

2009 Report of the Arab Forum for Environment and Development

# ARAB ENVIRONMENT CLIMATE CHANGE

IMPACT OF CLIMATE CHANGE ON ARAB COUNTRIES

EDITED BY: **MOSTAFA K. TOLBA** AND **NAJIB W. SAAB**

المنتدى العربي للبيئة والتنمية  
ARAB FORUM FOR  
ENVIRONMENT AND DEVELOPMENT



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2009 REPORT OF THE ARAB FORUM FOR ENVIRONMENT AND DEVELOPMENT

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## Preface

*'Impact of Climate Change on the Arab Countries'* is the second of a series of annual reports produced by the Arab Forum for *Environment and Development (AFED)*. The first AFED report, published in 2008 under the title *'Arab Environment: Future Challenges'*, covered the most pressing environmental issues facing the region, and went beyond to provide a policy-oriented analysis. The report was presented to AFED's annual conference which convened in Manama in October 2008. That conference decided on a set of recommendations that were endorsed by national and regional institutions. The report's findings helped to raise awareness across the region, and its recommendations resonated in policies and official positions.

The 2009 AFED report has been designed to provide information to governments, business, academia and the public about the impact of climate change on the Arab countries, and encourage concrete action to face the challenge. The report analyzes the Arab response to the urgent need for adaptation measures, and uses the latest research findings to describe the vulnerabilities of natural and human systems in the Arab world to climate change and the impacts on each sector of human activity. The systems selected for this study include: coastal areas, food production, fresh water, human health, bio-diversity, in addition to the consequences on housing, transport, and tourism. In an attempt to help shape adequate policies, the report discusses options for a post-Kyoto regime and outlines the state of international negotiations in this regard.

AFED reveals in the report the findings of a pan-Arab opinion survey it conducted in 2009, illustrating public attitudes regarding climate change. Another special feature is a study carried out for AFED by the Center of Remote Sensing at Boston University, which analyzes various scenarios of impacts of climate change, especially on coastal areas, based on space images of the region.

The report identifies the major sources of greenhouse gas emissions in the Arab world, found to contribute merely 4.2% to the global emissions. However, the impact of climate change on the fragile environment of the region and its people is expected to be immense, which demands urgent planning for adaptation measures.

Climate change acts directly to change natural weather patterns, but the effects cascade quickly through many sectors. Scarcity of food and water, loss of coastal areas, disruption to ecosystems, and adverse effects on human health are just some of the direct threats. The economic sector is not immune and disruptions to infrastructure and tourism, for example, could conceivably cancel their economic benefits. For this reason, governments of the region have a large stake in making adaptation a national priority.

If this report can inform and help shape public policy in the Arab world on climate change, then it would have served its purpose. We also hope that the report would provide policy options which will assist Arab countries to be active parties in the upcoming negotiations for a Post- Kyoto treaty.

The editors wish to thank all those who supported this initiative, specifically Dr. Mohamed Kassas and Dr. Mohamed El-Ashry, who helped in laying down the methodology and appraising of the outcome. Thanks are also due to the authors and the many experts who contributed to the contents. AFED's special thanks go to the Environment Agency-Abu Dhabi, official sponsor of the conference to launch the 2009 Report and partner to many other AFED activities. AFED also wishes to thank the OPEC Fund for International Development (OFID) for its continuous genuine support to the Forum's programmes. Thanks are also due to the United Nations Environment Programme (UNEP) and all corporate and media partners who made this endeavor possible.

*The Editors*

## EXECUTIVE SUMMARY

# Arab Environment: Climate Change

## Impact of Climate Change on Arab Countries

### 2009 REPORT OF THE ARAB FORUM FOR ENVIRONMENT AND DEVELOPMENT (AFED)

The world is once again at a crossroads; as the scientific basis behind climate change is becoming more solid, the imperative for strong and collective action is becoming increasingly urgent. This urgency is one shared by all countries and regions of the world, as all will be affected. The Arab region is by no means an exception; in fact, given the very high vulnerability of Arab countries to the projected impacts of climate change, it cannot afford inaction on either the global, regional, or national scales.

Based on the findings of the Intergovernmental Panel on Climate Change (IPCC) and hundreds of references quoted in the 2009 Report of the Arab Forum for Environment and Development (AFED), we can categorically state that the Arab countries are in many ways among the most vulnerable in the world to the potential impacts of climate change, the most significant of which are increased average temperatures, less and more erratic precipitation, and sea level rise (SLR), in a region which already suffers from aridity, recurrent drought and water scarcity.

**Water resources** are dwindling. Regardless of climate change, the already critical situation of water scarcity in the Arab world will reach severe levels by 2025. A report recently published in Japan has warned that what is known as the Fertile Crescent, spanning from Iraq and Syria to Lebanon, Jordan and Palestine, would lose all traits of fertility and might disappear before the end of the century because of deteriorating water supply from the major rivers. Man-made problems, mainly the widespread construction of dams and unsustainable irrigation practices which waste about half of the water resources, and rates of human water consumption which are well above international standards in some Arab countries, are making the situation worse. The expected effects of climate change are likely to exacerbate this deterioration. With continuing increases in temperatures, water flow in the Euphrates may decrease by 30% and that of the Jordan River by 80% before the turn of the century. If this is the case in the Fertile Crescent, how will the situation be in other arid Arab countries? Water management is therefore an urgent issue. We need to improve efficiency, especially in irrigation, and to develop new water resources, including innovative desalination technologies.

**Sea level rise (SLR)** is likewise a big risk, since the bulk of the Arab region's economic activity, agriculture and population centres are in the coastal zone, which is highly vulnerable to sea level rise. This can be in the form of both coastal region inundation and increasing salinity of soil and available freshwater resources such as aquifers.



A simulation carried out for AFED by Boston University's Center for Remote Sensing revealed that a sea level rise of only 1 metre would directly impact 41,500 km<sup>2</sup> of the Arab coastal lands. The most serious impacts of sea level rise would be in Egypt, Tunisia, Morocco, Algeria, Kuwait, Qatar, Bahrain, and the UAE. The effects on the region's agricultural sector would mostly be felt in Egypt, where a 1 metre rise would put 12% of the country's agricultural land at risk. It would also directly affect 3.2% of the population in the Arab countries, compared to a global percentage of about 1.28%.

**Human health** would be adversely affected by higher temperatures, mainly due to changes in geographical ranges of disease vectors like mosquitoes, water-borne pathogens, water quality, air quality and food availability and quality. Incidence of infectious diseases like malaria and schistosomiasis will increase, mainly in Egypt, Morocco and Sudan. Malaria, which already infects 3 million people annually in the Arab region, will become more prevalent and enter new territories as higher temperatures reduce the incubation period, spread the range of malaria-bearing mosquitoes and increase their abundance. Higher CO<sub>2</sub> concentrations and fiercer and more frequent sand storms in desert areas will increase allergic reactions and pulmonary diseases all over the region.

**Food production** would face an increased threat, affecting basic human needs. Harsher and expanding aridity and changes in the spans of seasons may cut agricultural yields in half if no alternative measures are applied. Urgent adaptive measures are required, including changes in crop varieties, fertilizer and irrigation practices. Higher temperatures, lower rainfall and alteration in the span of seasons will require developing new varieties that can adapt to the emerging conditions. Crops which need less water and can withstand higher levels of salinity should be developed and introduced on a large scale.

**Tourism**, an important sector of the economy for a number of Arab countries, is highly vulnerable to climate change. An increase of between 1-4°C in average temperature will cause a drastic decline in the index of tourism comfort all over the region. Areas classified between "good" and "excellent" are likely to become "marginal to "unfavourable" by the year 2080, mainly because of hotter summers, extreme weather events, water scarcity and ecosystems degradation. Bleaching of coral reefs will affect tourism in countries in the Red Sea basin, mainly Egypt and Jordan. Beach erosion and sea level rise will affect coastal tourist destinations, mainly in Egypt, Tunisia, Morocco, Syria, Jordan and Lebanon, especially in locations where sandy beach stretches are narrow and buildings are close to the shoreline. Options for alternative tourism, which are less vulnerable to climatic variability, should be explored, such as cultural tourism. Countries with coastal areas highly vulnerable to sea level rise should develop alternative inland tourist destinations.

**Biodiversity** in the Arab countries, already deteriorating, will be further damaged by intensifying climate change. A 2°C rise in temperature will make extinct up to 40% of all the species. The Arab countries have many unique formations that are especially vulnerable to climate change risk, such as the cedar forests in Lebanon and Syria, the mangroves in Qatar, the reed marshes of Iraq, the high mountain ranges of Yemen and Oman, and the coastal mountain ranges of the Red Sea.

**Land use and urban planning** regulations in the Arab region largely ignore basic adaptation requirements to climate change. An estimated 75% of buildings and infrastructure in the region are at direct risk of climate change impacts, mainly from sea level rise, higher intensity and frequency of hot days and storm surges. Reliability of transportation systems, water supply and wastewater networks, and energy generation stations will be at risk. At a time when 42 small island-states have established the Alliance of Small Island States (AOSIS) to defend their common interests in the face of the damaging effects of climate change, we see artificial islands being built in some Arab countries and others being planned. These islands will be among the first to be swallowed by the rising sea level due to their small size and low elevation. Planning requirements specifying a minimum distance between permanent structures and the shoreline should take into account the threat of rising sea level. Choices of construction materials used for buildings and roads should consider the risk of rising temperatures. Plans for making infrastructure and buildings resilient to climate change are needed.

This AFED report has found that virtually no work is being carried out to make the Arab countries prepared for climate change challenges. Specifically, no concerted data gathering and research efforts could be traced regarding the impacts of climate change on health, infrastructure, biodiversity, tourism, water and food production. The economic impact seems to be totally ignored. Reliable records on climate patterns in the region barely exist.

Policymaking in the region has displayed, in many respects, deficiencies that need to be urgently remedied if Arab countries are to prepare for the potential negative impacts of climate change. Those range from sustainable management of natural resources to risk planning. The Maldives, for instance, has plans to save funds as an insurance policy to relocate its entire population in case of sea level rise.

In the face of these urgent challenges and vulnerabilities, this report addresses the key areas at stake and hopes to serve as a basis upon which informed decision-making, planning, and diplomatic efforts can be built.

## INTRODUCTION

# Arab Environment: Climate Change

2009 Report of the Arab Forum for Environment and Development (AFED)

## Impact of Climate Change on Arab Countries *Main Findings and Conclusions*

MOSTAFA K. TOLBA AND NAJIB W. SAAB

Ours is a habitable planet because of a combination of conditions congenial to life. Earth's climate is conducive to life because atmospheric greenhouse gas concentrations, most notably CO<sub>2</sub>, trap a portion of the sunlight reflected off its surface, thereby warming the planet. Since the Industrial Revolution human activities – in particular, fossil fuel usage, land use patterns, agriculture and deforestation – have increased greenhouse gas concentrations in the atmosphere, causing average temperatures to rise. That the climate is actually changing is now a globally accepted fact; even the few opponents who still deny that it is man-made agree that it is happening, but as a manifestation of a natural cycle.

By 2007, the Intergovernmental Panel on Climate Change (IPCC), the United Nations' scientific body on the issue, stated with high certainty that human causes lay behind most of the observed global temperature increases. Atmospheric CO<sub>2</sub> concentrations have increased from approximately 280 ppm (parts per million) in the pre-industrial age to around 430 today. At the level of 550 ppm, which could be reached as early as 2035, global average temperatures may rise by more than 2°C. Under a business-as-usual (BAU) scenario, the stock of greenhouse gases could more than triple by the end of the century, giving at least a 50% risk of temperatures rising by more than 5°C during the decades to follow. The scale of such an increase could be illustrated by the fact that the climate is presently 5°C warmer than in the last ice age, which was over 10,000 years ago.

The amount of carbon held in the oceans has increased, causing gradual but steady acidification that threatens marine ecosystems. Warmer water temperatures have also caused much coral bleaching. Increasing average temperatures have steadily caused melting of ice in the polar regions as well as of glaciers around the world. Warming ocean waters may cause the sea level to rise by up to 59 cm by 2100 according to IPCC 2007 estimates, or even up to 5 metres if the melting of the Antarctic ice sheet is taken into consideration.

The IPCC predicts that 20 to 30% of species will be made extinct if the temperature increases by more than 1°C, which is already virtually unavoidable. Extreme weather events and variability will also likely to ensue.

A number of recent studies suggest that the estimates of the 2007 IPCC Fourth Assessment Report were too conservative, and that projections will have to be altered to reflect stronger impacts. For example, developing world emissions have been growing much more quickly than previously thought, and they are now projected to surpass those from the developed world by 2010; this crossing point had previously been projected for 2020 or even later. The IEA's Reference Forecasts of Chinese CO<sub>2</sub> emissions, for instance, have been drastically revised upwards between 2000 and 2007. In September 2009 evidence was found by US scientists that the thickness of the Antarctic ice sheet has declined by 53% since the 1980 peak, creating the potential for worse than projected sea level rise.

Christopher Field, an American member of the IPCC and founding director of the Carnegie Institution's Department of Global Ecology at Stanford University, said at the annual meeting of the American Association for the Advancement of Science in February 2009 that the pace of climate change exceeds predictions, as emissions since 2000 have outpaced the estimates used in the IPCC's 2007 report. Lord Nicholas Stern likewise said in 2008 that in his 2006 Review of the economic impacts of climate change for the British government, which advocated strong and immediate climate change action, "we underestimated the risks... we underestimated the damage associated with temperature increases... and we underestimated the probabilities of temperature increases."

The climate change challenge is one that is global both in its causes and in its solutions. It is ubiquitous in that almost all human activities contribute to the problem, and will also be affected by its impacts.

Greenhouse gas emissions are a classical example of what economists call 'an externality': the costs are felt by everyone around the world, not just by the individuals or countries responsible for the emissions. The damage associated with climate change is not distributed proportionately according to emissions, as the burden is shared by those who contribute least to it. As an extra complication, the most serious damages will be not to present generations but to future ones, which do not have a strong voice at the negotiating table.

Finally, there is the temporal aspect of the problem. The costs of mitigation and adaptation to climate change will be incurred immediately while the benefits will be in the form of avoided future damages, which are difficult to quantify. In other words, politicians are finding it difficult to justify immediate costs in order to yield future benefits.

But the economic consequences of inaction are immense: it is estimated that for every 1°C rise in average global temperature, economic growth would drop by between 2-3%. The World Economic and Social Survey released by the UN in 2009 estimates the costs of mitigation and adaptation at 1% of World Gross Product (WGP), which is small compared to the costs and risks of the impacts of climate change. If action is not taken, or is delayed "by continuing in the present business-as-usual scenario, or making only marginal change, the permanent loss of projected WGP could be as high as 20%." These figures would dwarf the losses of the economic meltdown of 2008-9. The dilemma is that the impacts of climate change will be most acutely felt in developing countries, which possess the least capacity to cope and adapt, both technologically and financially. This makes technology transfer and appropriate financial packages crucial for any global agreement or effective action to deal with climate change.

It is no longer a question of whether or not climate change is happening. The question now is how climate change will manifest itself regionally and locally and what can be done about it. For governments, the key issue is balancing short-term economic growth with long-term sustainable development. A complicating factor is the scientific uncertainty surrounding climate change: the exact impacts of climate change and their locations cannot be predicted with perfect accuracy, nor can so-called “tipping points” – points beyond which climate changes are irreversible – be fully and accurately predicted.

However, this AFED Report argues that the climate change challenge should be treated like any other decision made in the face of uncertainty: a risk-management, or insurance, framework. Utilizing the insurance principle, as long as there is sufficient likelihood of significant damage, we take measured anticipatory action, the costs of which are fully justified. What is required is an honest evaluation of the level of insurance deemed necessary to protect – with an acceptable amount of certainty – against the impacts of climate change. Uncertainty is not and should not be an excuse for inaction.

As stated previously, effectively battling climate change will require concerted global action. The division of responsibilities – “common but differentiated responsibilities,” according to the UNFCCC – runs into issues of equity. How should the different responsibilities be fairly distributed? Without adequately answering this question, any climate change agreement will be neither acceptable nor sustainable. At the same time, any acceptable and sustainable climate change agreement will also have to be effective. It will need to be acceptable to all, respected by all, sufficiently ambitious, and flexible enough to adjust to changing scientific and technological information.

While this report endorses the view that developed countries will need to take the lead in global climate change action, developing countries will also need to play their part. Moreover, while all countries have a legitimate right to economic development, this need not necessarily conflict with strategies to reduce emissions. With the help of developed countries, developing countries should be able to reduce their carbon intensity to set them on a path to sustainable development. This should be achieved through effective mechanisms of technological and financial transfers and investment, in a legally binding treaty.

Looking ahead to the negotiations in Copenhagen, it is clear that developing countries are hesitant to commit to any obligations that place significant restrictions on their economic growth. They point to their priority responsibilities to provide employment opportunities and better standards of living for their populations.

At the same time, developed countries, in particular the United States, will not accept a climate change agreement in which the major emitters among the developing countries are allowed to continue with “business as usual” development. There must be give and take between the two groups, developed and developing.

Since the successful meeting of the Conference of the Parties in Bali in December 2007, little progress has been made in the negotiations for a post-2012 agreement on climate change. The Bali Action Plan/Road Map calls for a long-term goal for global emissions reduction and mitigation actions by developed and developing countries. Besides mitigation, it also includes adaptation, reforestation, tech-

nology cooperation, and finance. With Copenhagen fast approaching, the negotiations have stalled and there is little or no agreement on any of these.

Disagreement is not only between developed and developing countries, it is also among developed countries. The G-8 Summits in 2008 and 2009 agreed to reduce global greenhouse gas emissions by 50% by 2050 and to limit the rise in worldwide temperatures to no more than 2 degrees Celsius. Developing countries do not want to support a global target in fear that they will be asked to accept intermediate targets leading to the 2050 one. In addition, there is disagreement among developed countries on near-term sharing of the burden of emissions reduction. The EU can commit to 20% reduction by 2020 from 1990 levels and can go to 30% if others make the same commitment. Similarly, Japan would reduce their emissions by 25% by 2020 from 1990 levels. On the other hand, US legislation, if it becomes law, would result in a 17% reduction by 2020 from 2005 levels.

Many had hoped that world leaders gathered in New York, on September 22, 2009, for a global summit on climate change might move things forward as they did in 2007 before Bali. Those hopes were dashed. In speech after speech, presidents and prime-ministers spoke of the importance and urgency of confronting climate change but stopped short of providing specifics of what they were prepared to do in Copenhagen and beyond.

While some believe that a strong deal is still possible, others have begun to talk of a “political declaration” rather than a full agreement. Such declaration would recognize actions being taken and/or planned by countries in their own best interest (for example, energy efficiency and renewable energy) and continue negotiations.

The Arab region's minimal contribution to climate change through its limited greenhouse gas emissions, at less than 5% of the global figure, is dwarfed by the region's immense vulnerabilities to climate change. Arab countries have a vested interest in pushing forcefully for a strong treaty that incorporates a diversity of strict climate change mitigation and adaptation measures and, more importantly, to ensure financial and technical assistance to those who need it for achieving its targets.

Arab governments, as an indication of their willingness to participate in the global efforts to mitigate climate change, can stress the development of clean energy technologies, particularly in light of the abundant renewable energy resources available in the Arab world, specifically solar, wind and hydro. Finally, with an eye on the Copenhagen negotiations in December 2009, Arab countries would do well to formulate a unified position on the key issues at stake.

## **CLIMATE CHANGE MITIGATION EFFORTS**

Arab countries, though not primary contributors to atmospheric greenhouse gas emissions, will have to undertake mitigation efforts as part of global action. A review of Arab national communications reports to the UNFCCC and current projects and initiatives shows that Arab countries are in fact implementing various climate friendly policies and measures, encompassing both measures to reduce anthropogenic GHG emissions as well as those to enhance carbon sinks.

Specific examples in the Arab world are the commercialization of wind energy in Egypt; widespread use of solar heating in Palestine, Tunisia, and Morocco; the introduction of compressed natural gas (CNG) as a transport fuel in Egypt; the first concentrated solar power projects in Egypt, Tunisia, Morocco, and Algeria; the first two Arab green building councils in The UAE and Egypt; the massive forestation program in the UAE; Masdar, the first zero-carbon city in Abu Dhabi; the pioneering carbon capture and storage project in Algeria; and Jordan's introduction of duty and tax exemptions to encourage the import of hybrid cars. However, most of these initiatives are fragmented and do not appear to have been implemented as part of a comprehensive policy framework at the national level, let alone at the regional one.

In a particularly promising development, the newly established International Renewable Energy Agency (IRENA) has chosen Masdar City in Abu Dhabi as the agency's first headquarters. This is not only very important for the developing world as a whole but will hopefully also lead to significant research and investments into renewable energy in the Arab region.

Arab-Arab cooperation can also be improved, for example in the areas of energy efficiency and renewable energy, the use of compressed natural gas as a transport fuel, and investing in carbon capture and storage. Given the importance of the fossil fuel industry in the Arab region, Arab countries have a vested interest in helping develop carbon capture and storage technology to help offset emissions due to fossil fuels usage. Ultimately, if this technology can be made sufficiently viable, it will be an important part of global climate change mitigation strategies. As fossil fuels will remain an important part of the energy mix in any future scenario, carbon capture and storage is an important area into which Arab scientists have to get involved and resources need to be devoted.

## **PUBLIC PERCEPTION OF CLIMATE CHANGE**

AFED conducted a pan-Arab survey in order to explore awareness of climate change among the Arab public, their perceptions of the need to take action, and their willingness to personally contribute to climate change mitigation and adaptation measures.

The results of the survey showed increasing awareness: 98% believed that the climate is changing, and 89% believed this was due to human activities. 51% believed that governments were not acting adequately to address the problem, while 84% believed climate change posed a serious challenge to their countries. Over 94% believed that their countries would benefit from participating in global action to deal with climate change, and 93% pledged to participate in personal action to reduce their contribution to the problem.

Asked to choose sectors where climate change will have a major impact in their countries, it was notable that not a single respondent said there would be no effect at all. The majority, at the regional level, gave priority to health, drinking water and food, followed by coastal areas. Those surveyed were also asked to choose the three most important measures to mitigate the causes and to adapt to the effects of climate change. Changing consumption patterns, mainly reducing the use of energy, was the main measure chosen, followed by education and awareness. Ratifying and implementing international treaties came third.



The respondents to the AFED survey revealed a clear desire for their governments to participate and cooperate proactively in order to reach a solution to the problem of climate change; the Arab public seems ready to accept and be part of concrete national and regional action to deal with climate change. The sceptical attitudes which prevailed among some groups on the facts and causes of climate change, either denying it entirely or limiting it to natural causes, are receding. Government inaction is no longer an option.

## **CLIMATE CHANGE IN THE ARAB WORLD: VULNERABILITIES AND IMPACT**

### **COASTAL AREAS**

The Arab region's coastal zones are of immense importance. The total length of the coastal zone in the Arab region is 34,000 km, of which 18,000km is inhabited. Most of the region's major cities and economic activity is in the coastal zones. Vastly fertile agricultural lands are located in low-lying, coastal areas such as the Nile Delta, and popular tourist activities depend on marine and coastal assets, like coral reefs and associated fauna.

Individual Arab countries will be affected differently under various climate change related sea level rise projections. Qatar, the UAE, Kuwait, and Tunisia are most vulnerable in terms of their land mass: 1 to 3 % of land in these countries will be affected by a 1 metre SLR. Of these, Qatar is by far the most exposed: under various different SLR projections the figure rises from approximately 3% of land (1m) to 8% (3m), and even up to more than 13% (5m).

As for SLR's effect on GDP, Egypt's economy is by far the most vulnerable: for SLR of 1 metre, more than 6% of its GDP is at risk, which rises to more than 12% for an SLR of 3 metres. Qatar, Tunisia, and the UAE are also exposed, as over 2% of their respective GDPs are at risk for an SLR of 1 metre, rising to between 3 and 5% for SLR of 3 metres.

When it comes to the agricultural sector, Egypt will be most impacted by SLR. More than 12% of Egypt's best agricultural lands in the Nile Delta are at risk from SLR of 1 metre, and this figure rises dramatically to 25% (SLR of 3m) and even almost 35% (extreme SLR of 5m).

### **HUMAN HEALTH**

Increasingly, scientists are beginning to recognize climate change as an emerging risk factor for human health. A number of projected climate change impacts will have negative implications for human health. The health effects can be direct, such as extreme weather events like storms, floods, and heat waves, or indirect, such as changes in the ranges of disease vectors (e.g., mosquitoes), water-borne pathogens, water quality, air quality, and food availability and quality. Furthermore, the actual health impacts will be different for different Arab countries, according to local environmental conditions, socio-economic circumstances, and the range of adopted social, institutional, technological, and behavioural measures.

The limited research conducted in Arab countries has shown that climate change



plays an important role in the spread of vector-borne infectious diseases, such as malaria and schistosomiasis (Egypt, Morocco and Sudan). It also affects the seasonal concentrations of some allergens in the atmosphere, causing allergic reactions and pulmonary diseases (Lebanon, Saudi Arabia and UAE), and worsens the public health impact of heat waves especially in Arab countries with hot summer climates.

Heat waves are projected to become more intense, frequent, and prolonged due to climate change. A number of studies in the region have looked at heat-related mortality rates, and have consistently found a significant association between temperature and mortality.

The link between infectious diseases – which globally kill between 14 and 17 million people each year – and climatic conditions has been studied extensively. Malaria, for instance, which infects about 3 million people in the Arab region each year, may become more prevalent as higher temperatures reduce the disease's incubation period, spread the range of malaria-bearing mosquitoes, and increase mosquito abundance.

Indirectly, a number of climate change impacts discussed in various sections of this report may also have health ramifications. For instance, sea level rise and coastal flooding may impact food security and lead to malnutrition and hunger, and reduced precipitation and increased temperatures may aggravate water scarcity, increasing its negative impact on human health.

Health systems in the Arab world need to be adapted and prepared to respond to the consequences of climate change.

## **FRESH WATER**

Water is scarce across the region, with available water resources below 1,000 m<sup>3</sup> per capita per year in all Arab countries except Iraq, Lebanon, and Syria. Although the Arab region occupies 10% of the planet, it contains less than 1% of the world's freshwater resources. The predicted impacts of climate change in the Arab region, namely increased temperatures as well as reduced and more erratic precipitation, will exacerbate an already critical state of vulnerability, and place even more stress on the limited fresh water resources. Both the quantity and quality of fresh water resources are in danger. High population growth rates in the region, and the high rate of per capita consumption of fresh water, make the problem chronic and aggravate its impact, with around 80% of fresh water resources devoted to agriculture.

Climate change is expected to affect the flow of rivers, which could cause water shortages (in case of decreased rainfall) or flooding (in case of periodic increased rainfall). Water regimes in riparian countries will also affect Arab countries dependent on rivers originating elsewhere, such as Iraq, Syria, Egypt and Sudan.

Recommended adaptation measures include changing cropping patterns, adopting water saving techniques, introducing integrated water resource management, developing new varieties of crops that are more resilient to higher temperatures and soil salinity, and initiating innovative desalination technologies. Finally, Arab countries have to reconsider allocating water for different development

activities based on water use efficiency represented by production per cubic meter of water, rather than production per unit area of land, i.e., optimizing water use, especially in agriculture, which gives maximum economic return per unit volume of water.

## **FOOD PRODUCTION**

Food security in the Arab world has long been subject to environmental and socio-economic pressures. The dominant arid conditions, limited water resources, erratic cropping patterns, intensive grazing, population growth, and low knowledge and technology levels all affect food production systems in the region.

The dominant agricultural system in Arab countries is rainfed agriculture; as such, annual agricultural productivity and food security are highly correlated to the annual variability of precipitation. Climate change may increase the variability of rainfall and thus increase incidents of drought.

Projected climate changes may have disastrous effects on agricultural production in the Arab world. As a number of studies have shown, increased temperatures cause much higher water needs in summer crops. Water scarcity in the Arab region is projected to increase rather than decrease, and therefore agriculture – and in turn the Arab region's food security – is highly vulnerable to climate change, with the risk of 50% decrease in food production if current practices continue.

What policies can help adapt the Arab world's agricultural sector to climate change? This AFED Report recommends that crop varieties, fertilizer, irrigation and other water management practices should be altered, as necessary, in light of climate change vulnerabilities. Also, information on climate variability and seasonal climate forecasting need to be improved in order to reduce production risk.

## **TOURISM**

Tourism is important for a number of Arab economies. However, like most sectors of economic activity, it is vulnerable to the impacts of climate change.

The attractiveness of a tourism destination depends to a significant degree on the climate, although clearly a number of other factors are also important. Using an index of various climatic factors, the index of tourism comfort measures the degree of climatic comfort at a given site. With climate change, however, the climatic factors change. For example, the arid lands in the Arab region will expand, moving north in North Africa.

The index of tourism comfort will probably decline in the Arab world in the coming decades. The areas currently classified as "good", "very good" and "excellent" will be less favourable by the year 2080, with climate change to blame. Many of the projected climate changes in the Arab region will impact the attractiveness of Arab tourist destinations. Hotter summers, droughts, extreme weather events, water scarcity, and ecosystem degradation are examples.

Coral reefs are important tourist attractions for Egypt and Jordan, but are at the same time extremely vulnerable to climatic changes, brought about by increased temperatures and ocean acidity, both of which contribute to coral bleaching. Beach erosion is also a risk to the attractiveness of coastal areas. Narrow low-lying sandy beaches will be badly affected and these stretches would become unsuitable for sea-goers.

Much will depend on how well the sector can adapt. Future tourism development must take anticipated changes into account through integrated and inclusive planning, such as clearer guidelines on the allowed distance between permanent structures and the shoreline. Options for alternative and more sustainable tourism which is less sensitive to climatic variability, such as cultural tourism, should be explored. Finally, more inland and desert tourist destinations should be developed.

## **INFRASTRUCTURE**

Climate change is expected to significantly affect infrastructure across the Arab world. Transportation infrastructure is generally vulnerable to projected increases in the intensity and frequency of hot days, storm activities, and sea level rise. Infrastructure in the coastal zones is particularly vulnerable to SLR and possible storm surges. These risks are highest in Egypt, Bahrain, and the UAE.

Reliability of water supply systems will be impacted by diminishing fresh water supplies and higher average temperatures. Wastewater networks are particularly vulnerable to excessive rainfall events and SLR. Energy generation will be hampered by higher ambient temperatures which will reduce the efficiency and capacity of gas turbines, and reduce the cooling efficiency of thermal plants. Energy distribution and transmission systems will be more prone to failure as extreme weather events become more frequent.

What should be done? Infrastructure should be enhanced to withstand climate change, design criteria and operations should be upgraded to take it into account, new technologies should be utilized and the public should be brought into the decision-making process.

## **BIODIVERSITY**

Many plant and animal species in the Arab world already face threats to their survival, and their vulnerability will be exacerbated by the projected impacts of climate change. The number of species in the Arab world is already low by global standards, and the general harshness of the arid climate makes the region especially vulnerable to significant species loss. Using the IUCN threat categories, Yemen has by far the highest number of threatened plant species at 159, while Sudan and Somalia have 17 each.

Djibouti, Egypt, Jordan, Morocco, Saudi Arabia, Somalia, Sudan and Yemen all have more than 80 threatened animal species, with Egypt topping the list at 108 species. Climate change could alter the animal composition of entire ecosystems.

Ornithological diversity is a major asset to the Arab world and is very threatened

by climate change. Many Arab countries lie on important bird migration routes. In particular, Djibouti, Mauritania, and Bahrain are home to millions of migratory birds and large breeding colonies.

Unique species that are restricted in their habitat range, and/or are at the margin of their ecological tolerances, are most vulnerable to climate change. In the Arab region, these habitats include the mangroves in Qatar, the cedar forests in Lebanon and Syria, the islands of Djibouti, the marshes of Iraq, the high mountain ranges of Yemen and Oman, and the large rivers of the Nile (Egypt and Sudan), the Euphrates and Tigris (Iraq and Syria), and Yarmuk (Syria and Jordan).

The Arab region as an interlinked geographical entity should develop and implement regional mechanisms for coordinating activities in this field. Species range-shifts and impacts of extreme events often occur on regional scales so an effective climate change strategy must include mechanisms for coordinating conservation actions at the regional level across political boundaries and agency jurisdiction.

## **CONCLUDING REMARKS**

In the Arab region, the vulnerabilities to the potential impacts of climate change are high, current capacities and actions are inadequate, and effective strategies for mitigating and adapting to climate change are urgently required. The fact that the region's contribution to the problem is relatively small does not mean that political and diplomatic complacency is an option. Arab countries are among the most vulnerable to the potential impacts of climate change because of their existing vulnerabilities, notably water scarcity and recurrent drought.

Alarmingly, this report has found that virtually no work is being carried out to make the Arab countries prepared for climate change challenges. Specifically, no concerted data gathering and research efforts could be traced regarding the impacts of climate change on health, infrastructure, biodiversity, tourism, water and food production. The economic impact seems to be totally ignored. Reliable records on climate patterns in the region barely exist. This highlights the need for high quality climate information and research, as regional climate predictions are critical for planning and risk management. Land-use, physical planning and building standards, which take account of climate change, have to be imposed on buildings and long-lived infrastructure. Government policies that promote low-carbon and efficient goods and services, and endorse sustainable management of natural resources and coastal protection, are overdue. The private sector needs to be brought in by offering the right incentives for implementing effective solutions.

This report argues that, in the case of Arab countries, adaptation will provide local benefits in the short term and provide – as by-products - immediate solutions to inherent Arab problems not entirely caused by climate change, such as drought, water scarcity and air pollution.

There are a number of promising initiatives in the Arab region: Abu Dhabi Future Energy Company (Masdar) is building an innovative zero-carbon clean energy hub, and the King Abdullah University of Science and Technology (KAUST) in Saudi Arabia has been established as a centre of excellence on ener-

gy studies; both are perfect manifestations of transforming oil income into future technology. There is also AFED's Arab Green Economy Initiative, an exercise in public-private partnership. It is essential that these initiatives become part of an integrated, large and sustainable development plan.

The Council of Arab Ministers Responsible for the Environment (CAMRE) issued a landmark Declaration in 2007, which adopted the scientific consensus that was reached by the IPCC, accepting that the increase of global temperatures was mainly due to human activities. The ministers stated their "determination to strive to achieve" several objectives, including: adopting national and regional action plans dealing with climate change issues in order to assess possible impacts and develop mitigation and adaptation programmes; promoting the production and use of cleaner fuels; making energy use more efficient in all sectors; diversifying energy sources in accordance with the prevailing economic and social conditions; expanding the use of cleaner production techniques and environmentally friendly technologies; and expanding the use of economic incentives to encourage more efficient products. In the context of adaptation, the declaration focused on the need for necessary infrastructure to reduce potential risks, including the efficiency of natural resource management and advanced monitoring, control and early warning systems as well as the establishment of climate research and study centres.

This comprehensive declaration of intentions constitutes the basis for action that should include specific objectives and implementation plans within a fixed timeframe. Delays are no longer an option, especially amid crucial negotiations that will define the international position towards climate change for the post Kyoto era.

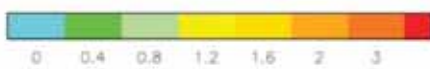
The challenges facing the Arab world from climate change are immense, but the bleak situation can still be averted if the region acts fast. Inaction is no longer an option.

**REGIONAL CLIMATE MODEL PROJECTIONS OF AVERAGE TEMPERATURE CHANGES (°C) FOR THE 2020s, 2040s AND 2070s, RELATIVE TO THE 1990s**

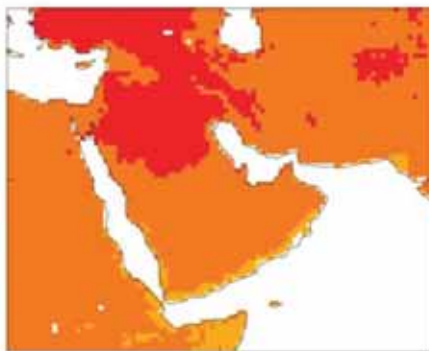
**2020s RCM**



**2040s RCM**



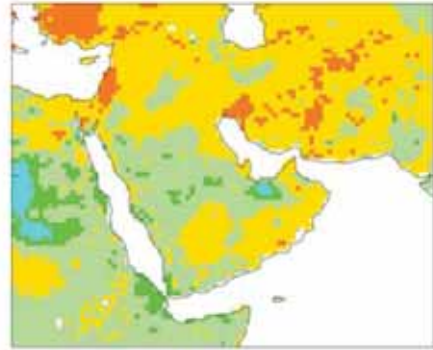
**2070s RCM**



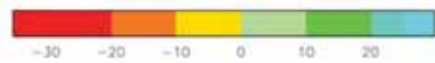
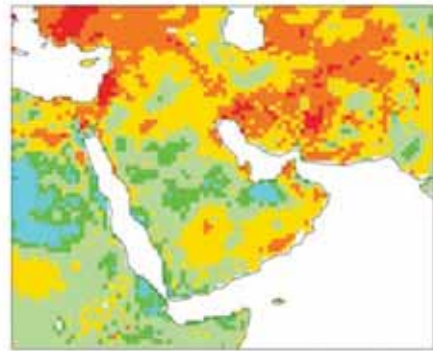
Source: Hemming D, Betts R, & Ryall D. 2007.

