impossible, which mean that climate models assume that the natural causes are stable in the future, that adds another factor of the uncertainty that is extremely difficult to assess.

Generally, science makes predictions about how a system will be followed and then measured seriously. The problem for ecologists is to try to focus on making testable predictions about the real environment we live in to understand natural processes so that we can either respond or control future events. The natural system, in contrast to experimental systems, is full of uncertainties caused by all possible types of interacting factors, and so uncertainty enters into daily routines in the environmental field.

The important and convincing message that has been revealed in the work of (Rueter, 2013) is that we cannot just study a problem and gather a lot of information to make a good and appropriate decision on something. There are some cases where the uncertainty is very high where it is impossible to predict the results with any degree of certainty.

The same reference has identified three types of unknowns: **Risk**, a potential estimate of the likelihood of an event occurring or being exposed. If, for example, we calculate the risk or potential damage from exposure, we can calculate how much money and effort we have to spend to control this risk. **Uncertainty** is a wide range of potential results and complexity that makes it impossible to determine a set of probabilities. For example, we can create a set of scenarios and use them to describe the different paths that may occur in the future, but we do not have a specific way of knowing the future that will happen. Finally, **Indeterminacy** where there is a set of information that we are not able to know. The author asserts the reason here that sometimes we concentrate our energy and resources to address a problem which results in a very large set of results that may include a set of surprises and often surprises.

The surprise is a change in the system which is qualitatively different from what we expected. For example, the response of nature to overfishing was not as predicted and logical "lack of fish," but the surprise was that excessive fishing led to an increase in the number of jellyfish in a very large amount (Rueter, 2013).

These problems in future projections do not detract from the work of model developers, but they should develop also some ideas about how to live with them as they are inevitable problems and affect the success of measuring accurate climate predictions in the future. In this sense, this study will not review or rely on any future climate models or specific projections in the study area. Rather, the focus will be on the vulnerability and responsiveness.

6.1.17 Vulnerability Assessment

Is to determine the extent to which the community is affected by the risks as identified and evaluated in the above points, as the good profile of the community identifies the sites and places of the people in the community and the important facilities on the maps, and the risk assessment places the risks on those maps, enabling the vulnerability assessment by comparing areas where risks overlap with important people and facilities, allowing the assessment of possible losses in dollars, and prioritizing the most serious risks.

Hazard vulnerability assessments describe who is threatened (hazard identification) and what is being exposed to (potential loss, injury, damage, negative effects on livelihoods), and the effects of such exposure. In other words, the goal is not only to identify the risk factors (who and what is vulnerable) but also the driving forces that are vulnerable in a particular place. These assessments can be qualitative in their approach or quantitative in estimating populations at risk and rating vulnerability. Risks can be single or multiple and can range from localized site-specific analyzes to more regional ones (Cutter et al., 2009).

Climate-related Hazards impact of climate change on hazards is hard to quantify because, under a constant climate, it is generally an order of magnitude below the natural existing uncertainty. Conversely, vulnerability is not well understood and few rigorous methods are available to quantify this factor (Gilard, 2016).

6.1.18 Risk Assessment

The quality of risk assessments is critical to making informed and good risk management decisions. It is important to understand risk-related vulnerabilities and to make it clear to decision-makers and civil society as a whole, to bridge the gap between academics, decision-makers, and the public (Sørensen & Jebens, 2015).

Risk assessment may include quantitative and qualitative techniques and information to describe the nature of risks. Specific techniques are particularly useful in conditions such as climate change, where there is uncertainty about probability and consequences. Regardless of the sources of uncertainty, the initial assessment process can provide a comprehensive and rigorous means of prioritizing the risks of climate change. After identifying or determining the types of risks that threaten each sector, further planning is needed to reduce uncertainties (Cutter et al., 2009).

6.1.19 Risk Reduction

There is a range of ways to reduce risk, begins first with identifying the risk, and is called "**Risk Assessment**" by this method ways to minimize risk exposure is developed and called "**Risk management**". It is important to keep in mind that although risk management measures exist, they may not be sufficient to protect those who are exposed to risk. To be effective, it must demonstrate how to avoid risk to all concerned in many ways for example raising awareness and repeating important messages whenever possible using the various media and this step called "**Risk Communications**". So, dealing with risk implies risk assessment, management, and communication efforts.There is a rule when dealing with risk (the more you are exposed, the greater the risk).

6.1.20 Vulnerability

There is great interest in the concept of vulnerability, where there are many definitions in the literature, derived from different conceptual models and frameworks.

Vulnerability can be defined as "the characteristics of a person or group and their situation that influence their capacity to expect, cope with, resist and recover from the impact of a natural hazard" (Wisner et al., 2004). This means that the person's vulnerability is determined by influencing one or more elements that are at risk to some extent. These elements vary according to economic, cultural, and social differences and may be tangible or intangible, including life risks and changes in livelihoods and property. There are vulnerabilities at all levels of global, national, and local and can have an effect known as the snowball effect; for example, the global economy can affect the local one. It is mostly dynamic and depends on time and can change annually or even every hour. Vulnerability is highly dependent on community actions and can increase or decrease as a result (Sørensen & Jebens, 2015).

6.1.21 Understanding Vulnerability

Vulnerability is a term that has been mentioned frequently in the literature on disaster management. However, as stated in (Yasir, 2009) the definition of this term is still controversial, with each scientific field-shaping it differently. It was mentioned in the same reference that the first who used this term were engineers in the application of the physical structures, and the term was then expanded over the years by sociologists to include the social, economic, political, and institutional aspects. More than 25 different definitions have been identified in the current literature reflecting its multifaceted nature.

Concerning natural hazards, vulnerability can be defined as an inadequate capacity to overcome disasters and their impacts. Although this term was introduced in disaster studies in the 1970s, it gained importance in the 1980s and has been defined in this period as a threat factor limiting the ability of society to absorb and recover from a dangerous and harmful event (Yasir, 2009).

In the 1990s, the concept of vulnerability was further changed as people were able to respond and protect themselves from disasters. Here the definition changes to become the characteristics of people or society that determine their capacity to expect, cope with, resist and recover from the impact of natural hazards.

In addition to these socio-economic processes, (Dow & Downing, 1995) add other demographic aspects, such as population ages and dependency, which are the conditions under which the characteristics that relate primarily to the physical, social, economic, and environmental factors are determined (Yasir, 2009). Others (Wisner et al., 2004) show that instead of simply taking care of these factors, there is a greater need to focus on the problems that arise from their interaction together. This approach transforms people from being mere passive recipients into active players by increasing their tendency to change.

Therefore, vulnerability is a multilayered and multidimensional perspective and must be addressed from all sides to determine it correctly. Some other studies have used a more integrated approach to determining vulnerability as a combination of potential exposure and social response within a specific geographic range (Yasir, 2009).

6.1.22 Vulnerability to Climate Change

Vulnerability varies widely across communities, sectors, and regions, and is addressed in a variety of ways by different specializations. Studies have begun to address the term “vulnerability“very early, and the literature on vulnerability has grown enormously over the past few years. It was defined by (Timmerman, 1981) as “The degree to which a system acts adversely to the occurrence of a hazardous event. The degree and quality of the adverse reaction are conditioned by a system’s resilience (a measure of the system’s capacity to absorb and recover from the event)” and in 1982 the definition of UNDRO (United Nations Disaster Relief Organization) was presented “Vulnerability is the degree of loss to a given element or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude.”

Then some other definitions addressed the social perspective such as Susman et al. 1984 “Vulnerability is the degree to which different classes of society are differentially at risk”, while Dow (1992) defined vulnerability as “the differential capacity of groups and individuals to deal with hazards based on their positions within physical and social worlds.” Cutter (1993) Vulnerability is the likelihood that an individual or group will be exposed to and adversely affected by a hazard. It is the interaction of the hazards of place (risk and mitigation) with the social profile of communities (Lynn et al., 2011).

Blaikie et al. (1994) argues that vulnerability is “the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard. It involves a combination of factors that determine the degree to which someone’s life and livelihood are put at risk by a discrete and identifiable event in nature or society” (Blaikie et al., 2003). And in the same year Bohle et al. (2003) defined vulnerability from a social perspective as “an aggregate measure of human welfare that integrates environmental, social, economic and political exposure to a range of potentially harmful perturbations. Vulnerability is a multi-layered and multidimensional social space defined by the determinate, political, economic and institutional capabilities of people in specific places at specific times.”

Later in 1994 Cannon related the vulnerability again to the risk and described it as “a measure of the degree and type of exposure to the risk generated by different societies concerning hazards. Vulnerability is the characteristic of individuals and groups of people who inhabit a given natural, social and economic space, within which they are differentiated according to their varying position in society into more or less vulnerable individuals and groups.”

The definition of UNEP (1999) was more comprehensive as they described the vulnerability as a function of sensitivity to present climatic variability, the risk of adverse future climate change, and the capacity to adapt. The extent to which climate change may damage or harm a system; vulnerability is a function of not only the systems’ sensitivity but also its ability to adapt to new climatic conditions. While UNISDR (2008) identified it as the conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards (Lewis, 2010).

From these different definitions, it could be concluded that vulnerability can refer to the sensitive systems, both natural and human, as the study area is located on the coastline, making it vulnerable to sea-level rise, as well as it is a low lying land and high densely populated area, and what multiple the vulnerability to climate change the agricultural land that secures the livelihood of local communities is vulnerable to salinization and sea-level rise as well as both floods and flash floods and also prone to urban encroachment leaving the community highly vulnerable to environmental changes. That is, vulnerability is the weakness of natural and human systems and their inability to deal with imminent or potential danger, i.e., the inability of natural systems to adapt quickly enough to changes and to cope with the negative effects.

The inability of communities to recognize the danger in the first place and to deal with it during its occurrence or after it ends; in other words, preparedness, resilience, and response at different stages greatly affect vulnerability, and based on the community's ability to carry out these previous steps, societies can be divided into more or less vulnerable.

The most vulnerable are those who have fewer options and those who are subject to restrictions such as related to gender, social class, physical disability, lack of education and work, ill people, and others who do not make their own decisions.

The inability of political systems represented in decision-makers and how they predict, deal with, and recover from a natural event can turn this event into a major disaster. In other words, failure to deal with a natural normal event transforms it into a natural disaster, and when vulnerability interacts with a hazard a disaster results.

Several major weaknesses in the study area are associated with many climate-sensitive systems, including, for example, food supplies represented in vulnerable agricultural land, weak infrastructure, health, water resources, and sensitive coastal systems among others.

Therefore, environmental, social, economic, and political considerations are the basis for evaluating the vulnerability of any society, and neglecting any part of them has a very significant impact on vulnerability assessment.

6.1.23 Social Vulnerability

Social vulnerability refers to the resilience of communities when faced with external pressures on human beings, health, and welfare, as in the case of natural and human disasters and disease outbreaks. Reducing social vulnerability can reduce human suffering and economic losses.

Some types of social vulnerability may be due to lack of awareness, wrong decision making, land misuse, abuse of natural resources, poverty, lack of control, disability, etc. There are millions of people who are somehow vulnerable to natural disasters and climate-related events, as they have no choice about where they live. They are subject to policies and laws which may not be democratic or external pressures without awareness of what is happening and without understanding their rights as citizens. The most vulnerable occurs as a result of exploitation, greed, marginalization, and abuse by some stakeholders putting the vulnerable population in more danger(Kelman & Lewis, 2010).

Social, political, and economic forces are pushing poor and marginalized communities to the most vulnerable areas around the world, causing more poverty and poor environments and the places, making these places very vulnerable to disasters. In Egypt, for example, those who live in flood plains are the poor who are driven by poverty to find anywhere without caring about their environmental status. Those who live in weak or partially destroyed buildings are the poor who do not have enough money to renew and preserve them.

Areas that are highly vulnerable to many climate-related events (e.g. flash floods) occupied by the poor and marginalized groups of citizens, as well as slums that are not serviced by good infrastructure, where the most vulnerable groups of society are at risk. Due to their social and economic situation, any environmental event turns into an environmental disaster in those areas at risk.

The livelihoods of the population are the source of their vulnerability, so the salinization of agricultural land on the northern coast of the Nile Delta as well as the salinization of freshwater resources puts people in these areas under greater pressure, making them more vulnerable to climate change.

Recent climate events on the northern coast of the Nile Delta in the last 10 years as well as the expected rise in sea level, the relatively high rainfall, the inability of the government to deal with these events, and the citizen's lack of awareness adding more vulnerability, especially shortly. Extreme events are expected to increase, and if the status of decision-makers and citizens will still stable, there will be no other option than to turn these events into real disasters. Some researchers have called this type of change "creeping environmental change" (Glantz, 1994; Kelman, 2009).

To reduce the risk of disasters, it is necessary to remove the root causes of vulnerability. Therefore, the analysis of weakness in the study area has to be rationalized and detailed, by reaching the poor and marginalized population, stakeholders, and some decision-makers to measure and test the vulnerability indicators in the real world.

This study will focus particularly on a poor and random area with a focus on all aspects of vulnerability to disasters related to climate as possible and try to enumerate all indicators of vulnerability in a sample of Egyptian society in some detail.

6.1.24 Vulnerability Process

The "vulnerability process" refers to the values, ideas, behaviors, and actions that have led to characteristics such as fragility, weakness, exposure, and susceptibility and that can perpetuate or absolve these issues (Kelman & Lewis, 2010).

6.1.25 Vulnerability and Poverty

Disaster literature has linked vulnerability to marginalization and poverty, and research has shown that vulnerability and poverty interact closely with one another. This is because poverty increases the inability to access resources that can enable people to adapt or become more resilient, and this group of people lacks quality education and appropriate work which makes them more vulnerable to disasters, which makes vulnerability a component of poverty (Yasir, 2009).

While (Wisner et al., 2004) suggest that vulnerability is a more complex concept because it combines both external and internal characteristics of the population, while poverty tends only to focus more on the personal needs of individuals. In the same vein (Yasir, 2009) suggests from quoting from the work of (Blaikie et al., 2003) that vulnerability is the potential for future loss of risk, while poverty is a measure of the current situation.

As Chambers et al. noted that anti-poverty programs focused on improving people's income while programs to combat or deal with vulnerability tend to enhance security and reduce potential losses to natural disasters.