**REGIONAL CLIMATE MODEL PROJECTIONS OF PRECIPITATION CHANGES (%) FOR 2020s, 2040s, AND 2070s, RELATIVE TO THE 1990s**

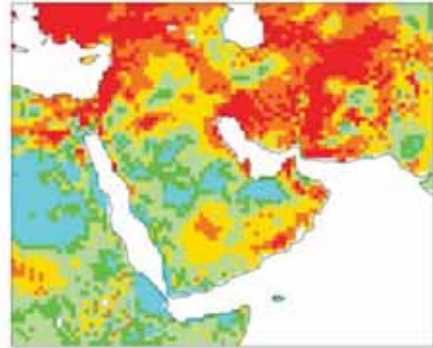
**2020s RCM**



**2040s RCM**



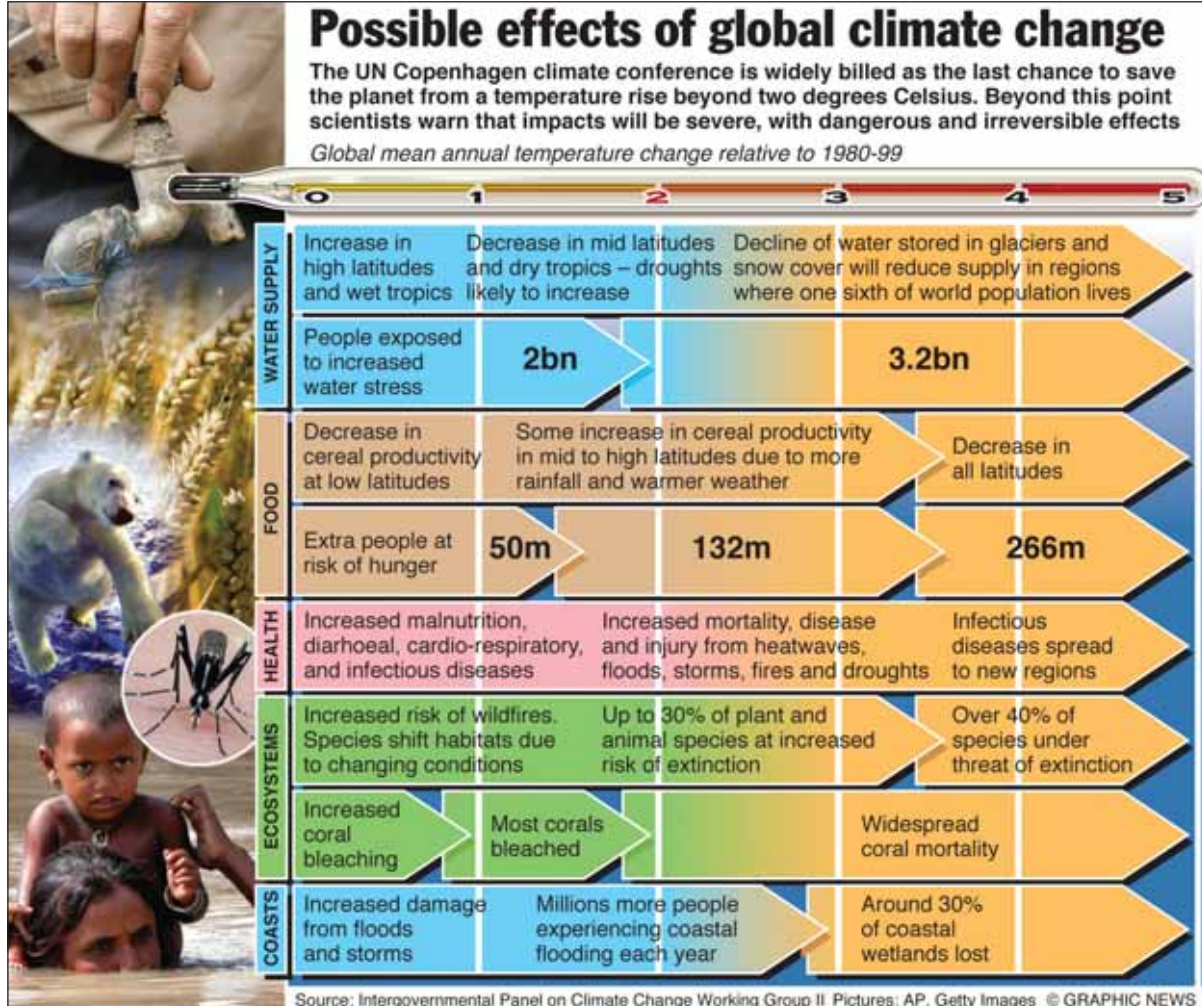
**2070s RCM**



Source: Hemming D, Betts R, & Ryall D. 2007.



STABILISATION LEVELS AND PROBABILITY RANGES FOR TEMPERATURE INCREASES



# Arab Public Opinion and Climate Change

NAJIB SAAB





## I. SUMMARY OF RESULTS

A pan-Arab survey conducted by the Arab Forum for Environment and Development (AFED) found that a resounding majority of 98% believed that the climate is changing, and 89% thought this was due to human activities, including excessive use of energy and depletion of resources. 51% of respondents thought that governments were not acting adequately to address the problem. A small portion of 5% at the regional level said they did not understand what climate change was, reaching a maximum of 11% in Syria. However, 95% of those who said they did not understand what climate change was, still answered that they believed it was happening. Those who said climate change posed a serious challenge to their countries accounted for 84%, reaching 94% in Morocco and 100% in Tunisia. It was remarkable to find that over 94% believed that their countries would benefit from participating in global action to deal with climate change, and 93% pledged to participate in personal action to reduce their contribution to the problem.

Asked to choose sectors where climate change will have major impact in their countries, it stood out that not a single respondent said there will be no effect at all. The majority, at the regional

level, gave priority to health, drinking water and food, followed by coastal areas. Those surveyed were also asked to choose the three most important measures to mitigate the causes and adapt to the effects of climate change. Changing consumption patterns, mainly reducing the use of energy, was the main measure chosen, followed by education and awareness. Ratifying and implementing international treaties came third.

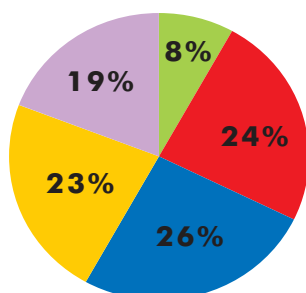
It was peculiar that respondents from some countries which face major threats did not fully recognize this: 36% in Sudan answered that climate change did not pose serious problem to their country, at a time when a World Bank report put Sudan on top of a list of twelve countries classified to be the most affected regarding agriculture and food production. A similar situation applies to Syria, where 33% of the respondents did not find that climate change was a serious threat to the country. In contrast, 100% of Sudanese and Syrian respondents agreed that the climate is globally changing. This reflects the general trend of approaching climate change in Arab media and by politicians as a global issue, with little being discussed about local implications.

The results clearly showed that climate change has become widely accepted by the public in Arab countries as a fact which needs to be

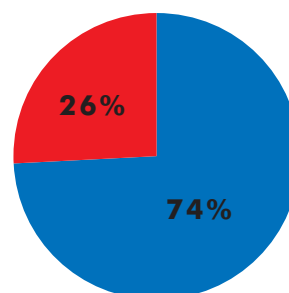


## SOCIO-ECONOMIC DISTRIBUTION OF THE SAMPLE

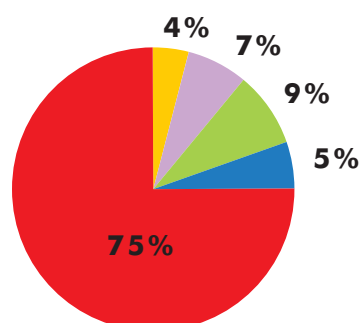
## Age



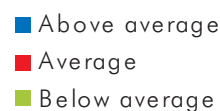
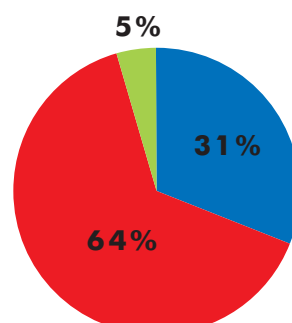
## Gender



## Education



## Family Income



addressed. Remarkably, the majority of respondents from all countries, regions and socio-economic backgrounds agreed that more should be done by governments. Moreover, the survey showed that the sceptical attitudes which prevailed among some groups on the facts and causes of climate change, either denying it entirely or limiting it to natural causes, are receding.

## II. DESCRIPTION AND BACKGROUND

The survey on public attitudes in the Arab countries pertaining to climate change was organized by AFED, as part of its 2009 expert annual report on the impact of climate change on the Arab region. The survey was conducted between February-May 2009, on a voluntary basis and

without interviewers. The questionnaire was distributed through Al-Bia Wal-Tanmia (Environment & Development) magazine, and eight daily Arabic-language newspapers. These included Al-Hayat (pan-Arab), An-Nahar (Lebanon), Al-Khaleej (UAE), Al-Qabas (Kuwait), Al-Ayyam (Bahrain), Ash-Sharq (Qatar), Al-Ahdath (Morocco), and Ad-Dustour (Jordan). The survey was also promoted on the pan-Arab Future TV and the Arabic service of

Arab countries. Starting with general questions about the extent of knowledge about what climate change means and whether it is considered to pose a real threat to the country of the respondent, questions moved into details of specifying sectors affected according to priority, and identifying major measures of mitigation and adaptation, and classifying the level of response of governments to deal with climate change.

Responses were received and processed from 19 Arab countries. Results were reflected in the report, as total average as well as per country. The sample analyzed included 2,322 responses from: Algeria, Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, United Arab Emirates and Yemen. The listing in the tables and charts followed sub-regional clusters not alphabetical order. The report classified country clusters as follows:

Levant: Iraq, Jordan, Lebanon, Palestine, Syria.  
Gulf: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates.

Arab African countries: Algeria, Egypt, Morocco, Sudan, Tunisia.

Other: Libya, Mauritania, Yemen (small sample for individual statistics for the first 2, and socio-economic/geographical considerations which dictated to keep Yemen out of clusters).

The majority of respondents replied by mail (53%), while 42% used e-mail, which reflects wider use of electronic media among participants. The remaining 5% replied by fax. As it was not a requirement to use the original questionnaire, many answered on photocopied sheets.

The answers were sorted and statistically tabulated by Pan Arab Research Centre (PARC), a Gallup associate. A data base, including socio-economic data, was prepared. In addition to allowing socio-economic analysis of the sample, it helped to eliminate duplication, as the program deleted multiple answers received from the same person.

The combination of voluntary respondents through a regional environmental magazine and eight leading daily newspapers, reaching both specialized readers and the general public, combined with internet access and promotion via

FIGURE 1 I UNDERSTAND WHAT CLIMATE CHANGE IS

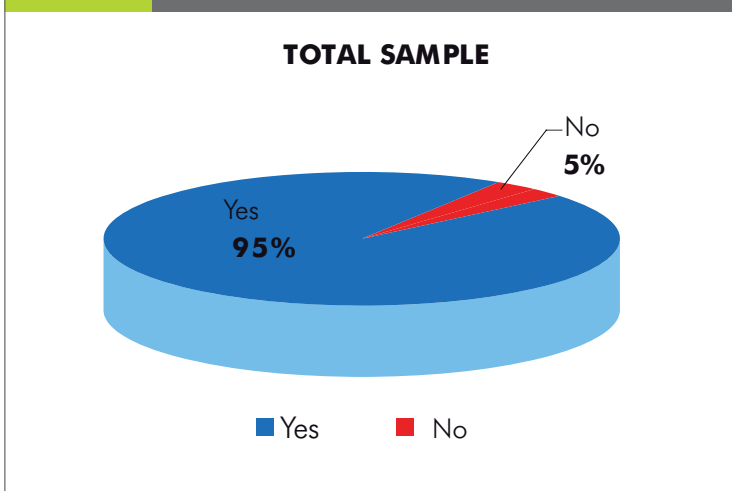
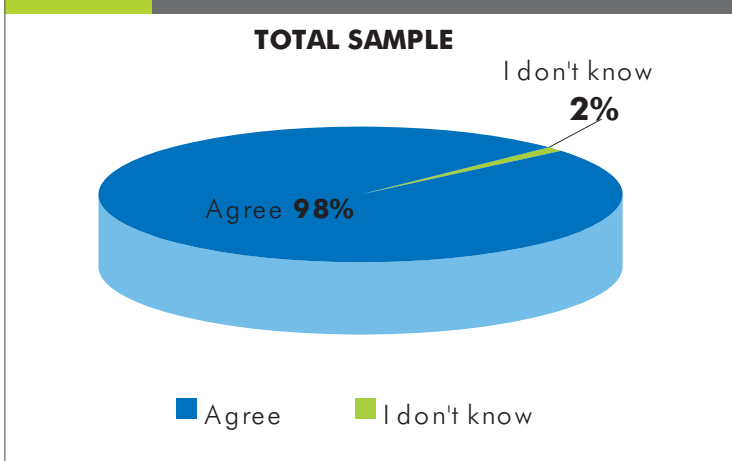
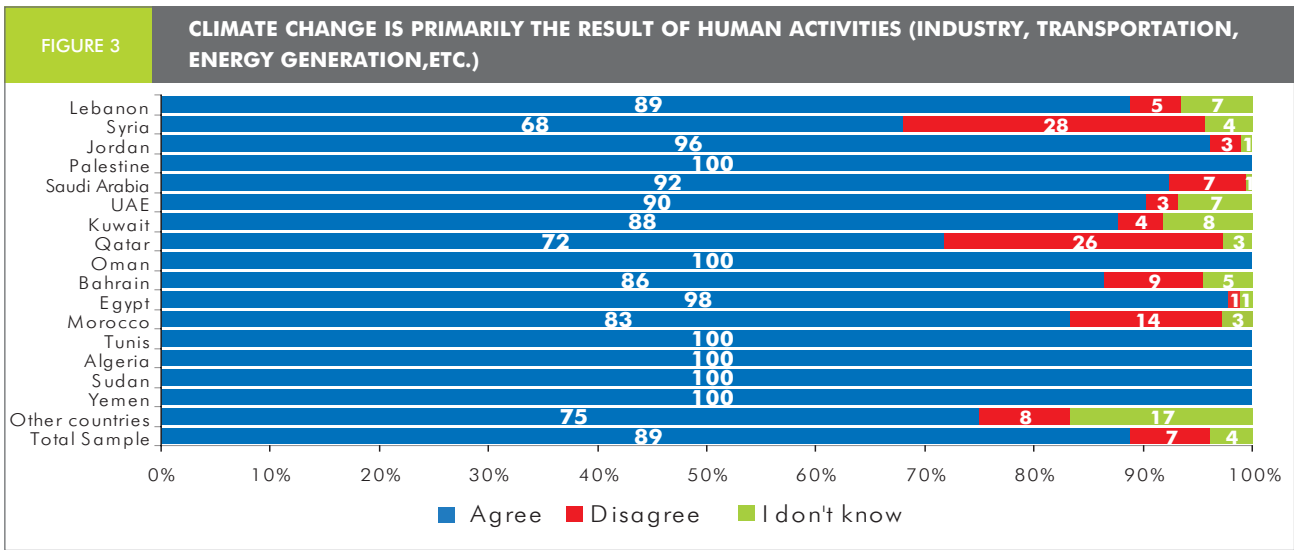


FIGURE 2 I BELIEVE THE CLIMATE IS CHANGING



Monte Carlo Dawliya radio and posted on the website of AFED.

Alongside data collection, the questionnaire was designed in a way to make use of the wide reach of partner media outlets to spread awareness on climate change and its possible consequences on



radio and TV, ensured a sample from a wide range of social, economic and educational backgrounds, that reflected broad spectrum of views. It is to be noted, however, that the sample includes a big segment of educated people; while this might reflect more the views of those nearer to decision making, it does not proportionally reflect the actual population mix.

The respondents have the following major characteristics: 75% possess university level education, 74% are males and 26% females, 42% were

above 41 years old, 8% below 20 and 50% between 21-40 years, Respondents were asked to classify their income group compared to the prevailing level of income in their country; 64% said they have average income, 31% above average and 5% below average. It is to be noted, therefore, that people with low-income and lower education levels were not proportionally represented. But as the sample was analyzed on socio-economic basis, it was possible to track differences in attitudes among different categories.

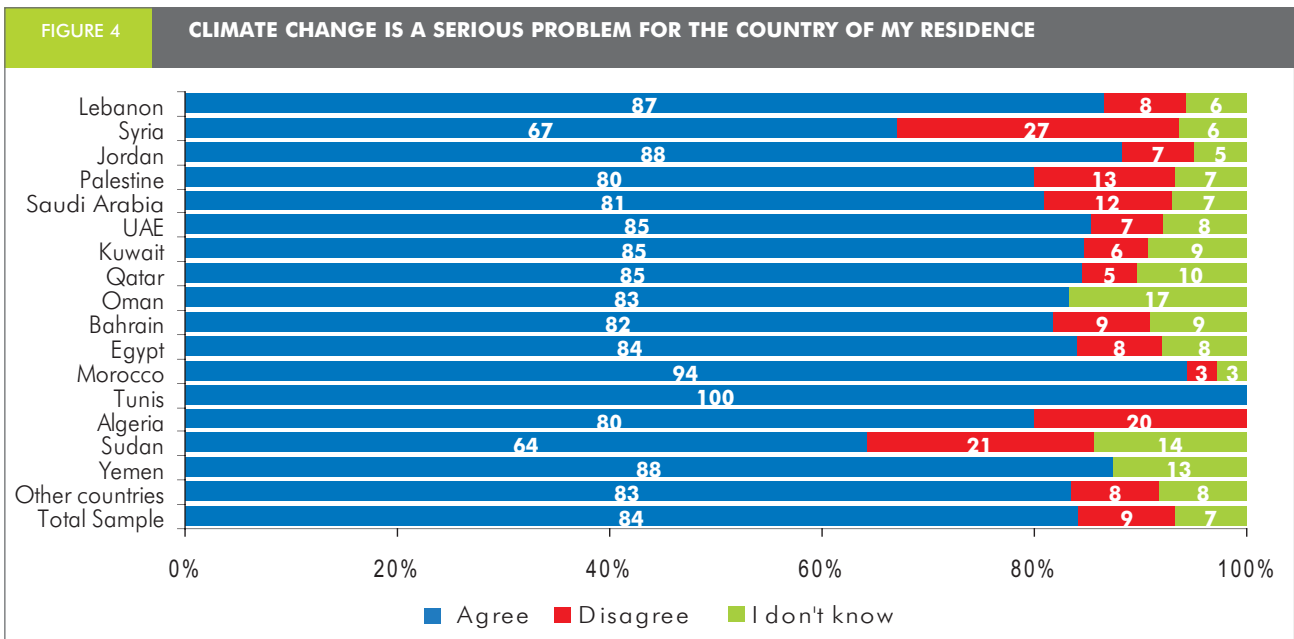
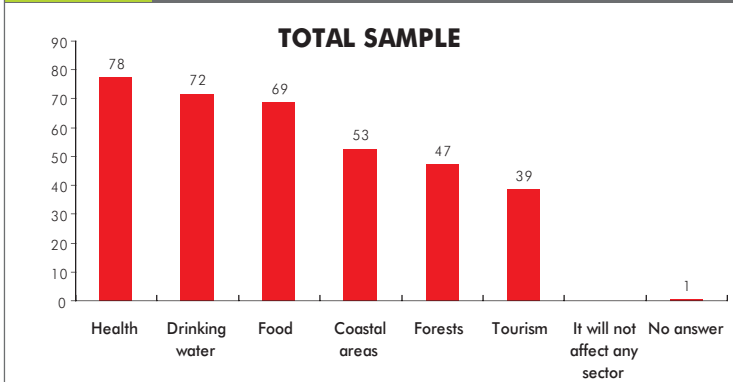


FIGURE 5

**DO YOU THINK CLIMATE CHANGE WILL AFFECT ANY ONE OF THE FOLLOWING SECTORS IN YOUR COUNTRY? (YOU MAY SELECT ANY NUMBER OF OPTIONS)**



### III. ARAB PUBLIC OPINION AND CLIMATE CHANGE SURVEY: DETAILED ANALYSIS

#### 1- Do you understand what climate change is?

The majority of respondents, 95%, answered positively, 5% said they did not understand or did not know. The highest percentage of those who answered 'yes' was in Qatar, Oman, Tunisia and Palestine (100%). The highest percentages of those who said they did not understand what climate change were scored in Syria (11%), Morocco (8%), Lebanon (7%), Saudi Arabia (6%), UAE (4%) and Egypt (3%).

While no major differences were observed among

regional groups (Levant and Egypt, Gulf, North Africa), variations showed among age groups, with the highest level of ignorance of the problem among those below 30-years old (7.5%) compared to only 3% among the over 41 group. Variations also showed within different education categories, with 10% of the below university level education group professing not to understand what climate change is, compared to 3% for university level respondents. This reflects the fact that higher education brings better awareness of environmental challenges. However, we would have expected higher awareness among younger generations compared to the older groups, which showed not to be the case.

#### 2- Do you believe that the climate is changing?

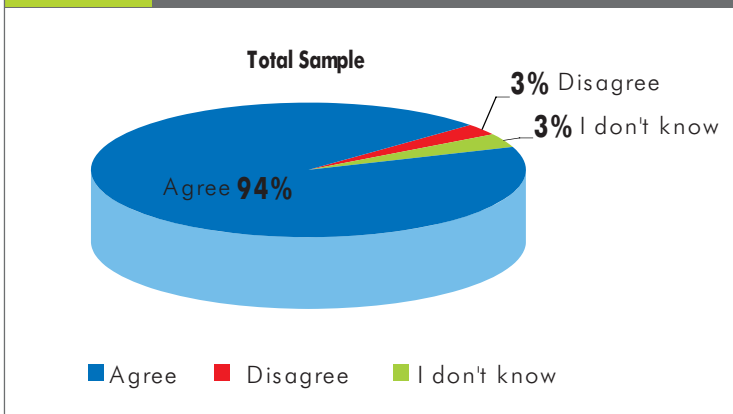
A resounding 98% answered that they believe the climate is changing. It was remarkable that the percentage reached 100% in some countries where the level of understanding of the climate change issue was the lowest, such as Syria, Morocco and Saudi Arabia. Regional group averages were uniform, and no major disparities were recorded among different age, education or income groups. Results show that among the 98% who agreed that the climate is changing, between 5-10% did not understand why.

#### 3- Is climate change mainly caused by human activities (industry, transportation, power generation, urbanization, etc)?

89% of the total sample agreed that climate change was primarily caused by human activity. The highest percentage of those who agreed was in North Africa (93%), followed by the Gulf countries (89%) and the Levant (86%). It is remarkable that the highest percentage of disagreement came from Syria (28% disagree, 4% do not know), followed by Qatar (26% disagree, 3% do not know) and Morocco (14% disagree, 3% do not know). The percentage of those who thought that climate change was mainly due to human activities was highest in Oman, Tunisia and Palestine (100%), Egypt (98%) and Jordan (96%). In Saudi Arabia, 92% said it was due to human activities, while 7% disagreed, compared to 90% who agreed in UAE and 88% in Kuwait. This clearly shows that the majority of respon-

FIGURE 6

**IT IS OF A HIGH IMPORTANCE AND BENEFIT THAT MY COUNTRY PARTICIPATE IN WORLDWIDE ACTION TO LIMIT CLIMATE CHANGE**

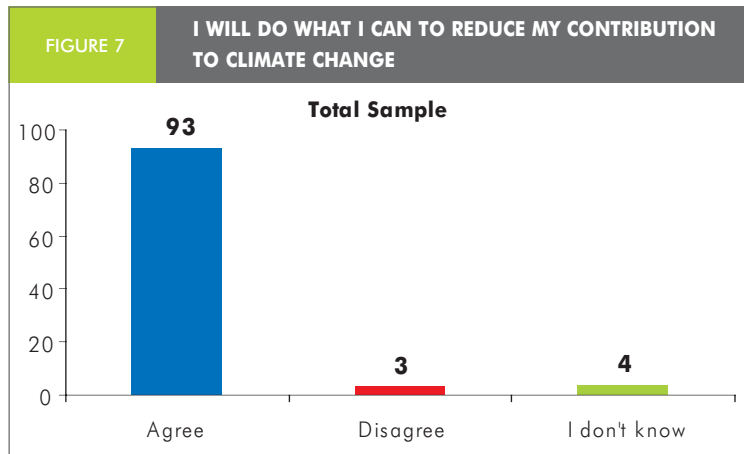


dents in the Gulf oil producing countries think that human activities are generally considered the primary cause of climate change. While no major variations show between genders and age groups, a disparity was noted between different education levels: while 92% of those with university education thought that climate change was caused by human activities, only 80% of those below university level agreed.

**4- Climate change is a serious problem for the country of my residence.**

84% of the respondents thought that climate change posed a real threat to their country of residence. The highest percentage came from Arab countries in Africa (88%) followed by Gulf countries and the Levant (both 83%). The highest portions of respondents who agreed were in Tunisia (100%) and Morocco (94%), while the lowest was in Syria (67%). The highest percentage of those who said that climate change did not pose a serious problem to their country was in Syria (27% disagreed and 6% said they did not know).

**5- Do you think that climate change will affect any one of the following sectors**



**in your country: Food, Health, Drinking Water, Coastal areas, Forests, Tourism? Will not affect any sector? No answer?**

Respondents were asked to choose from among six sectors most likely to be affected by climate change in their country. They could choose any number of sectors. It is significant that zero percent of participants answered that climate change had no effect at all on their country. At the regional level, health came on top with 78%, followed by drinking water 72%, food 69%, coastal

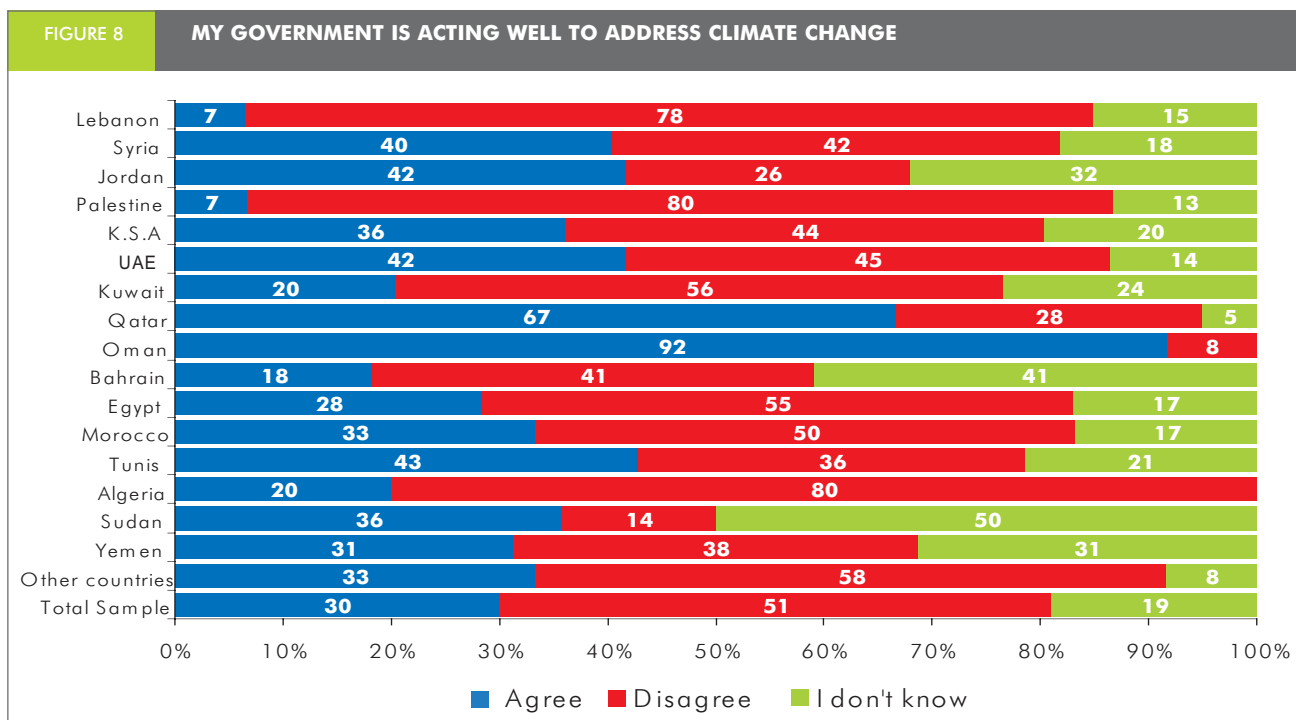
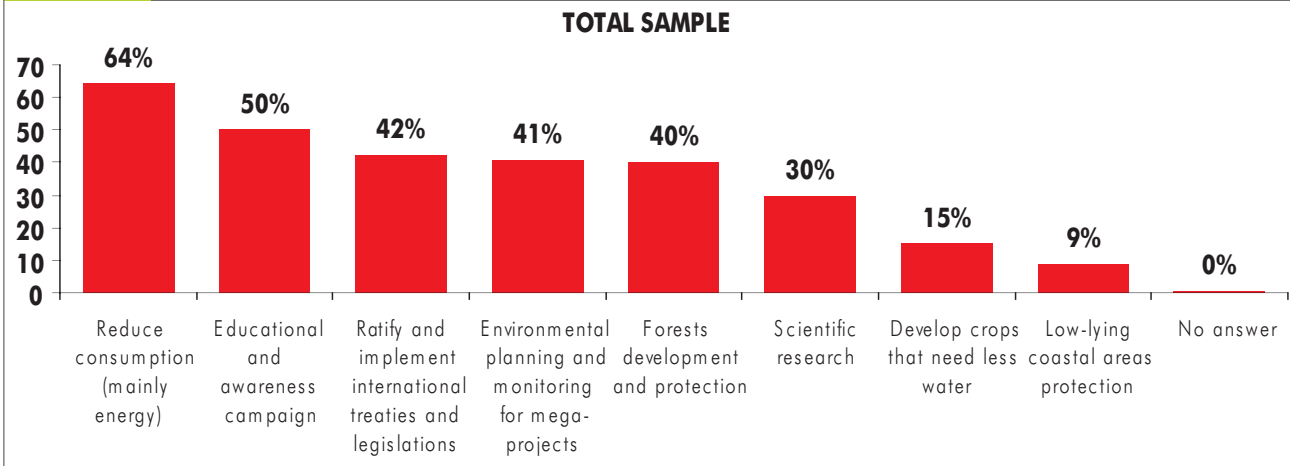




FIGURE 9

**IN YOUR OPINION, WHAT ARE THE MAIN 3 MEASURES TO MITIGATE CLIMATE CHANGE CAUSES AND ADAPT TO IT?**


areas 53%, forests 47%, and tourism 39%. Health was the first choice in all sub-regions. While drinking water was voted as the second priority affected sector in Levant and Gulf countries, it was overtaken in Arab African countries by food. Coastal areas, which scored fourth place in the total sample as well as in Gulf and Arab African countries, were overtaken by forests in the Levant, apparently driven by the recent forest fires in Lebanon, but also scored high in Morocco, Syria and Jordan.

**6- Is it of high importance and benefit that my country participate in global action to limit climate change?**

94% of the respondents agreed that their country should participate in worldwide action to deal with climate change challenges, and that this brings benefits. At a sub-regional level, 100% of participants from Arab African countries agreed, compared to 95% in the Gulf and 90% in the Levant. At the country level, the percentage of those who agreed reached 100% in Oman, Egypt, Morocco, Tunisia, Jordan, Palestine and Qatar, 95% in UAE and Kuwait, scoring the lowest support in Syria (83%) and Lebanon (89%). No major disparities showed among different socio-economic groups.

**7- I will do what I can to reduce my contribution to climate change.**

93% of the respondents agreed to participate in

personal action to help reduce their contribution to the causes of climate change. The highest percentage of those who agreed was in Africa (98%) with an equal figure in the Gulf and Levant (92%). While the positive response reached 100% in Morocco, Oman and Palestine, 98% in Jordan and Kuwait and 96% in Tunisia, it hovered around 90% in all other countries.

**8- My government is acting well to address climate change.**

Although the majority of the total sample of respondents thought that their governments were not doing enough to address climate change (51%), major variations showed among different sub-regions and countries. 59% in the Levant thought their countries were not doing enough, compared to 49% in Arab African countries and 44% in the Gulf group. Those who thought their countries were acting well to address climate change were 22% in the Levant, 32% in Arab African countries and 37% in the Gulf. The percentage of those who answered that they did not know was high for this question: 19% for the total sample, and nearly the same for each sub-region. Those mostly satisfied with their governments' action on climate change were in Oman (92%), Qatar (67%), UAE and Jordan (42%). The highest percentages of those who thought their governments were not doing enough were scored in Palestine (80%), Lebanon (78%), Kuwait (56%) and Egypt (54%). While no significant disparities

showed among different education and income levels, it was interesting to note that the percentage of females who deplored the inadequacy of government action was much higher than that of males (62% to 47%).

**9- In your opinion what are the main 3 measures to mitigate climate change causes and adapt to it? Choose up to 3 from: Reduce consumption (mainly energy); forest development and protection; ratify and implement international treaties; educational and awareness campaigns; scientific research; protection of low-lying coastal areas; develop crops that need less water; environment planning and monitoring of mega-projects.**

Reducing consumption, mainly of energy, was voted the number one measure to mitigate climate change, at both the regional level for the total sample (64%) as well as in the sub-regions, with minimal variations. Education and awareness campaigns followed in second place in total sample (50%) as well as in the Gulf (54%), while forest development and protection took second place in the Levant (53%), and ratifying and implementing international treaties scored second place in Arab African countries (52%). The third place at the regional level covering the total sample went for international treaties, while at the sub-regional level the third place was occupied by education in the Levant and the Arab African countries, and international treaties in the Gulf countries. It is to be noted that protection of low-lying coastal areas scored lower than 10% in most sub-regions, while it got 33% in Qatar, 19% in Saudi Arabia, 17% in Syria and 15% in Egypt. Scientific research scored remarkably high in Qatar, with 51%. Two results stood out in Oman: environment planning and monitoring of mega-projects scored first at 83% compared to a total average of 41%, and protection of low-lying coastal areas got zero, in spite of the damage caused by hurricane Gonu in 2007.

#### IV. CONCLUSION

The outcome of the 2009 AFED survey on Arab public opinion regarding climate change reveals



outright recognition of the problem at all levels and in all countries of the region. The high percentage of those who thought in 2009 that climate change posed a serious threat to their countries (84%) reveals a sharp increase compared to a pan-Arab survey carried out in 2000 by Al-Bia Wal-Tanmia (Environment & Development Magazine - EDM) when only 42% thought so (Arab Public Opinion and the Environment, 2000, EDM, UNEP, CAMRE). The results likely reflect the high profile climate change has acquired in both global political agendas and international media.

It is, however, interesting to note that 14% of those who agreed that the climate is changing globally, still did not think that this presented real challenges to their own country. This leads us to conclude that Arab public perception of climate change is largely derived from international media, in the absence of real work in the countries of the region to identify local and regional ramifications of the climate threat and make them available to the public. However, the survey clearly proves that the general opinion in Arab countries recognizes climate change as a reality, and largely accepts that it is mainly caused by human activities. It is significant that the majority thought that changing consumption patterns every where, mainly sustainable use of energy, is the prime measure needed to mitigate to the threat.

In conclusion, the Arab public seems to be ripe to accept and be part of concrete national and regional action to deal with climate change.



The survey was carried out between February-May 2009, on voluntary basis and without interviewers. Questionnaires were sorted by the Pan Arab Research Center (PARC), a Gallop associate, which prepared the statistical report. All figures were rounded to the nearest decimal.

For statistical purposes, countries were grouped in the following clusters:

- Levant: Iraq, Jordan, Lebanon, Palestine, Syria.
- Gulf: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates.
- African Arab Countries: Algeria, Egypt, Morocco, Sudan, Tunisia.
- Yemen was kept out of clusters for unique socio-economic and geographical considerations.
- Other: Libya and Mauritania were not analyzed individually due to small samples.

**QUESTION 1 I UNDERSTAND WHAT CLIMATE CHANGE IS:**

	Total Sample	Levant	Gulf	Arab Africa	Yemen	Other
	%	%	%	%	%	%
<b>Yes</b>	95	94	96	96	94	100
<b>No</b>	5	7	4	4	6	-

**QUESTION 2 I BELIEVE THE CLIMATE IS CHANGING**

	Total Sample	Levant	Gulf	Arab Africa	Yemen	Other
	%	%	%	%	%	%
<b>Agree</b>	98	98	99	99	94	100
<b>I don't know</b>	2	2	1	1	6	-

**QUESTION 3 CLIMATE CHANGE IS PRIMARILY THE RESULT OF HUMAN ACTIVITIES (INDUSTRY, TRANSPORTATION, ENERGY GENERATION, ETC.)**

	Total Sample	Levant	Gulf	Arab Africa	Yemen	Other
	%	%	%	%	%	%
<b>Agree</b>	89	87	89	93	100	75
<b>Disagree</b>	7	9	7	5	-	8
<b>I don't know</b>	4	5	4	1	-	17

**QUESTION 4 CLIMATE CHANGE IS A SERIOUS PROBLEM FOR THE COUNTRY OF MY RESIDENCE**

	Total Sample	Levant	Gulf	Arab Africa	Yemen	Other
	%	%	%	%	%	%
<b>Agree</b>	84	83	83	88	88	83
<b>Disagree</b>	9	12	8	7	-	8
<b>I don't know</b>	7	6	8	5	13	8

## QUESTION 5

DO YOU THINK CLIMATE CHANGE WILL AFFECT ANY ONE OF THE FOLLOWING SECTORS IN YOUR COUNTRY? (YOU MAY SELECT ANY NUMBER OF OPTIONS)

	Total Sample	Levant	Gulf	Arab Africa	Yemen	Other
	%	%	%	%	%	%
<b>Health</b>	78	72	84	78	56	83
<b>Drinking water</b>	72	68	77	68	81	58
<b>Food</b>	69	61	72	76	81	83
<b>Coastal areas</b>	53	45	62	52	19	58
<b>Forests</b>	47	62	35	42	44	50
<b>Tourism</b>	39	41	38	38	13	33
<b>It will not affect any sector</b>	0	-	0	-	-	-
<b>No answer</b>	1	1	0	-	-	-

## QUESTION 6

IT IS OF A HIGH IMPORTANCE AND BENEFIT THAT MY COUNTRY TO PARTICIPATE IN WORLDWIDE ACTION TO LIMIT CLIMATE CHANGE

	Total Sample	Levant	Gulf	Arab Africa	Yemen	Other
	%	%	%	%	%	%
<b>Agree</b>	94	90	95	100	100	83
<b>Disagree</b>	3	4	3	-	-	8
<b>I don't know</b>	3	6	2	-	-	8

## QUESTION 7

I WILL DO WHAT I CAN TO REDUCE MY CONTRIBUTION TO CLIMATE CHANGE

	Total Sample	Levant	Gulf	Arab Africa	Yemen	Other
	%	%	%	%	%	%
<b>Agree</b>	93	92	92	98	100	92
<b>Disagree</b>	3	4	4	1	-	8
<b>I don't know</b>	4	4	5	1	-	-

## QUESTION 8

MY GOVERNMENT IS ACTING WELL TO ADDRESS CLIMATE CHANGE

	Total Sample	Levant	Gulf	Arab Africa	Yemen	Other
	%	%	%	%	%	%
<b>Agree</b>	30	22	37	32	31	33
<b>Disagree</b>	51	59	44	49	38	58
<b>I don't know</b>	19	20	18	19	31	8

## QUESTION 9

## IN YOUR OPINION, WHAT ARE THE MAIN 3 MEASURES TO MITIGATE CLIMATE CHANGE CAUSES AND ADAPT TO IT?

	Total Sample	Levant	Gulf	Arab Africa	Yemen	Other
	%	%	%	%	%	%
<b>Reduce consumption (mainly energy)</b>	64	63	65	65	81	42
<b>Educational and awareness campaign</b>	50	51	54	42	63	42
<b>Rectify and implement international treaties and legislations</b>	42	35	45	52	31	42
<b>Environmental planning and monitoring for mega-projects</b>	41	41	41	38	31	67
<b>Forests development and protection</b>	40	53	31	31	63	33
<b>Scientific research</b>	30	22	33	41	31	33
<b>Develop crops that need less water</b>	15	17	12	19	-	8
<b>Low-lying coastal areas protection</b>	9	7	12	7	-	17
<b>No answer</b>	0	1	-	-	-	-

# GHG Emissions: Mitigation Efforts in the Arab Countries

IBRAHIM ABDEL GELIL



## I. INTRODUCTION

The ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC) is the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Accordingly, under Article 4.1(b) of the Convention, all Parties, including the Arab countries, are required to undertake efforts to reduce greenhouse gases (GHG) emissions and or enhance GHG sinks (UNFCCC, 1992).

As climate change is a global problem, it calls for a global solution taking into consideration the principle agreed upon in the Rio declaration in 1992, namely the principle of “common but differentiated responsibilities.” This implies that developed countries, which are historically responsible for the largest part of the accumulated GHGs in the atmosphere, should take the lead in reducing GHG emissions given their higher technological and financial capabilities. Developing countries, including the Arab countries, are requested to do their best to adopt development activities utilizing less energy, less water, and fewer raw materials, and to produce less waste.

Mitigation refers to efforts to reduce greenhouse gas emissions and to capture greenhouse gases through land use changes such as foresta-

tion or carbon capture and storage in deep geological formations. Policies and measures to reduce greenhouse gas emissions include improving energy efficiency to reduce energy consumption per unit of economic output, switching to low or zero carbon fuels such as switching from oil to natural gas, and using renewable energy sources such as solar and wind energy.

This chapter discusses the efforts undertaken by Arab countries to mitigate GHG emissions. It should be noted that such mitigation efforts are not necessarily undertaken within national climate change policies; rather, in most instances they have been adopted to achieve certain economic, social, or environmental objectives. This chapter draws mainly on two sources of information, national communications of some Arab countries submitted as part of their obligations within the UNFCCC and information available in the public domain. At present, 14 Arab countries have submitted their initial national communications; none has submitted their second communications yet. Initial national communications are meant to be the major source of information on the steps taken to mitigate climate change. So far, however, they rarely include detailed assessments of past and/or ongoing mitigation projects or activities; they focus instead on projects, activities or programs and measures that are envisaged for the future. Among the 14 initial national communications investigated, only Saudi Arabia’s report does not contain a section on mitigation. Most of the initial national communications have become outdated as some date back to as early as 1997 (Jordan), while the most recent one is that of the UAE (2007) (Table 1).

Apart from the initial national communications, documentations of Arab efforts to reduce GHG emissions are very scarce. Thus, it is likely that some of the ongoing or planned activities have been overlooked due to a lack of information. On the other hand, whenever enough data was available, various Arab experiences on specific mitigation areas are highlighted.

The Council of Arab Ministers Responsible for the Environment (CAMRE) at its 19<sup>th</sup> session in 2007 adopted the Arab Ministerial

TABLE 1

FIRST NATIONAL COMMUNICATIONS OF THE ARAB COUNTRIES

First national Communication	Country
2001	<b>Algeria</b>
2005	<b>Bahrain</b>
2003	<b>Comoros</b>
2002	<b>Djibouti</b>
1999	<b>Egypt</b>
1997	<b>Jordan</b>
1999	<b>Lebanon</b>
2002	<b>Mauritania</b>
2001	<b>Morocco</b>
2005	<b>Saudi Arabia</b>
2003	<b>Sudan</b>
2001	<b>Tunisia</b>
2007	<b>United Arab Emirates</b>
2001	<b>Yemen</b>

Source: [http://unfccc.int/national\\_reports/non-annex\\_i\\_natcom/items/2979.php](http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php)

Declaration on Climate Change, which constitutes the basis for future action and reflects the Arab position in dealing with climate change issues. The declaration stated that “Mitigation programs shall focus on: the production and use of cleaner fuels, improving the efficiency of energy use in all sectors, diversifying energy sources in accordance with the prevailing economic and social conditions, expanding the use of cleaner production techniques and environmental friendly technologies, as well as expanding the use of economic incentives to encourage more efficient products, along with speedy endeavours to conclude negotiations in the WTO to define lists of environmental goods so as to reduce or lift customs restrictions in accordance, and the utilization of carbon trading and its markets” (CAMRE, 2007). Currently, CAMRE is leading efforts to develop an Arab climate change action plan.

## II. THE ARAB ENERGY SECTOR

The energy sector in the Arab region has been and will continue to play a critical role in the region’s socioeconomic development. Oil revenues, estimated at \$419 billion in 2006, have been the major source of income in most of the Arab countries, especially in the Gulf region. According to the Arab Unified Economic Report, the oil and gas sector makes up about 40% of the total Arab GDP. The same report estimated that Arab countries hold nearly 58% of the world’s oil reserves, and nearly 30% of the world’s gas reserves. In 2006, the region accounted for nearly 32% of the world’s oil production, and 12.5% of the world’s gas production (LAS, 2007). The Arab countries rely heavily on oil and gas to meet domestic energy demand, they both account for nearly 97.5% of the total Arab energy consumption. The average per capita energy consumption level in the Arab countries (nearly 1.5 tonnes of oil equivalent, or TOE) lies between some developing countries such as China (1.3 TOE), India (0.5 TOE), and Brazil (1.1 TOE), and some developed economies such as the US (7.2 TOE), Japan (4.3 TOE), and Australia (5.8 TOE). There are remarkable disparities in per capita energy consumption amongst different Arab countries depending mainly on income levels, standard of living, degree of urbanization and climatic conditions.

The figure ranges from as low as 0.33 TOE in Yemen to as high as 22.07 TOE in Qatar (IEA, 2008).

Industry is the major energy consuming sector in the Arab countries, accounting for about 45% of the total consumption followed by the transport sector (32%). The residential, commercial and agriculture sectors make up the rest. This pattern of energy consumption determines the major sources of the GHG emissions, and in many instances identifies the policy priorities and measures needed to reduce such emissions.

### *Measures to mitigate GHG emissions*

Measures to mitigate GHG emissions include those which reduce GHG emissions from different anthropogenic activities as well as those which enhance carbon sinks. Major sources of GHG emissions are the energy sector, industrial sector, and the agriculture sector. In the energy sector, measures to mitigate GHG emissions cover the supply and demand sides. Measures in the supply side include energy efficiency in power generation and oil refining, use of combined heat and power to produce electricity and water, fuel switching away from carbon fuels, electricity imports through regional electricity networks, reduction of losses in transmission and distribution, and power generation using renewable energy resources such as wind and solar.

On the demand side, measures to improve energy efficiency in the major consuming sectors such as industry, transport, and residential and commercial sectors, include efficient lighting systems, improving efficiency of cooling and refrigeration, combustion efficiency improvements, recovery of waste heat, and many others.

These measures include improving energy efficiency throughout the economy, diversifying away from fossil fuels, and promoting the use of renewable energy alternatives. The national communication reports listed a set of planned projects in the energy supply sectors. These are related primarily to more efficient production and a wider adoption of renewable sources. Some of the projects proposed were to evaluate the market potential of solar, photovoltaic and wind technologies, to decentralize electrification by photovoltaic systems, and to adopt a combined cycle



expansion of thermal electrical plants which uses natural gas. Morocco, for example, reported projects for increasing the number of hydropower units, encouraging the use of solar water heaters, wind electricity generation, and desalination of water using wind energy. Algeria reported a project for reduction of gas flaring by 50 percent, and reduction of fugitive emissions from oil and gas installations (refineries, pipelines). Egypt's list of projects contained the first 140 MW integrated solar thermal/natural gas power plant.

Based on the submitted initial national communications from 14 Arab countries, the main measures reported are related to enhancement of electrical energy efficiency in lighting, cooling, cooking and air conditioning, and implementation of demand-side management programmes. Some other measures were reported to improve fuel efficiency of vehicles and promotion of public transportation systems. These policies and measures are explained here in more detail.

### ***The Transport Sector***

In the transport sector, policies and measures envisioned by Arab countries are aimed at creating sustainable transport systems. These include the development of road transportation master plans, modern efficient traffic management systems to reduce traffic idle time in cities, improvement of transport infrastructure, imposition of tariffs or taxes on cars; and application of varied road tolls, discouragement of the use of private vehicles and a concomitant improvement of the public transport systems, and improvement of vehicle maintenance or replacement of old vehicles.

Technological measures include introduction of less carbon alternative fuels such as LPG or compressed natural gas (CNG) vehicles, introduction of vehicle emission standards, fuel economy standards, and switching from diesel to electric traction on railways. Further, the effect of recent development of the information and communication technologies (ICT) in the Arab region on reducing demand on transport and thus reducing GHG emissions has not been estimated.

Increasing the use of public transport, a particularly promising option, has already been implemented or is under serious consideration in several of the region's major cities. The construction

of the underground rail system in Cairo, for example, has eased traffic congestion considerably in that city. Plans for light rail systems are also being considered for Damascus, Amman, Alexandria, Algeria, Morocco, Tunisia and Dubai. The expectation is that if public transport systems improve, many people will opt to use public transport instead of private cars (ESCWA, 2001). At present, policies to develop and promote public transport systems in the GCC are still in their infancy stage.

In Egypt, mitigating GHG emissions from the transport sector involves policies aiming to remove old vehicles from the streets, promoting efficient public transport, expansion of the underground Metro system, introducing alternative fuels such as CNG, and hybrid vehicles. A recent Global Environment Facility (GEF) supported sustainable transport program has been initiated which aims at: integrating sustainable transport planning principles into urban planning, facilitating modal shift to less polluting forms of public transportation, promotion of non-motorized transport facilities in middle size cities, traffic management and traffic demand management to discourage individual use of private cars. Mitigation options for the transport sector outlined in the first national communication included the following:

- Improvement of vehicle maintenance and tuning up of vehicle engines;
- Use of compressed natural gas as a vehicle fuel in transport;
- Re-introduction of the electrified railways in intercity and intra-city transport;
- Intensifying the use of environmentally sound river transport system;
- Extending metro lines to newly developed cities; and Encouraging private sector participation in financing and managing the new metro lines (Abdel Gelil, 2008a).

A major step in the process of upgrading Cairo's transport system has been the construction of an underground metro, the first of its kind in Africa and the Middle East. The nearly 63 km-long underground metro network links the five governorates comprising the Cairo Metropolitan region: Cairo, Giza, Qalyoubia, Helwan and the 6<sup>th</sup> of October. The network comprises two lines: line (1) Helwan - El-Marg



and line (2) Shubra - El-Kheima - Mouneeb. Line (1), which was completed in 2000, has a total length of 44 km, and it presently carries 1.5 million passengers per day. This project also included the electrification of the existing diesel trains in parts of the route. The second line's length is 19 km, and it was completed in 2005. The number of passengers using this line now is 1.2 million passengers per day. Future plans include building a third line of about 33 km and a design capacity of 2.1 million passengers per day from Cairo International Airport, east of Cairo, to Imbaba in the west. Construction of this line is expected to take 13 years to be completed. Three additional lines are also envisioned for the year 2022 (Egyptian Tunneling Society – ETS, 2004).

As per the UAE's first national communication, the amount of travel in cars and light duty trucks continues to grow due to increasing population and economic development. The overall efficiency of the passenger transportation system can be significantly improved through measures that limit the growth in vehicle miles travelled through land-use and infrastructure investments.

One such investment is a metro system that can simultaneously relieve urban congestion and reduce GHG emissions. Currently, Dubai has identified the need for an urban rail transit system to supply additional transportation capacity to relieve growing traffic, and support the city's continuing development. The first metro line in Dubai was inaugurated in September 2009. The Dubai Urban Rail Transit (Metro) will be the first such system on the Arabian Peninsula.

In Jordan, in order to improve the fuel efficiency of vehicles, and to help take old inefficient cars off the roads, the government encouraged taxi owners to replace their old cars with modern ones by providing tax and duties exemptions for new imported taxis. Additionally, the government is considering the introduction of double-deck buses in Greater Amman and other municipalities to reduce fuel consumption, achieve greater efficiency, and reduce GHG emissions. Another mitigation strategy in the transport sector in Jordan was the improvement of traffic management to ease traffic congestion through, for instance, building bridges and tunnels, and automating traffic lights. Moreover, the Jordanian government has intro-



duced tax exemptions on hybrid cars as an incentive to promote their use.

These measures have had considerable effects on reducing road congestion, minimizing idling time, and, thus, reducing transport energy intensity. Furthermore, the government recognizes the need for a major upgrading of the road transport system. This was realized by establishing a Road Maintenance Fund through public-private partnerships and a system of road-user tolls. According to Jordan's initial national communication, "the rapid construction of the Shidiya rail line is critical to the future of the railway sector. The government is considering private financing as part of a concession agreement for private operation and maintenance of rail services on this line." Other planned priority investment projects in the transportation sector include restructuring the public transport and development of a light-rail system. The government envisions that a substantial part of this planned development will be financed by domestic and foreign private sectors (Jordan, 1997).

In Yemen, the first national communication reported that energy use in the transport sector could be reduced through a number of measures including fuel efficiency improvement, traffic management, improvement of freight transport, switching to less carbon fuels such as LPG, and public education (Yemen, 2001).

The transport mitigation strategies in Sudan identified several priority areas for government policy: development of transportation infrastructure (roads, telecommunications, etc.), encourage public transport and improve traffic flow, apply speed limits standards and fuel economy standards, and encourage importation of efficient vehicles (Sudan, 2003).

### ***The Industrial Sector***

The industrial sector is another major energy consuming sector in most of the Arab economies. Most Arab countries, especially those which are highly endowed with hydrocarbon resources (oil and gas) are mainly dependent on those resources to fuel their industries. Energy intensive industries such as oil refining, metal extraction, chemicals and petrochemicals have been proliferating in the oil producing

countries. This has been a global trend since the first world energy crises in 1973. In 2006, these industries contributed 49.5% to the Arab GDP (LAS, 2007). Due to the central importance of these industries to the GDP, their low levels of energy efficiency and the huge capacity of fossil based desalination plants in the GCC region, the energy and carbon intensities of the GCC countries are ranked very high by international standards. For instance, in 2005, the energy intensity of Bahrain (0.77 toe/ \$1000) was more than double the world average (0.32 toe/ \$1000) and about seven times the Japanese intensity (0.11 toe/ \$1000).

GHG emissions from industry include those resulting from burning fossil fuels, indirect emissions resulting from the use of electricity, and emissions related to certain industrial processes such as aluminium smelting, iron and steel, cement, and the food industry.

Several technologies have proved to be technically and economically viable worldwide to improve industrial energy efficiency. These include industrial process control, waste heat recovery, improvement of combustion efficiency, energy management systems, combined heat and power (CHP), high efficiency lighting, high efficiency motors, and many others.

Several Arab countries have adopted successful programmes for improving industrial energy efficiency including building national capacities on energy audits, energy accounting, and energy efficient technologies.

Energy efficiency is an important strategy that has been adopted and promoted throughout the Egyptian economy. Given the critical energy situation in Egypt, the high level of energy consumption and the limited energy resources, it is imperative to conserve energy in the major energy consuming sectors, including the industrial sector which is the second largest consumer of electricity (36% of the total) (EEAA, 1999). Industrial energy efficiency measures included energy audits which showed an average potential saving of about 25% in Egypt mostly in the Egyptian Industries. Measures implemented include combustion efficiency improvement, waste heat recovery, power factor improvement and use of efficient lighting systems.



In the UAE, carbon emissions associated with electricity consumption in the industrial sector accounted for about 57% of all energy-related greenhouse gas emissions in 1994. It is expected that industrial energy consumption could be reduced by 25 percent or more with good pay-back through a combination of energy-saving measures for industrial motors. These include proper motors sizing to meet demand and using high efficiency motors. Another key energy saving strategy could be to install variable speed drives (VSDs) on applications of variable loads, in addition to leaks reduction from compressed air systems and high pressure steam systems (UAE, 2008).

The energy bill in the Jordanian economy reached about 800 billion Jordanian dinars in 2003 which accounts for nearly 13% of GDP and 45% of exports (NERC, 2008). This burden makes clear the urgent need to devise and implement an energy efficiency strategy. The proposed strategy contains many policies and measures to reduce energy consumption in the industrial activities, efficient lighting systems, variable speed drives, and efficient motors.

Lebanon is not an energy producing country, and

imported fossil fuel in Lebanon accounts for 97% of the country's energy bill and totalled around \$1.5 billion in 2004 (nearly 20% of the annual expenditures of the Lebanese government or about 7.5% of GDP). Energy consumption in Lebanon was responsible for approximately 15.3 million tons of carbon dioxide emissions in 2002. The Lebanese transport sector is the major energy consumer which made up about 42 % of total energy consumption in 1999 (WRI, 1999).

In 2002, Lebanon with support from UNDP/GEF started a project to reduce GHG emissions by improving demand side energy efficiency through the creation of a multi-purpose Lebanese Centre for Energy Conservation (LCECP). The Centre will simultaneously undertake activities to remove barriers to improve energy efficiency and provide energy efficiency services to the public and private sectors. There will be a broad range of supporting activities including technical support, financial incentives, information dissemination, awareness programs, policy analysis and program design. Achievements of the LCECP as of now include performing energy audits, undertaking training and public education activities, and fund raising for energy efficiency and renewable energy projects (LCECP, 2008).

Measures to reduce GHG emissions and improve energy efficiency reported through the first national communication include efficient motors, combustion efficiency improvements of boilers and furnaces, and improve efficiency of the cement industry. As the cement industry is the single largest source of Lebanese CO<sub>2</sub> emissions and a major energy user, mitigation measures reported included process modification and combustion efficiency improvements (Lebanon, 1999).

### **The Building Sector**

Energy use in buildings accounts for nearly 40% of global energy consumption and 36% of total energy-related CO<sub>2</sub> emissions. Half of this ener-

gy consumption occurs in industrialized countries, the remainder is consumed by the rest of the world (Price et al., 2005). In general, two major strategies have been used to improve energy efficiency in the building sector and thus reduce its GHG emissions. The first strategy is to improve building envelope energy performance. This is widely known as green building, sustainable building or energy efficient building concepts. The second strategy is to improve efficiency of energy consuming equipment used inside the buildings such as home appliances, lighting systems, air conditioning systems, computers and other office equipments and the like.

In response to recent environmental, economic, market and regulatory drivers, green building concepts and practices have become widely promoted worldwide. The U.S. Green Building Council has developed a Green Building Rating System called the Leadership in Energy and Environmental Design (LEED). Today, there are more than 50,000 LEED-accredited professionals in the US. Furthermore, the World Green Building Council (GBC) is a union of national councils. The current member nations of the World GBC represent over 50 percent of global construction activity, and touch more than 15,000 companies and organizations worldwide (USGBC, 2008).

The UAE is pioneering to apply the LEED certification system in new buildings, and in 2005 established the Emirates Green Building Council, meant to become a model for the Arab region to follow (Emirates GBC, 2008). Bahrain is also working towards achieving the same goal. Several other Arab countries have similarly been developing energy building codes.

Many Arab countries have already established different kinds of building codes. As part of the national energy efficiency strategy of Jordan, thermal insulation in residential and commercial building in certain zoning areas should be enforced. In addition, the preparation of an "Energy Efficiency Code" is a part of such a strategy (Shahin, 2005).

After many efforts to promote green architecture by several Egyptian institutions, Egypt developed residential building energy efficiency codes in 2003, and the new codes will be initially imple-

### **MASDAR CITY**

A pioneering initiative in the UAE is the construction of the world's first zero-carbon, zero-waste and car-free-city in Abu Dhabi, named MASDAR city. The city is planned to host 40,000 residents and receive another 50,000 daily commuters. It is envisioned to be a free zone clean-tech cluster home to around 1,500 visionary companies and research centres. The MASDAR Institute of Science and Technology is the first comer to the city and will be home to 100 students and faculty by fall 2009. Cars will be banned within the city; travel will be accomplished via public mass transit and personal rapid transit systems, with road and railways connecting commuters to other locations outside the city. The city will be walled, to keep out the hot desert wind. The lack of cars will allow for narrow, shaded streets that will also improve air circulation and reduce demand for air conditioning. The city will be oriented northeast to minimize the amount of direct sunlight on buildings' sides and windows. Solar panels and solar collectors on roofs and elsewhere will generate enough electricity to meet most of the city's electricity needs. Water will be provided through a solar-powered desalination plant. Landscaping within the city and crops grown outside the city will be irrigated with grey water and treated waste water produced by the city. It is planned that MASDAR City will be completed and be fully functional by 2012 (The Economist, 2008). Recently, MASDAR City was elected to host the newly established International Renewable Energy Agency (IRENA); this is a milestone achievement for Abu Dhabi and marks the first time that an Arab city plays host to the headquarters of an international organization (MASDAR, 2009)

Sources: The Economist (2008). MASDAR Plan.  
At [http://www.economist.com/science/qa/displaystory.cfm?story\\_id=12673433](http://www.economist.com/science/qa/displaystory.cfm?story_id=12673433)  
MASDAR (2009), <http://www.irenauae.com/en/home/index.aspx>



mented on a voluntary basis. If enforced, it was estimated that these codes would save about 20% of building energy consumption. According to Joe Huang (2003), there is little indication that previous efforts have succeeded in changing overall design practices in Egypt towards improved energy efficiency. Furthermore, the extent of the codes' enforcement and impacts of their implementation on building energy efficiency have not been assessed yet.

In Lebanon, a thermal energy standard for building is under development with the support of the ADEME of France. In addition, the Lebanese construction law provides economic incentives for voluntary thermal insulation of building. However, due to a weak legislative and institutional framework, subsidies of energy prices, and the absence of a national strategy, many energy efficiency projects in Lebanon, especially funded by donors from the EU, have failed to achieve tangible results (Mourtada, 2008).

In Syria, a code of practice of thermal insulation for buildings is being developed. The aim is to provide information to consumers regarding the advantages of building insulation in order to affect insulation purchase decisions. These guidelines would provide best practices of recommended insulation levels for new and existing buildings (Zein, 2005).

In Kuwait, where air-conditioning accounts for 50% of building energy demand, a code of practice for energy conservation was developed to set limits for the electrical consumption of air-conditioning systems for buildings. The code stipulates energy conservation measures and limits for different types of buildings.

Achieving sustainable building designs in the Arab countries is at its early stages of development, and only a very limited amount of scholarly review to document such efforts has been undertaken. For the last few decades, urbanization in the Arab region, especially in the GCC, has been characterized by forms of imported western architecture which are far from being in harmony with the Arab social, geographical and climatic conditions. High rise buildings with large areas of glass façade, and huge demand for electricity for air conditioning can be seen in all new urban centres such as Dubai, Abu Dhabi,



Doha, and the others. These unsustainable designs of residential and commercial buildings, besides being big consumers of energy and water, are massive contributors to GHG emissions.

The second GHG mitigation strategy in the building sector mostly reported in the national communication reports includes efficient lighting systems, certification and labelling of home appliances, and dissemination of improved stoves for cooking in rural areas. Lebanon, Tunisia, Algeria, Syria, and Egypt have projects for certification of home appliances at different stages of development.

The Egyptian government has successfully developed energy efficiency standards and energy labels for the three most market penetrated appliances in Egypt, namely room air conditioners,

washing machines and refrigerators. Energy efficiency specifications for these selected appliances were developed and approved by the Egyptian Organization for Standardization and Quality Control (EOS). A ministerial decree of the Minister of Industry was issued in 2003 concerning refrigerators, washing machines, freezers and room air-conditioning. It is mandatory for local manufacturers and importers of such equipments to meet these specifications, as well as to apply the Energy Efficiency Label (CLASP, 2008).

Tunisia has recently implemented a standards and labelling programme for household appliances and other energy-driven equipment. This programme, which was supported by the GEF and executed by l'Agence Nationale pour la Maitrise de l'Energie (ANME), led to the issuance of energy labelling and minimum energy efficiency standards for refrigerators in 2004. As a result, it is forecasted that by 2030 this programme will have saved 3.4 Mt of CO<sub>2</sub> emissions (LIHIDHEB, 2007).

The development of energy efficiency standards for home appliances is part of the National Energy Efficiency Program of the Ministry of Energy and Mines in Algeria. The energy efficiency law no.99-09 of 1999 and its executive regulations outlines the general rules concerning the energy efficiency of home appliances operating on electricity, gas and petroleum products. The law also stipulates that the energy performance requirements of those appliances have to be set by the government (CLASP, 2008).

After the discovery of oil in Sudan, it has been promoting a policy of switching from biomass to liquefied petroleum gas (LPG) for cooking. Sudan highlighted the impacts on Sudanese biomass stocks that sequester carbon of shifting from burning biomass to LPG for cooking in rural and urban households. The Khartoum Refinery has a capability of producing 500 tons/day of LPG. Recently, the government has implemented a number of policies to encourage the increased use of LPG in the household sector: the price was halved and the fees and customs on LPG stoves were decreased substantially.

Lighting consumes 19% of the global electricity production, and is associated with an annual 1.9 billion tons of CO<sub>2</sub> emissions. Globally more

than 70% of lamps sold are incandescent, while much more efficient (but also more expensive) compact fluorescent lamps (CFLs) account for just over 6% (GEF, 2008). According to the Worldwatch Institute (WWI), the total number of CFLs in use globally nearly doubled between 2001 and 2003 alone, growing from an estimated 1.8 billion to 3.5 billion units (WWI, 2008). Energy saving and the associated GHG reductions are correlated to the amount of fuel saved due to the reduction in electrical energy demand resulting from using low wattage lamps. The economics of using such efficient lamps depend mainly on the structure of electricity generation in every country, fuel used, and cost of fuels. One of the major barriers to the use of these highly efficient lamps in most Arab countries, as has been the case worldwide, is their high initial cost. One way to overcome that is the exemptions of these lamps from customs duties, especially important given that these types of lamps are rarely manufactured locally in the Arab countries. Another way is to develop innovative financing schemes through which end users will be paying the initial cost from the cost of electricity savings.

Though CFLs offer enormous economic and environmental benefits, only few Arab countries have strategies or national plans to disseminate them. In most cases, these efficient lamps are being distributed at the commercial level through retailers, or agencies of foreign manufacturers without any local government support. According to China Association of Lighting Industry, the volume of CFLs imports by the UAE in 2006 amounted to 65.9 million lamps (China Association of Lighting Industry, 2008).

Some projects funded by multilateral or bilateral donors have been promoting CFL lamps in some Arab countries; examples include Lebanon and Egypt. In 2008, the United Nations Development Programme (UNDP), in cooperation with the Ministry of Energy & Water and the Lebanese Centre for Energy Conservation (LCEC), launched a National Campaign for CFLs. This campaign aims to raise public awareness about the benefits of CFLs. LCEC has implemented various pilot projects replacing conventional light bulbs with CFLs in different Lebanese villages. As a result, local savings of around 13% on the total electricity bill were achieved.

Lighting accounts for nearly 23% of the total electricity consumption in Egypt, half of which is consumed in the residential and commercial sectors. The GEF/UNDP supported “Energy Efficiency Improvement & Greenhouse Gas Reduction Project” has undertaken some initiatives to promote CFLs. These include a study to reduce the custom duties on CFLs from 30% to 5% in order to help cut their initial cost, implement a lease program of CFLs by the state-owned electricity distribution companies, and encourage local manufacturing of CFLs. There is no available information on government’s incentives used to encourage local manufacturers; however, six local manufacturing plants were established. These activities, together with public education and marketing campaigns have led to increase the market size of CFL in Egypt to 4.4 million in 2007. It was estimated that the accumulated CO<sub>2</sub> reduction due to those activities up till 2007 was nearly 2.3 million tons (GEF/UNDP, 2008).

In Tunisia, several projects to disseminate about 10 million CFLs during the period 2007-2011 are planned under the Clean Development Mechanism (CDM) of the Kyoto Protocol. These projects are still under development. According to the ANME, nearly one million tons of CO<sub>2</sub> reduction is projected up to 2012 (ANME, 2008).

### **Fuel switching**

Worldwide, natural gas contributed about 17% of the total fuels for electricity generation in 2007. It is projected that natural gas will play an important role in the transition to low-carbon energy in the near future. This is because it produces less carbon dioxide per unit of energy than oil and coal do. Statistics show that the world’s consumption of natural gas has been expanding during the last decade. The same trend was seen in the Arab region. Switching to natural gas has been a crucial response to many factors including mitigation of air pollution and GHG emissions. The critical role natural gas is playing and is expected to play in the global energy market was emphasized with the recent establishment of the “Gas Exporting Countries Forum (GECF)” in 2008, which is hosted in Doha, Qatar. Leading Arab gas producers, namely Algeria, Egypt, UAE, Qatar, and Libya, have joined the forum.

Natural gas represents the second largest primary energy resource used in the Arab countries at nearly 23% of the final energy consumption in 2006. Twelve Arab countries are currently using natural gas, in some form, in power generation, industry, the residential and commercial sectors, and the transport sector. Arab gas reserves represent nearly 30% of global reserves. Total gas production in the Arab countries accounts for about 12.5% of the global gas production (LAS, 2007). Two regional gas projects are underway aiming to increase natural gas utilization in the Arab region. The first project, named the Arab gas pipeline, aims to connect the Egyptian gas network to Jordan, Syria, and then to Turkey with a total length of 1200 km. The second regional project named “Dolphin” will transport Qatari gas to the UAE with a total length of 370 km. Some other regional gas projects are planned such as a project between North African Arab countries, and between them and Europe.

In power generation, the switch from petroleum products to natural gas was the most commonly reported activity. For example, the use of natural gas was increased considerably in a number of countries. In Tunisia, most of the thermally generated energy supply comes from natural gas. This has avoided 900,000 t CO<sub>2</sub> emissions per annum, relative to a scenario in which oil-based products were used instead. Natural gas is also playing a key role in Egypt’s energy policy. Given its economic and environmental advantages, natural gas will improve the overall energy efficiency and environmental quality of Egypt. Switching from oil to gas was identified as a priority measure in the National Action Plan on Climate Change that was prepared by the Egyptian Environmental Affairs Agency in 1999. The energy policy of Egypt has been developed to promote the substitution of natural gas in various sectors. Strategies include: (i) developing gas infrastructure to expand gas markets and develop domestic gas demand – the market share of natural gas in the total hydrocarbon consumption has increased to about 45%; (ii) the substitution of heavy fuel oil with natural gas in electricity generation has made considerable reductions in air pollution; (iii) promotion of Compressed Natural Gas (CNG) as a transport fuel is also underway; and (iv) encouraging private sector investments in the gas industry. A number of pri-



vate firms have been formed to participate in the construction of gas pipelines, building CNG fuelling stations and converting vehicles to use CNG.

The Egyptian program to use CNG as a transportation fuel has proved to be successful; by 2008, there were 6 operating CNG companies, 116 CNG fuelling stations, and about 100,000 CNG vehicles were in use (EGAS, 2008).

A primary key to the CNG industry success in Egypt is a package of incentives offered by the government, including 5-year tax holidays for CNG companies, low-cost conversion charges for car owners, and the attractive price differential between CNG and gasoline (Abdel Gelil, 2008).

Additionally, more than 90% of the thermal electricity generated in Egypt is based on natural gas. Furthermore, a plan is being implemented to expand the use of natural gas in the residential sector, and about 2 million homes have already been connected.

In Bahrain, all of the power plants are currently running on natural gas. In Morocco, a 385 MW combined cycle power plant was commissioned in 2004. A similar one with a capacity of 360 MW was started in Algeria in 2005. Jordan has small reserves of natural gas used to fuel a small power plant to meet only about 4% of the country's needs. Within the Arab Gas Pipeline project, Egypt will supply gas to power plants and large industrial users in Jordan for 18 years. In the UAE, an initiative to develop an action plan to introduce natural gas as a transport fuel is planned. According to the Environment Agency of Abu Dhabi (EAD), 20 percent of government-owned vehicles and taxis in the emirate will be converted to run on CNG by 2012 (AFED, 2008).

### **Renewable Energy**

The Arab countries have a great potential for renewable energy, including solar and wind, as well as hydro and geothermal in specific locations, which are still underutilized. The share of renewable energy in the total installed generation capacity of the Arab countries remains relatively low, standing at around 7% in 2007, mostly from hydropower in Egypt, Syria, Iraq, Lebanon,

Sudan, Algeria, Morocco, Tunisia, and Mauritania. Solar and wind generation of electricity amounts to 257 MW and remains limited to Tunisia, Egypt, Jordan, Morocco, and Palestine (OAPEC, 2008).

Egypt ranked first in hydropower and wind energy generation in the Arab countries with a total installed capacity of 2,842 MW and 305 MW respectively in 2007/2008 (EEHC, 2008). Wind power is planned to be increased to 965 MW by 2012. In 2007, the Egyptian Supreme Energy Council adopted an ambitious plan aiming to increase the contribution of renewable to the total electricity generated to reach 20% by 2020; 12% of this target will be met by wind.

Assessments of wind resources indicate that some locations in the Arab countries have wind conditions that are more than adequate for electricity generation. Small and conventional applications of wind energy exist in Jordan and Tunisia. Only Egypt and Morocco have moved to commercial scale wind energy. In Morocco, installed wind capacity reached 54 MW in 2005 representing nearly 1% of the total installed capacity. Another 500 MW of wind farms are currently under construction.

Due to their geographic location, the Arab countries are blessed with an abundance of solar energy potential. Solar energy generation using photovoltaic (PV) technology is used in several stand-alone applications especially for water pumping, telecommunications and lighting for remote sites. The largest PV program exists in Morocco, where 160,000 solar home systems in about 8% of rural households are installed with a total capacity of 16 MW. Photovoltaic pumping applications are relatively developed in Tunisia with a total existing peak capacity of 255 MW (Abdel Gelil, 2008b).

Solar water heaters are achieving different degrees of market penetration, and are currently most successful in the residential and commercial sectors of Palestine, Jordan, Egypt, Morocco, and Lebanon. Table 2 shows that Palestine has the largest area of solar water heaters in the region. This is due to the current security situation and the unreliable electricity supply from Israel to the Occupied Palestinian Territories. It should be noted from the same table that solar water heaters

are mostly used in Arab countries with relatively few or no hydrocarbon resources.

Several Concentrated Solar Power (CSP) projects were announced but not completed in North African countries, namely Egypt, Morocco and Algeria. With escalating concerns of climate change, cost reductions and efficiency improvements of this technology, and the introduction of independent power producers (IPPs), CSP will play an important role in the electricity generation mix in those countries in the near future.

A recent plan announced in Algeria in 2007 included the building of four gas-CSP plants with total capacity of 1700 MW of which 250 MW will be solar. The four power plants will be gradually commissioned through 2015.

Egypt submitted an official request to the GEF to support financing the first solar thermal power plant. Work is underway to implement the first Egyptian hybrid solar thermal power plant of 140 MW capacity of which 20 MW will be solar, while the rest will be gas combined cycle. The plant is planned to be operational in 2010.

A similar project is under construction in Morocco to build a similar hybrid gas combined cycle 472 MW solar thermal power plant with a solar component capacity of 30 MW. The project was initiated in 1994 following a feasibility study of solar thermal power generation. Ain Beni Mathar in Eastern Morocco was finally selected to site the power plant.

Jerusalem District Electricity Company (JDECO) has signed an agreement with an American Company (Nanovo) to establish a concentrated solar power plant in Jericho, Palestine. The first phase of the project will have a 3 MW capacity and will cost up to \$17 million, financed by the American company. The next phase will expand the plant to a 100 MW capacity with a total cost of up to \$300 million (PERC, 2009).

In 2002, Jordan announced plans to build a 130 MW solar hybrid power plant. The project aimed at the development of 100-150 MW solar hybrid power plant assisted with fuel oil or natural gas at Quwairah south of Jordan on a Build Own Operate (BOO) basis.

The UAE has chosen a different path to promote CSP, focusing on promoting R&D through the Masdar Initiative. The UAE has 100 MW of CSP open for tenders planned to be expanded to 500 MW.

### **Measures to reduce GHG from Non-energy sectors**

Some other non-energy sectors and economic activities are contributing to the global anthropogenic emissions of GHGs. Examples are agriculture activities and solid waste management practices.

### **The Agriculture Sector**

Although CO<sub>2</sub> emissions from fossil fuels are the major cause of global climate change, about one-third of the total human-induced warming effect comes from agriculture and land-use change. This is mainly because agricultural activities are the major source of methane and nitrous oxides which both have much higher global warming potential (GWP) than CO<sub>2</sub>. Agricultural lands occupy 37% of the Earth's land surface and account for 52% and 84% of global methane and nitrous oxide emissions, respectively (Smith, 2007). On the other hand, the agricultural sector can be part of the mitigation strategies by reducing its own emissions, offsetting emissions from other sectors by removing CO<sub>2</sub> from the atmosphere (via photosynthesis) and storing the carbon in soils. These processes are major parts of the global carbon and nitrogen cycles. Through the adoption of agricultural best management practices, emissions of nitrous oxide from agricultural soils, methane from livestock production and manure, and CO<sub>2</sub> from on-farm energy use can be reduced.

TABLE 2

MARKET SIZE OF SOLAR WATER HEATERS IN SELECTED ARAB COUNTRIES

Country	Current market size (m <sup>2</sup> )
<b>Morocco</b> (annual)	130,000
<b>Algeria</b>	-
<b>Tunisia</b>	57,000
<b>Egypt</b>	500,000
<b>Palestine</b>	1,630,000
<b>Jordan</b>	825,000
<b>Lebanon</b>	177,993
<b>Syria</b>	200,000

(Source: SOLATERM Project Partners)

Measures reported in the national communications of some Arab countries under agriculture included: introduction of new varieties of rice and management of paddies to reduce CH<sub>4</sub> emissions, rational use of fertilizers to reduce N<sub>2</sub>O emissions, increase of soil water absorption, and reduction of burning agricultural residues. Measures in the livestock-related operations included changing of cattle fodders to reduce CH<sub>4</sub> emissions from enteric fermentation, manure management and management of livestock population.