6.1.26 Vulnerability Risk

There is a great need to review the basic concepts that place natural hazards in the context of vulnerability. To assess the impact of risks on individuals or communities, it is necessary to distinguish between 'hazard', 'risk', and 'vulnerability'components in disaster analysis. The risk can be defined in this case as a severe geophysical event that is likely to be the cause of the disaster. Thus risk can be defined as the probability of loss resulting from the interaction of a certain level of hazard and vulnerability (Yasir, 2009) (Fig. 6.1).

(Wisner et al., 2004) schematize this relationship as follows:

$$\text{R (Risk to Disaster)} = \text{H (level of hazard)} \times \text{V (degree of vulnerability)}\ 9$$

Based on the above equation, (Alexander, 2000) put the total risk as follows (as was mentioned in the study of (Yasir, 2009))

$$\text{Total Risk} = (\Sigma \text{ elements at risk}) \times (\text{hazard and vulnerability})$$

From the above, it is clear that total risk is a complex production of its various constituent elements (population, societies, infrastructure, economic activities, services, etc.) which are exposed to the threat of a hazard by staying in a position of vulnerability (Yasir, 2009).

(Alexander, 2000) argues that although vulnerability can be estimated in the absence of risk, it cannot quantify without including risk in the aggregate equation.

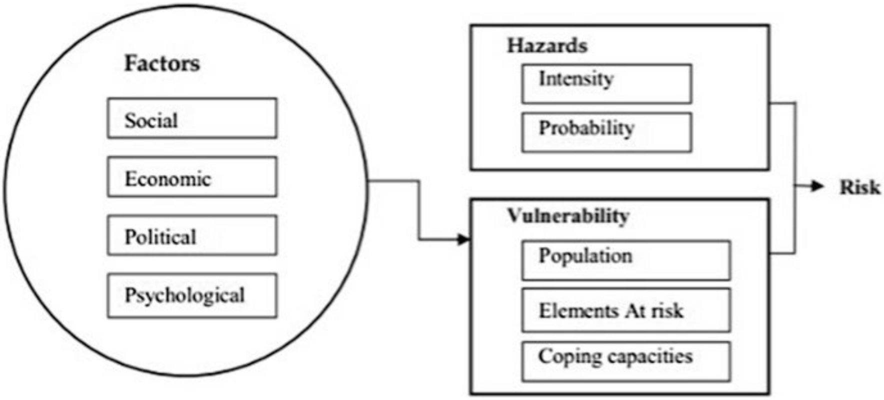

Fig. 6.1 Relationship between Hazard, Vulnerability and Risk. (Adopted from (Yasir, 2009) cited from Frantzova et al. (2008))

Intensive Risk is the risk associated with the exposure of a very large number of people and economic activities to serious and intense events and can lead to potentially catastrophic effects involving high rates of mortality and asset loss. Intensive risk is mainly a characteristic of large cities or high population areas that are not only exposed to extreme hazards such as strong earthquakes or heavy floods but also have very high levels of vulnerability to these hazards.

Extensive Risk is the widespread risk associated with the exposure of populations in each locality to frequent or persistent low- or moderate-intensity conditions, often of a high local nature, which can lead to devastating cumulative effects. High risk is a feature of rural areas and urban margins where communities are exposed to recurrent floods or landslides. This type of risk is also associated with poverty, urbanization, and environmental degradation.

Residual Risks are those risks that remain unmanaged until there are effective disaster risk reduction measures, which must therefore maintain emergency response and recovery capabilities. Residual risk means the continued need to develop and support the effective capacity of emergency services, preparedness, response, and recovery as well as social and economic policies as in safety nets and risk transfer mechanisms.

Risk Reduction there is a range of ways to reduce risk, begins first with identifying the risk and is called "**Risk Assessment**" by this method ways to minimize risk exposure is developed and called "**Risk management**". It is important to keep in mind that although risk management measures exist, they may not be sufficient to protect those who are exposed to risk. To be effective, it must demonstrate how to avoid risk to all concerned in many ways for example raising awareness and repeating important messages whenever possible using the various media and this step called "**Risk Communications**". So, dealing with risk implies risk assessment, management, and communication efforts. There is a rule when dealing with risk (the more you are exposed, the greater the risk).

Prospect Disaster Risk Management is management activities that address and seek to avoid the development of new and growing disaster risks (Thinda, 2009). This concept focuses on addressing risks that may develop in the future if risk reduction policies are not put in place, rather than waiting to deal with the risks that occur.

6.1.27 Vulnerability Analysis

The inconsistency between different vulnerability definitions makes it difficult to perform a vulnerability analysis correctly. The current methodologies for wide-scale vulnerability analysis have recognized the need to develop a more comprehensive approach to shift attention from existing methodologies to functional frameworks that focus more on processes rather than on the fixed boundaries of the social system (Yasir, 2009).

Several studies have analyzed the vulnerability concept where they have been concerned about the importance of the ability of people and society to protect themselves from disaster. Thus, capacity could be understood as the counterpart to vulnerability. The capacity of the society and population includes the willingness and presence of responsible local governments and leaderships and awareness among members of society among other things. By building capacities, the level of risk will move to an acceptable level where vulnerability decreases (Sørensen & Jebens, 2015).

(Wisner et al., 2004) identifies four main methods for evaluating vulnerability, each with its effects. The first approach takes the demographic perspective to see vulnerability as a societal situation where people are considered to be vulnerable. The second approach uses taxonomic behavior using physical, economic, social aspects of vulnerability. A third approach is a situational approach; it takes a multi-dimensional perspective as a dynamic rather than a static concept. The basic premise of this approach is that disasters are not seen as exceptional events but rather as an extension of the problems of daily life where vulnerability is a period that extends normal circumstances to exceptional situations. However, although this model is specifically designed to deal with organized complexity, it is limited because of its geographical peculiarities and cannot generalize results from the context of disasters.

The fourth approach is seen as contextual and proactive by (Wisner et al., 2004), who takes a participatory view of vulnerability analysis where community members participate as active agents of change rather than passive recipients of aid. With the involvement of the community in the actual evaluation process, the contextual and proactive approach goes beyond the scope of vulnerability to the empowerment of the society that forms the core of a democratic society, yet its success remains limited by the participatory capacities of the members of society and the long time frame (Yasir, 2009).

Together, these approaches suggest that vulnerability analysis needs to adopt a more comprehensive approach that requires a shift in the conceptualization of vulnerability from static to dynamic, and thus moving away from demographics and classifications to situational approaches.

The fourth case provides an additional benefit to the analysis of community capacity and adaptability, yet requires community participation that will be taken into account later.

6.1.28 Vulnerability Assessment

A vulnerability assessment is an analysis of the expected impacts and risks of an area or system and of a community or capacity to adapt to it. For vulnerability to be properly evaluated, sensitivity, susceptibility, and adaptability must first be identified (Byrne, 2014).

6.1.29 Vulnerability Measurement

The development of a tool for measuring vulnerability across all disciplines is difficult given the ambiguity of the definition of vulnerability from the beginning as well as the constant change of dynamic nature and changing scales of analysis (temporal and spatial). However with advances in the science of vulnerability in all disciplines and building on the motivation that empirical evidence-based information is needed to support planning pressures and vulnerability, especially for disasters, a range of approaches have been developed in this regard (Cutter et al., 2009).

A key indicator of leading economic indicators is a set of 10 economic variables used to estimate future economic activity, which has proved to be very strong in predicting economic recessions over the past 50 years. Economic, social, and environmental indicators have been started since the 1940s but have become more pronounced in the 1960s and 1970s, followed by environmental indicators. While the 1990s saw more emphasis on the development of environmental sustainability indicators as well as vulnerability.

However, there are some complexities when using indicators, as in the complexities that are often within a system of a given variable or set of variables, which has a significant impact on what is measured and how. This is clearly illustrated by issues such as social networks, trust in government, institutional capacity, and disaster preparedness, which are difficult to measure quantitatively. Besides, the availability of data presents another problem for both hazard and population parameters, and this in itself may hinder the selection of input variables (Cutter et al., 2009).

In this respect, the vulnerability can guide policy development on national and sub-national vulnerability and act as a means of measuring progress towards this specific goal (Birkmann, 2008).

6.1.30 Resilience

Resilience is not only a term for hazards or natural disasters (Timmerman, 1981). There are many examples of this concept in many areas, such as material science, engineering, psychotherapy, social sciences, biology, ecology, and many other sciences that use this term differently from one another.

From an environmental perspective, resilience was treated from the point of view that the risk was as much about normal community activities as it was about the extreme event itself, and it still works to this point of view. However, there is still a need to unify the traditional bilateral or doubled vision that separates social life from nature so that linking it enables understanding of vulnerability and resilience. Resilience itself is a natural and long-term social activity.

The IPCC definition of resilience (2012) puts it within the framework of the social or ecological capacity of the system to absorb disturbances while maintaining the same infrastructure, standard work methods, self-regulation, and adaptation. While UNISDR (**United Nations International Strategy for Disaster Reduction**) introduced another definition in 2008 that demonstrated resilience as the capacity of the system or the potentially vulnerable community to adapt, through resistance or change to reach and maintain an acceptable level of performance, which is determined by the degree to which social systems can organize themselves to increase capacity to learn from past disasters to ensure better protection from future disasters and to improve risk reduction measures as much as possible (Kelman & Lewis, 2010).

6.1.31 Pressure and Release Model

This model is a valuable tool for identifying disaster risk reduction measures by analyzing and understanding the root causes of a potential event. It explores the relationship between hazards and vulnerability and looks at the link between **root causes**, **dynamic pressure,** and insecure or **unsafe conditions**. This progress can be used in the vulnerabilities to describe and explain the interrelationships between different vulnerabilities. The root causes, dynamic pressure, and unsafe conditions by the model are three layers of social processes that lead to vulnerability. Root causes also give rise to several dynamic pressures that in turn explain how unsafe conditions have begun (Thinda, 2009).

In turn, this model allows for the assessment of effectiveness, the identification of capacities required, and the flexibility required to mitigate disasters. Root causes are often the result of very long-term actions and are implemented in society to the extent that does not change.

6.1.32 Previous Experiences

Past experiences could shorten the way to reach a suitable solution to deal with the vulnerability of the northern coast's community in Egypt. Not all studies in this field are useful to be applied in the study area, but we should choose what suits our society, our economic circumstances, and other considerations that make every society Unique in dealing with disasters.

Some studies (Sørensen and Jebens, 2015) show that until recently, developed countries were not interested in valuing their vulnerability, because as they thought, their society was well aware of disasters and they could deal with all kinds of disasters easily. But Hurricane Katrina was one of the most striking examples which revealed the error of this belief. Thus, the analysis of vulnerabilities in developed countries can reveal unexpected results, and all developed countries are now taking this action. So, by selecting the best results of their work it could save time and effort as well as allowing developing countries to develop new measures of their own.

The work of (Sørensen and Jebens, 2015) summed up the problems that should be addressed in Denmark to reduce vulnerability to climate change as follows: **First**, there are no political and financial linkages between DRM (Disaster Risk Management) as well as reducing the preparedness budgets, which suggest the presence of problems in political management, **Second**, the need to close the gap between the tools and maps in the academic community and the needs of decision-makers and the public; **Third,** Lack of knowledge and awareness of risk and risk reduction among the public; **Fourth,** lack of multidisciplinary work, especially between natural and social sciences.

The study also focused on qualitative approaches to identify various social vulnerabilities to improve risk management and advise on how to proceed with disaster risk management and adaptation to climate change.

The same work has shown that although Denmark is a developed country with both technical and financial solutions, only a few are thinking about the future, as well as a lack of public confidence in decision-makers. The results of the study showed that participants from civil society made it clear that they were not sure whether municipalities and emergency management can protect them at the time of disasters. The results also show that the past has shown that *a disaster is required before society implements risk reduction measures*, possibly because of a lack of awareness and knowledge of the real problem.

6.1.33 Vulnerability Mapping

A vulnerability map can determine the exact location where people, natural resources, or property may be in danger due to a potential disaster that may result in death, injury, pollution, or any other destruction of any kind. This type of map is created along with the various other types that present the risks in one way or another. The vulnerability map can indicate areas of housing in which a large population lives, suffers from randomization, or that the buildings are old and are not qualified to deal with natural events, such as in the case of floods. Also, identifying the commercial, tourist, and residential areas that may be affected in the event, which gives the possibility of developing a plan to deal with it (Edwards et al., 2007).

The best way to map vulnerability is to use GIS technology where all possible data can be placed to feed this program, such as land survey data, satellite imagery, land boundary maps, road maps, topographic maps, or other maps used for other related purposes.

6.1.34 Benefits of vulnerability Mapping

Vulnerability maps can illustrate the places at risk, the type of hazard, and the individuals exposed to it, which means a full understanding of the risks and vulnerabilities so that decision-makers can know what is needed to protect these areas and allow them to identify mitigation measures to prevent or minimize loss of life, injury, and environmental consequences. A major benefit of this type of map is the potential for use in all stages of disaster management: prevention, mitigation, preparedness, operations and relief, recovery, and lessons learned. For example, in the prevention phase, vulnerability maps can be used to avoid high-risk areas when developing residential, commercial, or industrial areas. It also tells technicians about where infrastructure can be affected in a disaster. A vulnerability map can contain evacuation routes for eviction in situations where this is required (Edwards et al., 2007).

These maps can be used to assess the disaster, how to deal with the disaster during and after it, evaluate the results, take lessons learned to correct the errors that were present before the actual event, as well as the ability to clarify the extent of damage, assess the quality of emergency management, to help for recovery.

6.1.35 Products of Vulnerability Mapping

Vulnerability maps exist in a large variety, having various content, various scales, and fulfilling different objectives. The basic vulnerability maps and few applied maps are (World Meteorological Organization, 2013).

Detailed descriptions and examples for each vulnerability mapping product are shown below.

- **Preliminary vulnerability map**

It is the map that indicates on a small scale the general or potential risks of some areas, and it is considered to be the first step to more detailed mapping and is therefore considered important (World Meteorological Organization, 2013).

The main objective of these preliminary maps is to identify the risks (eg, floods, flash floods, heavy precipitation, cold or heatwaves, and other hazards that are likely to occur in the study area) and determine the outer limits of the potential event.