The initial national communication of Egypt is nearly the only available report that describes in detail the different options available to Egypt to reduce CH<sub>4</sub> emissions from rice paddies. These options include: rice cultivation of short duration varieties, water management, fertilizer management, and control of soil temperature. The same report recommends some actions to reduce CH<sub>4</sub> emissions from livestock by altering fermentation patterns, i.e. altering the composition of fodders. Some of these options are already being implemented in Egypt such as cultivation of short duration varieties, water and fertilizer management with the aims of water management and reduction of use of agrochemicals.

Additionally, only Mauritania reported projects concerning improved water and fertilizer management, and improved efficiency of use of nitrogen fertilizers.

### **Waste Management**

Waste management practices produce greenhouse gas emissions in a number of ways. First, the anaerobic decomposition of waste in landfills produces methane. Second, open burning or incineration of waste produces combustion gases including carbon dioxide. In addition, combustion of fuels used in transportation of waste to disposal sites is another source of GHG emissions. Sound waste management practices such as waste prevention, minimization and recycling, better reduce GHG emissions from the waste sector. These include reduction of methane emissions from landfills through diverting organic wastes from landfills to composting or other biological treatment facilities, and reducing emissions from incinerators.

Generation of solid waste in the Arab region has been growing for the past few decades. This is attributed to population growth, urbanization, economic growth and rising standards of living in many countries. However, to different degrees, most of the Arab countries still lack integrated systems for solid waste management. Per capita generation of solid waste is normally correlated with income, and it reaches high levels in higher income countries of the GCC. Organic waste still represents more than 50% of the composition of solid waste in many Arab countries. This is a large potential source of methane emissions which has been underestimated.

Open dumping is the most common method of waste disposal throughout the Arab region. Municipalities usually dump solid wastes in low-lying land, or abandoned quarries rather than at designated dump sites, usually named landfills. In addition to being poorly managed, these sites generally lack most of the engineering and sanitary measures for leachate collection and treatment, and methane capture. In many instances spontaneous fires break out on these sites causing severe air quality problems. Two demonstration projects for capture of landfill gases in Amman and Kuwait were implemented though no documentations of the results are available.

Incineration and waste-to-energy technologies are capital intensive and only used in some cases of treating hazardous wastes such as in Bahrain and Egypt, both without energy recovery. Biological systems are either aerobic or anaerobic, but aerobic processes are most common in the Arab cities to produce compost. There are many composting facilities in Egypt, Syria, Lebanon, Tunisia, Saudi Arabia, Qatar, as well as in other Arab countries.

In the Arab national communication reports, measures reported to mitigate GHG emissions in this sector represented a wish list of different sound solid and liquid waste management practices. These included diversion of organic materials from landfills to produce compost, recovery of methane from landfills to generate electricity, and strengthening the legislative and institutional framework for better management of solid waste. In addition, measures frequently reported included education, training and public awareness on waste issues. Some of these activities are

underway, but mostly they are in the early stages of development in many countries.

### III. MEASURE OF CARBON SEQUESTRATION AND STORAGE

Mitigation of GHG means implementing policies and measures to reduce anthropogenic GHG emissions from sources such as power plants, industrial facilities and the transport sector, as well as to enhance natural GHG sinks such as forests, land use change and carbon capture and storage (CCS). This section discusses enhancements of carbon sinks through afforestations and CO<sub>2</sub> capture & storage.

#### **Land use change: Afforestation**

There is a widespread recognition of the potential of forests and land-use changes for offsetting emissions of GHGs. Measures proposed in national communications included promoting programmes of conservation, regeneration, reforestation, and afforestation.

In Sudan, two main groups of mitigation options were considered for increasing carbon sequestration and storage. The first group represents afforestation and rehabilitation options. These options refer to the afforestation and rehabilitation of wastelands, together with afforestation of 10% of the rain fed land and 5% of the irrigated agricultural land. The second group represents management options, which involve a natural resource management approach based on the conservation and rehabilitation of degraded forests and rangelands. Reforestation and biomass conservation projects are also key elements in Djibouti's proposed programme of action. Tunisia reported on a concerted approach with neighbouring countries, and with the international community for the implementation of a program aimed at combating desertification. Similar projects were also reported in Mauritania, Djibouti, and Morocco.

A promising CDM afforestation project is currently being proposed by the Egyptian Environmental Affairs Agency. The Greater Cairo Ring Road Afforestation project will help improve the air quality of Cairo. The forest that will be planted will be irrigated by treated agri-

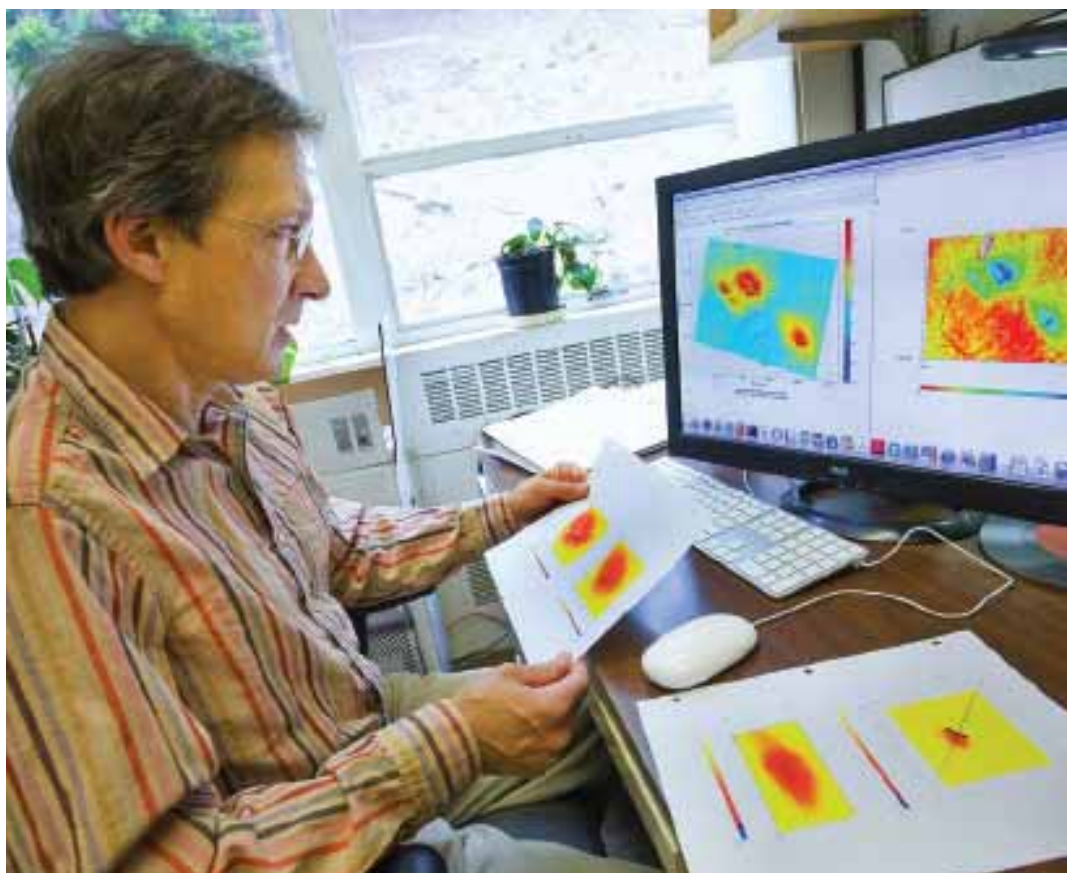
cultural drainage water and will absorb about 100,000 tons of CO<sub>2</sub>eq annually, helping to offset the carbon emissions from vehicles, industry and power plants. The project is currently under development. In addition, Japan Bank for International Cooperation (JBIC) conducted a preliminary study on the Egyptian Biofuel Industry Development in June, 2007. *Jatropha* test cultivation was started in 2003 as a part of Egypt's afforestation program. The Egyptian *Jatropha* yield turned out to be the highest production level compared to the Asian and African non-irrigated cultivation. Although the primary purposes of the Egyptian *Jatropha* model are anti-desertification and beneficial use of treated wastewater, the high production results caught the attention of private biofuel producers. Under that study, JBIC proposed an integrated strategic plan to realize the new biofuel industry with a "Public Private Partnership" (JDI, 2007).

Another remarkable afforestation experience is in the UAE. According to the Environmental Agency - Abu Dhabi, "Over the last few decades, over 120 million trees have been planted, as well as 25 million date palms. Over 92,000 hectares have been planted with forest trees. These are now helping to reverse the process of desertification and to stabilize the sand dunes that once moved inexorably across the land. They also provide attractive new habitats for wildlife, with many species of animals and birds increasing rapidly in numbers as they colonise the new areas of vegetation" (Environmental Agency Abu Dhabi, 2006).

#### **Carbon Capture and Storage (CCS)**

CO<sub>2</sub> capture & storage (CCS) is a process comprised of three steps. The first is CO<sub>2</sub> capture from CO<sub>2</sub> point sources such as power plants, industrial facilities, and natural gas wells with high CO<sub>2</sub> content emissions. The second step is transportation via pipelines to the storage site; and the third step is geological storage in deep geological formations including saline formations, depleted oil/gas fields, coal seams, and enhanced oil or gas recovery sites. In the combustion processes, CO<sub>2</sub> can be captured either in pre-combustion mode by treatment of fossil fuels or in post-combustion mode by treatment of the flue gases. Due to economies of scale, large point sources of CO<sub>2</sub> emissions have the highest potential of CO<sub>2</sub> capture. These include large industries such as oil and





gas, cement and steel and electric power plants. CO<sub>2</sub> has been injected and stored in oilfields as a means to enhance oil recovery since the late 1970s. Currently, the estimated global geological storage potential in depleted oil/gas fields equals 900 Gt of CO<sub>2</sub> (IEA, 2006). The IPCC Special Report on Carbon Dioxide Capture and Storage recently stated that: “CCS has the potential to reduce overall mitigation costs and increase flexibility in achieving greenhouse gas emission reductions.” (IPCC, 2005).

The first major location where CO<sub>2</sub> was stored in geological formations as a climate change mitigation option was under the North Sea. In 1996, StatOil, an oil company, started removing CO<sub>2</sub> from the natural gas and injecting it into a massive saline aquifer located 800–1000 meters under the North Sea (IEA, 2006).

Algeria hosts one of the world’s three largest demonstration sites of CCS which is the BP’s In Salah project, where CO<sub>2</sub> is captured and stored in a gas field. This demonstration project offers

an opportunity to collect baseline and monitoring data that is not associated with enhanced oil recovery. The project is aimed to ensure that secure geological storage of CO<sub>2</sub> can be cost-effectively verified, to demonstrate to stakeholders that industrial-scale geological storage of CO<sub>2</sub> is a viable GHG mitigation option, and to set precedents for the regulation and verification of the geological storage of CO<sub>2</sub>, allowing eligibility for GHG credits in the international carbon market. It is worth mentioning here that CCS projects are not yet eligible under the current modalities of the Clean Development Mechanism (CDM) of the Kyoto Protocol.

The Algerian project involves separating CO<sub>2</sub> from natural gas at the In Salah gas facility. The CO<sub>2</sub> is being re-injected into a sandstone reservoir for permanent storage. In this Gas project, the natural gas has a high level of CO<sub>2</sub> which is captured. The CO<sub>2</sub> free gas is processed for distribution as sales gas. About 1 million tons per year of CO<sub>2</sub> is compressed before it enters the CO<sub>2</sub> pipelines. These pipelines transport the CO<sub>2</sub> to

reservoirs which are up to 20 km away. Finally the CO<sub>2</sub> is injected into the reservoirs at depths of 1.8 to 2 km below the surface (KBR, 2006).

According to the IEA, this project has been storing about 1.2 million ton of CO<sub>2</sub> annually since 2004 with a cost of \$6/ ton CO<sub>2</sub> (IEA, 2006).

It is worth noting that the Arab region, especially in the GCC and other hydrocarbon producing countries, has a great potential of CCS technology by using depleted oil and gas wells for carbon storage.

#### IV. CONCLUSIONS

This review indicates that most of the Arab countries are implementing wide varieties of climate friendly policies and measures. These include policies and measures both to reduce anthropogenic GHG emissions as well as those to enhance carbon sinks. Though most of these policies and measures are being adopted in response to some economic, social, or environmental considerations, they would result in a significant reduction of GHG emissions. Some of these activities are well recognized worldwide such as commercializing wind energy in Egypt, wide use of solar heating in Palestine, Tunisia and Morocco, use of CNG as a transport fuel in Egypt, the first CSP projects in Egypt, Morocco, and Algeria, the first green building council in Dubai, the massive forestation program in the UAE, the first zero-carbon city in Abu Dhabi, and the pioneering CCS project in Algeria. As stated earlier, these initiatives are fragmented as there is little evidence that they have been implemented within an integrated policy framework.

In meeting their obligations to the UNFCCC, 14 Arab countries have submitted their initial national communications. None has completed the second one. The initial national communication of Saudi Arabia, the world's largest oil exporter, for unknown reasons, did not contain mention of any GHG mitigation efforts. In general, more efforts are needed to enhance the reporting quality of the national communication reports as they are important vehicles to showcase the Arab region's contributions to the international efforts to address the climate change challenge.



#### V. RECOMMENDATIONS

Based on the above analysis, Arab countries need to enhance the flow and availability of information on their efforts addressing climate change. This would result in improving policy development and enhance public awareness. Many potential areas of Arab-Arab cooperation could be identified. These include development of the under utilized renewable energy resources, use of CNG as a transport fuel to improve urban air quality while reducing GHG emissions, and tapping on the huge potential of carbon sequestration and storage in the oil producing countries especially in the GCC. It is recommended that Arab countries commit themselves to adopt national energy efficiency and renewable energy targets. Most of the Arab countries, especially in the GCC, need to adopt policies of sustainable transport. These might include building modern public transport systems to improve energy efficiency and abate vehicles emissions. The concept of "green building" should also be promoted and future urban expansions should achieve the highest levels of resources efficiency.



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# A Remote Sensing Study of Some Impacts of Global Warming on the Arab Region

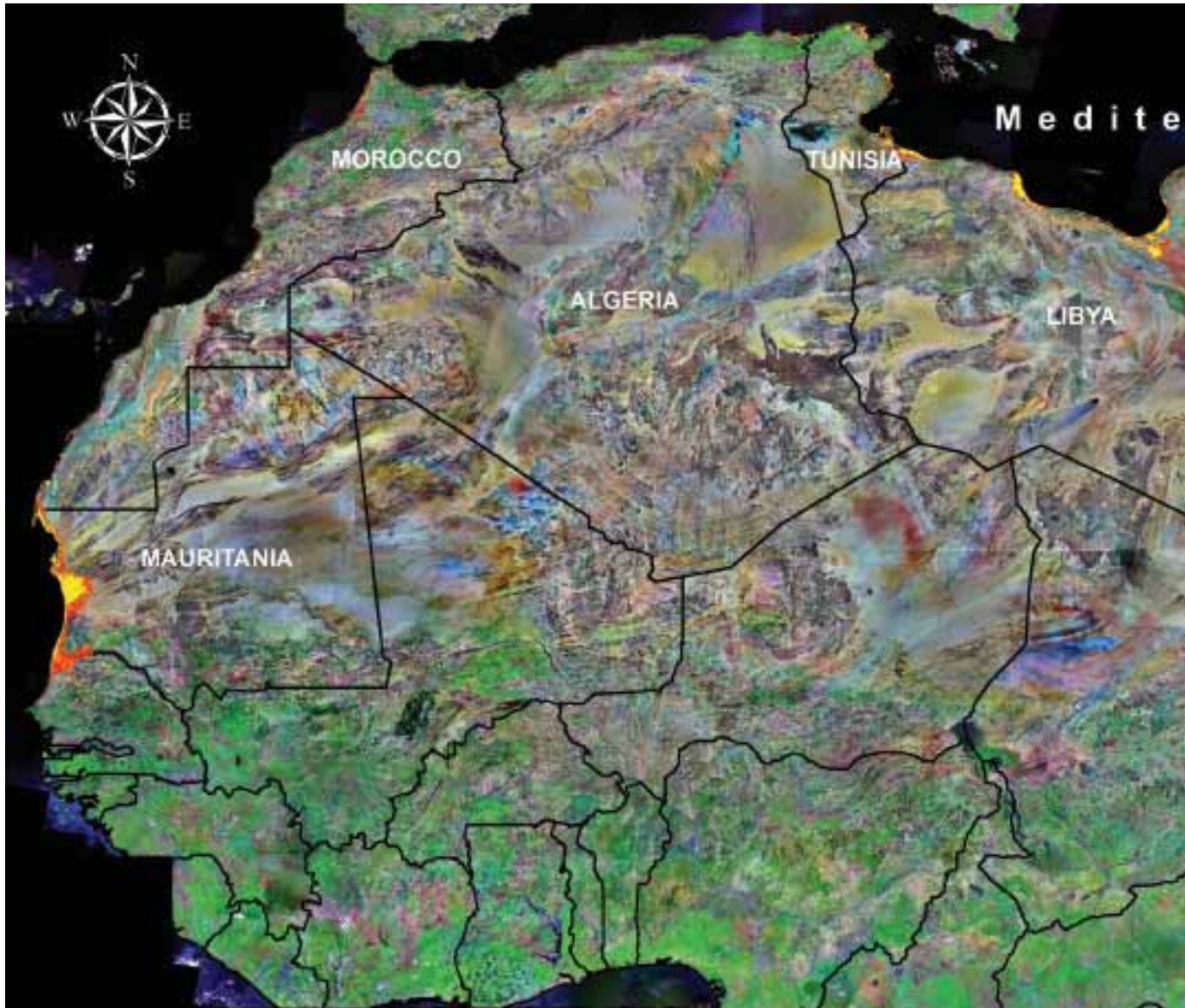
EMAN GHONEIM





FIGURE 1

SIMULATION OF SEA LEVEL RISE SCENARIOS AT DIFFERENT LEVELS



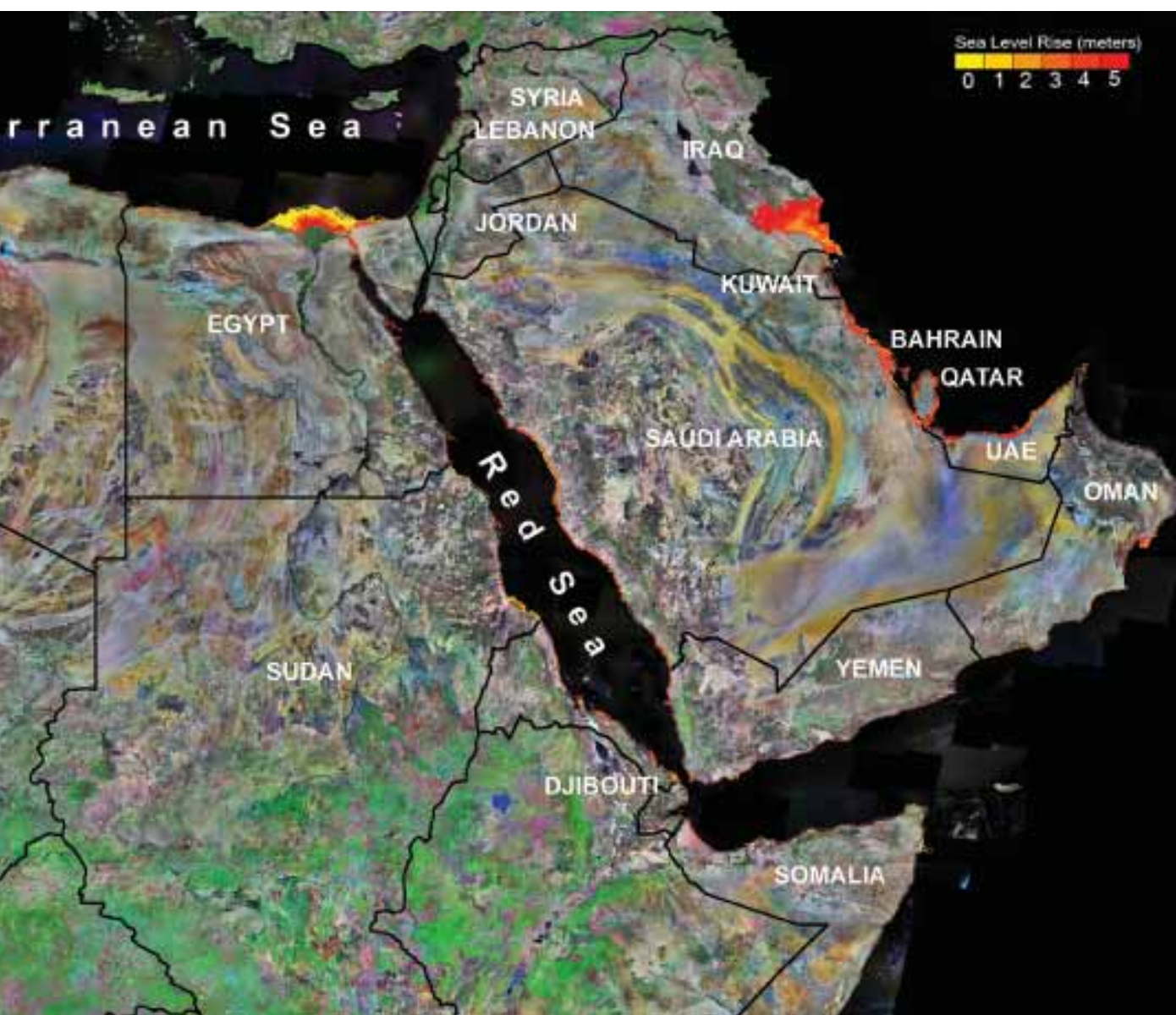
## I. INTRODUCTION

Global warming is one of the most serious challenges facing us today. Under the projected climate changes, many parts of the planet will become warmer. Droughts, floods and other forms of extreme weather will become more frequent, threatening food supplies, economic assets, and human lives. Plants and animals which cannot adapt to the changed weather con-

ditions will die. Sea levels are also rising and will continue to do so, forcing millions of people in coastal zones to migrate inland.

This study uses remote sensing techniques to depict the consequences on the Arab world of various climate change impact scenarios, ranging from conservative to extreme. It neither attempts to endorse a specific level of impact, a matter discussed in other chapters of the report, nor attempts





to be inclusive of all impacts of climate change which can be traced using remote sensing.

In light of the uncertainty surrounding the exact dynamics of climate change and scientific projections, this study takes into account the range from 1 m to 5 m SLR, without ascribing particular likelihoods to any particular value within that range; as such, the study seeks more to illuminate the potential disastrous ramifications of

SLR, whatever the exact SLR will be.

## II. IMPACT OF SEA LEVEL RISE ON THE ARAB COUNTRIES

The past century has witnessed a 17 cm rise in the sea level (IPCC, 2001) at a mean rate of 1.75 mm per year (Miller and Douglas, 2004). The IPCC's Fourth Assessment Report published in

FIGURE 2 SEA LEVEL RISE SCENARIO AT 1 METER



(CRS-BU, E. Ghoneim - AFED 2009 Report)

FIGURE 3 SEA LEVEL RISE SCENARIO AT 2 METERS



(CRS-BU, E. Ghoneim - AFED 2009 Report)

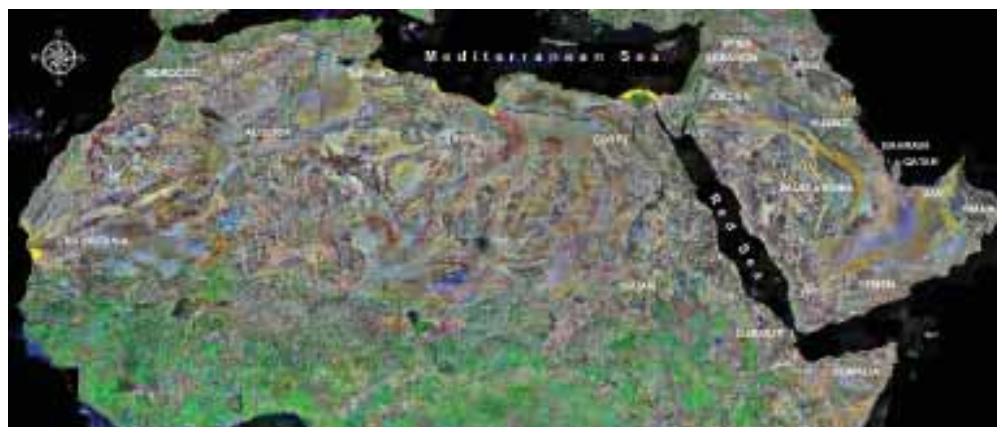
2007 predicted sea-level rise of up to 59 cm by 2100, excluding effects of potential dynamic changes in ice flow (IPCC, 2007). Taking into account the full “likely” range of predicted increases in temperature, SLR could even be amplified to up to 1.4 m by the year 2100 (Rahmstorf, 2007). Other researchers have predicted between 5-6 meters SLR in the event of the West Antarctic Ice Sheet collapse (Tol et al., 2006). As an indication of recent upward revision of projected climate change scenarios, Christopher Field, an American member of the IPCC and founding director of the Carnegie Institution’s Department of Global Ecology at Stanford University, said at the annual meeting of the American Association for the Advancement of Science in February 2009 that

the pace of climate change exceeds predictions, as emissions since 2000 have outpaced the estimates used in IPCC 2007 report.

Without any doubt, SLR is a global threat. With varying predictions on the extent of SLR, based on different variables which cannot all be foreseen, there is a near consensus on the need to apply precautionary principles to global warming. This explains why studies of impact, mainly those carried out by the World Bank, consider SLR scenarios between 1-5 meters. The threat emerges from the fact that a large percentage of the earth’s population inhabits vulnerable coastal zones. About 400 million people live within 20 km of a coast, worldwide (Gornitz, V., 2000). Worryingly, if the sea level rises by only 1 m, it



FIGURE 4 SEA LEVEL RISE SCENARIO AT 3 METERS



(CRS-BU, E. Ghoneim - AFED 2009 Report)

FIGURE 5 SEA LEVEL RISE SCENARIO AT 4 METERS



(CRS-BU, E. Ghoneim - AFED 2009 Report)

would affect more than 100 million individuals (Douglas and Peltier, 2002). “The melting or collapse of ice sheets would eventually threaten land which today is home to 1 in every 20 people” (Stern, 2006).

The coastal zone of the Arab world is no exception to the threat of SLR. Similar to many parts of the world, capital cities and major towns of Arab countries lie along the coast or on estuaries. Their expansions are extremely rapid and, therefore, these metropolises are at great risk of SLR.

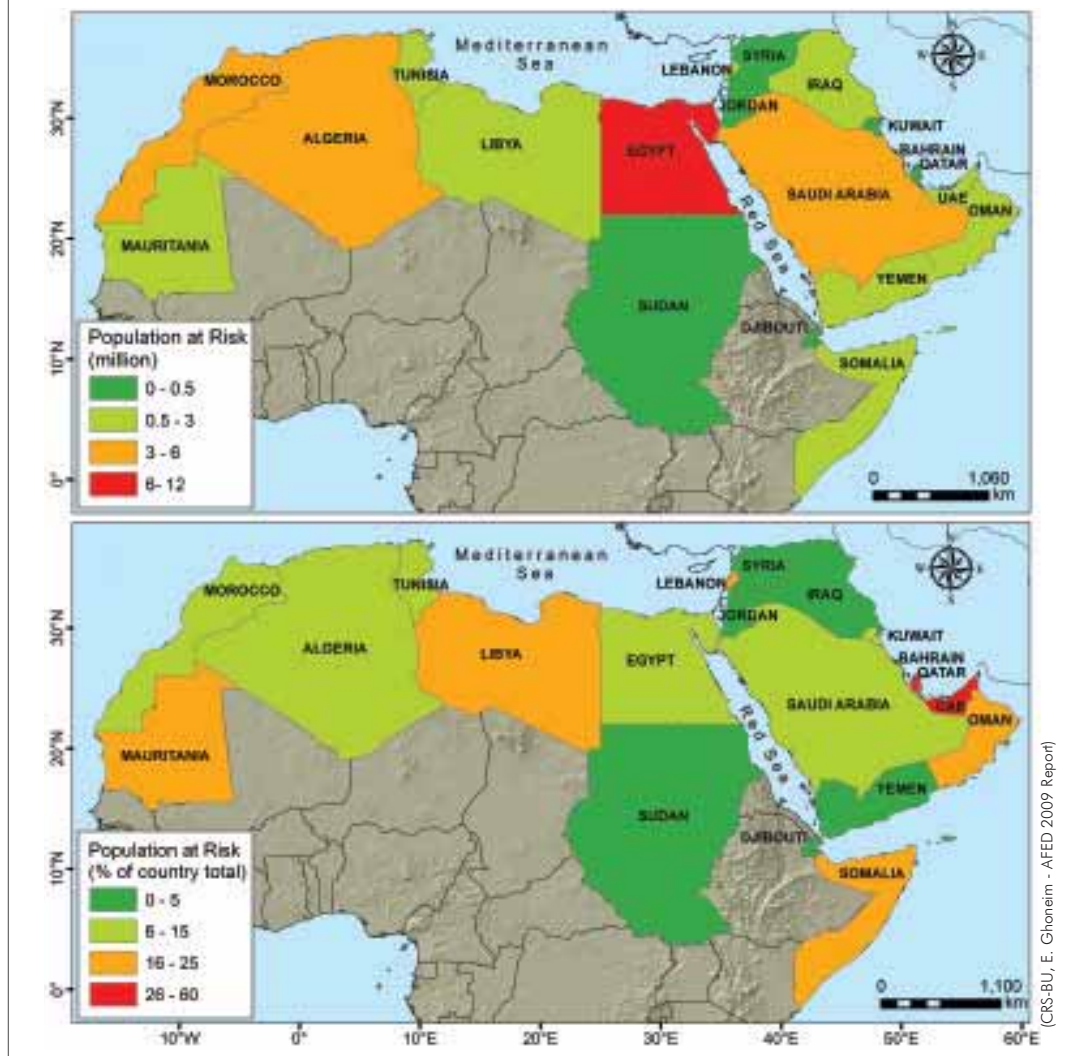
To view more closely the effect of SLR on the Arabian coastline and highlight those countries with high potential risk of SLR, a simulation for SLR has been conducted using the Geographical

Information System (GIS) and the Shuttle Radar Topography Mission (SRTM) data. These data, which are widely used in many scientific investigations, are considered to comprise the best Digital Elevation Model (DEM) on a global scale with consistency and overall accuracy (Suna et al., 2003; Ghoneim and El-Baz, 2007, Ghoneim et al., 2007). Figures 1 to 5 show results of this simulation.

Under the 1 m SLR scenario, the simulation reveals that approximately 41,500 km<sup>2</sup> of the territory of the Arab countries would be directly impacted by the rise of the sea level. Projected increases in sea levels will displace a quickly growing population into more concentrated areas. At least 37 million people (~11%) will be



FIGURE 6 POPULATION AT RISK AT EXTREME 5 METERS SEA LEVEL RISE



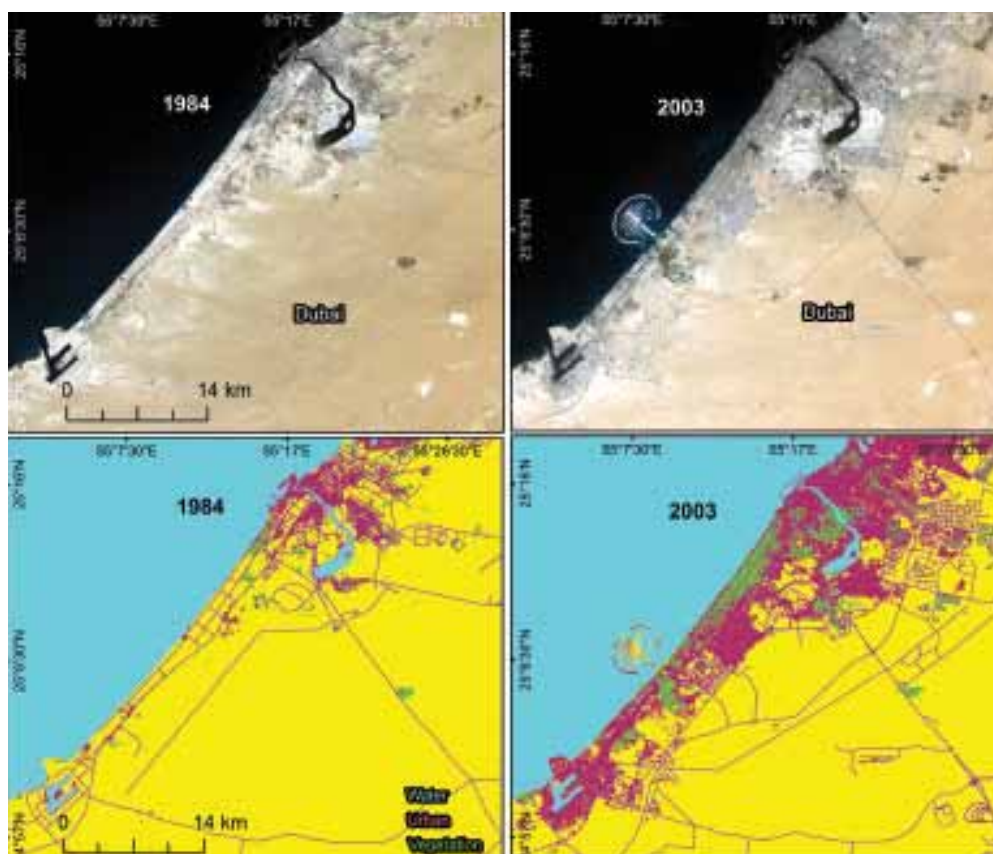
directly affected by SLR of 1 meter. In the case of 2, 3 and 4 m SLR scenarios, around 60,000, 80,700 and 100,800 km<sup>2</sup>, respectively, of the Arab coastal region will be seriously impacted. In the extreme case of 5 m SLR, such impact will be at its highest, as it is estimated that up to 113,000 km<sup>2</sup> (0.8%) of the coastal territory would be inundated by sea water (Figure 1-5).

Potential impacts of SLR, however, are not uniformly distributed across the Arab region. From Figure 6a it is obvious that the SLR impact will be particularly severe in some countries such as Egypt, Saudi Arabia, Algeria and Morocco, whereas it will have a lesser impact on others such as Sudan, Syria, and Jordan.

Egypt will be by far the most impacted country of the Arab world; at least 12 million Egyptians will be displaced with the 5 m SLR scenario. In fact, approximately one third of the Arab population impacted will be from Egypt alone. At the nation level, the United Arab Emirates (UAE), Qatar and Bahrain will witness the highest SLR effect in terms of the percentage of population at risk from the total country population. Here, we project that more than 50% of the population of each country will be impacted by 5m SLR (Figure 6b). The current analysis indicates that Bahrain and Qatar would experience a significant reduction of about 13.4 % and 6.9%, respectively, of their land as a result of the 5 m SLR scenario.

FIGURE 7

BASED ON SATELLITE IMAGE CLASSIFICATION AND CHANGE DETECTION ANALYSIS, IT IS ESTIMATED THAT IN ONE OF THE STUDY SITES IN THE UAE, URBAN GROWTH HAS EXPANDED ALMOST THREE TIMES IN AREA (FROM 78.54 KM<sup>2</sup> TO 226.11 KM<sup>2</sup>) DURING THE LAST 20 YEARS (1984 TO 2003). GREEN LANDS OF THE SAME STUDY SITE HAVE ALSO DOUBLED IN THEIR SURFACE AREA (FROM 26.62 KM<sup>2</sup> TO 47.57 KM<sup>2</sup>) DURING THE SAME PERIOD.



### III. COASTAL URBANIZATION

There are factors – both human and natural – that might contribute and intensify the impact of the SLR. For example, for most parts of the Arab world, rapid and uncontrolled urbanization is occurring at a large scale along the vulnerable coastal areas. Continuation of such urbanization patterns will draw still greater populations into these low-lying hazardous zones and, consequently, SLR would most likely have a profound impact on the people and on infrastructure development in the coastal areas of the region.

Monitoring historical changes in urbanization can be used to identify future trends in urban

expansion independent from climate change, and therefore suggest places that will need to better incorporate climate risks into planning processes. Based on satellite image classification and change detection analysis of the present study (Figure 7), it is estimated, for example, that in Dubai, urban growth (including green areas) has almost tripled its surface area in less than 20 years (between 1984 and 2003). With the addition of the new urbanized area of the Dubai Palm Islands project, the percentage of people and infrastructure likely to be affected by coastal inundation or flooding will be immense.