By superimposing the potentially affected areas with land-use maps or other layers in the GIS database like densely populated places; "hot spots"can be identified in the community under study. This type of map is therefore referred to as simplified risk maps. This map can be used for general purposes or even for detailed assessments. These maps are also important in that knowledge of the type of potential risk is closely linked to making decisions on the future development of the region.

- **Event map**

This type of map shows the locations and extent of disasters in different ways. It is based on events that occurred in the past, both near and far. Event data are collected to feed this type of map through a variety of sources. The importance of this type of map lies in the use of past events to raise awareness among local populations and thus reduce potential losses. Specialists and decision-makers also use this kind of mapping to respond to emergencies. After extreme events, this kind of map is referenced to conclude to reduce the likelihood of recurrence of the same event in the areas where it occurred and to avoid future damage to the least possible extent.

- **Hazard map**

This map shows some detailed data about the expected event as it is in the range, speed, and expected direction of the event. For example, in the case of floods, there is a set of key elements that must be incorporated into the risk map for a particular probability of occurrence, as in flood extent (areas covered by water), flow velocity (m / s), water depth (m); as well as other parameters such as flood propagation (km / h), flood depth * velocity (m * m/s; as an indicator for the degree of hazard) (World Meteorological Organization, 2013).

Hazard layers are superposed with the topographic map of the area, DEM, and the geomorphological map to show the hazard in high accuracy, and to determine where it may be happening. This type of mapping provides basic information for the development of technical guidance on various issues related to disaster management, assisting various stakeholders including local governments to make right and correct decisions for disaster management, developing a risk mitigation plan, and developing comprehensive risk management plans; these maps are also important in emergency management.

- **Vulnerability map**

This map shows the potential harm to people with priority given to a particular group of people (such as the elderly, the disabled, and others), assets, infrastructure, and economic activities at risk either directly or indirectly, and information is presented either quantitatively or qualitatively through different indicators.

Vulnerability maps provide the basis for risk maps that are needed for contingency planning. These maps show the potential consequences of an event on human activity. These maps are important to ensure proper planning for the future away from potential danger. The database for this type of the map must be regularly and continuously updated for variable vulnerability parameters as they are changing over time.

- **Risk map**

These maps include potential hazards with the vulnerabilities of current or potential economic activities at risk. These kinds of maps are an update of the hazard maps and vulnerability maps, which show the average damage per unit of space, often expressed in terms of monetary (the potential loss per unit area and time), which is necessary for the economic assessment.

Risk maps are an assessment tool, thus supporting prioritization for risk reduction. It is also very important for land use planning, where future development planners are concerned with maps that present potential risks in the future. These maps can also identify and see the consequences of past mistakes (World Meteorological Organization, 2013).

- **Zoning map**

This type of mapping can be considered as an important type of planning, as it illustrates existing risks and classifies them (low, medium, high). This map is based on a hazard map as well as monitoring land use in a particular area.

- **Emergency map**

This map is based on hazard, vulnerability, and risk maps according to its purpose. Emergency response requires precise settings because response time is a limiting factor.

Emergency preparedness plans are also possible scenarios that can develop during the event, including worst-case scenarios. The following elements are very closely associated with each other; they are warning, emergency planning, and rescue operations. Forecasting and warning are key elements of risk management to avoid loss of life.

Emergency maps can identify the area or locations where the hazard is expected to occur and indicate fast and safe routes for evacuation. Emergency maps are developed on a needs basis; however, the real importance of this map lies in the ability to implement it.,

- **End-user map**

(Hazard zoning, emergency, insurance, etc.): There is a variety of end-user maps. They are all deduced in one or the other way from the base maps. The end-user maps address different planning issues and are developed according to the need. Here only end-user maps (hazard zoning and emergency map) (World Meteorological Organization, 2013).

6.2 Geographic Information Systems

There are multiple definitions of Geographic Information Systems (GIS) perhaps the most common definition is the one of the National Center of Geographic Information and Analysis-a GIS that defined it as "a system of hardware, software and procedures to facilitate the management, manipulation, analysis, modeling, representation, and display of georeferenced data to solve complex problems relating to planning and management of resources" (Hulbutta, 2009).

GIS is considered an essential tool for resource planning and management. GIS allows the user to analyze spatial information, modify data, map, and display results. It is used in a wide range of applications, such as risk management, identification of risk areas, and other multiple applications.

The power of GIS comes from the ability to create interactive queries and connect different information in a spatial context and reach a conclusion about this relationship. New information can also be created and presented in different ways to suit specific purposes. The information consists of several different layers containing a specific geographic reference so that they all can be linked together (Fig. 6.2).

Each layer consists of one type of information and together forms a database containing information, that information can answer the various questions in mind. Making the GIS a good tool for different types of analysis, for example, the consequences of specific climatic events in a given area can be assessed and an appropriate plan of action developed (ESRI, 2013).

6.2.1 Nature of Geographical Data

The map is the most common form where geographic data is represented, and geographic features include four main components: its geographic position, attributes, spatial relationships, and time. Geographical data are essentially a form of spatial data. The GIS requires the use of a common coordinate system for all data sets that will be used together.

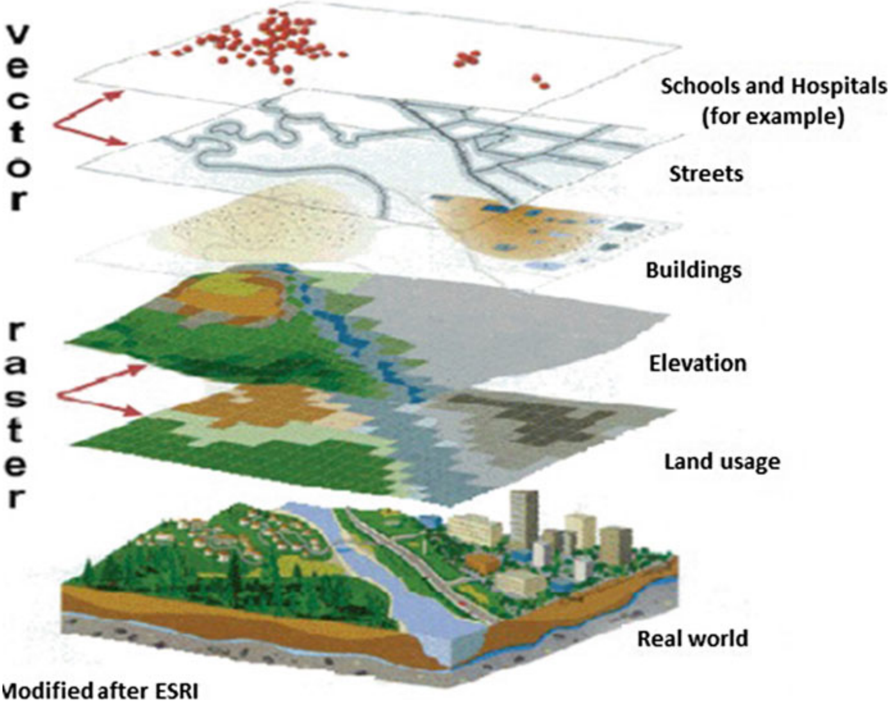

Fig. 6.2 Shows the real world which consists of several layers. (ESRI, 2013)

6.2.2 Data Entry

Both spatial and attribute data are entered into a computer system by different input devices like scanners, digitizers, keyboards, mice, etc. For entering spatial data scanner, digitizer, the mouse is used, while the attribute data representing in reports and tables among other things enter my keyboards. Since the data are derived from a different set of sources, they have a different set of scales, projections, reference systems, and so on. So there is a great need to standardize the database according to common standards.

6.2.3 Building GIS

The use of Geographic Information Systems (GIS) is a useful tool for various and diverse environmental studies, a particularly powerful system for studying climate change and sea-level rise with spatial representation and analysis, where it is easy to explore the problem and develop a strategy to reduce it.

Steps to build GIS begin with data collection and processing and finally the output results. In the case of **data collection**, data for the construction of geographic information systems include topographic maps, socio-economic data, statistical data, scheduled data, and field surveys conducted to verify the accuracy of the data obtained (Hulbutta, 2009).

As for **data processing**, it passes through a set of stages that begin with the **input stage**. Maps are the main spatial input of GIS through different methods, either through digital conversion or by importing data from other computer information systems. Then, **the editing stage** is the correction of the error that may result from the previous stage (input stage) as it involves many types of errors, so this step is very important to correct and complete errors and add more preliminary data.

This is followed by the **data management** phase where data is stored and retrieved from the database. The methods used to implement these functions affect the efficiency of the systems tool for all operations with different data. Then the **Data Manipulation and Analysis phase**. This phase identifies information that can be generated by GIS. Through this phase, it is possible to do several things, including relate multiple data files by shared key fields and treat the resulting collection as a unit for all tabular processing functions, including data entry, analysis, and report generation. Calculate automatically values of new or existing fields with arithmetic expressions or table lookup in related files. Modify the database by adding and removing files or fields. Finally summarize user-specified fields (ESRI, 2013).

The final form of **output** can be either in the form of maps, reports, or tables. The desired format is determined according to users' needs and therefore user participation is important in determining output requirements. The output is the procedure by which information from the GIS is presented in a form suitable to the user.

The interdependence of ecosystems and human impact on the environment is a complex challenge for governments and individuals, as well as for environmentalists and specialists from all disciplines. GIS technology is used to support and communicate information to decision-makers and the public. GIS allows the integration and analysis of multiple layers of location-based data, including environmental measurements, which means GIS is a powerful software that allows the linking of an unlimited amount of information to a particular geographic location. The importance of geographic information systems is to ensure accurate reporting while improving data collection, improving decision-making processes, increasing productivity with simplified work processes, providing better analysis of data and multiple display options, and developing predictive scenarios for several different studies (Blaikie et al., 2003).

It is useful to have a good idea of the actual needs of the designated information before starting to compile and input data, as this will help prioritize spatial data. So, the next lines explore vulnerability mapping as it is the main point in this work.

6.3 Egypt

6.3.1 Background

Egypt lies between Latitude 22° and 32°, and the country's maximum distances are 1024 km from north to south, and 1240 km from east to west. Egypt is bordered by the Mediterranean Sea to the north, by Sudan to the south, by the Red Sea, Palestine, and Israel to the east, and by Libya to the west. The total area of Egypt is 1,001,450 km2, with a land area of 995,450 km2 and a coastline of 3500 km on the Mediterranean and the Red Sea. The surface level extremes range from 133 m below sea level in the Western Desert to 2629 m above sea level in the Sinai Peninsula.

The general climate of Egypt is dry, hot, and desertic, with a mild winter season with rain over the coastal areas, and a hot and dry summer season. Data collected by the Egyptian Meteorological Authority and local universities for the period 1961–2000 indicate that there is a general trend towards warming of the air temperature, with increases in the number of hazy days, the misty days, the turbidity of the atmosphere, frequency of sand storms and hot days. At the time of the last census (2006), the total Egyptian population amounted to 76.5 million, with an average growth rate of about 2.3% per year. In 2006, the GDP and the GNP amounted to about 107 billion US$ and 113 billion US$ respectively. Egypt is categorized as a lower middle-income country, with its GNP per capita being 1556 US$ in 2006.

A survey of the detailed quantitative assessment of the vulnerability of the Nile delta coast of Egypt to the impacts of sea-level rise is presented. GIS and remote-sensing techniques are used together with ground-based surveys to assess the vulnerability of the most important economic and historic centers along the coasts, the cities of Alexandria, Rosetta to the west, and the city Port-Said to the east.

Results of the analysis of satellite images and GIS (El Raey et al., 1997) indicate that, in these cities alone, over two million people will have to abandon their homes, 214,000 jobs, and over $ 35.0 billion in land value, property, and tourism income may also be lost due to an SLR of 50 cm. The loss of the world-famous historic, cultural and archeological sites is unaccountable for. The vulnerability of other low lands in Egypt, outside these cities remains to be assessed.

Development of institutional capabilities for ICZM and upgrading awareness are highly recommended for adaptation in the long run. Periodic nourishment of Alexandria and Rosetta beaches, detached breakwaters, and dune fixation are recommended for no regret management measures. A UNDP project is already in progress.

The vulnerability of various resources of Egypt to the impacts of climate change has been recognized for a long time (Sestini, 1991). In particular, quantitative vulnerability assessment of water resources, agricultural resources, and coastal zone resources has been investigated thoroughly. The coastal zone of Egypt,c in particular, is most vulnerable to the impacts of climate changes.

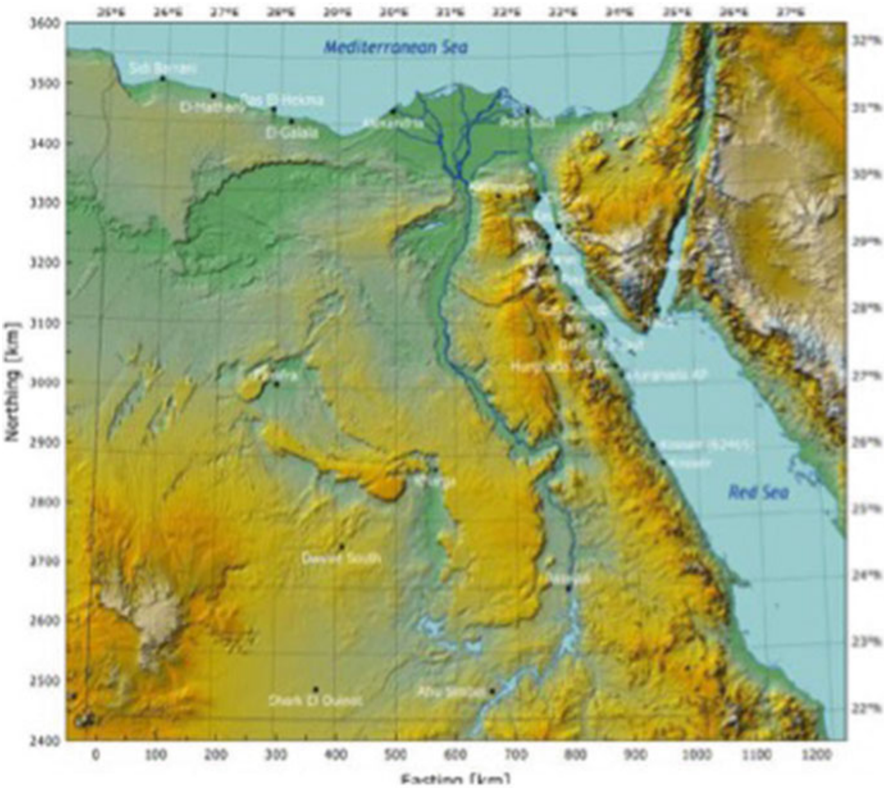

Fig. 6.3 Topography of Egypt

change, not only because of the impact of sea-level rise but also because of the impacts on water, agriculture (food security) and tourism resources, and human settlements. A framework of an action plan has recently been advanced by Egyptian authorities.