In order to estimate the total extent of the areas at risk by SLR in more detail, a Digital

FIGURE 8a

**DIGITAL ELEVATION MODEL OF THE THREE EMIRATES OF SHARJAH, AJMAN AND UMM AL-QUWAIN WHICH SHOWS THAT A SEA LEVEL RISE OF 1 METER WOULD INUNDATE 1.2% OF SHARJAH, 8.1% OF AJMAN AND 5.9% OF UMM AL-QUWAIN.**

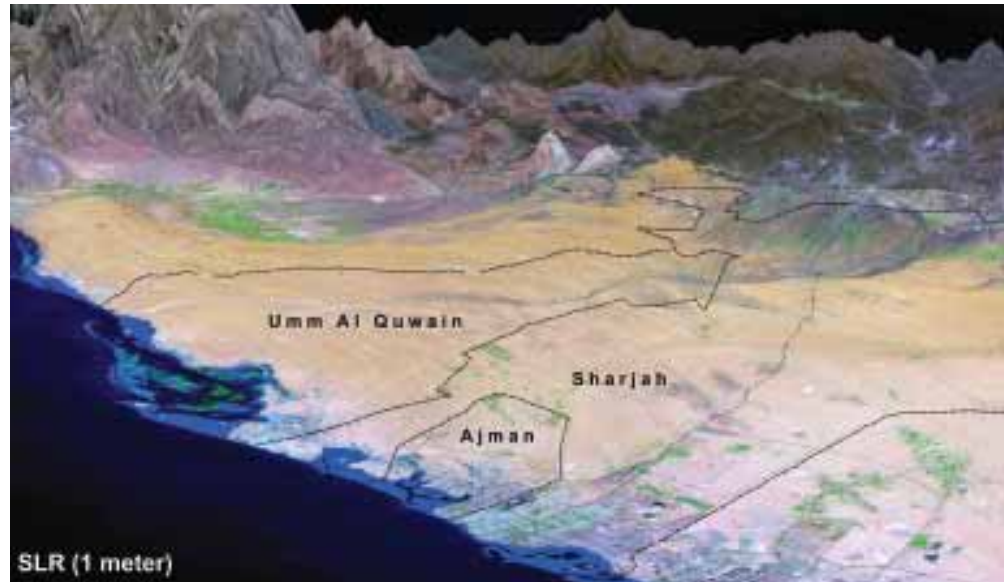


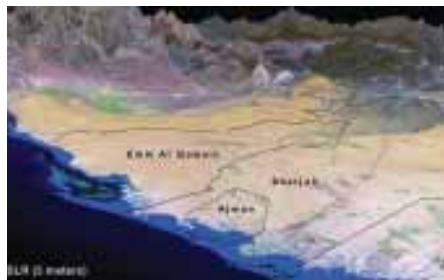
FIGURE 8b

**ZERO METER SLR**



FIGURE 8c

**UNDER THE EXTREME CASE OF 5 METER SLR SCENARIO, 3.2% OF SHARJAH, 24% OF AJMAN AND 10% OF UMM AL-QUWAIN LANDS WOULD BE INUNDATED BY SEA WATER.**



Elevation Model (DEM), for the coastal zone of the three Emirates of Sharjah, Ajman and Umm Al-Quwain, has been constructed from topographic maps. Based on the derived-DEM, it was found that approximately 332 km<sup>2</sup> of the land area of the three Emirates lies below 10 m and is hence highly vulnerable to SLR. Results reveal that a projected SLR of 1 m would inundate approximately 8.1% of the Emirate of Ajman, 1.2% of the Emirate of Sharjah and 5.9% of the Emirate of Umm Al-Quwain (Figure 8b). With the 5 meter scenario, these flooded lands will be increased to reach about 24%, 3.2% and 10% for the three Emirates, respectively (Figure 8c).

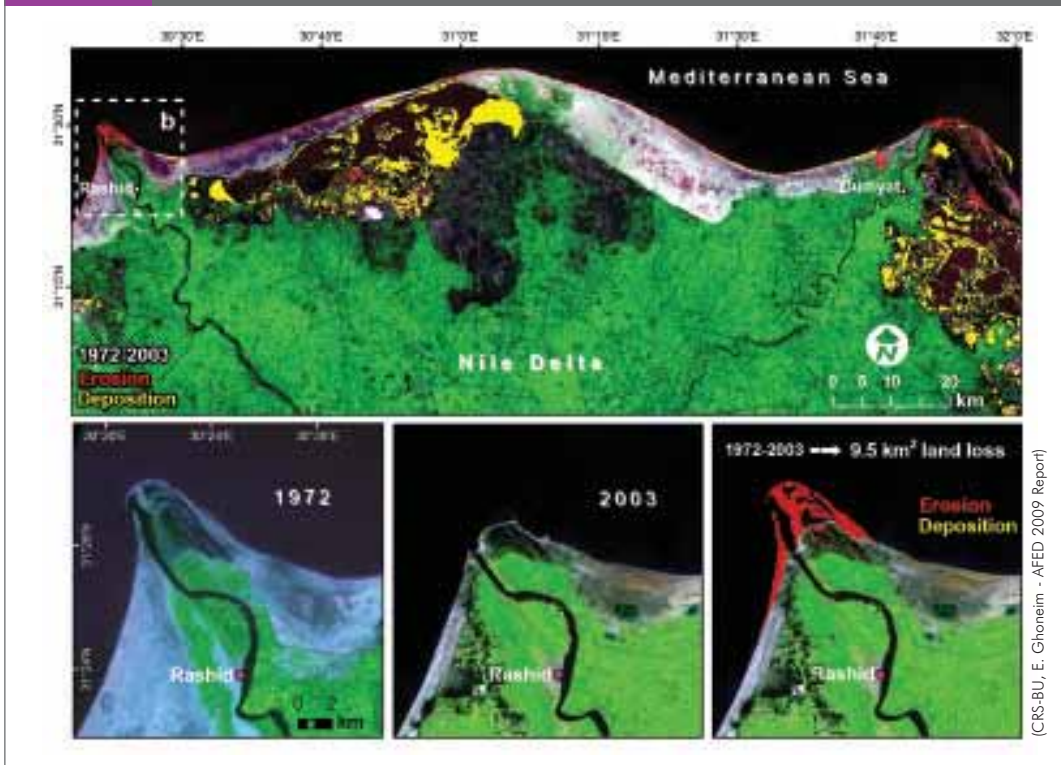
#### **IV. IMPACT OF SEA LEVEL RISE ON THE NILE DELTA**

In the Arab region, locations that occupy low-lying areas, such as deltaic plains, will face even more serious problems due to SLR. River deltas are particularly vulnerable since increases in sea level are compounded by land subsidence and human interference such as sediment trapping by dams (Church et al., 2008). In the Arab world, the two major deltaic areas are that of the Nile River in Egypt and the Tigris and



FIGURE 9

LANDSAT SATELLITE IMAGES SHOW VAST COASTAL EROSION IN THE NILE DELTA WITH A RETREATING RATE OF UP TO 100 METERS PER YEAR IN SOME AREAS



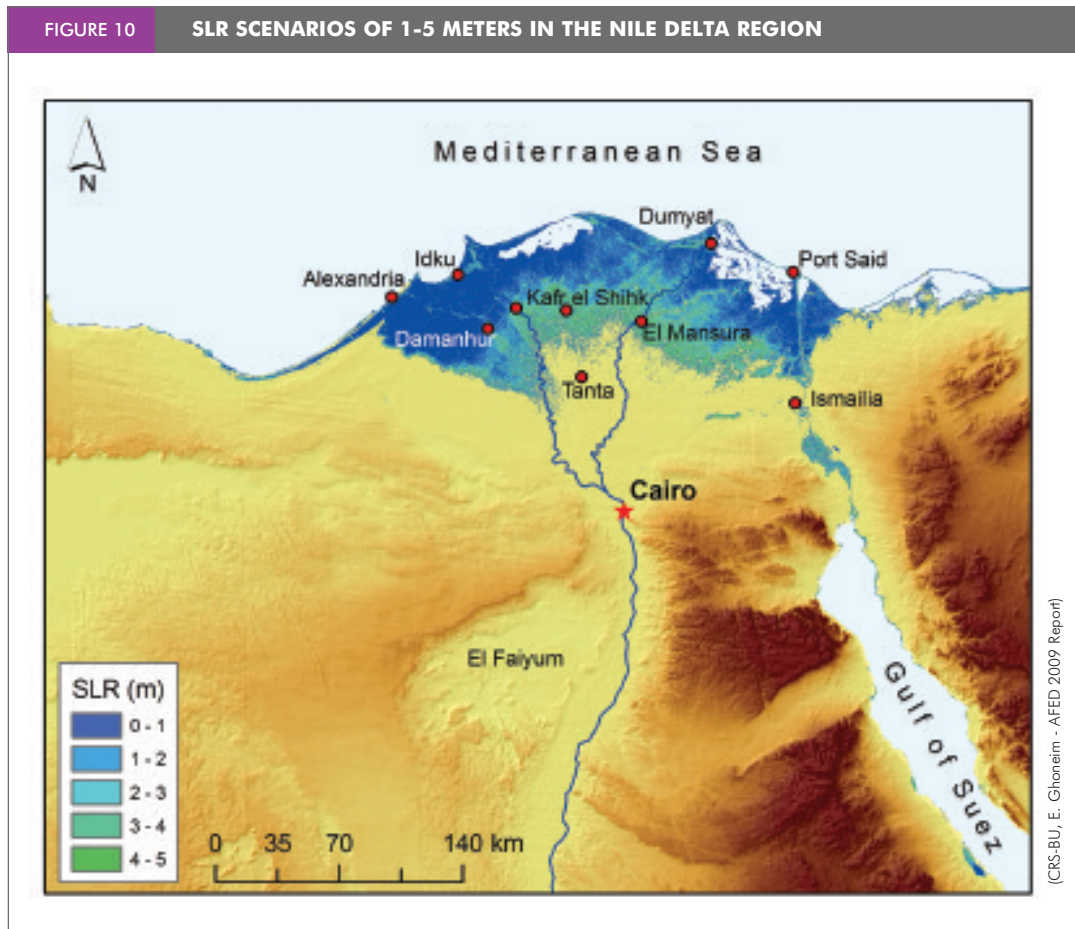
Euphrates in Iraq. These locations are highly populated areas and among the most important agricultural lands in the region. As illustrated from the computed SLR (see Figure 1), these two areas are regionally the most vulnerable. In fact, impacts will be much bigger when combined with increase in the incidence of extreme events on low-level areas.

The total area of Egypt is slightly over one million km<sup>2</sup>, most of which has an arid and hyper-arid climate. Roughly 94% of Egypt's land mass is made up of desert. The fast growing population, now approaching about 81 million, inhabits less than 6% of the country's land area. This land area, which is located in the Nile Delta and the Nile valley, contains the most productive agricultural land and hence the main food source for the entire country. The Nile Delta, which is about 24,900 km<sup>2</sup> in area, alone accounts for about 65% of Egypt agricultural land. This delta, once the largest depocenter in the Mediterranean, is an extreme example of a flat low-lying area at high risk to SLR (El-Raey, 1997). The delta is presently retreating due to

accelerating erosion along the coastline. This has generally been attributed to both human and natural factors. The construction of the Aswan High Dam (1962) and the entrapment of a large amount of sediments behind it, in Lake Nasser, are major factors causing erosion in the Nile Delta. The entrapment of another considerable quantity of Nile sediments by the extremely dense network of irrigation and drainage channels and in the wetland of the northern delta has also contributed greatly to the delta's erosion (Stanley, 1996). At present, only a little amount of the Nile River sediments is carried seaward to replenish the Nile Delta coast at its northern margin. Even the very small remaining amount of the delta sediment presently reaching the Mediterranean is removed by the strong easterly sea currents.

Moreover, the delta's subsidence of about 1 to 5 mm per year (Stanley, 2005), due to both natural causes and heavy groundwater extraction, is influencing the coastal erosion tremendously. Such coastal impact is evident in satellite images, where coastal erosion can be clearly

FIGURE 10 SLR SCENARIOS OF 1-5 METERS IN THE NILE DELTA REGION



seen close to the Rosetta and Damietta promontories (Figure 9). Analysis of Landsat images reveals that the promontory of Rosetta, in particular, has lost approximately 9.5 km<sup>2</sup> in area (Figure 9b) and its coastline has retreated 3 km inland in only 30 years (1972 - 2003). This means that this part of the delta is retreating at an alarming rate of about 100 m per year.

Under SLR scenarios, much more of the Nile Delta will be lost forever. Remote sensing and GIS analysis depict areas of the Nile Delta at risk of 1 m SLR and the extreme case of 5 m SLR (Figure 10). Based on this figure, it is estimated that a sea level rise of only 1 m would flood much of the Nile Delta, inundating about one third (~34%) of its land, placing important coastal cities such as Alexandria, Idku, Damietta and Port-Said at a great risk. In this case, it is estimated that about 8.5 % of the nation's population (~7 million people) will be displaced.

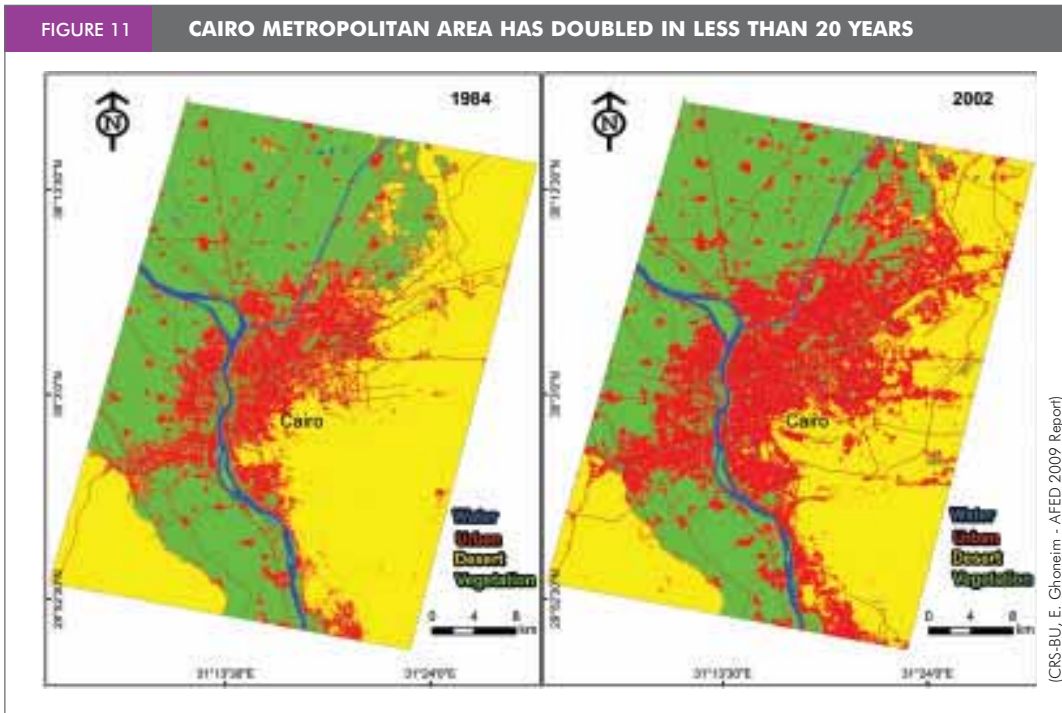
In the extreme case of 5 m SLR, more than half (~58%) of the Nile Delta will be facing destructive impacts, which would threaten at least 10 major cities (among them Alexandria, Damanhur, Kafr-El-Sheikh, Damietta, Mansura and Port-Said), flooding productive agricultural lands, forcing about 14% of the country's population (~11.5 million people) into more concentrated areas to the southern region of the Nile Delta, and thus would contribute to worsening their living standards.

## V. IMPACT OF URBANIZATION AND URBAN HEAT ISLAND

The southern part of the Nile Delta is presently suffering from the uncontrolled urbanization of the city of Cairo, the capital city of Egypt. Results of the current investigation show that the total built-up area in Cairo has expanded significantly over the last few decades. The high

FIGURE 11

## CAIRO METROPOLITAN AREA HAS DOUBLED IN LESS THAN 20 YEARS



(CRS-BU, E. Ghoneim - AFED 2009 Report)

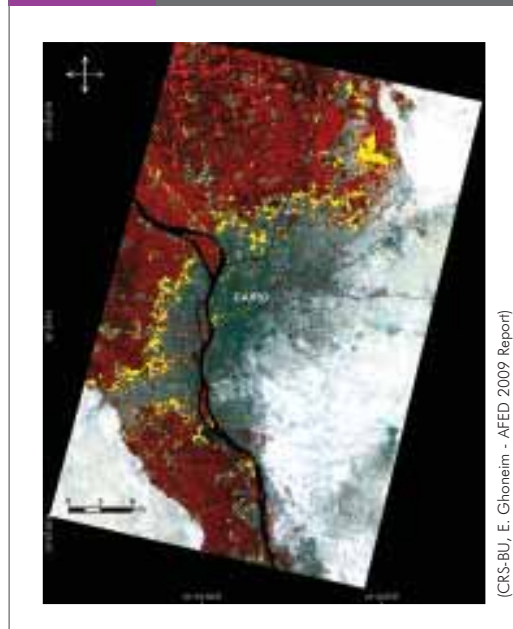
economic growth and employment opportunities in this city caused an influx of labour migration. Local increase of population plus migrants caused the city to expand rapidly and in an uncontrollable fashion. As shown in Figure 11, the Cairo metropolitan area has doubled in size in less than 20 years (1984-2003). Presently, the city has a population of about 17.5 million people, making it the largest and most populous metropolitan area in the Arab world.

As Cairo grows outward, a host of problematic issues are raised. The first of these issues is the loss of prime cultivated lands to urban expansion and development, due to the increase in housing demand. Analysis shows that about 12% (-62 km<sup>2</sup>) of the farmland areas in the vicinity of Cairo were lost in 18-year time span between 1984 and 2002 (Figure 12). Many large cities of the MENA region (for example Beirut, Figures 14 and 15) show the same disturbing trend of green cover and agricultural land loss for urban expansion. Once these lands have been converted to urban use, green areas and agricultural lands are generally lost forever, cutting down the carbon sinks, and in the long term could cause food scarcity.

Another problematic issue that relates to urban-

FIGURE 12

## 12% OF THE FARMLAND AREAS IN THE VICINITY OF CAIRO WERE LOST IN 20 YEARS



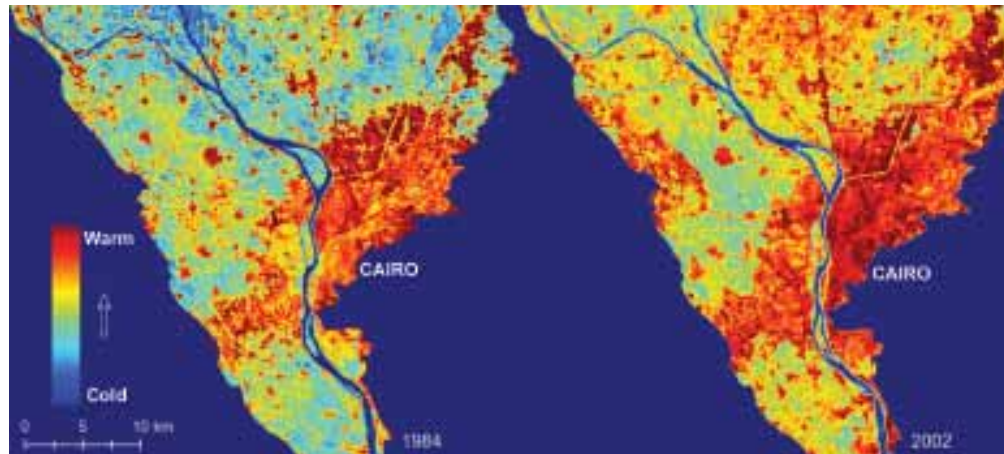
(CRS-BU, E. Ghoneim - AFED 2009 Report)

ization is the Urban Heat Island effect (UHI), for which the temperatures of central urban locations are several degrees higher than those of nearby rural areas of similar elevation.



FIGURE 13

**RAPID URBAN GROWTH IN CAIRO BETWEEN 1984-2002 CAUSED SIGNIFICANT RISE IN SURFACE TEMPERATURE (SHOWN IN RED COLOR), REFERRED TO AS URBAN HEAT ISLAND (UHI) EFFECT**



(CRS-BU, E. Choneim - AFED 2009 Report)

Urbanization can have significant effects on local weather and climate (Landsberg, 1981), which in turn can contribute greatly to global warming. Urban expansion usually arises at the expense of vegetation cover when open space is converted to buildings, roads, and other infrastructure. Urban materials used to build these structures do not have the same thermal properties as vegetation cover, and consequently, can largely influence the local urban climate. The urban geometry of a city can increase surface temperatures as well by obstructing air flow and preventing cooling by convection.

Studies on surface temperature characteristics of urban areas using satellite remote sensing data have been conducted primarily using the thermal-infrared band from Landsat Enhanced Thematic Mapper Plus (ETM+) data. As illustrated in Figure 13, Cairo shows a significant rise in surface temperature with a general trend of warmer urban areas versus cooler surrounding cultivated land.

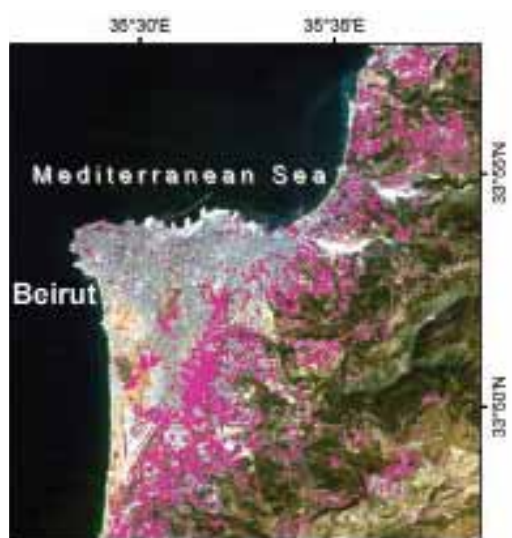
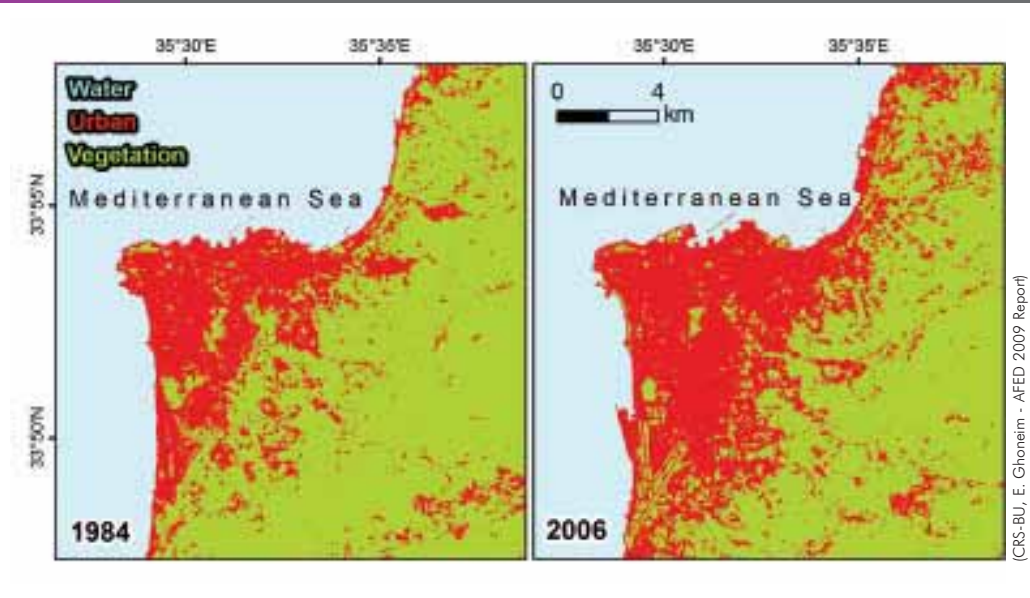
In the future, urban climate change will be of importance to a larger and larger number of residents of the Arab world. With such a significant and rising fraction of the Arab world's population concentrated in urban areas, local climatic effects will be felt by a great number of people.

## VI. DUST STORMS IN THE ARAB DESERTS

Aerosol pollution caused by dust storms can modify cloud properties to reduce or prevent precipitation in the polluted region. Aerosol containing black carbon can impact the climate and possibly reduce formation of clouds. The decrease in precipitation from clouds affected by desert dust can cause drier soil, which in turn raises more dust into the air, consequently providing a potential feedback loop to further decrease rainfall. Moreover, anthropogenic changes of land use exposing the topsoil can initiate such a desertification feedback process. (Rosenfeld et al., 2001)

Urbanization not only increases the local temperature but also creates industrial districts that cause atmospheric pollution and reduce local air quality. With the continuous build-up of climate change emissions in the atmosphere from unregulated industrial emissions, many desert regions will get hotter and drier in a phenomenon called the amplification effect; that is, already hot and dry places on Earth will become even more so. Consequently, dust storms in the desert will become more frequent and intense.

Research shows that dust storms are increasing

FIGURES  
14, 15**EXPANSION OF URBANIZATION IN COSMOPOLITAN BEIRUT BETWEEN 1984 AND 2006: 15.8% OF THE GREEN COVER WAS LOST**

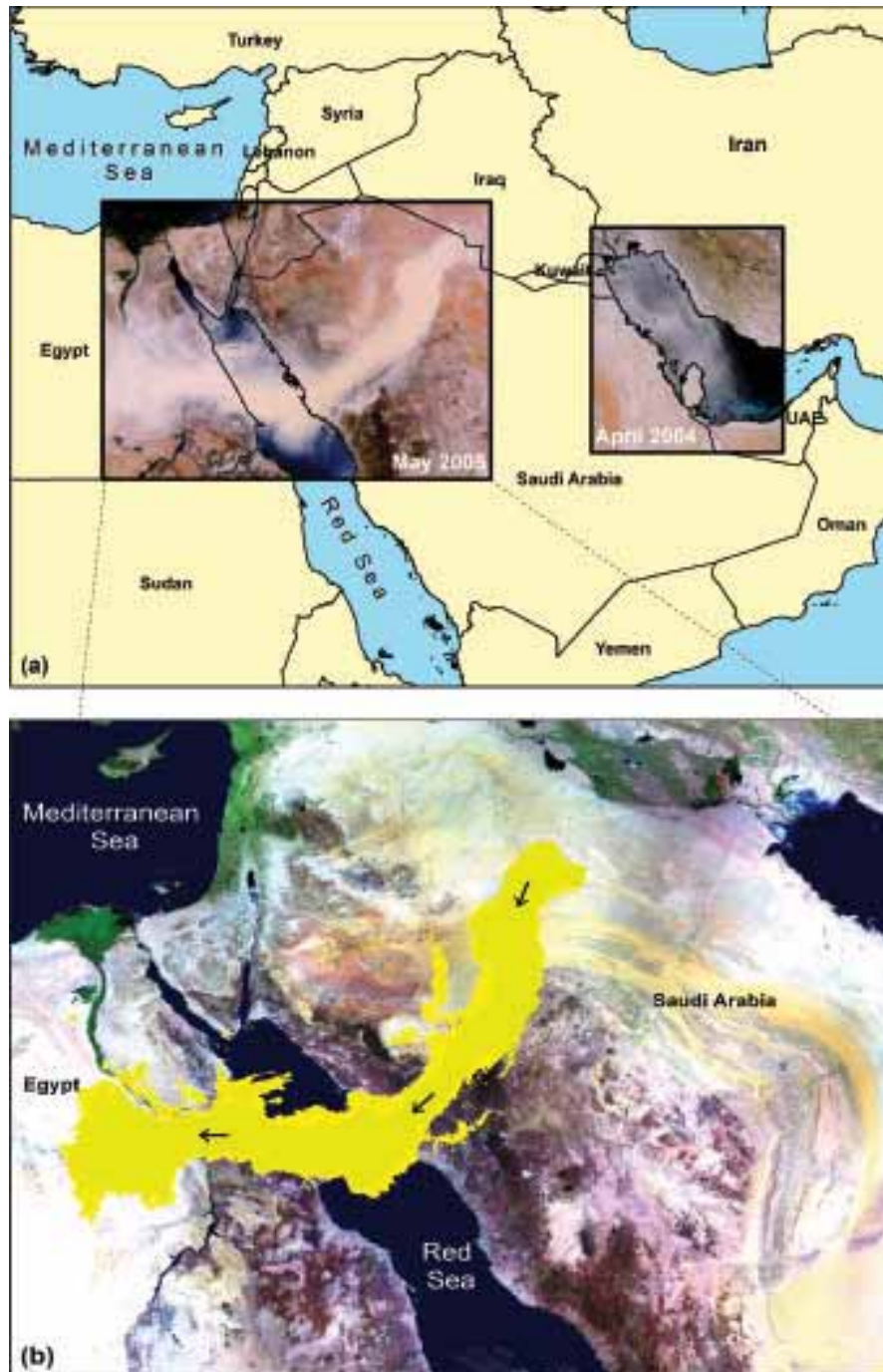
in frequency in specific parts of the world, including Africa and the Arabian Peninsula. For example, the annual dust production had increased tenfold in the last 50 years in many parts of North Africa. Dust storms are also accelerating in the Arab region due to the fact that local soil cover is being loosened by off-road vehicles (e.g., the effect of the Iraq wars), livestock grazing, and road development for oil and gas production, particularly in the Gulf region.

The availability of large and daily coverage satellite imagery by, for instance, the MODIS Terra and Aqua sensors enable us to monitor dust storms on a daily basis and identify their main source globally. For example, as shown in Figure 16a, a thick snake of yellowish dust originating from the border of Iraq with a southwest moving front can be clearly seen in one of the MODIS-Aqua images (acquired in May 2005). This storm is so thick that it hides a large part of the Red Sea beneath it. Image classification accentuates such phenomena and reveals the mega dimension of such dust storms; Figure 16b shows a storm which reached up to 1700 km in length. This storm crossed Saudi Arabia and all the way past the green ribbon of the Nile Valley to the western desert of Egypt.

Another example of a mega dust-storm is captured by a MODIS-Terra image (acquired in May 2004). Here, a thick pall of sand and dust can be seen blown out from the Iranian Desert over the Gulf and engulfing Kuwait, the eastern coast of Saudi Arabia, Bahrain, Qatar and United Arab Emirates (see Figure 16a).

FIGURES  
16(a) 16(b)

16(a), LEFT: A MODIS-AQUA IMAGERY SHOWS A MEGA DUST STORM ORIGINATING FROM IRAQ IN 2005 16(a), RIGHT: A MODIS-TERRA IMAGERY ILLUSTRATES A THICK PALL OF SAND AND DUST BLOWING FROM THE IRANIAN DESERT IN 2004 16(b): SATELLITE IMAGE CLASSIFICATION DEMONSTRATES THE MEGA DIMENSION OF A DUST STORM THAT REACHED 1700 KM IN LENGTH. THIS STORM CROSSED SAUDI ARABIA PAST THE GREEN RIBBON OF THE NILE VALLEY TO THE WESTERN DESERT OF EGYPT



(CRS-BU, E. Ghoneim - AFED 2009 Report)



## VII. CONCLUSION

In the Arab world, segments of coastal areas are important and highly populated centres of industry, manufacturing and commerce. With its nearly 34,000 km of coastline, the Arab world is susceptible to sea level rise. The potential exposure of many of its countries and cities such as Alexandria, Dubai and many more to the impact of sea level rise may be fairly significant, based on today's socio-economic condition in coastal areas. After accounting for future development and population growth in these regions, sea level rise has been shown to pose important policy questions regarding present and future development plans and investment decisions.

Notably, urbanized sandy coasts have been extensively cited as particularly vulnerable if future development is concentrated close to the shoreline and if sensitive ecosystems exist in close proximity to these urbanized areas. Such regions will experience problems such as inundation, coastal erosion and impeded drainage. Moreover, the continuing rapid and dense urban development of many areas in the Arab world would result in a dramatic alteration of the land surface, as natural vegetation is removed and replaced by non-evaporating, non-transpiring surfaces. Under such circumstances, surface temperature of these areas will rise by several degrees. On the long term, such urban Heat Island effect (UHI) could have severe negative consequences on the local weather of the Arab region, which in turn would contribute significantly to global warming.

Furthermore, the increasing frequency of dust storms is one of the serious environmental challenges facing the Arab region. Such storms would induce soil loss, decrease of precipitation and agricultural productivity, dramatic reduction of air quality and ultimately affect human health. Although it seems that we are not totally prepared to face all such destructive effects of the SLR, UHI and dust storms, recent advances in remote sensing, increased availability of high resolution space imagery and the accessibility to more detailed datasets of digital elevation, population and land cover-use, have all the potential to provide improved surveillance of such negative effects and their associated impacts on the entire Arab world. Such observational data can then be used as a solid basis upon which policies could be made.

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### NOTE

Images produced and analyzed for AFED 2009 Report by E. Ghoneim at the Center for Remote Sensing, Boston University.



## *Impact of Climate Change: Vulnerability and Adaptation* **Coastal Areas**

MOHAMED EL-RAEY



## I. INTRODUCTION

Arab countries are situated in a hyper-arid to arid region with some pockets of semi-arid areas. The region is characterized by an extremely harsh environment, with issues including scarcity of water resources, very low precipitation, low biodiversity, excessive exposure to extreme events, and desertification.

The Arab region consists of 22 countries who are all members of the League of Arab States (LAS), 10 in Africa and 12 in West Asia. It enjoys extended coastal zones on the Mediterranean Sea, the Red Sea, the Gulf and the Atlantic Sea where large percentages of the population live in a number of highly populated economic centres. In addition, growth trends of both population and tourism in the coastal areas have been well observed (Massoud et al., 2003).

In 2003 the total population of the region

reached 305 million, giving the region 4.7% of the world's population. Over the last two decades, the population grew at an average rate of 2.6% per annum, with an increase in the total urban population from 44% to almost 54%. Meanwhile, the development and poverty situations in the region are highly uneven and poverty is a serious problem in many Arab countries. Almost 85 million people are below the poverty line of \$2/day, accounting for almost 30% of the region's total population in 2000 (LAS, 2006).

As a result of increasing populations and the expansion of tourism, unplanned urbanization and industrialization of almost all coastal centres have been observed at high rates. The need for efficient transportation systems and a shortage of strategic planning, low awareness and law enforcement have significantly contributed to increasing pollution and a deterioration of the quality of life in many population centres.

The marine side of the coastal zones of Arab

TABLE 1 THE ESTIMATED AREA, COASTLINE AND THE POPULATION WITHIN 100KM OF THE COAST (%)

Country	Area (Km <sup>2</sup> )*	Coastline (Km)**	Population/1000***	Population Growth (%)***	Population within 100 km of coast (%) in 2000****
<b>Bahrain</b>	740	590	753	1.8	100
<b>Iraq</b>	435,052	58	28,993	-	5.7
<b>Kuwait</b>	17,818	499	2,851	2.5	100
<b>Oman</b>	309,500	2,092	4,017	2.2	-
<b>Qatar</b>	11,427	563	2,595	1.8	88.5
<b>United Arab Emirates</b>	83,600	1,318	4,380	2.3	84.9
<b>Saudi Arabia</b>	2,250,000	2,640	24,735	2.4	30.3
<b>Djibouti</b>	23,200	370	833	1.6	100
<b>Jordan</b>	92,300	26	5,924	3.2	29
<b>Somalia</b>	637,657	3,025	8,699	3.1	54.8
<b>Sudan</b>	2,505,000	853	38,560	2.1	2.8
<b>Comoro</b>	2,236	340	839	2.2	100
<b>Yemen</b>	555,000	1,906	22,389	3.1	63.5
<b>Egypt</b>	1,002,000	2,450	75,498	1.8	53.1
<b>Palestine (Gaza Strip)</b>	27,000	40	841	-	100
<b>Lebanon</b>	10,452	225	4,099	1.1	100
<b>Syria</b>	185,180	193	19,929	2.4	34.5
<b>Algeria</b>	2,381,741	998	33,858	1.5	68.8
<b>Libya</b>	1,775,000	1,770	6,160	1.9	78.7
<b>Mauritania</b>	1,030,700	754	3,124	2.7	39.6
<b>Morocco</b>	710,850	1,835	31,224	1.2	65.1
<b>Tunisia</b>	165,150	1,148	10,327	1.0	84
<b>TOTAL</b>	14,211,603	22,105	262,628,000		

Sources: Modified after: (WRI/EarthTrend\*, 2000); The World Fact Book\*\*, 2006; Encyclopedia Britannica1; POPIN\*\*\*, 2006; (WRI/EarthTrend,\*\*\*\*,2000)

TABLE 2

## A COMPARISON OF IMPACTS OF SEA LEVEL RISE ON INDICATORS OF VARIOUS REGIONS, IN PERCENTAGE TERMS

Indicators	World	LA	MENA	SSA	EA	SA
<b>1m SLR</b>						
<b>Area</b>	0.31	0.34	0.25	0.12	0.52	0.29
<b>Population</b>	1.28	0.57	3.20	0.45	1.97	0.45
<b>GDP</b>	1.30	0.54	1.49	0.23	2.09	0.55
<b>Urban extent</b>	1.02	0.61	1.94	0.39	1.71	0.33
<b>Ag. extent</b>	0.39	0.33	1.15	0.04	0.83	0.11
<b>Wetlands</b>	1.86	1.35	3.32	1.11	2.67	1.59
<b>5m SLR</b>						
<b>Area</b>	1.21	1.24	0.63	0.48	2.30	1.65
<b>Population</b>	5.57	2.69	7.49	2.38	8.63	3.02
<b>GDP</b>	6.05	2.38	3.91	1.42	10.20	2.85
<b>Urban extent</b>	4.68	3.03	4.94	2.24	8.99	2.72
<b>Ag. extent</b>	2.10	1.76	3.23	0.38	4.19	1.16
<b>Wetlands</b>	7.30	6.57	7.09	4.70	9.57	7.94

LA: Latin America and Caribbean; MENA: Middle East and North Africa; SSA: Sub-Saharan Africa; EA: East Asia; SA: South Asia.

Source: Dasgupta et al., 2007

countries is considered rich in its marine biological resources including a high biodiversity of fisheries, coral reefs and mangrove ecosystems. As a result, the coastal zone has been a very important asset for the attraction of national and international tourism and an important contributor to national economies.

The Arab region is therefore considered among the world's most vulnerable regions to the adverse impacts of climate change; it will be especially exposed to diminished agricultural productivity, higher likelihood of drought and heat waves, long-term dwindling of water supplies, loss of coastal low-lying areas and considerable implications on human settlements and socioeconomic systems (IPCC, 2007). Specifically, the impact of sea level rise (SLR) is considered serious for many of the Arab countries (e.g. Agrawala et al., 2004; Dasgupta et al., 2007).

Table 2 presents a comparison of the vulnerability of the coastal zone among various regions of the world according to specific indicators (Dasgupta et al., 2007)

While the land area of the Middle East and North Africa region would be less impacted by SLR than the developing world generally (0.25% vs. 0.31%

with a 1m SLR), all other indicators suggest more severe impacts of SLR in this region. In particular, with a 1m SLR, 3.2% of its population would be impacted (vs. 1.28% worldwide), 1.49% of its GDP (vs. 1.30% worldwide), 1.94% of its urban population (vs. 1.02% worldwide), and 3.32% of its wetlands (vs. 1.86% worldwide) (Dasgupta et al., 2007).