6The shoreline of Egypt extends for more than 3500 km along the Mediterranean Sea and the Red Sea coasts, (Fig. 6.3). The Nile delta coast under `consideration, constitutes only 250 km and hosts several highly populated cities, such as Alexandria, Port-Said, Rosetta, and Damietta. These cities also encompass a large portion of the Egyptian industrial and economic sectors. Also, the Nile delta coastal zone includes a large portion of the most fertile low land of Egypt. As a result of the large human activities in these cities, it suffers from some major problems including population pressure, interference of land use, pollution, waterlogging, and lack of institutional capabilities for integrated management.

The objective of this work is to survey the results of a detailed quantitative assessment of the vulnerability of important cities of Egypt to the Mediterranean Sea; namely Alexandria, Rosetta, and Port-Said.

Geographic information systems, remote sensing, and modeling techniques together with ground-based surveys were used to assess potential impacts on each sector and to evaluate socioeconomic losses. The stepwise vulnerability assessment procedure suggested by IPCC has been followed to identify and quantify potential risks of each environmental sector for each district of these cities. A summary of the main results is presented below.

6.3.2 Alexandria City

Alexandria city is located to the west of the Rosetta branch of the River Nile and is famous for its beaches, historic and archeological sites. It is the second-largest city in Egypt with a population of about 4.0 million. It hosts the largest harbor in the country and about 40% of the Egyptian industrial activities. During summer, the city receives over a million tourists. The extension of the city to the south is delayed by the existence of a large water body, Lake Maryut, south of the city. The level of water in Lake Maryut is kept at 2.8 m below SL by continuous pumping of lake water, into the Mediterranean.

To assess the impacts of SLR on Alexandria city, a multi-band high-resolution LANDSAT image (TM, September 1995) of the city is classified to identify and map land-use classes. A geographical information system is built and upgraded in ARC/INFO environment and included layers of

- City district's boundaries
- Topographic maps,
- Land cover from satellite image classification,
- Land use classes,
- Population distribution and employment of each district

Figure 6.4 shows a part of the classified image for Alexandria city (Fig. 6.5).

A scenario of sea-level rise of the city of Alexandria of 0..25, 0.5, and 1.0 m over the next century is assumed, taking land subsidence (2.0 mmyr^{-1}), into consideration. The percentage of the population and land-use areas at risk for each scenario level are identified and quantified by GIS analysis. Table 6.1 shows results of the risk of inundation due to each scenario, if no action is taken, or 'business as usual. These results, together with statistical ground-based employment data are extrapolated to assess the potential loss of employment for each sector. This is also presented in Table 6.2.

Results of the analysis of satellite imagery and the GIS (El Raey et al., 1997, 1999; EL Raey & Atricia, 2011) indicate that for an SLR of 0.5 m if no action is taken, an area of about 30% of the city will be lost due to inundation. Over 2 million people will have to be moved away 195,000 jobs will be lost and an economic loss of land and properties of over $30 billion is expected over the next century. Figure 6.3 shows estimates of losses for each sector of each district in the city of Alexandria.

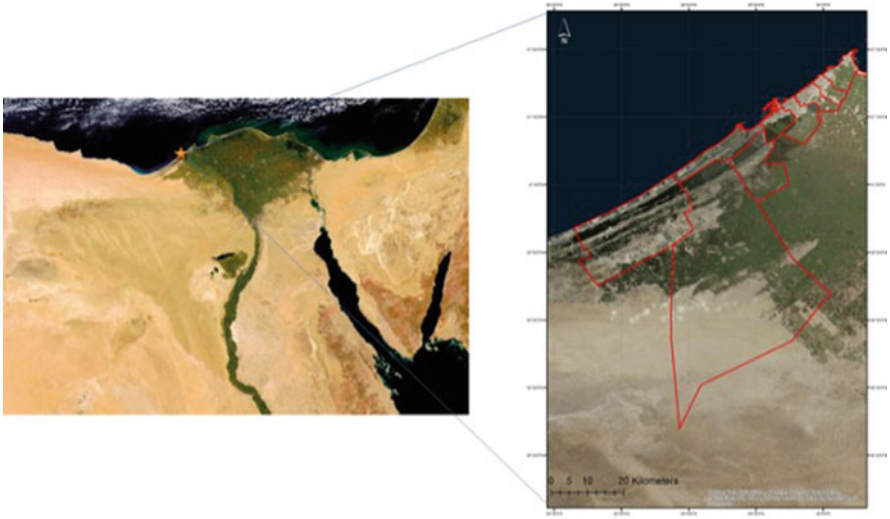

Fig. 6.4 Egypt Nile delta with Alexandria to the west and Port Said to the east

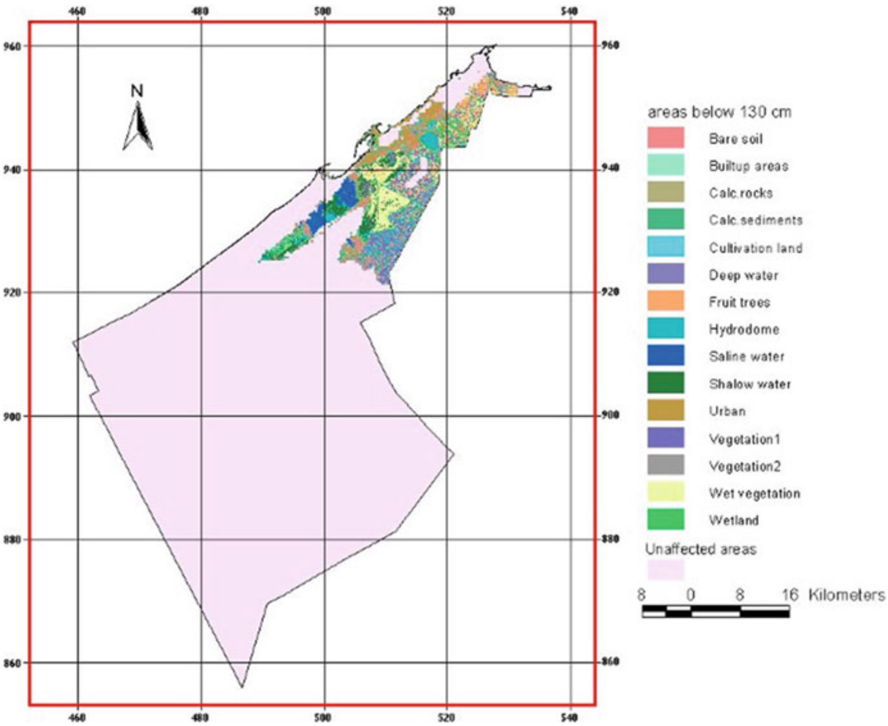

Fig. 6.5 Alexandria Governorate and districts classified image

Table 6.1 Percentage areas, populations, and land use above each elevation contour

Sector/elevation (m)	0.0	$SLR = 0.25$	$SLR = 0.5$	$SLR = 1.0$
Population	54.9	40.1	33.1	24.0
Beaches	98.7	89.1	52.2	36.0
Residential	73.8	72.5	60.7	48.0
Industrial	46.1	43.9	34.1	27.8
Services	54.1	44.8	24.1	17.8
Tourism	72.0	69.0	51.0	38.0
Restricted area	80.0	79.0	75.0	73.0
Urban	62.0	56.0	44.0	33.0
Vegetation	45.0	41.0	37.0	25.0
Wetland	53.0	51.0	42.0	2.0
Bare soil	85.0	76.0	71.0	69.0

Table 6.2 Population expected to be displaced and loss of employment in each sector due to SLR scenarios in Alexandria Governorate

Year sector	2010, SLR = 18 cm	2025, SLR = 30 cm	2050, SLR = 50 cm
Area loss (km^2)	114	190	317
Population displaced × 1000	252	545	1512
Employment loss			
a-agriculture	1370	3205	8812
b-tourism	5737	12,323	33,919
c-industry	24,400	54,936	151,200
Total loss of employment	32,507	70,465	195,443

Given the severe losses in Alexandria due to sea-level rise, and the huge development in progress, and the frame of 'no regrets policy', it is suggested that both a strategic plan and a short-term plan, have to be adopted. An integrated coastal zone management approach, including building provincial institutional capacity, upgrading awareness, and expanding the GIS and decision-making process, must be adopted. On the short-term approach, it is concluded that periodic beach nourishment is the cheapest alternative available, against direct inundation. However, the impact of saltwater intrusion impact on water resources, soil salinization, and building structures has to be further investigated and mitigated (Fig. 6.6).

Because of the severe losses in Egypt due to sea-level rise, and the huge development in progress, and in the frame of 'no regrets policy', it is suggested that both a strategic plan and a short-term plan, have to be adopted. Integrated coastal zone management (ICZM) approaches, including building provincial institutional capacity, upgrading awareness, and expanding the GIS and decision-making process, must be adopted. On the short-term approach, it is concluded that periodic beach nourishment is the cheapest alternative available, against direct inundation. However, the impact of saltwater intrusion impact on water resources, soil salinization, and building structures has to be further investigated and mitigated.

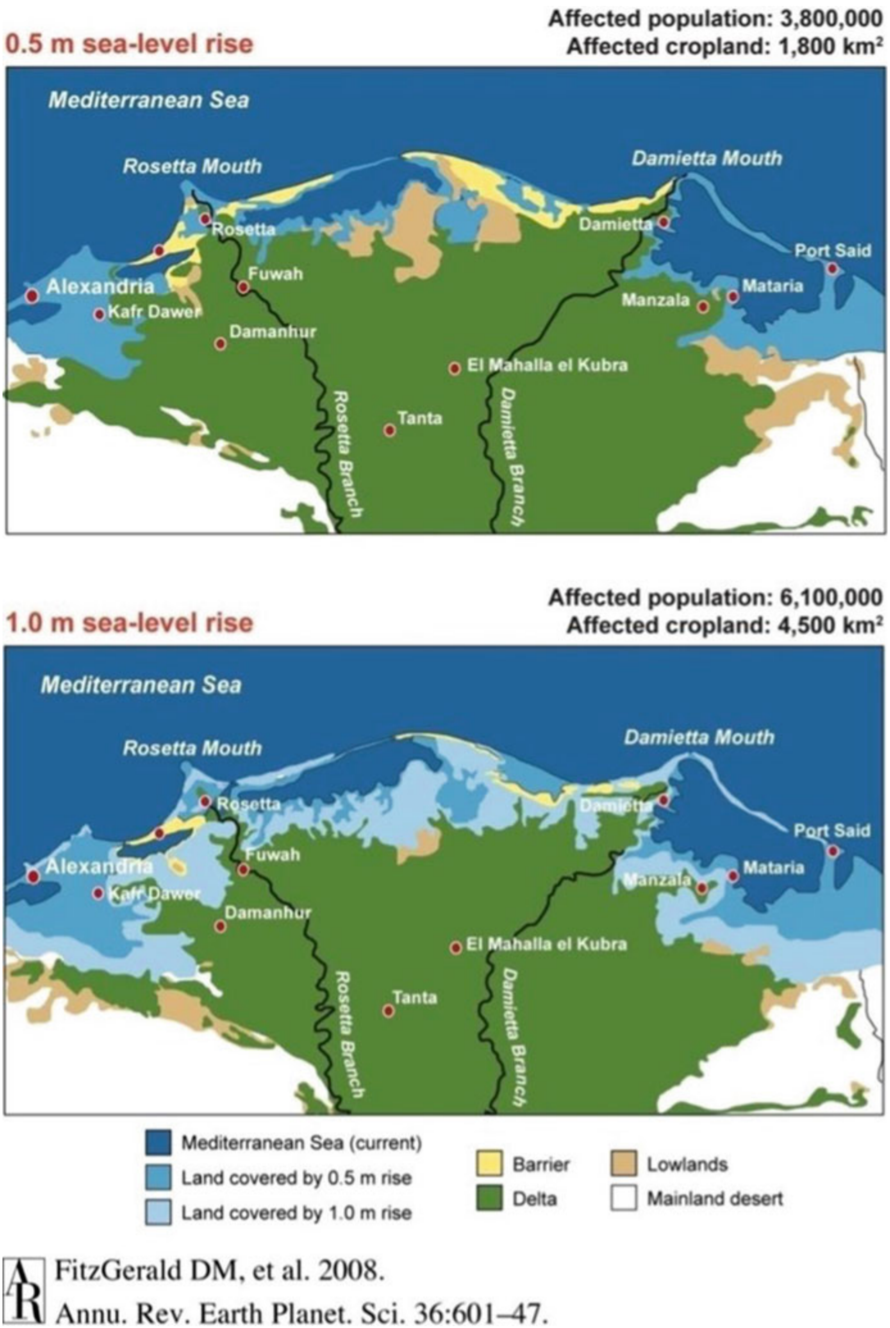

Fig. 6.6 The assessment of sea-level rise in the Nile delta, of Egypt. (According to FitzGerald et al., 2008)

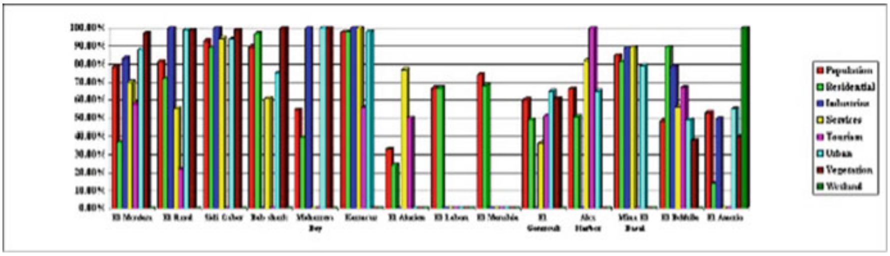

Fig. 6.7 Percentage vulnerability to SLR of Alexandria different localities of 1.0 m

6.3.3 Rosetta City and Vicinity

Rosetta city is a well-known Pharaonic and Islamic city located in the Rosetta region near the intersection of the Rosetta branch of the River Nile with the Mediterranean, east of Alexandria.