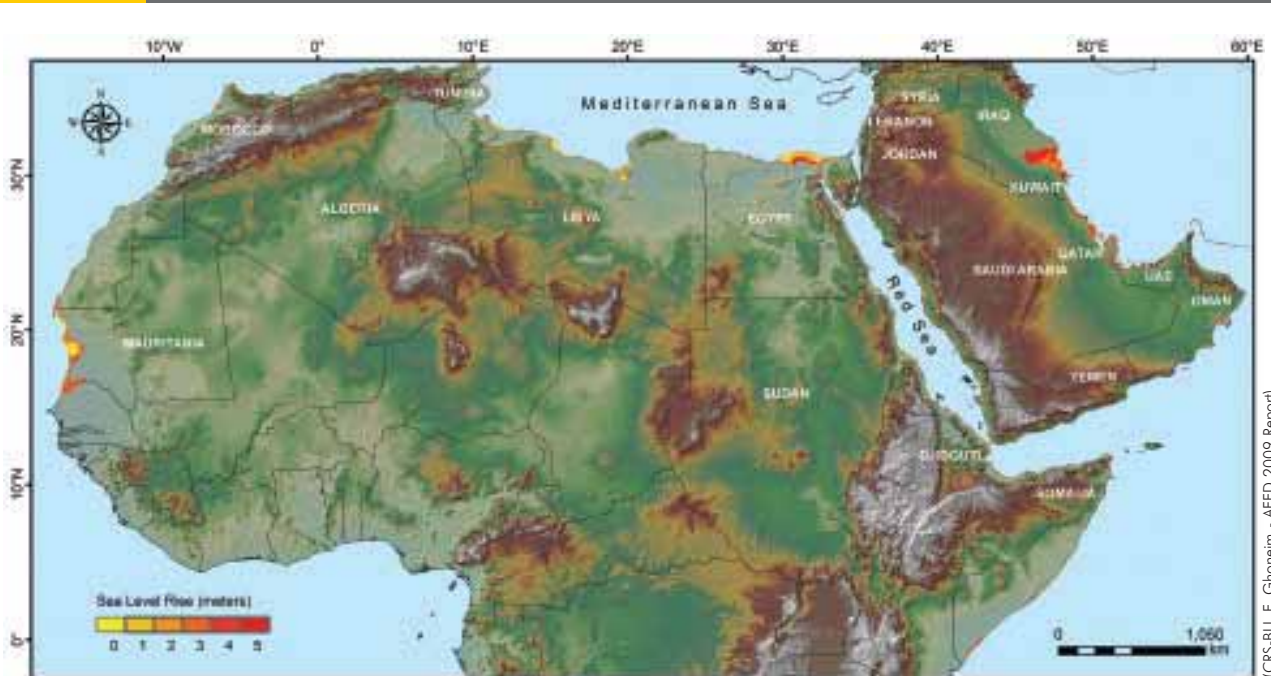
On the institutional side, some of the Arab countries have established environmental regulations for the protection and preservation of their coastal resources. However, without building strong capabilities for monitoring, assessment and law enforcement, it is expected that the deterioration of coastal resources will continue. Impacts of climate change and sea level rise in particular, should be added to the list of deterioration issues of main concern.

Although some Arab countries such as Lebanon, Egypt, Saudi Arabia, Tunisia, Morocco, Algeria and others have already started assessing their vulnerability to climate change in cooperation with the international community, international support is strongly required to include these issues in the national policies and strategies of all the Arab countries.

The objective of this review is to present a gener-

FIGURE 1

POTENTIAL IMPACTS OF SEA LEVEL RISE OVER THE ARAB REGION. NOTE THE VULNERABILITY OF THE NILE DELTA, IRAQ, GULF COUNTRIES AS WELL AS NORTH AFRICAN COUNTRIES.



(Special analysis carried out for AFED Report by E. Ghoneim at the Center of Remote Sensing, Boston University)

(CRS-BU, E. Ghoneim - AFED 2009 Report)

al survey of the vulnerability of the coastal resources in the Arab region and to identify and explore the need for proactive policies and measures for adaptation, and institutional capabilities for monitoring, assessment and upgrading of awareness.

## II. MARINE AND COASTAL RESOURCES IN THE ARAB REGION

From the coastal point of view, the Arab region could be divided into three major sub-regions. The following sections provide a brief overview of each.

### *The Mediterranean North African Sub Region*

The Mediterranean is virtually an enclosed sea bounded by Europe, Africa and Asia. It has a surface area of 2.5 million km<sup>2</sup>. The total length of the Mediterranean coastline is about 46,000km, of which 19,000km represent island coastlines. It is characterized by a relatively high degree of biological diversity. Its fauna is characterized by

many endemic species and is considerably richer than that of the Atlantic Ocean for instance. The continental shelf is very narrow and the coastal marine areas are rich ecosystems. The central zones of the Mediterranean are low in nutrients but coastal zones benefit from telluric nutrients that support higher levels of productivity. Among the ecosystems that occupy coastal marine areas, the rocky intertidal estuaries, and, above all, sea-grass meadows are of significant ecological value (UNEP, 2007).

In addition to its critical position at the middle of highly populated continents and its pleasant weather during summer, the Mediterranean Sea is an important destiny for tourism. In addition, being in the middle of trade between east and west it became an important traffic route for ships. The sandy extended beaches of low elevation on most of its coasts off of North Africa attract tourism from all over the region. In addition, the gradual development of large economic and industrial centres of Arab countries such as the cities of Alexandria, Port Said, Damietta, Benghazi, Tunis, Casablanca and Beirut helped the development of industry and



tourism among Arab and European countries of the region.

### **The Red Sea and Gulf of Aden Sub-region**

The Red Sea has a surface area of about 450,000 km<sup>2</sup> and varies in width from 30 to 280 kilometres. It has an average depth of about 500m, with extensive shallow shelves well known for their marine life and corals. The southern entrance at Bab-el-Mandab is only 130m deep, which restricts water exchange of water between the Red Sea and the Gulf of Aden (Gerges, 2002), hence the sea is vulnerable to increasing pollution by land-based sources from surrounding countries as well as the heavy shipping traffic through this passage. The Red Sea is also considered a very important water way for oil from the Gulf area through the Suez Canal to Europe.

Resources of the Red Sea and Gulf of Aden are a source of economic, social and cultural prosperity, providing subsistence and commercial food supplies, as well as domestic and international tourist destinations. They also provide a strategically important transport route for shipping (especially petroleum products) and trading of rich and varied cultural heritage. Together, they are also a globally significant repository of marine and coastal biodiversity, having the highest biodiversity of any enclosed sea.

The Red Sea is a rich and diverse ecosystem. It contains fairly distinct faunal species subsets, many of which are unique. Approximately 6.3% of the coral species are endemic to the Red Sea. Mangrove and seagrass communities are an important feature of the coastal areas and provide significant productivity and input of nutrients. Inshore, halophytic salt marsh vegetation and sabkhas (seasonally flooded low-lying coastal plains) cover much of the coast (Gerges, 2002).

The Red Sea is characterized by its high biodiversity of marine habitats, life, corals and sea grass. It therefore attracts tourism from all over the world all year around. A large number of highly populated resorts and diving centres have been established with a variety of tourism services. Tourism centres have been established at many coastal areas along the Red Sea including the Gulf of Suez and Gulf of Aqaba. In addition, large tourist

and economic cities such as Sharm El Sheikh and Hurghada as well as a number of industrial cities such as Suez, Jeddah and Aqaba are situated along its coast.

### **The ROPME Gulf Sub-region**

The ROPME Gulf sub-region has a surface area of 239,000 km<sup>2</sup>, a mean depth of 36 m, and an average volume of 8,630,000 km<sup>3</sup>. Because of the relative shallowness and water clarity of the coastal areas, the Gulf supports highly productive coastal habitats, such as the extensive intertidal mudflats, seagrass and algae beds, mangroves and coral reefs (Munawar, 2002). The most pressing environmental concerns include the decline of seawater quality, degradation of marine and coastal environments, coral bleaching and coastal reclamation (ROPME, 2004).

The sub-region is also extremely rich in terms of marine life, and it hosts many good fishing grounds, extensive coral reefs, and abundant pearl oysters. It has come under pressures from fast urbanization and industrialization. In particular, petroleum spillages during the recent wars and conflicts have placed severe stresses on the region.

## **III. ISSUES OF MAIN CONCERN**

The Arab world's coastal regions suffer from a number of important environmental problems including:

- **Population growth, unemployment and shortage of awareness**

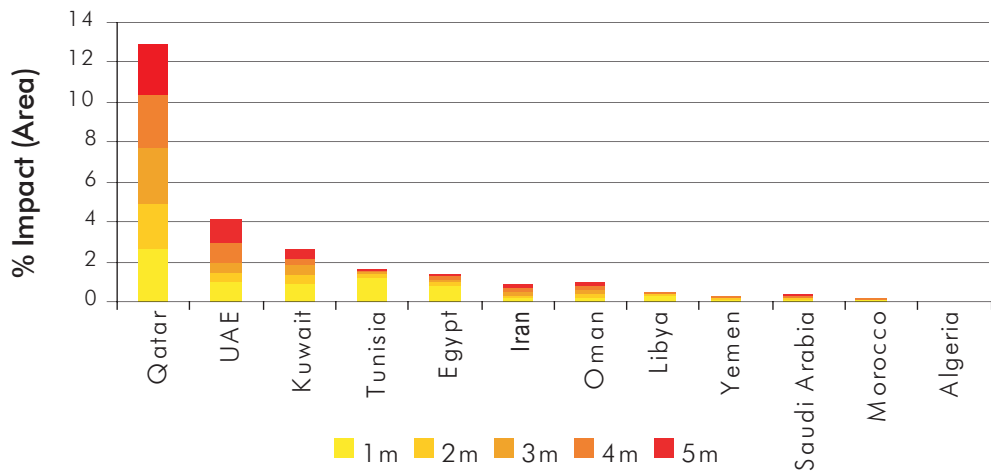
Population growth rates in the coastal regions are much higher than those in other regions, which are already high. The shortage of employment opportunities is the main concern of many of the Arab countries not only because of the low capacities but also of the shortage of specialized experts.

- **Unplanned Urbanization**

Many Arab coastal cities are expanding at high rates, without due consideration to planning for future needs. Many slum areas are being created with associated shortages of adequate sanitation and socioeconomic problems. In addition, the shortage of proper land use planning has created many problems of services and overconsumption.

FIGURE 2

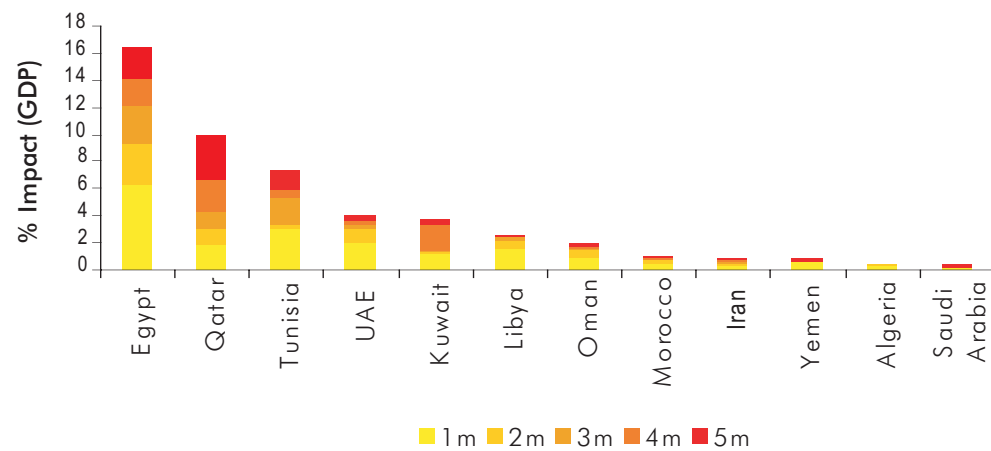
## A COMPARISON OF PERCENTAGE IMPACTS OF SEA LEVEL RISE ON LAND AREAS OF ARAB COUNTRIES



Source: Dasgupta et al., 2007  
 Note: Countries not mentioned did not provide data

FIGURE 3

## A COMPARISON OF PERCENTAGE IMPACTS OF SEA LEVEL RISE ON THE GDP OF ARAB COUNTRIES



Source: Dasgupta et al., 2007  
 Note: Countries not mentioned did not provide data

Large scale structures have been built on many of the coastal areas without due consideration to the potential impacts of sea level rise.

#### • **Pollution and water scarcity**

Excessive domestic and industrial pollution is characteristic of many coastal cities in the Arab region. Even though there are many laws and regulations against domestic and industrial pol-

lution, very limited control is actually exercised because of the lack of institutional capabilities for monitoring and control.

Moreover, the situation of water scarcity that prevails over the region has been a decisive political, geographic and domestic factor in the region's development. Contamination of ground water and impacts of wastewater are widespread in many rural areas.

FIGURE 4

### A COMPARISON OF PERCENTAGE IMPACTS OF SEA LEVEL RISE ON THE AGRICULTURAL PRODUCTION OF ARAB COUNTRIES

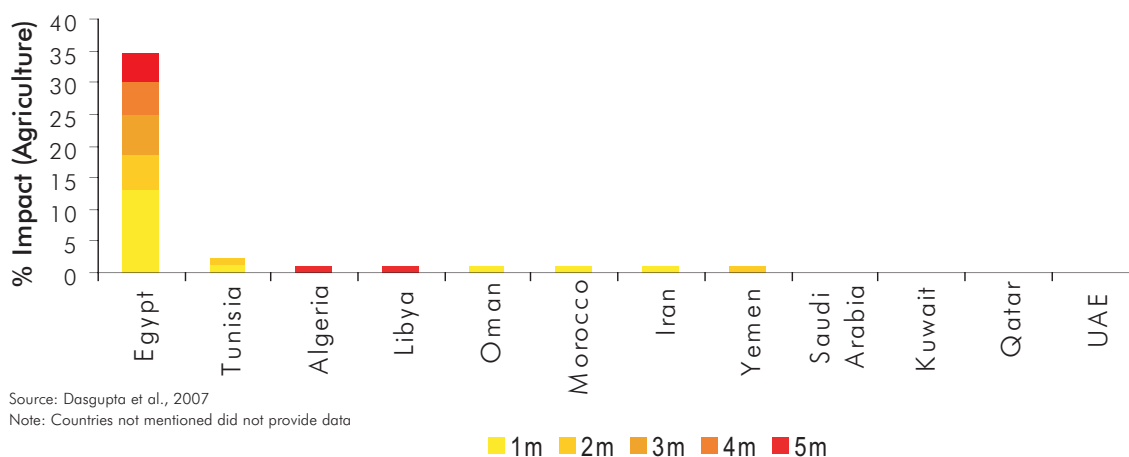
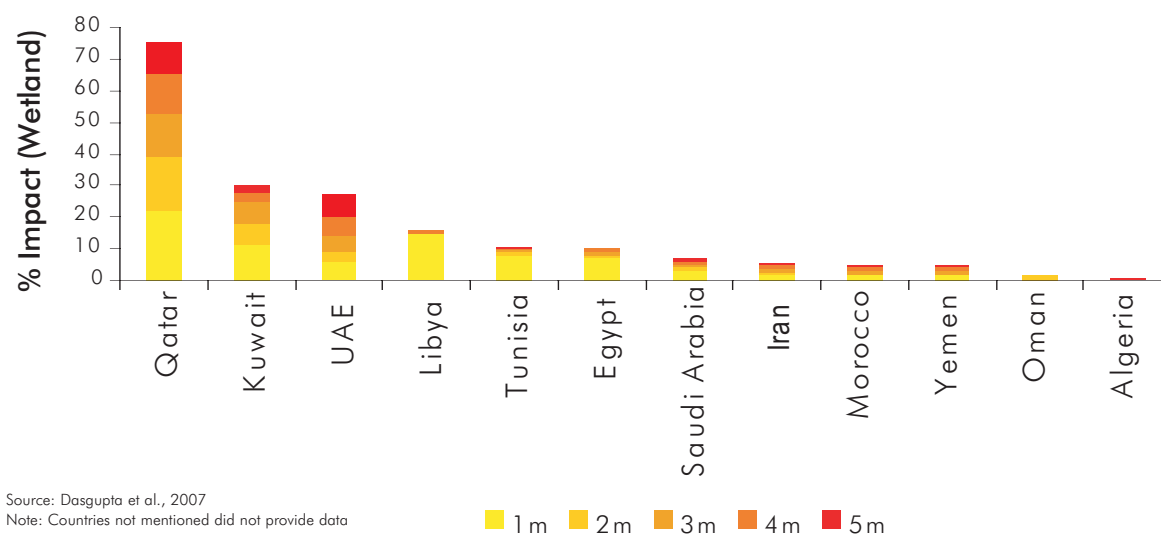


FIGURE 5

### A COMPARISON OF PERCENTAGE IMPACTS OF SEA LEVEL RISE ON THE WETLANDS OF ARAB COUNTRIES



- **Shortage of institutional capabilities for management**

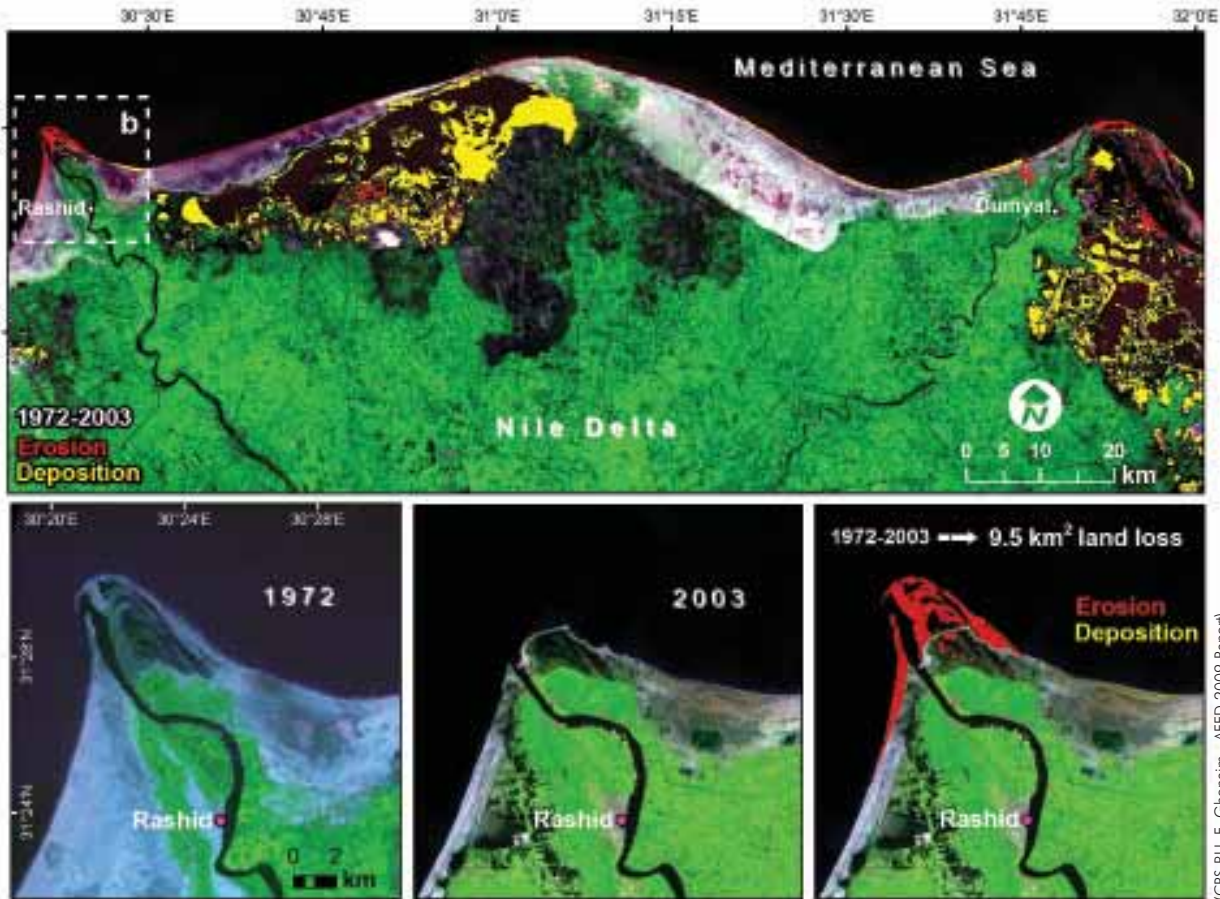
This is truly the main problem, as institutional management capabilities are needed for proper assessment and control of pollution as well as other unplanned and illegal activities. There is very limited information on land subsidence, especially in areas where extraction of petroleum has been going on for a long time. There is no monitoring of ground water salinity or soil salinity.

- **Low elevation land and land subsidence**

The spreading of low elevation areas on the coastal zone constitutes a major source for the risk of inundation. This is a common problem in the Nile Delta region and many of the coastal touristic cities such as Alexandria, Benghazi, Casablanca, Jeddah and Dubai. Land subsidence increases this risk, but it is not well monitored in many of the coastal areas of the Arab coasts where huge extractions of oil and gases are taking place.

FIGURE 6

COASTAL EROSION CHANGES AS OBSERVED FROM ANALYSIS OF SATELLITE IMAGES MORE THAN 30 YEARS.



Special analysis carried out for AFED Report by E. Ghoneim at the Center of Remote Sensing, Boston University

#### • **Lack of data and information**

The near lack of data and information on various aspects of vulnerabilities along the coastal zone is another characteristic of the region. Very limited time series data are available on extreme events, changing sea level, ground water salinity and land subsidence in the coastal regions.

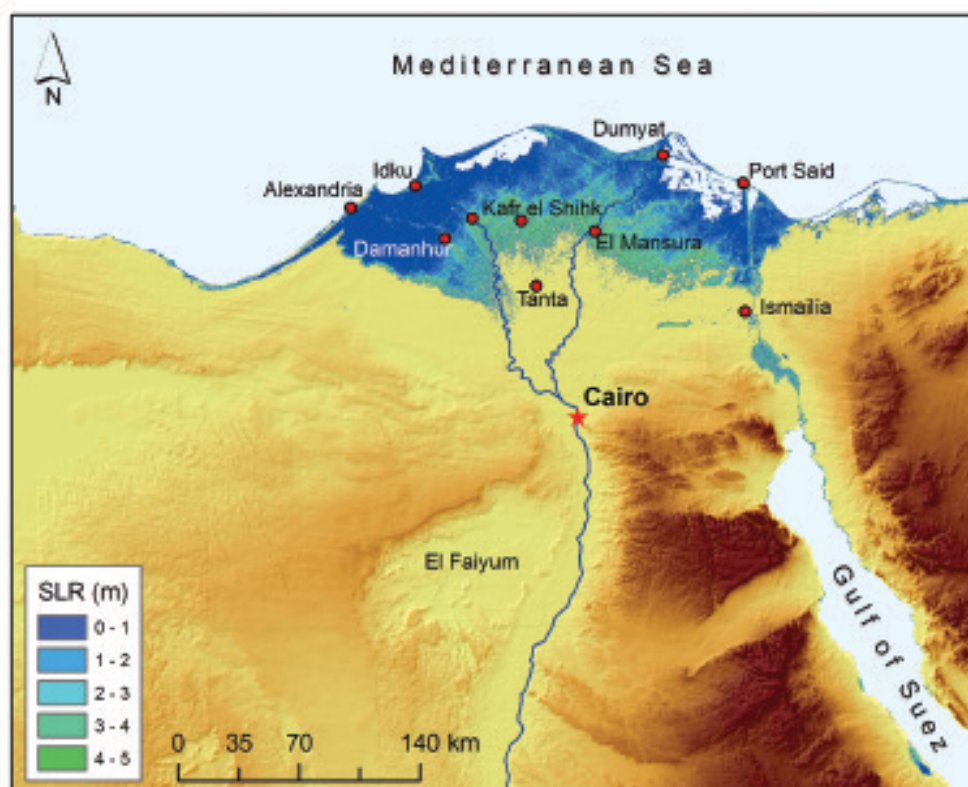
#### **IV. VULNERABILITY OF THE ARAB COASTAL ZONE TO IMPACTS OF CLIMATE CHANGE**

Very limited studies of the integrated impacts of climate change on the Arab coastal zones are available; however, there are a number of scattered studies on some cities (e.g. Sestini, 1991;

El Raey et al., 1995). In addition, many Arab countries have submitted their initial communications to the UNFCCC with a somewhat preliminary overview of their vulnerabilities. However, a recent study carried out by the World Bank for developing countries has stressed the vulnerability of the Arab region and has estimated percentage potential impacts of sea level rise on countries of the region (Dasgupta et al., 2007). Figures 2 through 5 present the results of this comparison of vulnerabilities of various sectors of countries of the region due to a sea level rise of 1m and 5m. While a sea level rise of more than 1m is a most unlikely scenario (in this author's point of view), a comparison of percentage impacts among certain countries and across sectors in the region is nonetheless very useful to consid-



FIGURE 7

**THE VULNERABILITY OF THE NILE DELTA REGION TO THE POTENTIAL IMPACTS OF SEA LEVEL RISE.**

(CRS-BU, E. Ghoneim - AFED 2009 Report)
Special analysis carried out for AFED Report by E. Ghoneim at the Center of Remote Sensing, Boston University

er for planning.

The World Bank study clearly shows that Qatar will be the most impacted country by sea level rise in terms of the percentage of vulnerable land area and in terms of the percentage of wetland affected by sea level rise. Egypt will be the most impacted from the points of view of percentage impact on GDP and agricultural production.

Some specific sub-regional details are presented below:

### ***Mediterranean Sea countries***

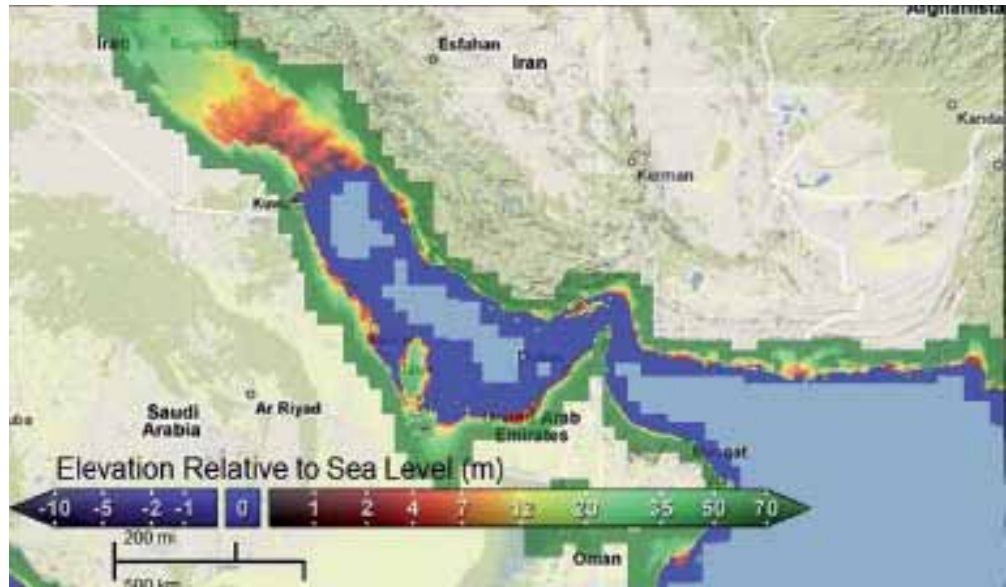
The Nile Delta region and the cities of Alexandria, Rosetta and Port Said and their vicinity are undoubtedly the most vulnerable areas in the North African region (e.g., El Raey et al., 1995; El Raey, 1997a). The Nile Delta region is vulnerable to the direct risk of inundation of low land areas and the coastal areas

already below sea level and it is also vulnerable to salt water intrusion and increasing soil salinity of agricultural land. It is estimated that a population of over six million people lives in these vulnerable areas and these may have to move away and abandon these areas. Noting that the Nile Delta region produces over 60% of the agricultural production of Egypt and the above mentioned cities host more than 50% of the industrial and economic activities of the country, it is expected that the potential losses in Egypt will be extremely high if no action is taken.

One of the most important coastal problems is coastal erosion, which is also expected to change due to alterations of the coastal circulation pattern in the region due to climate changes. Figure 6 shows the dynamics of coastal erosion in the highly vulnerable region of Rosetta city and its vicinity. The rates of coastal erosion of the Rosetta promontory, for instance, due to losses of

FIGURE 8

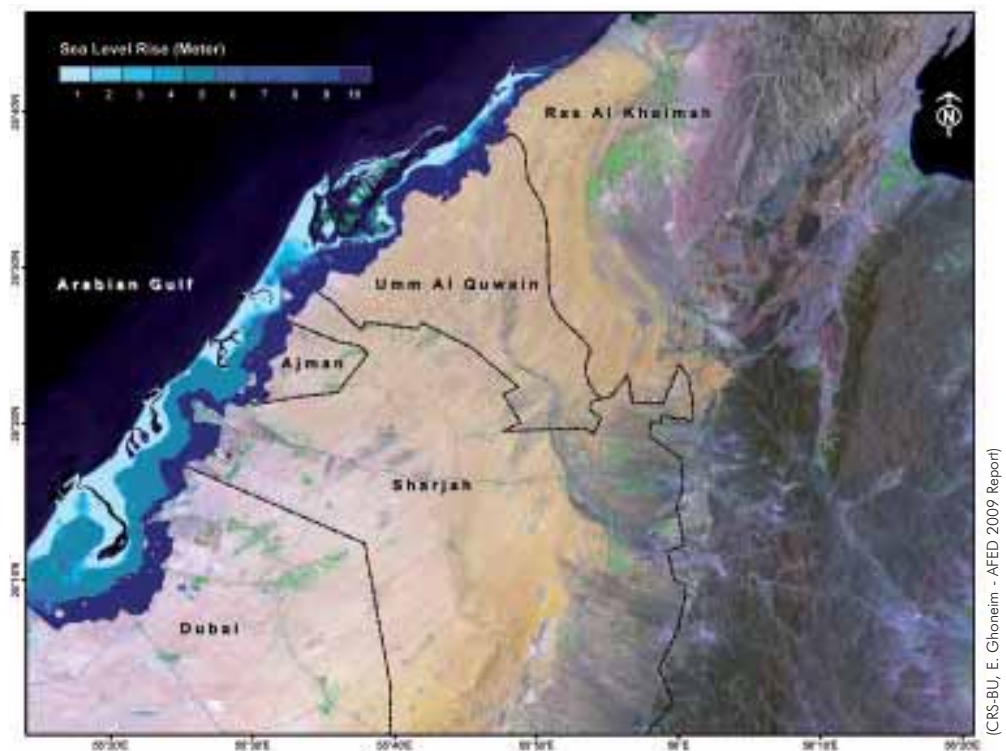
A SEA LEVEL RISE EXPLORER IMAGE ILLUSTRATING THE VULNERABILITY OF MANY OF THE ARAB GULF STATES AS WELL AS IRAQ TO POTENTIAL IMPACTS OF SEA LEVEL RISE



Source: Sea Level Rise Explorer, 2009

FIGURE 9

THE VULNERABILITY OF THE COASTAL ZONE OF THE UNITED ARAB EMIRATES.



Special analysis carried out for AFED Report by E. Ghoneim at the Center of Remote Sensing, Boston University

(CRS-BU, E. Ghoneim - AFED 2009 Report)

silt after the establishment of the Aswan High Dam, exceeded 50m/year. These rates are expected to increase due to sea level rise.

In addition, negative impacts of climate change on various aspects of trading in the region such as export, Suez Canal revenue, migration of poor communities and socioeconomic implications are also expected.

The deltaic plain of the Medjerda River in Tunisia is another example of an area vulnerable to a rising sea level. In addition, there are several other vulnerable low land areas near the cities of Benghazi in Libya, Casablanca in Morocco and Nouakchott in Mauritania .

### **The ROPME and Gulf Countries**

The Gulf is highly vulnerable at its northern tip north of Kuwait and south of Iraq (Shatt el Arab). According to results presented in the Sea Level Rise Explorer (2009) shown in Figure 8, it is clear that despite the limited coastline of Iraq on the ROPME Gulf region, the vulnerable low land areas extend as far inland as near Baghdad.

The coastal areas of all Arab Gulf states are highly vulnerable to the potential impacts of sea level

rise; this is most worrying given that very limited information is available on land subsidence due to oil and gas extraction in this region. In addition, many of the large and small islands in the Gulf region are highly vulnerable to the impacts of sea level rise.

Bahrain is among those highly vulnerable islands. Figure 10 shows the projected impacts of sea level rise estimated based on analysis of satellite images; almost 11% of the land area of the kingdom will be lost due to sea level rise of 50 cm if no action is taken for protection (Al Janeid et al., 2008).

### **Red Sea Countries**

Encouraged by its oil resources, the attractive marine life and the favourable climate, major oil and tourist industries have evolved on the coasts of the Red Sea. Tourism here is based mainly on the coral reef, sea grass, mangrove communities and associated rich marine life. Protectorates have been established by the Egyptian authorities in the Sinai Peninsula along the Gulf of Aqaba and huge infrastructure has also been established by many countries in the region.

The coastal tourist industry in Egypt is booming

FIGURE 10

ESTIMATED IMPACTS OF VARIOUS SCENARIOS OF SLR ON THE KINGDOM OF BAHRAIN

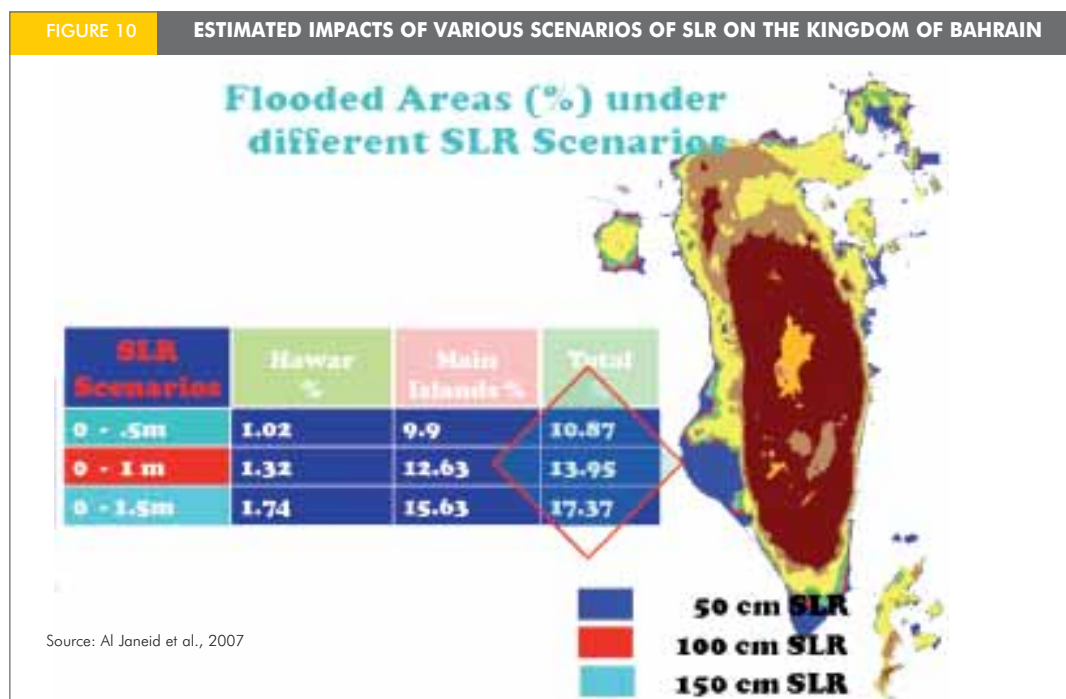




FIGURE 11

### NATURAL PROTECTORATES ESTABLISHED IN THE SINAI PENINSULA ON THE GULF OF AQABA AND GULF OF SUEZ



(EEAA Protectorates of Egypt)

Sharm El Sheikh and Hurghada. Significant tourist development has also taken place at many minor towns on the Gulf of Aqaba coast as well as at Safaga and Quseir on the Egyptian Red Sea coast, and the northern sector of the Gulf of Suez. To an extent this has probably exceeded carrying capacities of the area. Evidence of reef degradation due to tourism and other activities is clear even in areas such as the Ras Mohammad National Park in Egypt (El Shaer et al., 2009). Large recreational cities and centres have been developed in Saudi Arabia along the Jeddah coastline.

Saudi Arabia lies at the crossroads of three continents, Europe, Asia and Africa. It extends from

the Red Sea on the west with a coast of 1,760 km long, to the Gulf on the east with a 650 km long coast. More than 50 percent of the population of Saudi Arabia lives within 100 km of the Saudi coastline. The coastal region houses cities, towns, and myriads of factories and processing plants. The interface between the land and sea is the main site for the import and export of goods and services essential for the wellbeing and economic prosperity of the country. The coastline is the location of desalination plants that supply the bulk of the country's drinking water, oil refineries and petrochemical factories, and a number of cement plants in addition to a growing recreational and tourism industry (Saudi Arabia Initial National Communication, UNFCCC).

Because of the great length of the Saudi Arabian coastline, only vulnerable industrial and populated coastal zone cities that could be affected by SLR have been mentioned. On the eastern coast of Saudi Arabia along the Gulf, Dammam, Ras Tanura, Jubail and Khafji have been selected as the most vulnerable coastal zone areas. On the western coast, along the Red Sea, Jeddah, Rabigh, Yanbu and Jizan have been selected as the most vulnerable coastal areas.

In general, the coastal zone problems are already critical in many parts of the Red Sea and Gulf of Aden. The potential impacts of the predicted global changes will be diverse and important for human populations. The major impacts will follow from one or more of the following mechanisms: shoreline retreat; flooding and flood risk; direct exposure to coastal environment; and saline intrusion and seepage (Tawfiq, 1994).

It is expected that in the absence of strong institutional systems for monitoring, a shortage of awareness, and inadequate law enforcement capabilities, the coastal resources in the Red Sea will continue deteriorating and that the losses due to climate changes in the region will be far less than those due to human activities.

## V. EXTREME EVENTS

The Arab region is well known to suffer from extreme events of many types: earthquakes, droughts, flash floods, dust storms, storm surges and heat waves. The damage associated with



many of these extreme events has not been well quantified. Recently, some areas have been exposed to volcanic activities (Saudi Arabia), and some others are exposed to snowing in the middle of the desert (Algeria, private communication). It is also well known that many extreme events are affected by El Niño and/or the ENSO phenomenon. Two examples of cases with exceptional floods resulting in extensive material and human damage are presented below (e.g., Agoumi, 2003):

• **Climate-related disaster in Algeria in November 2001**

Extreme rainfall equivalent to an entire month of rain in several hours was recorded, and wind speeds reached 120 kilometres per hour. Most of the damage was concentrated in Algiers where this extreme event claimed 751 victims and caused damage estimated at US\$300 million. There were 24,000 displaced persons and more than 2,700 homes were severely damaged. Between 40,000 and 50,000 persons lost their homes and nearly 109 roads were damaged. Despite being forecast by Algerian and foreign weather services the magnitude of the human and material damage was categorized as one of the most severe in the past 40 years.

• **Climatic disaster in Morocco in November 2002**

Morocco experienced some of the worst flooding in its history, with considerable material and human damage. Initial estimates put the damage at 63 dead, 26 missing, and dozens wounded, while 24 houses collapsed and 373 were flooded. Hundreds of hectares of agricultural land were damaged; hundreds of heads of livestock swept away, and industrial plants sustained severe damage. The most important refinery in the kingdom (SAMIR) caught fire, leading to more than US\$300 million in losses. This wet, rainy year followed several dry or partially dry years.

Severe dust storms have been well known in the Arab region for quite some time. However, the severity of damage and the frequency of occurrence have been observed to increase (UNISDR, 2009). Figure 13 shows the trajectory of the Khamasin storms of North Africa and Figures 14a and 14b represent examples of satellite images and

FIGURE 12

**DISTRIBUTION OF COASTAL CITIES OF SAUDI ARABIA ALONG THE RED SEA AND THE GULF**



FIGURE 13

**TRAJECTORY OF KHAMASIN SAND STORM FROM NORTH AFRICA TOWARDS THE EASTERN MEDITERRANEAN**



Source: Abdelkader et al., 2009

ground observations of these dust storms.

Climate change is expected to exacerbate many of these extreme events by increasing their severity and frequency. New evidence also suggests that climate change is likely to change the nature of many types of hazards, not only hydro-meteorological events such as floods, windstorms, and droughts, but also events such as landslides, heat waves and disease outbreaks, influencing not only the intensity, but also the duration and magnitude of these events. Most of these extreme events cross coastal boundaries and are known to be regional in nature.

FIGURE 14(a)

**A SAHARAN DUST STORM OBSERVED BY A SATELLITE CROSSING THE MEDITERRANEAN AND IMPACTING THE WHOLE REGION**



FIGURE 14(b)

**AN EXAMPLE OF A DUST STORM ON A SAUDI ARABIAN INDUSTRIAL FACILITY**



The output of research suggests that there is good reason to be concerned about the dynamic, non-linear and uncertain relationships between climate variability, climate change, and extreme events, and their implications for human security.

The Arab region is not immune to other extreme events such as cyclones, hurricanes and tsunamis. The latest events, cyclone Gonu in Oman and the flood in Yemen, were very recent and clearly illustrate the importance of development of early warning signs that require the adoption of policies and measures for preparedness and risk reduction.

A recent analysis been carried out by Dasgupta et al. (2009) studied the potential impacts of increasing frequencies and severities of storm surges based on best available data of human population, socioeconomic conditions, the pattern of land use and available Shuttle Radar Topography Mission (SRTM) coastal elevation data. The results indicated that storm surge intensification would cause additional GDP losses (above the current 1-in-100-year reference standard) in the Middle East and North Africa of \$12.7billion. The increase in impact on agricultural areas is significant for the MENA region, mainly because Egyptian and Algerian cropland in surge zones would increase from the existing estimated 212 km<sup>2</sup> to approximately 900 km<sup>2</sup> with SLR and intensified storm surges. The percentage increase in surge regions for MENA countries are shown in Figure 15.

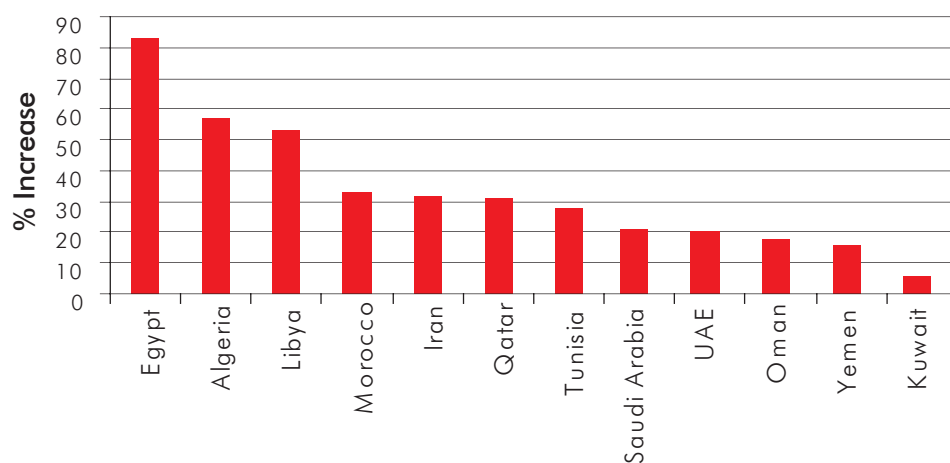
## VI. ADAPTATION MEASURES

Although the Arab region does not contribute more than 4.5% of world greenhouse gas emissions, it is among the most vulnerable regions in the world to the potential impacts of climate changes. The Arab countries therefore have to follow strong programs for adaptation of all sectors. Adaptation measures should include at least:

- Carrying out a detailed vulnerability assessment using high resolution satellite imagery and recent Digital Elevation Models (DEM) to assess vulnerable areas and identify vulnerable stakeholders given scenarios of SLR of the IPCC and taking into consideration land subsidence.

FIGURE 15

PERCENTAGE INCREASE OF SURGE REGIONS MENA



Source: Dasgupta et al., 2009

- Establishing an institutional system for risk reduction for integrating and coordinating research and carrying out training on the national and regional scales.
  - Establishing strong monitoring systems for coastal zone indicators and law enforcement. Developing a database for national and regional indicators of climate change
  - Developing a Regional Circulation Model (RCM) for the impact of climate change on MENA countries and the Red Sea. Building capacities and reducing uncertainties of predictions
  - Adopting an integrated coastal zone management approach to protect coastal resources with special reference to expectations of future severities and increasing frequencies of extreme events
  - Adopting a proactive planning approach and developing policies and adaptation programs for no regret planning, protection of the low land areas in the coastal region and coastal cities in the Nile Delta, Tunisia, Mauritania and Gulf region, exchanging experiences and success stories.
  - Upgrading awareness of decision makers on strategic aspects and developing employment opportunities for vulnerable groups.
- the Arab region are highly vulnerable to the potential impacts of climate change. Proactive action needs to be taken, both in terms of expanding knowledge and cooperation, and implementing mitigation and adaptation policies. The main conclusions and recommendations are listed below:
- Although all of the Arab countries do not contribute more than 4.5% to the total emissions of GHGs, the coastal zones of most of them are highly vulnerable to the potential impacts of sea level rise and the expected increased severity and frequency of extreme events.
  - Even though some of the Arab countries have established institutional capabilities for the mitigation of greenhouse gas emissions, none has established such systems for adaptation and self protection.
  - Excluding Tunisia and Morocco, no integrated national strategic action plans have been established for the vulnerable countries.
  - A strategic assessment and risk reduction of climate change impacts must be carried out as a joint effort through the League of Arab States.
  - An early warning system of tsunamis for the Mediterranean and the Gulf regions must be established through satellite systems.
  - Proactive planning and protection policies and measures should be initiated for vulnerable sectors with particular emphasis on the coastal zone.

## VII. CONCLUSION AND RECOMMENDATIONS

This chapter has shown that the coastal areas in

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# *Impact of Climate Change: Vulnerability and Adaptation* **Food Production**

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## I. INTRODUCTION

Food security in the Arab world has experienced a long history of environmental and socio-economic pressures. The dominant arid conditions, limited water resources, erratic cropping patterns, low knowledge and technology levels are the main factors presently affecting food production systems in the Arab world.

Most recent assessments have concluded that arid and semi-arid regions are highly vulnerable to climate change (IPCC, 2007a). On the other hand, at a high level conference of the Food and Agriculture Organization (FAO) held in Rome in June 2008, the delegates asserted that agriculture is not only a fundamental human activity at risk from climate change, it is a major driver of environmental and climate change itself. The projected climatic changes will be among the most important challenges for agriculture in the twenty-first century, especially for developing countries and arid regions (IPCC, 2007a).

By the end of the 21<sup>st</sup> century, the Arab region will face an increase of 2 to 5.5°C in the surface temperature. This increase will be coupled with a projected decrease in precipitation up to 20%. These projected changes will lead to shorter winters and dryer summers, hotter summers, more frequent heat wave occurrence, and more variability and extreme weather events occurrence (IPCC, 2007b).

## II. KEY IMPACTS AND VULNERABILITIES OF THE AGRICULTURE SECTOR IN THE ARAB WORLD

The risks associated with agriculture and climate change arise out of strong complicated relationships between agriculture and the climate system, plus the high reliance of agriculture on finite natural resources (Abou-Hadid, 2009). The inter-annual, monthly and daily distribution of climate variables (e.g., temperature, radiation, precipitation, water vapour pressure in the air and wind speed) affects a number of physical, chemical and biological processes that drive the productivity of agricultural, forestry and fisheries systems (IPCC, 2007a). In the cases of forestry and fisheries systems, vulnerability depends on exposure and sensitivity to climate conditions, and on the capaci-

ty to cope with changing conditions.

The current total cultivated area in the Arab region makes up about 5% of the total global cultivated area, and it represents about 5% of the total area of Arab world (FAO, 2008b). Most of the Arab region's lands are classified as hyper-arid, semi-arid and arid land zones (WRI, 2002). The relationship between the cultivated area and the population is one of the major challenges facing food production in the region. The land share per capita is decreasing annually as a result of rapid population growth rates and urbanization (AOAD, 2008). By 2007, the average agricultural land share in the Arab region was about 0.23 ha per capita, which is slightly lower than the world average of 0.24 ha per capita.

The dominant agricultural system in Arab countries is rainfed agriculture; the total irrigated area in the Arab world is less than 28% (FAO, 2008b). Therefore, annual agricultural productivity and food security are highly correlated to the annual variability of precipitation, which has exhibited major changes in recent decades (Abou-Hadid, 2006). Irrigated agriculture is widely represented in the Arabian Peninsula countries and Egypt, where fully irrigated agriculture makes up 100% and 95% of the total cultivated area, respectively.

The agricultural productivity of most crops exhibited noticeable increases during recent years. The per capita food production index (PCFPI) shows the food output, excluding animal feed, of a country's agriculture sector relative to the base period 1999-2001 (FAO, 2008b). The PCFPI value of the Arab region increased from 99.8 in 2003 to 112.3 by 2005, an increase of 13%, whereas the world values of the PCFPI increased during the same years by 20% (AOAD, 2008). The productivities of crops under irrigated agriculture in the Arab region improved due to switching to new cultivars, applying modern technologies and improving management programs; to yield some of the highest productivities all over the world in some Arab countries, such as in Egypt and Sudan. On the other hand, the majority of Arab countries have serious problems in agricultural production as a result of limited economic resources, low levels of technology, limited crop patterns, and environmental limitations and pressures (Agoumi, 2001).

The FAO (2005) expects growth rates in world agricultural production to decline from 2.2%/yr during the past 30 years to 1.6%/yr during the 2000 to 2015 period, 1.3%/yr between 2015 and 2030 and 0.8%/yr between 2030 and 2050. This still implies a 55% increase in global crop production by 2030 and an 80% increase to 2050 (compared with 1999 to 2001). Globally, to facilitate this growth in output, 185 million ha of rain-fed crop land (+19%) and 60 million ha of irrigated land (+30%) will have to be brought into production. Expanded land use and improved technology are the essential reasons contributing to yields' expected rise. Cereal yields in developing countries are projected to increase from 2.7 tonnes/ha currently to 3.8 tonnes/ha in 2050 (FAO, 2005). These improvements in the global supply-demand balance will be accompanied by a decline in the number of undernourished people from more than 800 million at present to about 300 million, or 4% of the population in developing countries, by 2050 (FAO, 2005). Notwithstanding these overall improvements, important food-security problems remain to be addressed at the local and national levels. Areas with high rates of population growth and natural resource degradation are likely to continue to have high rates of poverty and food insecurity (Alexandratos, 2005). Cassman et al. (2003) emphasize that climate change will add to the dual challenge of meeting food demand while at the same time efforts are in progress for protecting natural resources and improving environmental quality in these regions.

The production and dissemination of seasonal climate forecasts has improved the ability of many resource managers to anticipate and plan for climate variability (Harrison, 2005). However, problems related to infectious disease, conflicts and other societal factors may decrease the capacity to respond to climate variability and change at the local level, thereby increasing current vulnerability. Policies and responses made at national and international levels also influence local adaptations (Salinger et al., 2005). National agricultural policies are often developed on the basis of local risks, needs and capacities, as well as international markets, tariffs, subsidies and trade agreements (Burton and Lim, 2005).

Water balance and weather extremes are key to

many agricultural and forestry impacts. Most Arab countries are characterized by limited water resources and high water demands. The total annual renewable water resources in the Arab world are about 460 km<sup>3</sup>, or about 0.9% of the global annual renewable water resources. Based on annual water resources per capita, all Arab countries are facing a vulnerable water situation, except Iraq which has renewable water resources of more than 2900 m<sup>3</sup>/capita/year. Lebanon and Syria are currently facing water stress (1,000 to 1,700 m<sup>3</sup>/capita/year), while the rest of the Arab countries are facing water scarcity (less than 1,000 m<sup>3</sup>/capita/year) (AFED, 2008). The agriculture sector uses over 80% of the total water resources of the Arab world. However, the water use efficiency of the agriculture sector in most of the Arab countries is low (Montazar et al., 2007).





The water situation in the Arab region is threatened by both environmental and socio-economic pressures. Many negative impacts of climate change on freshwater systems are observed in recent studies. These impacts are mainly due to the observed and projected increases in temperature, evaporation, sea level and precipitation variability (IPCC, 2007a). Decreases in precipitation are predicted by more than 90% of climate model simulations by the end of the 21st century for the North Africa and Middle East region (IPCC, 2007b).

Changes in annual mean runoff are indicative of the mean water availability for vegetation. Projected changes between now and 2100 show some consistent runoff patterns: increases in high latitudes and the wet tropics, and decreases in mid-latitudes and some parts of the dry tropics. Declines in water availability are therefore projected to affect some of the areas currently suitable for rain-fed crops (e.g., in the Mediterranean basin and sub-tropical regions) (Christensen et al., 2007).

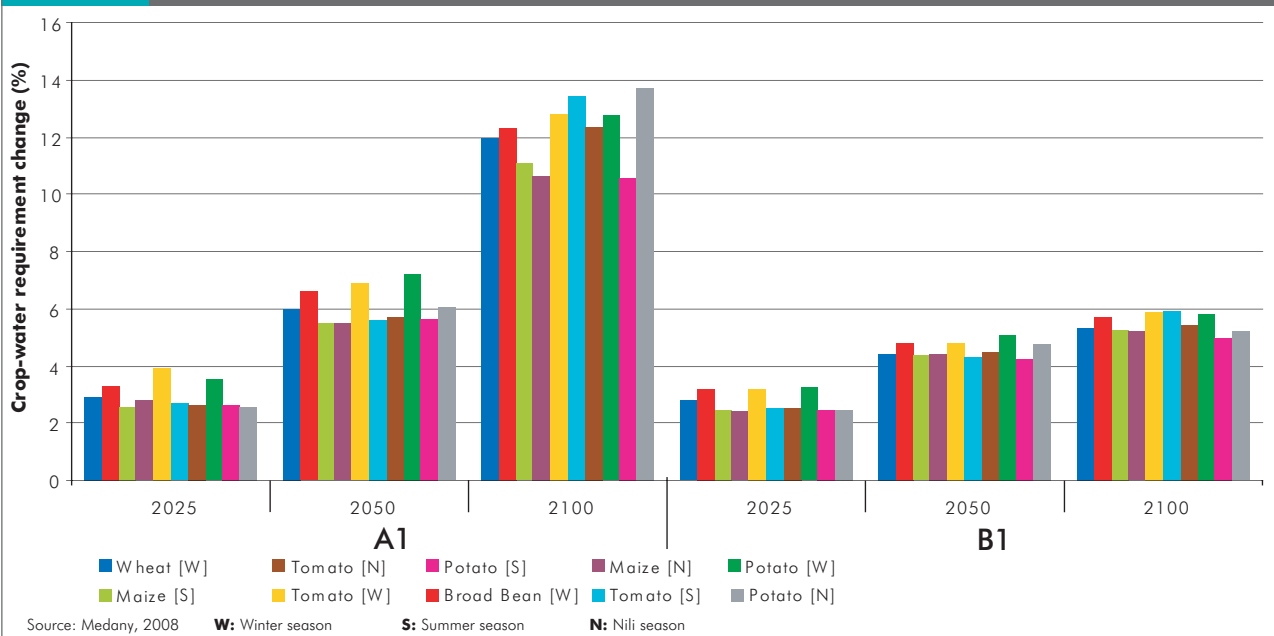
Climate change will increase consumptive water use in key sectors in the future, especially in countries that have limited water resources, high population growth and high development rates

(Medany, 2007). Magano et al. (2007) point out that irrigation demands will increase and the irrigation period of supplementary irrigation will become longer under projected climate changes. For example, the total annual reference irrigation demands of Egypt are projected to increase by 6 to 16% by the 2100s, due to the increase in reference evapotranspiration values, which will lead to a general increase in the crop-water demands. Figure 1 illustrates the change in crop-water requirements of major field and vegetable crops due to the change in temperature and CO<sub>2</sub> levels based on the IPCC SRES A1 and B1 scenarios for the 2025s, 2050s and 2100s (Medany, 2008).

Smallholder agriculture is used here to describe rural producers, who farm using mainly family labour and for whom the farm provides the principal source of income (Cornish, 1998). Pastoralists and people dependent on artisanal fisheries and household aquaculture enterprises (Allison and Ellis, 2001) are also included in this category. Smallholders in most of the Arab countries are poor and suffer in varying degrees from problems associated both with subsistence production (isolated and marginal location, small farm size, informal land tenure and low levels of technology), and with uneven and unpredictable exposure to world markets, which

FIGURE 1

**CHANGE BETWEEN CURRENT AND FUTURE VALUES (FOR YEARS 2025s, 2050s AND 2100s) AT NATIONAL LEVEL SEASONAL CROP-WATER REQUIREMENTS OF SOME FIELD AND VEGETABLE MAJOR CROPS**





have been characterized as “complex, diverse and risk-prone” (Chambers et al., 1989). Risks are also diverse (drought and flood, crop and animal diseases, and market shocks) and may be felt by individual households or entire communities (Scoones et al., 1996). Subsistence and smallholder livelihood systems currently experience a number of interlocking stressors other than climate change and climate variability (Iglesias, 2002). It is likely that smallholder and subsistence households will decline in numbers, as they are pulled or pushed into other livelihoods, with those that remain suffering increased vulnerability and increased poverty (Lipton, 2004).

The impacts of climate change on subsistence and smallholder agriculture, pastoralism and artisanal fisheries will include, (i) the direct impacts of changes in temperature, CO<sub>2</sub> and precipitation on yields of specific food and cash crops, productivity of livestock and fisheries systems, and animal health; (ii) other physical impacts of climate change important to smallholders such as decreased water supply for irrigation systems, effects of sea level rise on coastal areas, increased frequency of tropical storms (Adger, 1999), and other forms of environmental impact still being identified, such as increased forest-fire risk (Agrawala et al., 2003) and remobilization of dunes (Thomas et al., 2005); and (iii) impacts on human health, like malaria risk .

### III. IMPACT OF CLIMATE CHANGE ON CROP PRODUCTION

Plant response to elevated CO<sub>2</sub> alone, without climate change, is positive and was reviewed extensively in a vast number of studies (see references). Recent studies confirm that the effects of elevated CO<sub>2</sub> on plant growth and yield will depend on photosynthetic pathway, species, growth stage and management regimes, such as water and nitrogen (N) applications (e.g. Ainsworth and Long, 2005). On average across several species and under unstressed conditions, recent data analyses find that, compared to current atmospheric CO<sub>2</sub> concentrations, crop yields increase at 550 parts per million (ppm) CO<sub>2</sub> in the range of 10-20% for C<sub>3</sub><sup>i</sup> crops and 0-10% for C<sub>4</sub><sup>ii</sup> crops (Ainsworth et al., 2004; Long et al., 2004).



Some studies using re-analyses of recent FACE (Free Air Carbon Enrichment) have argued that crop response to elevated CO<sub>2</sub> may be lower than previously thought, with consequences for crop modelling and projections of food supply (Long et al., 2006). Many recent studies confirm that temperature and precipitation changes in future decades will modify, and often limit, direct CO<sub>2</sub> effects on plants. For instance, high temperatures during flowering may lower CO<sub>2</sub> effects by reducing grain number, size and quality (Caldwell et al., 2005). Increased temperatures may also reduce CO<sub>2</sub> effects indirectly, by increasing water demand (Xiao et al., 2005).

Future CO<sub>2</sub> levels may favour C<sub>3</sub> plants over C<sub>4</sub> (Ziska, 2003), yet the opposite is expected under associated temperature increases; the net effects remain uncertain. In particular, since more than

TABLE 1

PROJECTED CHANGES IN CROP PRODUCTION OF SOME MAJOR CROPS IN EGYPT UNDER CLIMATE CHANGE CONDITIONS

Crop	Change in %		Sources
	2050s	2100s	
Rice	-11%		Eid and EL-Marsafawy (2002)
Maize	-19%		Eid et al. 1997b
	-14%	-20%	Hassanein and Medany, 2007
Soybeans	-28%		Eid and EL-Marsafawy (2002)
Barley	-20%		Eid et al. 1997b
Cotton	+17%	+31%	Eid et al. 1997a
Fava bean	-4.4 to -6.6	+6 to +11%	Hassanein and Medany (2009)
Potato	-0.9 to -2.3%	+0.2 to +2.3 %	Medany and Hassanein (2006)
Wheat	-4.8 to -17.2	-26 to -38%	Eid et al 1992a, b, Eid et al 1993a, b, c, Eid 1994, Eid et al 1994a, b, and Eid et al 1995a, b

80% of total agricultural land, and close to 100% of pasture land, is rain-fed, general circulation model (GCM) dependent changes in precipitation will often shape both the direction and magnitude of the overall impacts (Reilly et al., 2003).

IPCC (2007a) reported that agricultural production in many African countries is projected to be severely compromised by climate variability and change. Yields from rainfed agriculture in Africa could be reduced by up to 50% by 2020, and the projected sea-level rise will affect low-lying coastal areas with large populations, which will require a total cost of adaptation that could amount to at least 5-10% of GDP.

For the Arab world, the overall conclusion of most studies indicates a general trend of reduction for most major field crops. El-Shaer et al. (1997) concluded that climate change could do severe damage to agricultural productivity if no adaptation measures were taken. Table 1 shows the impact of climate change on some major crops in the Egyptian cropping pattern, indicated in previous studies. By the year 2050, climate change could increase water needs by up to 16% for summer crops but decrease them by up to 2% for winter crops (Eid and El-Mowelhi, 1998).

On the other hand, there are additional negative impacts of increased climate variability on plant production due to climate change. Understanding links between increased frequency of extreme climate events and ecosystem disturbance (fires, pest outbreaks, etc.) is particularly important to quantify impacts (Hogg and Bernier, 2005).

Furthermore, CO<sub>2</sub>-temperature interactions are recognized as a key factor in determining plant damage from pests in future decades, though few quantitative analyses exist to date; CO<sub>2</sub>-precipitation interactions will likewise be important (Zvereva and Kozlov, 2006).

For instance, the impact of climate change on pests and diseases was studied for some important diseases at the national level, such as pear early blight, potato late blight (Fahim, et al., 2007), and wheat rust diseases (Abo Elmaaty et al., 2007). Importantly, increased climate extremes may promote plant disease and pest outbreaks (Gan, 2004).

#### IV. IMPACT OF CLIMATE CHANGE ON LIVESTOCK AND GRAZING

Pastures comprise both grassland and rangeland ecosystems. Rangelands are found on every continent, typically in regions where temperature and moisture restrictions limit other vegetation types; they include deserts (cold, hot and tundra), scrub, chaparral and savannas. Pastures occupy 33% of the total area of the Arab region. However this area is under risk due to climatic variability related events (e.g. drought, floods) and desertification (AOAD, 2008).

Pastures and livestock production systems occur under most climates and range from extensive pastoral systems with grazing herbivores, to intensive systems based on forage and grain crops, where animals are mostly kept indoors. The combination of increases in CO<sub>2</sub> concentra-

tion, in conjunction with changes in rainfall and temperature, is likely to have significant impacts on grasslands and rangelands, with production increases in humid temperate grasslands, but decreases in arid and semi-arid regions (IPCC, 2007a).

Animal requirements for crude proteins from pastures range from 7 to 8% of ingested dry matter, up to 24% for the highest-producing dairy cows. In conditions of very low Nitrogen status in pasture ranges under arid and semi-arid conditions, possible reductions in crude proteins under elevated CO<sub>2</sub> may put a system into a sub-maintenance level for animal performance (Milchunas et al., 2005). The decline under elevated CO<sub>2</sub> levels (Polley et al., 2003) of C4 grasses, which are a less nutritious food resource than C3 (Ehleringer et al., 2002), may also compensate for the reduced protein content under elevated CO<sub>2</sub>. Generally, thermal stress reduces productivity and conception rates, and is potentially life-threatening to livestock. Because ingestion of food and feed is directly related to heat production, any decline in feed intake and/or energy density of the diet will reduce the amount of heat that needs to be dissipated by the animal. Mader and Davis (2004) confirm that the onset of a thermal challenge often results in declines in physical activity with associated declines in eating and grazing (for ruminants and other herbivores) activities. New models of animal energetics and nutrition (Parsons et al., 2001) have shown that high temperatures put a ceiling on dairy milk yield irrespective of feed intake. Increases in air temperature and/or humidity have the potential to affect conception rates of domestic animals not adapted to those conditions. This is particularly the case for cattle, in which the primary breeding season occurs in spring and summer months. Amundson et al. (2005) reported declines in conception rates of cattle for temperatures above 23.4°C and at high thermal heat index.

Moreover, impacts on animal productivity due to increased variability in weather patterns will likely be far greater than effects associated with the average change in climatic conditions. Lack of prior conditioning to weather events most often results in catastrophic losses in confined cattle feedlots (Hahn et al., 2001), with economic losses from reduced cattle performance exceeding those associated with cattle death losses several-

fold (Mader, 2003). In dry regions, there are risks that severe vegetation degeneration leads to positive feedbacks between soil degradation and reduced vegetation and rainfall, with corresponding losses of pastoral areas and farmlands (Zheng et al., 2002). A number of studies in Africa (Batima, 2003) show a strong relationship between droughts and animal death. Projected temperature increases, combined with reduced precipitation in North Africa would lead to increased loss of domestic herbivores during extreme events in drought-prone areas. With increased heat stress in the future, water requirements for livestock will increase significantly compared to current conditions, so that overgrazing near watering points is likely to expand (Batima et al., 2005).

## V. IMPACT OF CLIMATE CHANGE ON FISHING AND AQUACULTURE

Aquaculture resembles terrestrial animal husbandry and therefore shares many of the vulnerabilities and adaptations to climate change with that sector. Similarities between aquaculture and terrestrial animal husbandry include ownership, control of inputs, diseases and predators, and use of land and water. Some aquaculture, particularly of plants, depends on naturally occurring nutrients, but the rearing of fish usually requires the addition of suitable food. Capture fisheries depend on the productivity of natural ecosystems and are therefore vulnerable to climate change induced changes affecting production in natural aquatic ecosystems.

IPCC (2007a) reports a number of key negative impacts of climate change on aquaculture and freshwater fisheries, including (i) stress due to increased temperature and oxygen demand and increased acidity (lower pH); (ii) uncertain future water supply; (iii) extreme weather events; (iv) increased frequency of disease and toxic events; (v) sea level rise and conflict of interest with coastal protection needs; and (vi) uncertain future supply of fishmeal and oils from capture fisheries. Positive impacts include increased growth rates and food conversion efficiencies, increased length of growing season, range expansion and use of new areas due to decreases in ice cover.

Temperature increases may cause seasonal



increases in growth, but it may affect fish populations at the upper end of their thermal tolerance zone. Increasing temperature interacts with other changes, including declining pH and increasing nitrogen and ammonia, to increase metabolic costs. The consequences of these interactions are speculative and complex (Morgan et al., 2001).

Changes in primary production and transfer through the food chain due to climate will have a key impact on fisheries. Such changes may be either positive or negative and the aggregate impact at the global level is unknown (IPCC, 2007a). However, climate change has been implicated in mass mortalities of many aquatic species, including plants, fish, corals and mammals, but a lack of standardized epidemiological data and information on pathogens generally makes it difficult to attribute causes (Harvell et al., 1999).

## VI. IMPACT OF CLIMATE CHANGE ON FOREST PRODUCTIVITY

Forests cover almost 928 thousand ha or 6.6% of the Arab world's area. Approximately one third of this area is located in Sudan. Modelling studies predict increased global timber production. Whereas models suggest that global timber productivity will likely increase with climate change, regional production will exhibit large variability, similar to that discussed for crops. Climate change will also substantially impact other services, such as seeds, nuts, hunting, resins, plants used in pharmaceutical and botan-

ical medicine, and in the cosmetics industry; these impacts will also be highly diverse and regionalized. Recent studies suggest that direct CO<sub>2</sub> effects on tree growth may be revised to lower values than previously assumed in forest growth models. A number of FACE studies showed average net primary productivity (NPP) increases of 23% in young tree stands at 550 ppm CO<sub>2</sub> (Norby et al., 2005). However, in a 100-year old tree stand, Korner et al. (2005) found little overall stimulation in stem growth over a period of four years. Additionally, the initial increase in growth increments may be limited by competition, disturbance, air pollutants, nutrient limitations and other factors (Karnosky, 2003), and the response is site- and species-specific.

A number of long-term studies on supply and demand of forestry products have been conducted in recent years (IPCC, 2007a). These studies project a shift in harvest from natural forests to plantations (Hagler, 1998). Finally, although climate change will impact the availability of forest resources, the anthropogenic impact, particularly land-use change and deforestation, is likely to be extremely important (Zhao et al., 2005).

## VII. ADAPTATION OF AGRICULTURE IN THE ARAB WORLD

In 2001, the IPCC identified 'Adaptation' as any adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. This term



refers to changes in processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate. It involves adjustments to reduce the vulnerability of communities, regions, or activities to climatic change and variability (IPCC, 2001a).

The high vulnerability of the agricultural sector in developing countries should place it at the top of priority lists of adaptation plans. Although climate change is projected to have serious impacts on the agricultural sector in the Arab world, only modest efforts and steps are currently being taken in the areas of scientific research, mitigation and adaptation.

Agriculture has historically shown high levels of adaptability to climate variations. For cropping systems there are many potential ways to alter management to deal with projected climatic and atmospheric changes (Challinor et al., 2007). These adaptations include:

- a) Altering inputs such as varieties, species, fertilizer, and amounts and timing of irrigation and other water management practices;
- b) Wider use of simple technologies;
- c) Water management to prevent waterlogging, erosion and nutrient leaching in areas with rainfall increases;
- d) Altering the timing or location of cropping activities;
- e) Diversifying income by integrating other farming activities such as livestock raising;
- f) Improving the effectiveness of pest, disease and weed management practices; and
- g) Using seasonal climate forecasting to reduce production risk.

Many options for policy-based adaptation to climate change have been identified for agriculture, forests and fisheries (Easterling et al., 2004). These can either involve adaptation activities such as developing infrastructure or building the capacity to adapt in the broader user community and institutions, often by changing the decision making environment under which management-level, adaptation activities occur. Designing and applying national adaptation strategies for the agriculture sector faces a group of barriers, including limitations of the existing scientific base, policy perceptions under current conditions and pressures, poor adaptive capacity of rural

communities, lack of financial support, and the absence of an appropriate institutional framework.

Medany et al. (2007) conclude that designing an adaptation strategy for the agriculture sector should consider the simple and low cost adaptation measures that may be inspired from traditional knowledge to meet local conditions and to be compatible with sustainable development requirements. It is not preferable to use imported solutions based on high levels of technology and high initial costs. Moreover, technology and knowledge transfer activities are encouraged to support adaptation strategies. Addressing climate change mitigation and adaptation in development strategies means strengthening these strategies and increasing their efficiency and durability.

Medany et al. (2007) recommend the following to enhance the planning of mitigation and adaptation strategies for the agricultural sector under Egyptian conditions:

- Improving the scientific capacity should be among the top priorities of development planning.
- Political and financial adoption of adaptation strategies.
- The bottom-up approach of planning and implementing adaptation and mitigation strategies could be more efficient.
- Developing community-based measures by stakeholders' involvement in adaptation planning, and improving the adaptive capacity of the different human sectors.
- Increasing the public awareness and improving the concept of climate and its relation to environmental and human systems.
- Improving adaptive capacity of the community should be based on a clear scientific message, and enjoy strong governmental support.

Attaher et al. (2009) studied the farmers' perception for adaptation planning in Nile Delta region, and concluded that farmers have a real initiative to act positively to reduce the impact of climate change. Moreover, although community engagement in adaptation planning is very important, the scientific evaluation should be taken into account to set a more practical list of adaptation measures.

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## NOTES

- 1 C<sub>3</sub> carbon fixation is a metabolic pathway for carbon fixation in photosynthesis. This process converts carbon dioxide and ribulose biphosphate (RuBP, a 5-carbon sugar) into 3-phosphoglycerate through the following reaction:  
$$\text{CO}_2 + \text{RuBP} \longrightarrow 2 \text{ 3-phosphoglycerate}$$

This reaction occurs in all plants as the first step of the Calvin cycle.
- 2 C<sub>4</sub> carbon fixation is one of three biochemical mechanisms, along with C<sub>3</sub> and CAM photosynthesis, functioning in land plants to “fix” carbon dioxide (binding the gaseous molecules to dissolved compounds inside the plant) for sugar production through photosynthesis. Along with CAM photosynthesis, C<sub>4</sub> fixation is considered an advancement over the simpler and more ancient C<sub>3</sub> carbon fixation mechanism operating in most plants. Both mechanisms overcome the tendency of RuBisCO (the first enzyme in the Calvin cycle) to photorespire, or waste energy by using oxygen to break down carbon compounds to CO<sub>2</sub>. However C<sub>4</sub> fixation requires more energy input than C<sub>3</sub> in the form of ATP. C<sub>4</sub> plants separate RuBisCO from atmospheric oxygen, fixing carbon in the mesophyll cells and using oxaloacetate and malate to ferry the fixed carbon to RuBisCO and the rest of the Calvin cycle enzymes isolated in the bundle-sheath cells. The intermediate compounds both contain four carbon atoms, hence the name C<sub>4</sub>.



*Impact of Climate Change: Vulnerability and Adaptation*  
**Fresh Water**

DIA EL-DIN EL-QUOSY



## I. INTRODUCTION

The Arab world is one of the most water stressed regions in the whole world, and climate change, which is projected to increase the frequency and intensity of extreme weather events such as droughts and floods, as well as decrease precipitation, will contribute to even worse water scarcity in the region. It is not only the quantity of fresh water that might be affected by climate change, the quality of groundwater might also be worsened, as fresh water supplies might get contaminated by sea water intruding coastal aquifers, thereby affecting potable water supplies for millions of Arabs.

About two thirds of the renewable water resources of the Arab world originate outside the region. Eighty percent of the area of the Arab countries is barren desert, and therefore the region is mainly arid with small pockets of semi-arid climatic conditions. The average annual rainfall varies between 0 and 1800 mm while the average evaporation rate is more than 2000 mm/year.

The area of the Arab world contains almost ten percent of the dry land on earth while water resources do not exceed one percent of the world's total. Despite this water poverty, eighty percent of the water budget in the Arab world is allocated to agriculture, the highest water consuming development activity, while industry consumes 12% and the remaining 8% is allocated to domestic and potable use. Although about 2000 billion m<sup>3</sup> of rain falls every year on the Arab countries, the amount of effective rainfall that is beneficially utilized is much less than this figure; huge quantities are lost in evaporation from free water surfaces, evapotranspiration of aquatic plants in swamps and marches, or lost to the sea or the ocean.

There are 34 continuously flowing fresh water rivers in the Arab world; their catchments may be as small as 86 km<sup>2</sup> in the case of the Zahrani river in Lebanon, and 2.8 million km<sup>2</sup> in the case of the Nile.

The percentage of water used in the Arab world out of the total available is less than 50%, which means that almost 50% of the renewable water resources are still unutilized. Nonetheless food

imports to the region make up more than 50% of food consumption and only 25% of arable land is cultivated.

Annual renewable water resources in the Arab region are about 244 billion m<sup>3</sup>/year of which 204 billion m<sup>3</sup>/year are surface flows and 40 billion m<sup>3</sup>/year are renewable groundwater. Withdrawal in some Arab countries exceeds the renewable supplies, while others are just at the limit.

It is not only the limited water resources that pose problems; the harsh climatic conditions and the use of the majority of Arab countries' water in water consuming activities like agriculture add to the magnitude of the issue. This is exacerbated by high population growth rates, which add a chronic nature to the problem and aggravate its impact. If all this is crowned by climate change, the situation might reach an intolerable condition which may ultimately affect the environmental, economic, social, political and even security stability of the region.

One of the major drawbacks of research in and on the Arab region is data availability: regular measurements, continuous monitoring and neutral evaluation of the water status in the area is either missing or only available in isolated surveys that might be separated by long time spans with non-available records. This adds to the uncertainty of the effect of climate change on water resources in most of the Arab countries. This chapter is an attempt to shed some light on climate change and climate variability as phenomena that might affect water availability in the Arab region and how vulnerable Arab countries can mitigate and adapt to their positive and negative impacts.

## II. HYDROLOGICAL DIVISION OF ARAB COUNTRIES

The Arab countries can be divided from the hydrologic point of view into the following subdivisions:

- Al Mashrek countries: Iraq, Syria, Lebanon, Jordan and Palestine.
- Al Maghreb countries: Libya, Tunisia, Algeria, Mauritania and Morocco.



- Nile Basin countries: Egypt and Sudan.
- Arabian Peninsula: Saudi Arabia, Kuwait, United Arab Emirates, Qatar, Oman, Bahrain and Yemen.
- Sahel countries: Somalia, Djipouti and Comoros Islands.