It has a population of 2.5 million people. Excessive erosional rates have been observed near Rosetta promontory, due to cessation of sediments after building the High Dam on the River Nile about 1000 km to the south. The region surrounding the city is well known for its water-logging and water-bogging problems.

To assess quantitatively possible impacts of sea-level rise, a high-resolution GIS of the city and surrounding area is built. The GIS includes layers of:

1. Political boundaries
2. Topographic maps
3. Land use (urban. Vegetation, historic,. . .)
4. Socioeconomic maps.

Detailed ground surveys were carried out to update and verify available maps. Impacts were evaluated based on land cover/land-use losses for every 20 cm of sea-level rise (SLR). Figure 6.4 shows a series of GIS plots illustrating vulnerable and safe areas for each 20.0 cm of SLR. Results were extended to estimate employment losses and economic losses for a 50 cm SLR scenario based on extrapolated scenarios. Estimates showed that about 1/3 of the employment power in the city will be affected and a loss of about $2.9 billion in land and property is expected, over the next century. The loss of historic and archeological sites is again unaccounted for. Table 6.3 presents the results of the impacts on each employment sector.

The government has built a massive sea wall near the tip of the promontory, as a protective measure against erosional problems, and excessive salinization. However, recent observations indicate that this massive hard structure is seriously challenged by coastal erosion. Beach nourishment may be a possible solution. Plans for the development of the area should seriously consider the ICZM approach in which decision-making is based on a detailed GIS suitability analysis.

Table 6.3 Results of the impacts on each employment sector

A sector of economic activities	Actual Employment × (10^3)	Employment Expected loss (jobs)
Agriculture and fishing	18.5	4633
Conversion industries	4.5	502
Municipal utilities	0.139	78
(electricity, gas, and water supplies)		
Construction and buildings	1.355	433
Commercial	2.877	1640
Transportation	2.191	1248
Community services	6.275	3576
Total	35.936	
		(33.7% of all employment)

6.3.4 Port-Said City

Port-Said city is located on the Mediterranean Sea to the east of the Damietta branch of the River Nile, at the entrance exit of the Suez Canal. In addition to its strategic position, it is the second-largest tourist and trade center of Egypt on the Mediterranean. Lake Manzala, the largest of Nile delta lakes is located just to the west of the city and receives a sizable amount of effluent pollution from various sources on the eastern region of the delta. A field survey has concluded that the Mediterranean coast of the city hosts the most important economic and tourist areas of the city, in addition to its relatively low elevation. The impact of SLR on this part of the city is carried out in detail (Fig. 6.8 and Table 6.4).

6.4 Saudi Arabia

6.4.1 Background

The Kingdom of Saudi Arabia comprises about four-fifths (80%) of the Arabian Peninsula, occupies approximately 2,250,000 km^2 area, and bordered on the west by the Red Sea; on the east by the Arabian Gulf, Bahrain, Qatar, and the United Arab Emirates; on the north by Jordan, Iraq, and Kuwait; and on the south by the Sultanate of Oman and Yemen.

Saudi Arabia‘s Red Sea coast on the west stretches to approximately 1760 km, while its eastern coast on the Gulf covers 650 km, including 35 km^2 of mangroves and 1480 km^2 of coral reefs. The country has an arid climate with an average annual rainfall of 70.5 mm. Almost two-thirds of the country is arid steppe and mountains with peaks as high as 3000 m, and most of the remainder is sand desert (Fig. 6.9).

Fig. 6.8 A satellite figure of Port Said and Port Fouad

Table 6.4 An assessment of conditions at the Nile Delta (Frehy etal 2021) has been carried out recently on Alexandria and found that the city is hugly vulnerable. The government in Cairo has taken steps to carry out integrated coastal zone management (ICZM) and have asked UNDP Cairo to carry out risk assessment. Estimation of expected economic loss in land cover Rosetta – (1995–1996 prices)

Land cover	Lost area (m2)	Square meter price 1990, in the US ($)	Total estimated cost in the US ($) (Millions)
Coast bare land	3,581,740	200	716
Marine bushes	4,504,750	150	675
Palm cultivation	5,790,260	200	1158
Bare land	27,508	250	7
Urban clusters	1,251,204	300	375
Total	15,155,462	–	2931

Saudi Arabia consists of a variety of habitats such as sandy and rocky deserts, mountains, valleys, meadows, salt-pans ('sabkhas'), lava-areas, etc. It includes most types of terrain which can be generally divided into two distinct groups of rocks; the Arabian shield and the Arabian Platform. Seventy-eight percent of the population is concentrated in the urban areas (Saudi, 2005).

Coral Reefs represent the most significant habitat found along the Saudi shores (both Red Sea and Arabian Gulf). Coral reefs play an important role in the coastal

Fig. 6.9 Saudi Arabia and Jordan to the North

ecosystem. These reefs as well as the Mangrove forests form the basic framework of tropical habitats and provide shelter and food for a wide array of marine life. The highest coral diversity occurs in the central Saudi Arabian Red Sea area. Coral reef harbors a longstanding and important artisan fishery.

6.4.2 Vulnerability to Sea Level Rise

While mangroves are found scattered along much of the Red Sea coast, the major concentration is in the southern red sea where factors such as increased sediments create an environment more conducive to their development. Agricultural development, properly planned and managed, could be beneficial to certain coastal habitats such as mangroves. Mangroves have a variety of values: they provide food in the form of detritus, shelter for numerous organisms (such as mollusks, crabs, shrimps, and fish) fodder for camels, and goats, and fuel for human use. Mangroves are also important nesting sites for several species of birds.

The development of coastal recreational facilities and coastal villages in the Ras Hatiba area north of Jeddah and shrimps aquaculture along the southern Red Sea coast have contributed to the decline of Saudi Arabia's coastal mangroves.

Coastal cities of Saudi Arabia extend along the Red Sea coast as well as the Arabian Gulf coast. Four coastal cities have been selected as the most vulnerable cities to Accelerated Sea-level Rise (ASLR) along the Red Sea namely Jeddah, Rabigh, Yanbu, and Gizan). The selection of these cities was based on the population growth, socio-economic activities, and historical and cultural importance to the

Fig. 6.10 The Saudi Arabian Cities on the Red Sea

Kingdom. Again, on the Arabian Gulf cities such as El Khafji, Al Jubail, Al Dhahran and Al Khobar (Fig. 6.10) could be considered vulnerable.

The following potential impacts were identified in a study on Saudi SLR impacts (Saudi, 2005).

An increase in sea level rise will increase the intrusion of saline water from both the Arabian Gulf and the Red Sea into coastal aquifers, which will potentially affect the freshwater supply in coastal zones. In cases of flooding in coastal areas, saltwater will further intrude into aquifers. This intrusion will increase the demand for 88 h water from other sources, mainly Desalination Plants. At the same time, sea-level rise will increase the saltwater intrusion of estuaries, potentially benefiting marine fish at the expense of freshwater ecosystems.

Groundwater levels in these areas might also be affected by the intrusion of saline water. The groundwater level itself and the soil structure determine the potential for the intrusion of saline waters. Managed areas with a reduction in groundwater level because of drainage are more vulnerable to intrusion.

Sehat and Qateef are the main agricultural cities along the Arabia Gulf and Gizan along the Red Sea. These cities could be impacted by Accelerated Sea Level Rise. Recently increase in soil salinity has been observed in some of these coastal cities. This increment has impacted the production of cultivated products. It is suspected that saltwater intrusion may be one of the factors impacting agricultural activities.

One of the most significant impacts of sea-level rise is the acceleration of coastal erosion as well as the inundation of mangroves, wetlands, and coral reefs. The rich biodiversity of the wetlands in Saudi Arabia is seriously threatened by the loss of wetlands due to sea-level rise. The effect of sea-level rise will depend on the type of mangrove forest. These mangrove forests may either keep pace with the rising sea level rise or may be submerged. Large-scale changes in species composition and zoning in mangrove forests are also expected due to changes in sedimentation and organic accumulation, nature of coastal profile, and species interaction.

An additional threat of Accelerated Sea Level Rise affecting the Saudi Arabian coasts will come from an exacerbation of sandy beach erosion. As the beach is lost, fixed structures nearby are increasingly exposed to the direct impact of storm waves, and will ultimately be damaged or destroyed unless expensive protective measures are taken. It has long been speculated that the underlying rate of long-term sandy beach erosion is two orders of magnitude greater than the rate of rising sea level. Therefore, any significant increase in sea level has direct consequences for coastal inhabitants.

Results from the studies on various aspects of the impacts and possible responses to sea-level rise on the Saudi Arabian coasts indicate that a sizable proportion of the Arabian Gulf and the Red Sea will be affected by a combination of inundation and erosion, with consequent loss of developed properties including industrial, recreational and residential areas.

No detailed socioeconomic study of accelerated sea-level rise has been carried out yet in Saudi Arabia. However, it has been estimated that 20% of Saudi Arabian coastal areas have been subject to development, 130 km along the Arabian Gulf coasts and 352 km along the Red Sea coasts. A conservative scenario of 1% annual coastal development was applied on the Arabian Gulf and the Red Sea coasts. This scenario was applied to the coastal erosion model to estimate the area of sandy beaches that may demolish as a result of sea-level rise.

Considering the annual coastal development in the Kingdom is 1% and the IPCC Sea Level Rise projection Scenarios towards the year 2100 and by applying Bruun model to estimate the high-risk areas subjected to coastal erosion along the Arabian Gulf, it was found that:

- For the Low Sea Level Rise Scenario (LSLRS) of 0.2 m rise, 401 hectares of sandy beaches are estimated to be lost by the year 2100.
- For the Medium Sea Level Rise Scenario (MSLRS) of 0.49 m rise, 984 hectares of sandy beaches are estimated to be lost by the year 2100, and
- For the High Sea Level Rise Scenario (HSLRS) of 0.86 m rise1, 726 hectares of sandy beaches are estimated to be lost by the year 2100.

6.4.3 Institutional and Practical Adaptation Measures (El Raey, 2008)

It is well recognized that the following adaptation measures at least are needed:

1. An integrated institutional structure must be developed. A Regional Circulation Model (RCM) has to be developed and a strong institutional monitoring system has to be established.
2. A monitoring system of tide gauges and systematic observations of the coastal zone with provisions for land subsidence must be established.
3. An early Warning Center for climate change, which must be able to predict flash flood and other phenomena, must be established

6.5 Libya

6.5.1 Background

Officially the Great Socialist People's Libyan Arab Jamahiriya is located in North Africa. Bordering the Mediterranean Sea to the north, Libya lies between Egypt to the east, Sudan to the southeast, Chad and Niger to the south, and Algeria and Tunisia to the west. With an area of almost 1,800,000 km2, Libya is the fourth largest country in Africa by area. The capital, Tripoli, is home to 1.7 million of Libya's 5.7 million people. The three traditional parts of the country are Tripolitania, Fezzan, and Cyrenaica. Libya has the highest HDI in Africa and the fourth-highest GDP (PPP) per capita in Africa as of 2009, behind Seychelles, Equatorial Guinea, and Gabon. These are largely due to its large petroleum reserves and low population (Fig. 6.11).

Libya has a small population residing in a large land area. Population density is about 50 persons per km^2 in the two northern regions of Tripolitania and Cyrenaica but falls to less than one person per km^2 elsewhere. Ninety percent of the people live in less than 10% of the area, primarily along the coast. About 88% of the population is urban, mostly concentrated in the two largest cities, Tripoli and Benghazi. With

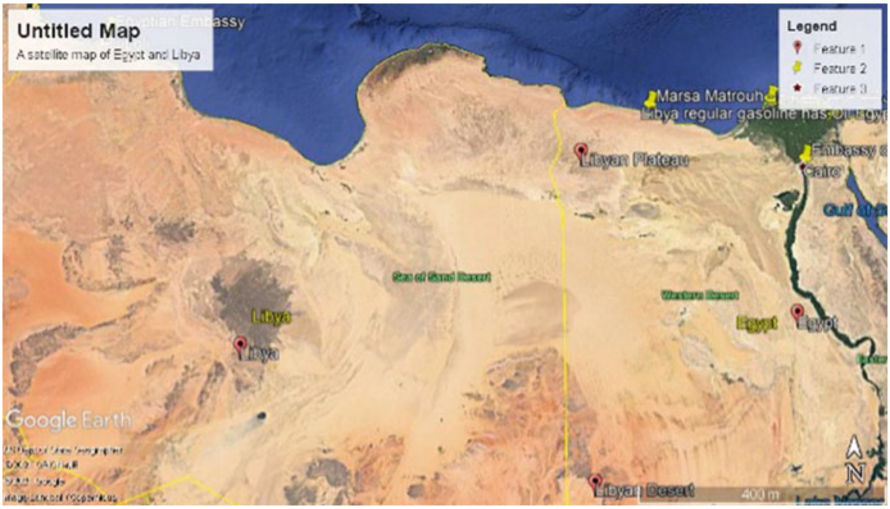

Fig. 6.11 EGYPT and Eastern Libya

the longest Mediterranean coastline among African nations, Libya‘s mostly virgin beaches are an important social gathering place.

6.5.2 Vulnerability to Sea Level Rise

Regardless of the inland areas that lie below the sea level, most of the coastal area at the southern part of Sert Bay is vulnerable to direct inundation and/or saltwater intrusion as seen by comparison to the simulation of sea-level rise of 1 m. Besides, many of the coastal cities such as Benghazi, Libya‘s second-largest city are considered vulnerable to sea-level rise and potential impacts of extreme storm events. Saltwater intrusion on already scarce groundwater resources may also be damaging to important water resources.

Sert Bay as Seen Today a Sert Bay in Libya After 1.0 Sea-Level Rise (Fig. 6.12)

Practical and Institutional Adaptation Measures

- Building up institutional and human capacity for monitoring coastal parameters including land subsidence, developing databases and modeling are necessary prerequisites for adaptation
- Development of proactive planning and integrated coastal zone management is also necessary
- Carrying out a complete vulnerability survey of the coastal zone and associated protection measures are necessary
- A program of upgrading awareness and resilience of the community must start for the decision-makers and population at large.

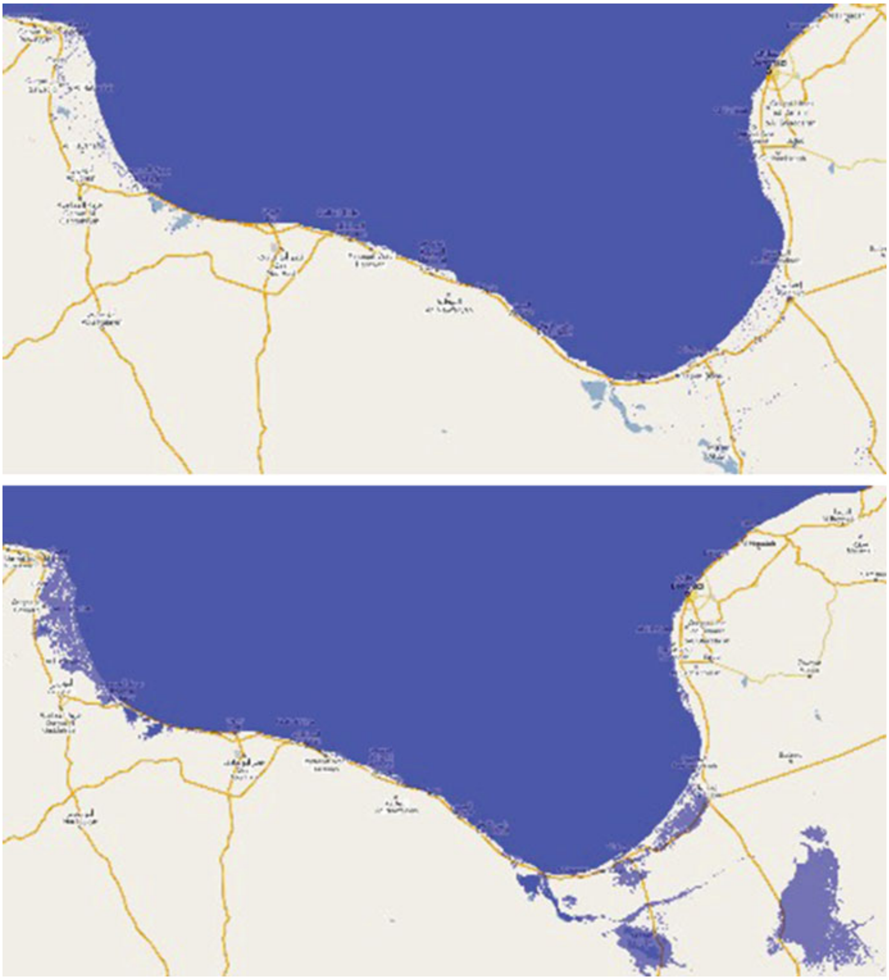

Fig. 6.12 a & b Sert Bay in Libya in case the sea rises by 50 cm. Notice the formation of a lake on the eastern side of the bay

6.6 Morocco

6.6.1 Background

The Moroccan Atlantic coast is the most important area for the national economy, taking into account its demographic and economic weight. The Atlantic coast of Morocco is divided into:

61% of the urban population of the large cities
80% of permanent manpower of industries

53% of the tourist capacity
92% of the foreign trade.

However, this situation is changing with the realization of the new port Tangier Med and the economic development it brings to the Mediterranean coast of Morocco (Etude V&A, 2006). The total coastal population represented more than 50% of the population of Morocco, increasing on average by 2.77% per annum, whereas the total population of Morocco increased only by 2.5% per annum on average for the same period. The densely populated coast is subject to major pressures from human development and this is only projected to increase in the future. The urban population of the coastal areas did not cease growing since the beginning of the century. The density of the population reaches 162 habitants/km ^{2} between Kenitra and Casablanca, compared to the 93 inhabitants/km ^{2} on the Mediterranean coast (Etude V&A, 2006).

77% of Morocco's industrial activities are located in the coastal areas and 98% of Moroccan foreign trade relies on shipping as a transportation method. Therefore, the economic importance of coastal areas is imperative. Also increasing popularity of beach tourism highlights the importance of coastal areas to Morocco's economy. Beach holiday was the primary motivator for both national and international tourism in Morocco, and the coastal areas boast more than 50% of accommodation capacity, the most dynamic centers being Agadir and Casablanca (Etude V&A, 2006).

6.6.2 Vulnerability to Sea Level Rise

The coasts of Morocco already strongly weakened by human activities would be confronted with major socio-economic and environmental difficulties if no adaptation measures or vulnerability studies are undertaken. A 2002 study by the Ministry of Environment identified two coastal zones as being most vulnerable: The coast of Saïdia and the coast of the bay of Tangier.

Fig 20 through Fig. 21 shows the variation of land use and elevation along the coastal strip of the Mediterranean coast of Morocco. The figures demonstrate the vulnerability of the dense urban areas and tourist units to potential impacts of sea-level rise and saltwater intrusion. Figure 6.12 presents a simulation of the land to be flooded in case of SLR of 2 m FIGDigDigital (Fig. 6.13 and 6.14).

Bio-Geophysical Impacts of SLR Impacts of sea-level rise on coastal areas are numerous and varied but the most significant are generally and in the case of Morocco: the low-lying coastal flooding, coastal erosion, and salinization of estuaries and coastal aquifers

- **Phenomenon of flooding**: The first threat is that of flooding of evergreen coastal marine waters which are currently poorly or partially emerged, as the shores of deltaic plains, salt marshes, mangroves, coral reefs, etc. There seem to have

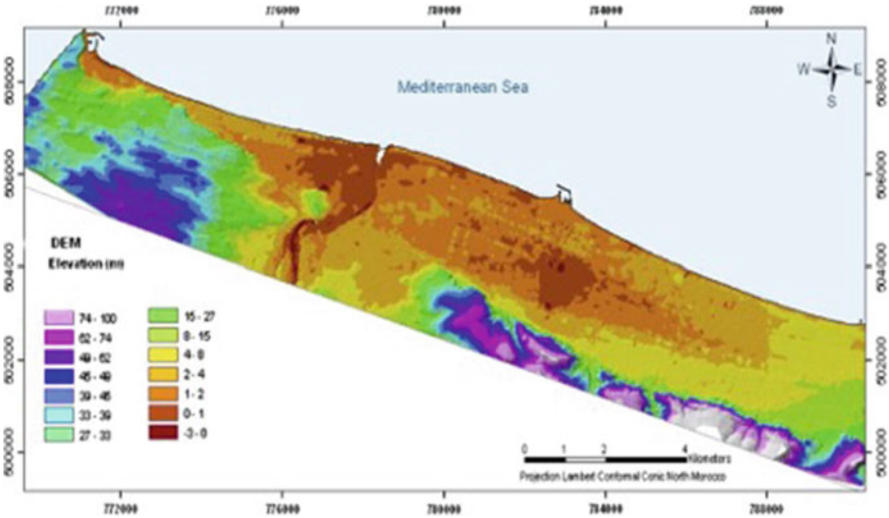

Fig. 6.13 Digital Elevation Model DEMof Eastern Mediterranean coast of Morocco (Snoussi et al., 2008)

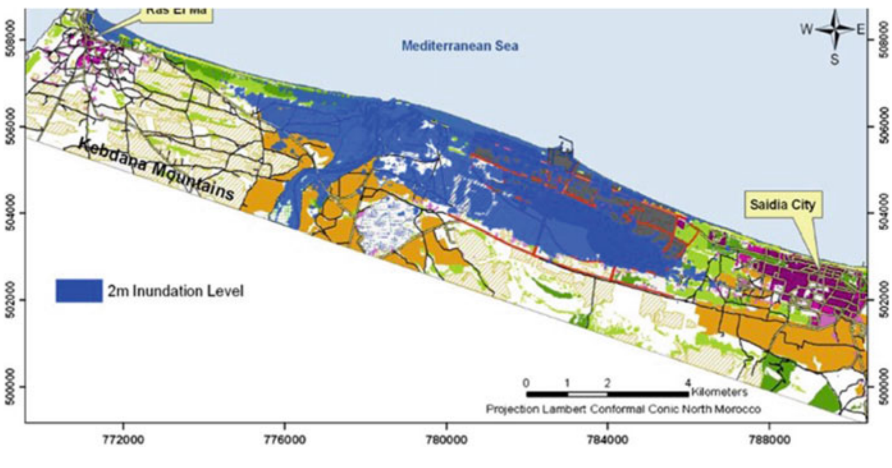

Fig. 6.14 The coastal area of Eastern Mediterrnean illustrating inundation level (Snoussi et al., 2008)

increased the intensity and wave heights over the past three decades, and that the waves of storms were more frequent with the expected climate CC.

In Morocco, the importance of the coastline (3500 km), is marked by a large number of environments marginal-coastal and coastal wetlands such as lagoons, estuaries, berries or less closed beaches, coastal islets, and predisposes. These areas generally have a low topography and high vulnerability to flooding by seawater.

Coastal wetlands of Morocco are renowned for their ecological values, as well as goods and services they provide to local populations, who long have developed know-how traditional use of natural resources. The flooding of these wetlands could ultimately damage their ecological, social, and economic conditions and force people who depend on their activities (including agriculture and livestock) to new conditions by their conversion to fishermen, aqua-culturalists, and others. The barrier beaches could also readily admit a cross-cut larger volume of seawater, which could be detrimental to the vegetation of halophilic salt marshes, which will be subject to a longer duration of submergence and higher salinity, for all species sensitive to salinity and water column, for salt marshes which could be used for grazing, and the protection works (breakwaters, jetties, groins, etc..)

- **Coastal Erosion**:

In Morocco, two-thirds of the beaches are eroding, particularly among the cliffs Jorf Lasfar and Oualidia recede seven major coastal environments of the Atlantic are total or partial closure and port facilities have increased volumes dredging of 15% during the last 5 years. It is often difficult to attribute these changes to a single cause. While the share of anthropogenic activities is undeniable, these findings could provide tangible evidence of a rise in sea level combined with strong swells storms becoming more frequent.

6.6.3 The Phenomenon of Salinization

The phenomenon of salinization (Increasing the salt content of freshwater by seawater intrusion) is likely to affect estuaries and coastal aquifers. Indeed, the SLR may lead to an increase in the depth of estuaries but especially a greater penetration upstream intrusion of saltwater. Increased salinity of surface water will no doubt have an impact on the fauna and flora. It seems that disturbances of this kind should be more sensitive in areas with a low tidal range.

Concerning fresh groundwater, if the sea level increases, the separation between the continental freshwater and saltwater marine will move sideways to the ground, and level piezometric groundwater will be enhanced. Thus, this will result in a reduction in the volume of fresh groundwater through salt wedge intrusion. The hydrogeology of low areas, often composed of alluvial sedimentary permeable soil can be changed. The aquifers at risk of a rise of the same order as that of sea level would have a considerable impact on vegetation, and even at ultra-high elevations.

Many studies have shown salinity more or less advanced into coastal aquifers. This has been attributed to several anthropogenic factors (including over-pumping, the return of irrigation water, etc.) which are the main cause of the decreased levels of freshwater as a result of the invasion of the salt wedge. However, no study has explicitly linked salinity to sea level rise due to CC. The penetration of the salt tide further upstream is felt in several estuaries, without series of temporal data can confirm. Many living species may disappear because they cannot adapt to changes in salinitY.

Socio-Economic Impacts of SLR

- **Agriculture:** The intrusion of saltwater into groundwater can affect the quality of products and yields significantly.
- **Water resources**: As the sea rises, the fresh groundwater and surface water can be displaced by saltwater, which can have significant adverse impacts on the drinking water supply. Following CC, prospective studies have shown that in 2020 the water cut by 10–15%. The SLR would therefore exacerbate the reduction in coastal areas.
- **Fisheries and Aquaculture**: SLR could affect coastal activities such as (fishing, coastal lagoon, the harvest of shellfish and seaweed, etc.). Besides, aquaculture activities that are related to physical and chemical conditions (salinity, chemistry, temperature, oxygenation, etc.) specific husbandry should adapt to changes associated with SLR, the increased temperature, and salinity.
- **Tourism**: Impacts of CC and the SLR on tourism will affect quality and availability of water resources, erosion of beaches, and loss /degradation of coastal infrastructure. A very powerful example is that of the Bay of Tangier, which represented the first station national tourism in the years 1970–1980. It has fallen sharply in the years 1990, mainly because of the chronic degradation of its coastline. Thus, Tangier has lost 53% of its international nights, resulting in a decrease in tourism revenues ($ 20 M / year), income crafts (25%), and tourist transportation (40%) (Snoussi et al., 2008). SLR would have catastrophic effects if nothing is done to rehabilitate and protect the bay.
- Thermal power plants installed on the coast, refining plants, and deposits industrial centers and roads along the coast, are particularly vulnerable to SLR plus swells from storms or surges.
- **The sanitation sector**: In the big coastal cities, were particularly systems of sewage and stormwater that would be threatened by SLR? Coastal stations of water treatment may be damaged and no longer fulfill their function, which will be detrimental to water quality, and consequently to the health of populations.
- **Forests**: Forests on the coast would be affected by the marine invasion and salinization waters of the aquifer.

In conclusion:

1. A change in sea level, even a few inches may, in different segments of coastline, cause a significant withdrawal of the shore either by erosion or flooding;
2. The intrusion of seawater can lead to forms of degradation by salinization in extensive grounds operated by coastal agriculture; Early warning systems of extreme events such as heatwaves, flash floods, and dust storms must be established
3. Policies and measures should be developed based on model studies and participation of stakeholders
4. Upgrading awareness programs of Stakeholders should also be carried out

The main coastal port structures, harbor pools, and sanitation are also vulnerable to rising sea levels. Rising sea levels will not only impact the environment but also different sectors of the economy including in particular tourism, and will require interventions (protection, rehabilitation) which are not always easy or even possible sometimes. Hence the interest is to give priority to the issue of rising sea levels in future decisions for the management of coastal environments.

studies and research to identify vulnerabilities to rising sea levels across Morocco have remained very limited and data that may help in realizing such studies are unavailable. Also, it is urgent to establish a research program integrated with sampling measurements and modeling of the tidal effect of the elevation sea level on coasts and in the image of what has been done in neighboring countries.

Practical and Institutional Adaptation Measures

Based on previous considerations, it is suggested that the following adaptation measures are necessary:

1. Projects for vulnerable sectors (such as the coastline, forest, or precarious human establishments) have to be identified and protection measures worked out.
2. Establishing a strong institutional capacity for monitoring, building a geographic database, modeling, and assessment
3. Adopting proactive planning and integrated coastal zone management approaches for development along the coast
4. Upgrading awareness of decision-makers and stakeholders of the potential impacts of sea-level rise on various aspects of development

But, it is clear that the Moroccan economy, which is still caught up in the problems of development and struggles against poverty, cannot withstand the costs of such projects without sacrificing the major components of its social and economic development programs (education, health, basic infrastructures, rural development, etc.).

6.7 Algeria

Due to its geographical position and climatic characteristics, Algeria is highly vulnerable to climate change. Even a small temperature rise would lead to various socio-economic problems that hinder the development of the country. The models predict that rainfall events are less frequent but more intense, while droughts are more common and longer. The spatial and temporal distribution of rainfall will also change. The analysis of climate data from 1931 to 1990 in northern Algeria reveals a rise in temperature of 0.5 °C would reach an increase of 1 °C by 2020.

A temperature rises of 2 °C is expected by 2050. The decrease of water resources, declining agricultural yields, encroaching desert, the challenge of planning, and the energy consumption for air conditioning are only the initial impacts to which Algeria must find answers supportable economically and socially. Thus, although the contribution of Algeria to global warming is minimal (less than 0.5% of global GHG emissions), the country is very vulnerable and should integrate adaptation into its development policy. We present in this study an analysis of the current situation about support sustainable development and climate change issues, the footprint of Algeria, trends in emissions of CO_2 in Algeria, mitigation and adaptation strategy Algeria, national climate plan, and especially the impact of the new national plan for promoting renewable energy adopted in 2011 and expects to produce 40% of electricity needs from solar. Avenues of consideration that can mitigate the impacts induced by medium-term climate change will also be presented. Due to its geographical position and climatic characteristics, Algeria is highly vulnerable to climate change. Even a small rise in temperature would lead to various socio-economic problems that hinder the development of the country.

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6.8 Tunisia

6.8.1 Background

Based on updated climate projections from the latest IPCC report, this chapter presents the.

vulnerability of different sectors to climate change (water resources, agriculture, and ecosystems, coast and fisheries, tourism, health,

der), by describing the potential impacts of climate change on each sector and their capacity to adapt. An overview of the main ongoing or scheduled adaptation initiatives is also provided, followed by a presentation of the priority axes and strategies of adaptation to climate change in Tunisia.

For this third national communication, the outputs of a set of models used in the latest IPCC report(AR5) with two representative concentration pathways (RCP 4.5 and 8.5) are analyzed to provide climate change projections for Tunisia at both the 2050 and 2100 horizons. These data come from the simulations of all EURO-CORDEX models at a 12.5 km resolution.

6.9 Synthesis of Climate Projections for Tunisia

Past Climate Trends in Tunisia In Tunisia, over the 1978–2012 period, we observe a significant upward trend in annual maximum, average, and minimum temperatures of around 2.1 ° C, with regional disparities.

Observations show a slight upward (statistically insignificant) trend for the total annual rainfall over this same period of observed data. Nevertheless, the disparities between seasons and the interannual variability are very strong. The beginning of the 1980s is known for a succession of several dry years in Tunisia, influencing the general trend of the curves Regarding meteorological and climatic extremes, a change in the frequency of thermal and rainfall extremes is observed over the past period, based on the observed data from the meteorological station S of the Tunisian National Institute of Meteorology (INM).

2050 and 2100 Climate Projections Under RCP 4.5 and RCP 8.5 Scenarios Projections show an increase in annual temperature at the 2050 and 2100 horizons for both scenarios .his increase ranges between 1 ° C and 1.8 ° C by 2050 on average for the set of studied models and between 2 ° C and 3 ° C at the end of the century, with the RCP 4.5 scenario. For tender the RCP 4.5 scenario, the seasonal rainfall projections show a much more pronounced.

variability by 2100 with significant rainfall decreases in summer in southern Tunisia (− 35%) and a slight increase in rainfall in autumn in the northwest of the country (+ 5%). Under the RCP 8.5 scenario, the seasonal rainfall projections show very pronounced decreases in precipitation (−35%) in winter in southern Tunisia and spring in northern Tunisia, which differs from the scenario RCP 4.5.

Regarding climate extremes, Tunisia could experience more frequent and longer heatwaves by.

2100 under the scenario RCP 8.5. On the other hand, the cold waves would decrease as well as the episodes of extreme rainfall.

6.9.1 Water Resources

Among the 36 billion of m3 of rainwater that Tunisia receives each year, 16.3 billion of m3 (45%).

can be mobilized. 4.8 billion m3 (13%) constitute the annual potential for blue water which can be used to meet socio-economic needs6. The main permanent watercourse is the Medjerda River, which has its sources in Algeria and on which is set the Sidi Salem dam, the largest one in Tunisia. 11.5 billion m3 (32%) infiltrates into the soil and constitutes water reserves for rainfed agriculture forests and rangelands. The remaining 19.7 billion m3 (55%) evaporate, are stored in the wetlands, or flow towards the sea.

An increase in the intensity and frequency of dry periods, combined with the increase in temperature, should reduce soil moisture and surface and underground water stocks. These impacts of climate change are likely to be worsened by the increasing water needs, notably for human use, but more particularly for agriculture, given the increase in evapotranspiration and the decrease in soil humidity Groundwater forms 44.5% of Tunisia's water potential, with 226 shallow water tables and 340 deep aquifers. Most of the groundwater comes from deep aquifers in the south, among which the largest resources are non-renewable fossil groundwater (610 Mm3 / year are non-renewable, coastline, the overall decrease of water resources due to climate change could be significant. In particular, we could assist in a drying up of water sources, which constitute the main resources in some rural areas of the country.

Among a set of about 215 water tables in Tunisia, almost a quarter is located in the coastal area. These coastal aquifers store about 290 Mm3, i.e. 40% of the groundwater potential and almost 6% of the total water resources that can be mobilized in the country. Seawater intrusion into the coastal waters tables will contribute to their progressive salinization, especially since many of these aquifers already show signs of degradation (salinization, overexploitation). Sea level rise could be responsible for the loss of 220 Mm3 of water resources, i.e. about 30% of the total groundwater potential and 75% of the phreatic resources.

Water use conflicts are already observed and are intensifying in Tunisia, especially during drought periods. Rural areas relying on springs for drinking will be greatly affected, given the drying up of b.

6.9.2 Major Initiatives for Adaptation

Given the fact that Tunisia is already affected by water scarcity in some regions and that the rate of conventional water resources mobilization reaches 92%, various adaptation measures have already been implemented. These measures include investments for a greater mobilization of unconventional water. For instance, the seawater desalination plant in Djerba will be operational in 2018 and the desalination plants in Sfax, Zarrat, and Sousse should be operational by 2020. These investments should allow securing the supply of drinking water until 2030. The potential reuse of wastewater, estimated at 300 Mm^3, is also an ongoing adaptation measure in Tunisia.

The possibility of transferring a part of the surplus water from the extreme north, estimated at 400 Mm3 / year, to the center of the country in the area of Kairouan, is currently under study. This would be done through the reinforcement of infrastructures: connection of dams, doubling of transfer lines, the building of new storage facilities. A national program for artificial groundwater recharge, by surface water or treated wastewater, is also initiated. However, the volume of water injected underground is dependent on the availability of surface water, which has decreased from 66.2 Min 1996 to 30.52 Mm3 in 2015.

Water and soil conservation is part of a new strategy integrating the impact of climate change on the national territory. Adaptation measures are also initiated in the agricultural sector to reduce the water demand, such as the use of conservation agriculture9. A national water-saving strategy in the agricultural sector implemented since 1995 led to the equipment of more than irrigated perimeters with water-saving techniques, which reduced the water demand in some of these areas.

However, the effectiveness of this strategy is limited by the obsolescence of the facilities (65% of the meters are and ecosystems, Tunisian agriculture is of crucial importance because of its contribution to national food security.

Tunisia has more than ten million hectares of agricultural land representing 62% of the country's total area, with 32% of the total area covered by annual and permanent crops. Livestock production, with more than 400,000 breeders, is dominated by a flock of sheep, cattle, goats, and poultry. The agriculture and agri-food sector accounted for 11.5% of the GDP in 2012. The agricultural sectovides permanent income for 470,000 farmers, contributing to the stability of the rural population, which represents 35% of the country's population.

Climate change impacts on the sector 30%. Globally, the consequences of climate change would be economically negative for the most vulnerable populations, notably for women, of whom 32.3% live in rural areas and who constitute more than 70% of active jobs in agriculture and forestry. Poverty is likely to intensify and to affect small farmers whose agricultural activities, already economically unprofitable, may disappear under the impact of climate change. As a consequence of the expected decline in suitable areas for agriculture, and considering constant yields, agricultural GDP would decline by 5–10% in 203.

Many ecosystems would also be strongly impacted by climate change. An increase in forest fires is expected, which currently already reduce the forest area by 1200 ha each year, leading to the gradation and loss of biodiversity. Alfa ecosystems and rangelands are already under heavy anthropogenic pressure like overgrazing. A study conducted in 2014 in the governorate of Medenine13estimated that the reduction of natural fodder resources would be around 23% and 26% respectively.

In 2020 and 2050, threatening the sustainability of pastoralism. Wetlands would also be threatened by increased salinization and eutrophication. The oasis ecosystems are already highly vulnerable due to their strong dependency on water resources. For the Tunisian oasis zone, average warming of 1.9 ° C is expected by 2030 and 2.7 ° C by 2050, with decreasing rainfalls by 9% in 2030 and 17%in 2050, and an increase in evapotranspiration of 8% by 2030 and 14% by 205014.

Major Initiatives for Adaptation Initiatives for climate change adaptation in agriculture are generally multi-scalar and more developed since the revolution. Meteorological and climatic monitoring has been widely developed to anticipate extreme events that can cause severe damages and losses on agricultural yields.

Looking for more efficiency in water use within irrigated perimeters, Tunisia began its National Program on Water Saving in 1995. In 2015, notably, t response to climate change impacts already obese rved, localized irrigation (drip irrigation) is applied to 46% of the total area of irrigated perimeters, compared to 30% for sprinkler irrigation and 24% for gravity irrigation15. Several other adaptation measures are implemented in the agricultural sector to reduce the water demand, such as the use of conservation agriculture, both at a local and regional scale. In terms of traditional agriculture, one of the initiatives for adaptation is to educate farmers and encourage them to use ancestral know-how.

Each governorate, depending on the types of agriculture developed within its geographical area, has also planned adaptation to climate change by strengthening participative Deba t es between managers and farmers and/or inhabitants of rural areas for example. Capacity building of dedicated national services is also a priority. Several strategies have been recently developed to protect.

Tunisian ecosystems from the impacts of climate change. Many strategies focus on sensitive oasis ecosystems. Moreover, in 2015, a study formulated strategic directions and developed a plan for the adaptation to climate change. of biodiversity, in all its components. However, the implementation of the advocated actions and recommendations of all these studies and strategies remains constrained.

The coast has a total length of 2290 km, distributed as follows: 1280 km of continental coastline, 450 km of island coastline, and 560 km of lagoons. The three main types of fishing encountered in Tunisia are trawling lamp fishing and inshore fishing. The main marine production area..is located in the governorates of Sousse, Monastir, and Nabeul, while the production of continental aquaculture, is mainly located in the governorate of Béja. Fishery production has steadily increased since the 1990s, reaching a total production of 118,000 tons in 2012, with an annual growth rate of 2.6% between 1996 and 2012. The production of the year 2016 was estimated at 126,528 tons, for a total amount of 828 million dinars.

For this third national communication, the outputs of a set of models used in the latest IPCC report (AR5) with two representative concentration pathways (RCP 4.5 and 8.5) are analyzed to provide climate change projections for Tunisia at both the 2050 and 2100 horizons. These data come from the simulations of all EURO-CORDEX models at a 12.5 km resolution. 1. Synthesis of climate projections for Tunisia ~Past climate trends in Tunisia, over the 1978–2012 period, we observe a significant upward trend in annual maximum, average, and minimum temperatures of around 2.1 ° C, with regional disparities. Observations show a slight upward (statistically insignificant) trend for the total annual rainfall over this same period of observed data. Nevertheless, the disparities between seasons and the interannual variability are very strong. The beginning of the 1980s is known for a succession of several dry years in Tunisia, influencing the general trend of the curves.

Regarding meteorological and climatic extremes, a change in the frequency of thermal and rainfall extremes is observed over the past period, based on the observed data from the meteorological stations of the Tunisian National Institute of Meteorology (INM) Projections show an increase in annual temperature at the 2050 and 2100 horizons for both scenarios. This increase ranges between 1 ° C and 1.8 ° C by 2050 on average for the set of studied models and between 2 ° C and 3 ° C at the end of the century, with the RCP 4.5 scenario. For the RCP 8.5 scenario, this increase ranges between 2 ° C and 2.3 ° C by 2050 on average for the set of studied models and between 4.1 ° C and 5.2 ° C at the end of the century. The coast in the North and the East of Tunisia would warm up less quickly than the West and the extreme South.

6.10 Jordan

6.10.1 Background

Jordan lies in the north of the Saudi Arabian Kingdom, It has one city on the eastern side of the Gulf of Aqaba called Aqaba city, having a coastal zone of 27 km along the Gulf

Currently, there is intensive exploitation of underground resources8, which provide around 81% of the water needs of the irrigated sector. The decrease in available stocks would be more pronounced in the north of the country which concentrates 80% of the resources already mobilized, and in the center of the country where groundwater is the main resource for agriculture and drinking water.

As Jordan is one of the most vulnerable countries to the risks of climate change the country is undergoing a rapid and effective process of enhancing its institutional and policy-relevant framework for addressing climate change challenges. It is the first country in the Middle East to develop a national climate change policy in 2013.

Jordan has three distinct ecological systems: (i) Jordan Valley which forms a narrow strip located below the mean sea level and has warm winters and hot summers with irrigation mainly practiced in this area; (ii) the western highlands where rainfall is relatively high and climate is typical of Mediterranean areas; and (iii) the arid and semiarid inland to the east (estimated to cover over 80% of the total area), known as the “Badia”, where the annual rainfall is below 50 mm. Badia is an Arabic word describing the open rangeland where Bedouins (nomads) live and practice seasonal grazing and browsing. According to the IUCN Red List of 2006, Jordan has 47 globally threatened species. Of the 83 mammal species existing in Jordan, 12 are considered globally threatened. As for birds, there are 15 globally threatened species in Jordan. Around 2500 (Fig. 6.15).

Based on long historical data obtained from Jordan Metrology Department (JMD), climatic variables are changing significantly at both the national and station level, indicating that climate change is becoming more apparent. Both the Mann-

Fig. 6.15 Average mean Temperature in Jordan

Kendall rank trend test and linear regression trends indicate that the annual precipitation tends to decrease significantly with time at a rate of 1.2 mm per year. Simultaneously, the mean, maximum and minimum air temperature tends to increase significantly by 0.02, 0.01, and 0.03 °C/year, respectively.

On the other hand, the relative humidity tends to increase significantly by an average of 0.08%/year, while class A-pan evaporation seems to have non-realistic estimations of decreasing significantly by 0.088 mm/year. The number of days of dust storms tends to decrease significantly by 0.09 days/ year and 0.06 days/year for visibility less than 1 km and 5 km. Besides, the historic data tested on both annual and monthly basis indicated that precipitation reduction is highly significant during the whole rainy season except for January. Similarly, during the dry seasons of June, July, and August, the precipitation has tended to increase over time, although this increase is considered negligible in its quantity as indicated by the magnitude of the slope. Interpolated spatial maps show the locations of these changes to be more apparent at both northern and southern parts. Dynamic downscaling for this study was achieved using the Africa CORDEX domain, in which 43 grid points with 50 km resolution were crossed throughout the country. Nine different GCM coupled with two RCMs for two RCPs (4.5 and 8.5) were used to assess future projections as compared to reference historic data (1980–2010).

Three-time horizons were selected; 2020–2050, 2040–2070, and 2070–2100. Climatic indices were extracted, processed, and debiased using delta and quantile-quantile scientific techniques. The selected climatic variables represent precipitation, mean temperature, maximum temperature, minimum temperature, wind speed and direction, relative humidity, class A evaporation, drought indices at 3 and 6 months basis, number of consecutive dry days, number of heavy rainfall days, and snow depth. The suggested reference model that was close to the median from all 9 models was "SMHI – NCC-NorESM-LR" a combination of the Norwegian Earth System Model as global climate model, and the Swedish SMHI regional climate model.

This model was further used to further to interpolate the climatic indices at 1 km resolution using combined statistical projections at the station level (Delta method) and geostatistical interpolation using the digital elevation model (DEM).

Based on the definitions of exposure consisting of likelihood, geographic magnitude, and confidence, the IPCC definitions were used. The qualitative measures (e.g. rare, unlikely, possible, likely, and extremely likely were based on the probability of occurrence per year, while the confidence scale was based on the processing of a multi-model ensemble (i.e. Very high, high, medium, low, and very low confidence). The projections' results agree with previous work of Second National Communication (SNC) to UNFCCC and are consistent with IPCC-AR5. For the year 2085, the two RCPs extremely likely predicted rise in mean temperature for all of the country, up +2.1 °C [+1.7 to +3.1 °C] for RCP 4.5, and + 4 °C [3.8–5.1 °C] for RCP 8. The increase was predicted to be homogeneous for the RCP 4.5, and stronger for the Eastern and the Southern regions for RCP 8.5.

Future dynamic projections predict extremely likely warmer summer compared to other seasons. Compared to the SNC that used CMIP3 results, multi-ensembles projections of CMIP5 results coupled with regional climate models in CORDEX give a more consistent trend to a likely drier climate. In 2070–2100, the cumulated precipitation could likely decrease by 15% [−6% to −25%] in RCP 4.5, by – 21% [−9% to −35%] in RCP 8.5. The decrease would be more marked in the western part of the country. It is more likely to have drier autumn and winter as compared to spring, with a median value of precipitation decrease reaching −35% in autumn in 2070–2100. Also, the dynamic projections predict more extremely likely heat waves where the analysis of summer temperature, monthly values, and the inter-annual variability reveal that some thresholds could be exceeded especially for a summer month where the average maximum temperature for the whole country could exceed 42–44 °C.

Drought events were likely predicted as indicated by the two indices of consecutive dry days and SPI. The maximum number of consecutive dry days would likely increase in the reference model of more than 30 days for 2070–2100 20 Jordan's Third National Communication on Climate Change Executive Summary period. The SPI indicates more frequent droughts with a 3 to 4 years lag. In contrast to drought, annual values still show possible heavy rainy years at the end of the century. More intense droughts would be (partly) compensated by rainy years, in a context of a general decrease of precipitation. Potential evaporation would also likely increase. However, the occurrence of snow would be unlikely to decrease.

Finally, the future projections unlikely to predict no trend for winds, where maximum wind speed does not evolve significantly. Climate exposure, risks, sensitivity, impacts, and adaptive capacity:

Concluding Remarks

1. All seven countries are vulnerable to climatic changes one way or another. The following management and policy suggestions are in place:
   (a) Institutional setup
   (b) Proactive Planning
   (c) Monitoring system and Research capabilities
   (d) Identification and assessment of options for adaptation
   (e) Upgrading resilience and awareness
   (f) Regional . . . .follow-up of implementation
   (g) Adoption in the educational system

6.11 Summary of Action Plan

6.11.1 Institutional Capacity

1. MENA countries must develop a regional center or organization for climate change. The center should collect and analyze data, build a geographic database and establish monitoring systems for indicators of concern to all Arab countries. It should be responsible for carrying out and enforcing strategies, plans, policies, and measures for proper adaptation
2. MENA countries must introduce concepts of ICZM and disaster reduction in the educational system and must develop the institutional capacity for integrated coastal zone management and build up capacity and follow up in these directions

3. MENA countries must develop the institutional capacity for risk reduction by adopting Early Warning Systems of flash floods, storm surges, and heatwaves.
4. MENA region countries must develop transparent data and information systems to allow early warning of problems

Awareness

1. All MENA region countries must develop awareness programs for upgrading the resilience of vulnerable communities, population, stakeholders, and investors
2. MENA Region countries must Work to create new job opportunities in safe areas and exercise environmental law enforcement of regulations such as SEA, EIA

Monitoring

1. It is necessary to monitor and assess land subsidence especially in coastal areas of excessive urban loads and excessive rates of oil and/or water extraction

References

Alexander, D. (2000). Vulnerability to landslides. In T. Glade, M. Anderson, & M. Crozier (Eds.), *Landslide hazard and risk* (pp. 175–198). John Wiley & Sons.

Becken, S. (2007). *Climate change and tourism – advances in knowledge and practice*. People Research Centre, Lincoln University.

Birkmann, J. (2008). *Measuring vulnerability to natural hazards*. UNU-Press.

Blaikie, P., Cannon, T., Davis, I., et al. (1994). *At risk: natural hazards, people's vulnerability and disasters*. Routledge.

Blaikie, P., Wisner, B., Cannon, T. & Davis, I. (2003). *At-risk: natural hazards, people's vulnerability, and disasters*.

Bohle, H.-G., Downing, T. & Watts, M. (2003). Climate change and social vulnerability: the sociology and geography of food insecurity. *Global Environmental Change, 4*, 37–48.

Byrne, T. R.. (2014). *Household adaptive capacity and current vulnerability to future climate change in Rural Nicaragua*. M.Sc., University of Lethbridge.

Cutter, S. (1993). Vulnerability to environmental hazards. *Progress in Human Geography, 20*, 529–539.

Cutter, S. L., Emrich, C. T., Webb, J. J., & Morath, D. (2009). *Social vulnerability to climate variability hazards: a review of the literature*. Hazards and Vulnerability Research Institute. Department of Geography. The UniversConclusionsCcC.

Dow, K. (1992). Exploring differences in our common future(s): the meaning of vulnerability to global environmental change. *Geoforum, 23*, 417–436.

Dow, K. & Downing, T. (1995). Vulnerability research: where things stand. *Human Dimensions Quarterly, 1*, 3–5.

Edwards, J., Gustafsson, M., & Näslund-Landenmark, B. (2007). Handbook for vulnerability mapping. In *Disaster reduction through awareness, preparedness, and prevention mechanisms in coastal settlements in Asia*. Swedish Rescue Services Agency.

El Raey, M. E. (1997). *Vulnerability assessment of the coastal zone of the Nile Delta, in the impact of sea-level rise; ocean and coastal manag* (pp. 371–329).

El Raey, M. E. (2008). *Impact of sea-level rise on the Arab region*. Published Report.

El Raey, M. E., & Atricia, K. (2011). *Mbote* (pp. 773–788). Springer.

El Raey, M., Fouda, Y., & Nasr, S. (1997). GIS assessment of the vulnerability of Rosetta, area to the impacts of sea-level rise. *Environmental Monitoring and Assessment*.
El Raey, M., Frihy, O., Nasr, S., & Dewidar, K. H. (1999). Vulnerability assessment of sea- level rise on port said governorate. *Environmental Monitoring and Assessment, 56*(2), 118–128.
ESRI. (2013). *Principals of remote sensing*.
Etkin, D. (1999). Risk transference and related trends: driving forces towards more mega-disasters. *Environmental Hazards, 1*, 69.
FitzGerald, G., Fenster, M., Argow, B., & Buynevich, I. (2008). Coastal Impacts Dueto Sea-Level Rise. *Annual review on earth planetary science, 36*, 601–647
Frantzova et al. (2008). Creative Commons Attribution 4.0 International.
Gilbert, C. (1995). Studying disaster: A review of the main conceptual tools. *International Journal of Mass Emergencies and Disasters, 13*, 231–240.
Gillard, O. (2016). *Hazards, vulnerability, and risk* (pp. 19–29).
Giorgi, F. (2010). Uncertainties in climate change projections, from the global to the regional scale. *EPJ Web of Conferences, 9*, 115–129.
Glantz, M. (1994). *Creeping environmental phenomena and societal responses to them*. Workshop report. National center for atmospheric research. Boulder, USA, 274 pp.
Harrod, R. P., & Martin, D. L. (2014). *Bioarchaeology of climate change and violence ethical considerations*. Springer.
Hegerl, G. C., & Zwiers, F. W. (2007). Understanding and attributing climate change. In *Climate change 2007: The physical science basis. Contribution of working Group I to the fourth assessment report of the intergovernmental panel on climate change*. Cambridge University Press.
Hulbutta. (2009). GIS analysis of global impacts from sea level rise. *Photogrammetric Engineering & Remote Sensing, 75*.
IPCC. (2012). *Managing the risks of extreme events and disasters to advance climate change adaptation, A special report of working Groups I and II of the intergovernmental panel on climate change*. Cambridge University Press.
Kelman, I. (2009). Understanding vulnerability to understand disasters. *Center for International Climate and Environmental Research* - Oslo (CICERO).
Kelman, I., & Lewis, J. (2010). Places, people, and perpetuity: community capacities in ecologies of catastrophe. *ACME: An International E-Journal for Critical Geographies, 9*, 191–220.
Lewis, D. (2010). *Emergency management 101: "The questions you should be asking in your community"*. Utah League of Cities and Towns, Annual Convention.
Lockwood, J. P., Hazlett, R. W., & Wiley-Blackwell. (2011). Volcanoes: Global Perspectives. *Pure and Applied Geophysics, 168*, 1871–1872.
Lynn, K., Mackendrick, K. & Donoghue, E. M. 2011. *Social vulnerability and climate change: synthesis of literature*. United States Department of Agriculture Forest Service. Pacific Northwest Research Station.
Moss, R. H., Brenkert, A. L. & Malone, E. L. (2001). *Vulnerability to climate change: A quantitative approach* 88
NASA & GISS. (2013). *Global climate change.*
National Research Council, N. (2012). Climate change, evidence, impacts, and choices. *National Academy of Sciences*.
Quiggin, J. (2008). Uncertainty and climate change policy. *Economic Analysis and Policy, 38*, 203–210.
Rahmstorf, S., Caesar, L., Robinson, A., Saba, V., & Feulner, G. (2018). An observed fingerprint of a weakening Atlantic Ocean overturning circulation. *EGU General Assembly, 20*.
Rueter, J. (2013). *Environmental sciences and management program*. Chapter 9 – Risk and Uncertainty.
Scheer, D., Benighaus, C., Benighaus, L., Renn, O., Gold, S., Roder, B., & Bol, G. F. (2014). The distinction between risk and hazard: understanding and use in stakeholder communication. *Risk Analysis, 34*, 1270–1285.

Sestini, G. (1991). *The implication of climate changer to the Nile Delta*. Report for the Nile DeltaeportWC/14Nairobi, Kenya, UNEP.

Snoussi, M., Ouceni, T. & Nazgin, S. S. (2008). *Precision.*

Sørensen, C. S. & Jebens, M. (2015). How can awareness in civil society and governance be raised? Reducing risks from coastal hazards. *Proceedings of the 24th New South Wales coastal conference.*

Thinda, T. K. A. (2009). Community-based Hazard and vulnerability assessment: a case study in Lusaka informal settlement, City of Tshwane. In *A mini-dissertation submitted in partial fulfillment of the requirements for the degree of masters in disaster risk management.* The University of the Free State

Timmerman, P. (1981). Vulnerability. *Resilience, and the Collapse of Society Environmental Monograph, Institute of Environmental Studies, 1*.

Trofimenko, N. (2011). *Climate change: current issues*. Kiel Institute for the World Economy.

UNEP (United Nations Environment Programme). (1999). *Chemical, human, environmental, and ecological risk assessment*. Training module No. 3, 67 pp.

UNFCCC. (2011). *Framework convention on climate change, water, and climate change impacts and adaptation strategies*

UNISDR. (2008). Hyogo framework for 2005–2015: Building the resilience of the nations and communities to disasters. Available at: www.unisdr.org/wcdr/intergover/official-docs/Hyogoframework-action-english.pdf.

Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004). *At-risk: natural hazards, people's vulnerability, and disasters* (2nd ed.). Routledge.

World Meteorological Organization, W (2013). *Integrated flood management tools series 20*

Yasir, A. (2009). *The political economy of disaster vulnerability: a case study of Pakistan earthquake 2005*. London School of Economics & Political Science.