Each of the above five regions has its distinct hydrological characteristics that can briefly be explained as follows:

#### ***Al Mashrek Region***

- Iraq and Syria are partially dependant on the Tigris and Euphrates rivers, originating from Turkey. The two countries have rainfall of reasonable intensity and groundwater potential in both countries is relatively high. Syria enjoys small flows caused by snow melt from the peaks of some local mountains.
- Lebanon depends on a number of local rivers or rivers shared with one or more of the neighbouring countries.
- The per capita shares of water in Lebanon as

well as in Syria and Iraq are the highest among all Arab countries.

- Jordan and Palestine are the water poorest in this region since they depend upon the Jordan river and small quantities of rainfall and groundwater.

#### ***Al Maghreb Region***

- All five Maghreb countries depend mainly on rainfall and partially on modest groundwater reserves.

#### ***Nile Basin Region***

- The southern part of Sudan enjoys ample precipitation which can meet the prevailing evaporative demand; however, rain gradually vanishes north of the capital Khartoum. Following the signing of the Nile Water Agreement in 1959, Sudan and Egypt divided the average natural flow at Aswan (84 billion m<sup>3</sup>/year) to one quarter for Sudan (18.5 billion m<sup>3</sup>/year), three quarters for Egypt (55.5 billion m<sup>3</sup>/year) and the remaining 10 billion m<sup>3</sup>/year were left to make up for natural evaporation from Lake Nasser.



- The natural flow of the Nile forms 95% of the Egyptian water budget, with the remaining 5% composed of minor quantities of rain which falls on the coast of the Mediterranean and Red Seas (about 1.5 billion m<sup>3</sup>/year) plus modest reserves of groundwater aquifers.

#### **The Arabian Peninsula**

- This is the poorest region with respect to water resources, where rainfall is rare by all standards, groundwater either does not exist or has already been depleted and surface water is vir-

tually non-existent. The region depends for its water needs mainly on the desalination of water from the Gulf. Yemen is the only country in the Arabian Peninsula which depends on rainfall and partially on groundwater.

#### **Sahel Countries**

- Somalia, Djibouti and the Comoros Islands are all dependant on rainfall with modest potential of groundwater.

The above brief description of the hydrological situation in the Arab countries reveals a number of important facts:

- The lowest vulnerability to climate change is in the case of the Arabian Peninsula where the internal renewable water resources in the region at the present time are very limited. Whatever happens is not going to reduce the already very low internal renewable water resources.
- The four countries largely dependant on river flows originating outside their boundaries, namely Egypt, Sudan, Iraq and Syria are not only vulnerable to reduced or increased flows caused by climate change, they are also vulnerable to the actions taken by upstream riparian countries which may affect river flows downstream.
- Al Maghreb countries are the most vulnerable to climate change since they are almost fully dependant on rainfall. Libya is an exception with the Great Manmade River now forming the major source of water to the country. The river is fed by pumping water from the Nubian Sandstone aquifer shared with Egypt, Sudan and Chad. However, the life time of the project is only fifty years, after which the country will have to find other alternatives.
- Djibouti and the Comoros Islands are more threatened by sinking caused by sea level rise than by high or low natural fresh water flows.
- Jordan and Palestine possess at the present time the lowest per capita share of water in the Arab world (100-200 m<sup>3</sup> per capita per year). The vulnerability of sharing their water resources with Israel which is expanding in terms of both



space and population appears to outweigh the vulnerability which might be caused by climate change.

### III. CLIMATIC OBSERVATION IN THE ARAB WORLD

The Arab region is the poorest area in the world with respect to the presence of climatic observation stations. The only cited stations are one at the northern end of the Red Sea and two stations on the coast of the Atlantic Ocean.

In the meantime, there is no local circulation model that has been developed to predict the future situation in the region, predicted to have a greenhouse gas emissions-caused increase in surface temperatures and the consequent effects on spatial and temporal variability of rainfall and runoff. The only model under development at the present time is that prepared by the United Kingdom Meteorological Office for the purpose of predicting Nile flows under different climatic scenarios. The model is developed by statistical and dynamic downscaling from a Global Circulation Model (UKMO) and is expected to be in practical use during the coming 12 to 24 months.

The extreme event of the tropical cyclone Gonu which hit the coast of Oman in 2007, the snow which covered the mountains of the United Arab Emirates, and the extremely low temperatures which affected palm trees in the Arabian Peninsula and Jordan, drew the attention of the Arab world to the risks of climate change, risks that might intensify in the future.

In spite of the above, only few countries in the Arab world have, in accordance with obligations to the UNFCCC, issued the first and second national communications and prepared a climate change strategy or framework.

The coastal strip in the Arab world extends for a distance of 34,000 km from the Atlantic Ocean through the Mediterranean and the Red Sea (from both sides east and west). The Arabian Sea to the Gulf hosts millions of Arabs and a large number of development activities. The initiative of the Saudi King who allocated funds for the purpose of climate change research was well

received by most Arab scientists and fully appreciated by all.

### IV. VULNERABILITY OF WATER RESOURCES IN THE ARAB WORLD TO CLIMATE CHANGE

In our investigation of the vulnerability of water resources in the Arab region to climate change, it was found more convenient to divide the region into the following subdivisions:

1. Mediterranean countries which include: Mauritania, Morocco, Tunisia, Algeria, Libya, Egypt, Palestine, Lebanon, Syria, and Jordan. Mauritania and Jordan are included because of their close proximity to the Mediterranean climate, especially with respect to the rain patterns. Turkey is included as the country of origin of the Rivers Tigris and Euphrates which forms a major source of water to Syria and Iraq.
2. Egypt and Sudan as the end users of Nile water, though Egypt also belongs to the group of Mediterranean countries.
3. Syria and Iraq as the end users of Rivers Tigris and Euphrates.
4. The Arabian Peninsula which includes Saudi Arabia, Kuwait, the United Arab Emirates, Qatar, Oman, Bahrain and Yemen.
5. Somalia, Djibouti and the Comoros Islands as African Sahel countries.

Each sub-division will now be discussed below.

#### ***Vulnerability of Mediterranean Countries to Climate Change***

The term Mediterranean climate has been used for the characterization of other areas which are not necessarily located on both sides of the Mediterranean Sea. This climate is known for its wet and mild winters, and its dry and generally warm summers. The Mediterranean Basin is considered a transitional region between mid-altitudes and subtropical climate regions, with a division line moving seasonally across the basin. The Mediterranean Sea itself exerts important influ-

ences on the environment, climate, economy and culture of the coastal areas providing them with an important source of moisture and a heat reservoir.

The situation in the Mediterranean region is very complex due to large differences between different areas. While at its northwest coast population growth has practically stopped, a two-fold increase is expected in North African countries during the first three decades of the 21<sup>st</sup> century, with an even larger growth taking place in Syria and Palestine, adding more stress to the already scarce water resources. Global projections present remarkable agreement on the Mediterranean region, where warming is expected to be larger than the global average with a large percent reduction in precipitation and an increase in inter-annual variability (Giorgi, 2006).

Global simulation can not be considered accurate for the description of the Mediterranean region and downscaling by statistical methods and dynamic models can, in some situations, be used to provide better insight and give results with higher precision. Development of a regional model simulation for the Mediterranean is presently missing and one needs to be made in the future. Moreover, room should be left for different approaches such as statistical downscaling and other techniques.

Lebanon, taken as one of the advanced countries with respect to climate change research, displays the following vulnerability issues (Assaf, 2009):

- Chaotic urbanization at the expense of forests and wood lands.
- Air, water and soil pollution.
- Increasing frequency of fires due to prolonged dry seasons.
- Change of water table level due to excessive pumping and quarrying activities.
- Overgrazing of rangelands.
- Land fragmentation.

Morocco is another example of an Arab Mediterranean country in which climate change research is well advanced. The country has prepared its First National Communication to the UNFCCC, and is in the process of developing the Second National Communication Report.

A map of composite indicators representing the

vulnerability of both agriculture and domestic water uses to climate stress in the form of long hot and dry spells was generated to identify areas of high vulnerability. The results indicated that the ecosystem of the Tensift River Basin is very vulnerable with various degrees of vulnerability in different parts of the region.

Libya has a prevailing Mediterranean climate and a geography characterized by coastal valleys and heights; rainy cold winters and dry hot summers; as well as the seasons of spring and autumn in which the khamasin winds – locally called Gebli winds – blow. The country has ratified a number of United Nations agreements and protocols and is treated as one of the Less Developed Countries in its mitigation and adaptation measures to climate change. Water resources in Libya are limited to rainfall in the north and modest quantities of groundwater in the south. Continued abstraction of fossil groundwater will bring the country's aquifers to a state of low feasibility by 2050.

If the intensity of rainfall is reduced, as predicted by many sources, then the country will have no other option but to depend heavily on desalination or to import surface water from neighbouring countries. Both alternatives are fairly costly especially as the country suffers a population growth rate which ranges between 2.5 and 3%.

Syria is vulnerable to climate change because of the following reasons:

- More than 75% of the cropped area is dependant on rainfall as the main source of water. Therefore, fluctuation in rainfall affects rain-fed agriculture.
- Fluctuation of temperature affects crop yields.
- Increased frequency and duration of droughts affect crop production and food availability.

In Egypt, rain-fed agriculture is limited to the north coast and is extended over a distance of 1200 km where modest precipitation of 100 – 200 mm intensity falls every year, in particular during the winter months (December - February). If this already limited amount of rain is reduced further, life in these regions will become intolerable unless Nile water is conveyed from the east and west branches of the Damietta and Rosetta branches of the Nile.



If this solution proves to be too expensive, the only remaining option would be desalination of sea and brackish groundwater which might be made cheaper if renewable energy (solar, wind, wave) were used. Alternatively, atomic energy, which is a matter of controversy at the present time, would be the ultimate resort.

In general, almost all Arab countries located on the Mediterranean will be affected by climate change at different levels. Countries which are more dependant on rainfall will certainly be affected most. Other countries which are less

dependant on rainfall will be less affected; however, water has to be made available for areas which are going to be indirectly affected due to their dependence on other water sources inside or outside the country.

A problem common to all Arab countries located on the coast of the Mediterranean is the possibility of having coastal aquifers contaminated if the sea level is increased, particularly in low-lying areas because of sea water intrusion. Coastal aquifers are very fragile systems of fresh water lenses sitting above huge bodies of brackish water

of relatively high salinity. Overexploitation of fresh water lenses plus the expected intrusion of sea water in low-elevation areas will certainly affect the use of these aquifers and possibly lead to the pollution of soil as well. If parts of the lands parallel to the sea shore are inundated, then it will not only be groundwater that is going to be affected, the whole landscape will be changed with vast areas of land abandoned and large numbers of citizens displaced.

### **Nile Basin**

The Nile Basin is composed of three main sub-basins:

- Equatorial Lakes sub-basin.
- Ethiopian plateau sub-basin.
- Bahr El Ghazal sub-basin.

Precipitation on the Ethiopian Plateau comes in one season and takes around 100 to 110 days lasting from early June to mid-September. The sub-basin is marked with steep slopes which cause heavy storms to erode vast areas of land. In the Bahr El Ghazal sub-basin, land is fairly flat and precipitation is spread over large areas of swamps and marches occupied by wild animals and aquatic plantations. The Equatorial Lake plateau is flat as well; however, the Nile's route allows water to flow downstream inside a regular channel. Both the Bahr El Ghazal and Equatorial Lakes sub-basins experience two rainy seasons, one of them is long (4-6 months) and the other is short (2-3 months).

Research on the Nile Basin has proved that the river's natural flow is very sensitive to precipitation which falls on the Ethiopian highlands. An increase of 20% in precipitation may increase the Nile's natural flow at Aswan by 80%. Conversely, if precipitation is reduced by 20%,

the natural flow may fall to a mere 20% of the usual average. To a lesser extent, natural flow is also sensitive to temperature variation, particularly in the Equatorial Lakes and Bahr El Ghazal sub-basins. An increase of two degrees Celsius in temperature might cause the natural flow to fall to 50% of the average in these two sub-basins.

These facts lead to the important conclusion that Egypt and Sudan are both extremely vulnerable to increased or decreased rainfall in the Nile Basin as well as to increased temperature levels. Both increased and reduced flows have negative effects on the two countries. If the natural flow is considerably increased, the storage capacity of both water systems might not be sufficient to accommodate these high flows which might cause destructive floods. Even if the storage capacity is adequate, as might be the case in Egypt, the conveyance and distribution network of canals and drains might not be sufficient. If the opposite happens, i.e. natural flows are substantially reduced, the two countries will face droughts that might not be tolerable.

The application of Global Circulation Models on the Nile Basin flows resulted in variable figures over a very wide range. This uncertainty confirms the fact that regional or even local circulation models are needed. Unfortunately these types of models are not available at the present time. The only attempts cited are the series of studies carried out by an Egyptian team of experts to use the United Kingdom Meteorological Office Circulation Model (UKMO) to produce a regional model on the Nile Basin by downscaling using statistical and dynamic modelling. This process needs one to two years to be completed and the results would yield the highest accuracy possible using the best globally available techniques at the present time.

### **Vulnerability of Water Resources in Turkey**

In an interesting study on one of the major river basins in Seyhan, Turkey, a team of Japanese scientists (Fujihara et al., 2008) explored the impact of climate change on the hydrology and water flows of the river. A dynamic downscaling method (pseudo Global Warming Method PGWM) was used to connect the outputs of two General Circulation Models (GCMs) namely:

### **THE WATER EXPLOITATION INDEX (WEI)**

The Water Exploitation Index is a figure calculated by dividing annual total abstraction of fresh water by the long-term average freshwater resources. It is used as a measure of how sustainable a country's use of fresh water resources is in light of water availability.

Source: European Environment Agency



MRI-CGCM2 and CCRS/NIES/FRCGC-MIROC under the SRES A2 scenario. The downscaled data covered 10 year time steps corresponding to the base (1990) and the future (2070). The simulation results for the future were compared with those for the present. The average annual temperature change in the future relative to the present were projected to be +2.0 °C and +2.7 °C by MRI and CCRS, respectively. Projected annual precipitation in 2070 decreased relative to base levels by 157 mm (25%) in MRI and by 182 mm (29%) in CCRS. The annual evapotranspiration decreased by 36 mm (9%) in MRI and by 39 mm (10%) in CCRS. This is mainly because of the reduction in soil moisture.

The annual runoff decreased by 118 mm (52%) in MRI and by 139 mm (61%) in CCSR. The analysis revealed that water shortages will not occur in the future if water demand does not increase. However, if the irrigated area is expanded under the expectation of current natural flow, water shortages will occur due to the combination of reduced supply and increased demand. This example is alarming to both Syria and Iraq since both countries will certainly be affected by water management regimes in Turkey. Water shortages in the upstream will no doubt have a negative effect on the downstream flows of the Tigris and Euphrates Rivers.

### ***Vulnerability of the Arabian Peninsula to Climate Change***

The Arabian Peninsula is marked with extremely high summer temperatures, low intensity of rainfall, and declining groundwater table levels due to over pumping and obviously high evapotranspiration rates. The area has more than half of the world's proven oil and natural gas reserves which enable most of its countries to adopt state of the art international technology in the desalination of sea water.

However, oil and natural gas reserves are not permanent and the region is under the threat of having climate change exacerbate the already high temperatures and low rainfall. Groundwater in most of the countries in the region is not renewable according to many sources and, therefore, continuous abstraction increases water table depth and in some cases deteriorates water quality

due to sea water intrusion.

Clearly, increasing aridity reflects the influence of climate change which is felt at a lower extent in the Dead Sea area where the water level fell by more than 100 meters due to excessive evaporation and decreased rainfall (Jorgensen, 2001). In general, the Water Exploitation Index in most Arab countries is in or close to the red: 83% for Tunisia, 92% for Egypt, 170% for Palestine, 600% for Libya, 50% for Syria, 25% for Lebanon, 20% for Algeria and 40% for Morocco (Acreman, 2000). Results obtained from HadCM2 (a well-recognized GCM) suggest that rainfall is expected to be reduced in North Africa and some parts of Egypt, Saudi Arabia, Syria, and Jordan by 20 to 25% annually. Temperatures are expected to increase by 2-2.75°C; near to the coast, the expected temperature increase will be lower (1.5°C). Winter rain (October-March) would be decreased by 10-15% but would be increased over the Sahara by 25%.

However, since the existing rate of rainfall above the Sahara is insignificant, the increase would be of insignificant order of magnitude (Ragab et al., 2001). Added to the decline in rainfall, vulnerability of imported water through the Nile, Tigris and Euphrates to climate change is high; what might aggravate this vulnerability are the actions taken by upstream riparians to increase their own demand and/or change their water management strategy.

## **V. MITIGATION**

Although the Arab countries are the world's largest producers of fossil fuel, mainly oil, consumption by the region is lowest in the world. The reason is that the industrial base in almost Arab countries is still juvenile. Most of the region's energy is used for household consumption, mainly lighting, cooling and the operation of household appliances.

The second main energy consuming sector in the Arab countries is the automobile sector. However, the contribution of the region to greenhouse gases especially carbon dioxide is very modest and does not exceed 5% of total world emissions. Nonetheless, some of the Arab countries are observing the requirements of the international community concerning the reduction of

greenhouse gases emissions and have taken initiatives in this area. Some of these measures are: Converting petrol-operating vehicles to natural gas.

- Use of solar and wind energy as a substitute to thermal and steam power plants.
- Reduction of the emissions of methane gas by reducing rice cultivation and livestock manure.
- Promotion of the Clean Development Mechanism (CDM) which enables developing countries to obtain technical and financial support from industrial countries and to raise the capacity of individuals to reduce greenhouse gas emissions.
- Termination of all sources of subsidies on the prices of fossil fuel.
- Application of carbon taxes on activities that result in the emission of greenhouse gases using the “Polluter Pays” principle.
- Arranging for national awareness campaigns on the impact of climate changes targeting school and university students, as well as the general public.

## VI. ADAPTATION

The Arab world will face not only increasing temperatures but, more importantly, also disruption of the hydrological cycle, resulting in less and more erratic rainfall that will aggravate even further the already critical state of water scarcity and difficulties with water allocation among different development activities.

Most poor residents of rural areas will suffer and will require a range of coping strategies to help them adapt to climate change. Strategies will include diversifying production systems into higher value and more efficient water use options. Improved water use efficiency can be realized by following supplementary irrigation techniques, adopting and adapting existing water harvesting techniques, conjunctive use of surface and groundwater, upgrading irrigation practices on the farm level and on the delivery side, and development of crops tolerant to salinity and

heat stress. Water quality should also be maintained at higher levels by preventing contamination through sea water intrusion.

In addition to the above general water saving measures, a number of country specific steps have to be taken according to each country’s needs and requirements. Some specific examples are outlined.

For example, the Egyptian Second National Communication, in 2009, calls for:

- Adaptation for uncertainty: this includes changing the operation of the Aswan High Dam by lowering the storage water level and, thus, allowing more space to receive higher floods and reduce evaporation from the exposed water surface at the same time, and increasing the irrigated area in the case of high floods.
  - Adaptation to increased inflow by providing additional storage structures upstream of the Aswan High Dam in order to reduce the risk of flooding downstream.
  - Adaptation to inflow reduction by applying the strategies stated in the country’s National Water Resources Plan (NWRP) which can be categorized into three main parts: (i) optimal use of available resources; (ii) development of new resources; and (iii) water quality preservation and improvement.
  - Minimizing water losses.
  - Change of cropping patterns.
  - Increased reuse of land drainage, treated sewage and industrial effluent.
  - Desalination of sea water and brackish groundwater.
- The Lebanese Ministry of Agriculture, as another example, has adopted the following adaptation measure (Assaf, 2009)
- Natural adaptation where vegetation and wildlife may acclimatize if climate change is still within their range of tolerance.

- Cultivation of drought-tolerant crops.
- Reduced habitat fragmentation by means of corridors and connections between different areas.
- Rationalized water and land use to protect wetlands and riparian habitats.
- Increased area and number of protectorates.
- Rational use of renewable and non-renewable water resources through the adoption of modern irrigation techniques as a substitute to the conventional systems in the irrigated areas.
- health, environment, housing and utilities.
- Combine policies of climate change in the national policy and update supporting legislation.
- Education and public orientation programs. Data collection, exchange and analysis.
- Study of the extent of exposure of the country to climate change.

## VII. CONCLUSION AND RECOMMENDATIONS

The Sudanese authorities have adopted the following strategies (Babikr et al., 2009) in their plans to adapt to climate change:

- Capacity building of relevant stakeholders for better understanding of climate change scenarios and risk analysis.
- Public awareness on climate change issues and implications.
- Crisis management.
- Technology transfer including modern irrigation systems, water harvesting, desalination, water transport and recycling of waste water.
- Afforestation and reclamation of marginal and waste land.
- Utilization of cost-effective environment-friendly energy.
- Combat desertification and land degradation. Sustainable and integrated water resource management.
- Construction of water storage facilities.
- Establishment of climate proof projects.

Libya places more emphasis on the following points:

- Preparation of an inventory of activities leading to the emission of greenhouse gases including the energy, transport, industry, agriculture,

The Arab world is located in one of the most arid areas of the world. The area of Arab countries contains almost 10% of the world's dry land, while the region's population is only 5% of the world population. Alarmingly, water resources in the Arab countries are very limited, making up only 1% of the world's renewable fresh water. Almost two thirds of water in the Arab world originates in non-Arab countries miles away. Almost 80% of water resources are used in the agriculture sector which consumes vast amounts of water due to severe climatic conditions. Fast growing population and the need to raise people's standard of living increase water consumption dramatically. The expected effects of climate change might aggravate the situation by reducing river flows and rainfall as well as deteriorating groundwater quality.

Mitigation of the causes of climate change includes: less and efficient consumption of fossil fuel, more production of renewable energy and more cultivation of forestry and green areas.

Adaptation measures include: protection of low-lying lands and river deltas from inundation and sea water intrusion, change of cropping patterns, adoption of water saving techniques and introduction of integrated water resource management.

Finally, Arab countries have to reconsider water allocation among different development activities where water use efficiency represented by production per cubic meter of water overrules production per unit area of land, i.e., optimization of water use which gives maximum economic return per unit volume of water.

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*Impact of Climate Change: Vulnerability and Adaptation*  
**Human Health**

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## I. INTRODUCTION

Climate change is an emerging risk factor on human health. According to the Intergovernmental Panel on Climate Change (IPCC), the scientific body of the United Nations Framework Convention on Climate Change (UNFCCC), the health effects can be direct such in the case of extreme weather events, like storms, “floods, and heat waves, or indirect such as “through changes in the ranges of disease vectors (e.g., mosquitoes), water-borne pathogens, water quality, air quality, and food availability and quality” (IPCC, 2007).

The actual health impacts, however, are not uniform across countries and regions. They vary in extent and nature depending on local environmental conditions, socio-economic circumstances, and the range of adopted social, institutional, technological, and behavioural measures (IPCC, 1998; Patz and Kovatz, 2002; WHO 2007, WHO, 2008a). This is reflected in the World Health Organization (WHO) estimation of the contribution of climate change to the global burden of disease measured in disability-adjusted life years (DALYs). The Arab region comprises 22 different countries, with the majority falling under two WHO sub-regional groupings. The Eastern Mediterranean Sub-Region (EMR-D), which includes Afghanistan, Djibouti, Egypt, Iraq, Morocco, Pakistan, Somalia, Sudan, and Yemen, is estimated to lose 213 DALYs per 100,000 people as compared to 14 DALYs/100,000 for EMR sub-region B, which groups Bahrain, Cyprus, Iran, Jordan, Kuwait, Lebanon, Libya, Oman, Qatar, Saudi Arabia, Syria, Tunisia, and the United Arab Emirates. Three Arab countries, Algeria, Comoros and Mauritania are classified under the Africa sub-region AFR (D). AFR (D) is estimated to lose 207 DALYs per 100,000 people for climate change (WHO, 2002).

Is it climate change? Is it poverty? Or is it the vulnerability of poor countries to climate change? Most probably it is a combination of these factors which explains the wide range of the global economic value of loss of life due to climate change (US \$6-88 billion, in 1990 dollar prices) as reported by the IPCC. The impact is projected to be greatest in low-income countries. According to the WHO Regional Office of Eastern

Mediterranean (WHO/EMRO, 2008a) the region is ‘one of the most vulnerable regions to climate change because of its arid nature and reliance on rain-fed food production’ and because of the endemic nature of many diseases and health problems which are sensitive to poverty and climate change, making the impact on this region greater than that on the world as a whole (Fankhauser and Tol, 1997).

This chapter reviews the impact of climate change on human health in general, with a focus on the Arab world. It also suggests selected adaptation practices within the context of regional resources and constraints.

## II. HEALTH IMPACTS OF CLIMATE CHANGE

The study of the impact of climate change on health is rather challenging. In few instances, health problems be it death or injury can be directly linked to climate or weather changes such as drowning due to floods or heatstroke due to heat waves. Even this can be considered as a cyclical variation in weather or climate, especially since many natural calamities have been reported in past history. The challenge is even bigger when indirect health effects are considered. For example, malaria-ridden countries might be at a higher risk if the mosquito zones expand or the mosquito biting season becomes longer because of increased warmth or shorter cold seasons. The same is true of mortality and morbidity due to air pollution where climate change adds insult to injury for overcrowded cities dependent on fossil fuel for energy or transportation. Hence, the study of the health impact of climate change is difficult on country or sub-regional level. Reports that succeeded in confirming this relationship have in most cases zoomed out and looked at wider geographical areas. This has not happened yet in the Arab world. In fact, studies on the topic of climate change and human health in Arab countries are rare if not almost nonexistent. The few potentially relevant published studies that were identified were reviewed to provide regional data and indirect evidence. Although clear associations between health and climate change have not been established through research, there are some obvious potential effects of climate change on health in the region.



Box on page 90 presents a summary of the health impact of climate change in Arab countries based on their national communication reports. The following sections review in detail two examples of direct effects of climate change on human health (heat waves and floods) and two examples of indirect effects (air quality and infectious diseases).

### ***Direct effects of climate change on health***

#### **i) Heat waves and heat-related impacts on health**

Health effects associated with exposure to extreme and prolonged heat appear to be related to environmental temperatures above those to which the population is accustomed (McGeehin and Mirabelli, 2001). Elevated temperatures during summer months are associated with excess morbidity and mortality. Exposure to extreme and prolonged heat is associated with heat cramps, heat syncope, heat exhaustion, and heatstroke (McGeehin and Mirabelli, 2001).

Heat waves in certain areas around the globe will be hotter, more frequent and longer (IPCC, 2007). The IPCC Fourth Assessment Report predicts that the temperature in the East Mediterranean Region will increase by 1-2°C by 2030-2050. The frequency of very hot days and heat waves in the East Mediterranean region will increase (WHO, 2008a), presenting an

important threat to health. Mortality and morbidity due to heat stress are expected to rise, especially among particularly vulnerable infant and older populations.

A time-series analysis study (El-Zein and Tewtel-Salem, 2004) of mortality and air temperature in Greater Beirut, covering the period between 1997 and 1999, reported a significant association between temperature and mortality. The authors concluded that heat-related mortality may constitute a significant public health concern even in temperate to warm climates. These results were reinforced in another study by the same authors (El-Zein et al., 2004). A number of other studies from the region have focused on heat-related morbidity. A clinical study from Kuwait (Al-Tawheed et al., 2003), covering the period between 1998 and 2001, showed an increase in cases of anuria (kidney shutdown- no urine) in hot weather. Makhseed et al. (1999), also in Kuwait, reported that the incidence of pregnancy-induced hypertension was highest in June (summer) and lowest in March (winter). They attributed this finding to high temperature and low humidity, although the results were not conclusive. In Abu Dhabi, Shanks et al. (2001) showed that temperature and humidity are strongly correlated with the number of heatstrokes dealt with at the hospital emergency unit. Maximum temperature alone was a better predictor of heatstroke than maximum humidity alone.

## CLIMATE CHANGE AND HEALTH IN ARAB COUNTRIES AS REPORTED IN NATIONAL COMMUNICATIONS SUBMITTED TO THE UNFCCC

Most of the Arab states have published national reports on the adverse effects of climate change in response to the request of the United Nations Framework Convention on Climate Change (UNFCCC). Climate change is projected to increase health related problems in the Arab region.

Climate change is projected to induce sea level rise and coastal flooding which will affect human settlements and infrastructure in low-lying coastal areas such as in Bahrain, Djibouti, Kuwait, Libya, United Arab Emirates, Egypt, Comoros, Lebanon, Tunisia, Morocco, and Saudi Arabia. Comoros's initial national communication report to the UNFCCC reports an expected collective food poisoning attributable to increased consumption of toxic marine organisms. Water availability is expected to decline in the region particularly for a number of countries including Bahrain, Sudan, Djibouti, Tunisia, Algeria, Morocco, Jordan, Syria and the United Arab Emirates. Water scarcity and damaged infrastructure is expected to inflict major health problems such as increased risk of cholera, predicted for United Arab Emirates, and dysentery. Reduction in water availability will lead to reduced food productivity. Reductions in crop production in Bahrain, Comoros, Morocco and Saudi Arabia would increase the potential risks of malnutrition and hunger for millions.

Egypt's initial national communication to the UNFCCC reported that climate change will have both direct

and indirect adverse impacts on human health in the country. Direct impacts of climate change on human health include physiological disorders, skin cancer, eye cataracts, damage to health infrastructures, deaths and injuries and heat strokes. Indirect impacts include factors like demographic displacements, social, economic, ecological and air pollution impacts.

Elevated ambient temperatures and humidity are projected to increase vector-borne disease such as malaria. Sudan, Yemen and Comoros report intensification of malaria whereas Lebanon reports increased malaria incidence. Additionally, a projected increase in water-borne diseases such as diarrhea, typhoid and hepatitis A is reported for Lebanon. Rainfall decrease and increase in temperature will increase air pollution and consequently cause an increase in respiratory illnesses among urban populations, particularly in Egypt, Lebanon and the United Arab Emirates. Elevated temperatures could increase thermal stresses and extreme weather disasters resulting in increased death and injury rates. Desertification is predicted for northern parts of Sudan, Morocco and Saudi Arabia. Increased sand storms would have negative impacts on health. In Comoros, increased incidence of cyclones, storms and flooding would cause the destruction of 17 health centers and 35 nursing stations. Kuwait, Libya, Syria, Oman and Qatar have no national reports on the adverse outcomes of climate change.

Sources: WHO/EMRO 2008a; UNFCCC 1997, 1999a, 1999b, 2001a, 2001b, 2001c, 2001d, 2003a, 2003b, 2005a, 2005b, 2007, 2008

### ii) Hurricanes and floods

Hurricanes and associated floods, such as hurricane Katrina in the US in 2005, are expected to become more frequent globally and more intense with climate change. According to leading reinsurance companies, it was found that natural catastrophes have tripled in the last 10 years (WHO, 2003). These natural catastrophes claim the lives of many people and injure a lot more. In addition to these direct effects on health, floods displace people, destroy their crops, and temporarily disrupt their livelihoods. In other words, victims of such floods are at

high risk of malnutrition, diarrhea and other water-borne diseases, and diseases caused by crowding and lack of hygiene (WHO, 2007). Populations with already "poor sanitation infrastructure and high burdens of infectious disease often experience increased rates of diarrheal diseases after flood events" (IPCC, 2007). In the 1980s, such events killed 692,000 and affected 1.34 billion. In the 1990s, these events killed 601,000 and affected 1.85 billion (WHO, 2003). In some regions of the world, floods and storms have become a major cause of death. In 1999, 30,000 died from storms followed by floods and landslides in Venezuela.



“The predicted trend towards increasingly variable rainfall is likely to increase the risk of weather-related natural disasters, such as floods... It is possible that climate change may also change the frequency of other weather disasters, such as wind storms, but there is less agreement about the nature and magnitude of change. Continuing sea level rise will also contribute, by making unprotected low-lying populations increasingly vulnerable to coastal floods...” (Campbell-Lendrum and Woodruff, 2007).

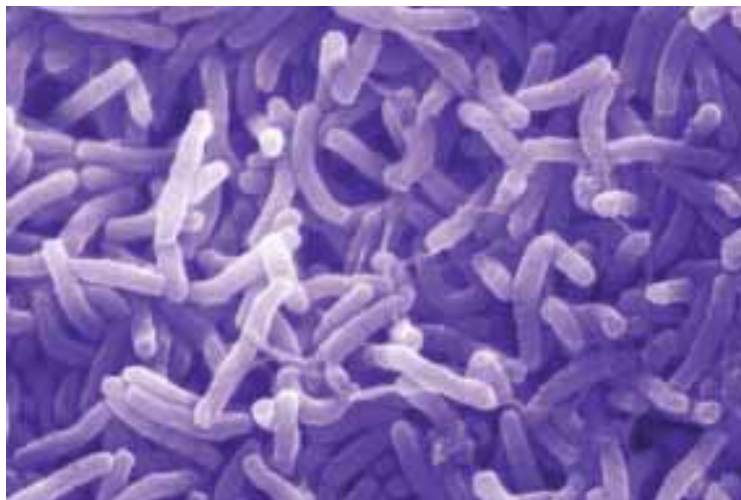
In the Arab region, we occasionally learn of a local flood or landslide due to heavy rainfall. These events cannot be directly attributed to climate change but obviously warn us of the devastating effects of floods if they happen at a larger scale. For example, on 16 May 2007, a flood devastated several villages in the Bekaa region in Lebanon. Crops were destroyed and people had to leave their houses because of high water levels. There were no follow up reports on the health, wellbeing, and livelihood of the displaced people which is not atypical in many developing countries. In addition, there is no proper research or documentation in most Arab countries on the frequency or intensity of such events. Mapping the effects of a given event may also be useful in identifying current and future populations at risk. Maps of flood risk zones can be eventually prepared and populations at risk can be warned in time.

Of more concern and relevance lately are the cyclone (Gonu) that hit Oman on June 6, 2007 and the floods that affected Yemen (Hadramout) in 2008. The Cyclone Gonu in Oman was considered one of the strongest in the Arabian Sea. According to the Oman News Agency (Associated Press, 2007), the cyclone killed 49 people in the country and around 20,000 people were affected. According to the World Health Organization (2008b) the floods in Yemen on October 24-25, 2008, left 180 dead and 10,000 displaced. The floods destroyed 2,000 homes, damaged water supply networks, and interrupted access to telephones and electricity.

#### ***Indirect effects of climate change on health***

The effect of climate change on existing environmental and public health problems is difficult to discern. The challenge is to identify the ‘additionality’, i.e., the increase in health problems that can be attributed to climate change as an additional risk factor. This requires advanced and far reaching research agendas and tools. Not much is known about the ‘traditional’ risk factors and causes of many public health problems in the Arab world, let alone the additional effect of climate change. The Arab world unfortunately remains one of the least published globally and, if published, in journals and reports that are not easily accessible by internet or recognized data





bases. For instance, Lebanon still lacks air quality monitoring programs which hampers any attempt to look at trends in air pollution or to critically examine its causes. In addition, environmental and public health problems are the outcome of the failure of a complex web of political, policy, social, economic, and physical (environmental) determinants. In spite of this, it is crucial to document what we know and anticipate the potential added effect of climate change.

This section will review the impact of air quality and infectious diseases on health and the potential contribution of climate change to both issues.

### **Air quality**

Air quality, measured using multiple indicators, is primarily determined by the contribution of different mobile (transportation) and fixed (generators, industry) sources of pollutants. This is further affected by the weather elements including temperature, humidity, and wind. Hence, it is obvious that climate change will have a direct impact on air quality and consequently on the health of exposed populations. This sub-section will focus on three indicators of air quality: aeroallergens, ground level ozone, and suspended particulate matter.

#### **i) Aeroallergens**

Weather determines the direction and magnitude of winds and consequently the presence, transport, and dispersion of dust aeroallergens. This has been documented around the world in many

studies which linked climate change to a wider spread of allergenic manifestations and the increase of reported asthma cases in affected areas (IPCC, 2007). Increases in CO<sub>2</sub> concentrations and in temperatures were associated with an increase in ragweed pollen production and the prolongation of the ragweed pollen season. Dust from Africa has been transported across the Atlantic as far as the Caribbean, where a dramatic increase in asthma cases has been reported as a result (Shinn and Griffin, 2003). It was reported that numerous species of bacteria and fungi well known to cause allergic reactions, pulmonary infections, or skin infections have survived the transatlantic transport (Shinn and Griffin, 2003).

The above findings have serious implications for almost all Arab countries which are in geographic proximity to deserts or are known for their large deserts such as in North Africa and the Gulf region. Changing wind patterns, under certain atmospheric conditions, can contribute to the long-range transport of desert dust and mould spores. This can occur over time-scales typically of 4-6 days, which can lead to adverse health impacts. Interestingly despite the dearth of studies in this field, four out of five identified studies were conducted in Arab countries with deserts and frequent sand storms. Al-Frayh et al. (1988) analyzed house dust samples in Riyadh and reported the presence of different types of fungal spores, among which many species are known to be allergenic. Hasnain et al. (1989) identified 32 generic categories of allergenic fungal spores in the atmosphere of Riyadh. Of these, *Cladosporium* was found to be highest in concentration. The concentrations of these spores are also seasonal with an increase in warmer months and a decline in winter. Some indoor air pollutants identified in this study were also linked to asthma. Later, Kwaasi (1998) found that sandstorm dust is a 'prolific source of potential triggers of allergic and non-allergic respiratory ailments' in Riyadh. Griffin (2007) reported an increase of 100% in the number of colony-forming units (CFU) over background levels during dust storms in Saudi Arabia. Dust storms and humidity were among several environmental risk factors associated with the prevalence of asthma in a cross-sectional study of 850 schoolchildren in the United Arab Emirates (Bener et al., 1996). A similar kind of study was conducted in Beirut by Al-Ajam et al. (2005) who

reported a seasonal pattern of mucormycosis, a rare fungal infection caused by Mucorales fungi, in 15 out of 16 cases of invasive mucormycosis. Weather patterns analysis, including temperature and rainfall, revealed clustering of cases at the end of the dry period of September to November rather than the period of May to July where temperatures are most favourable to Mucorales. The authors noted that this is a regional finding (Al-Ajam et al., 2005).

## ii) Other air pollutants

The WHO reports that over 1.1 billion people live in urban areas where outdoor air is unhealthy to breathe. These conditions worsen under certain weather patterns which enhance the formation of urban heat islands which in turn lead to elevated levels of certain pollutants (Morris and Simmonds, 2000; Junk et al., 2003). Two types of air pollutants will be considered in the following subsections: ground level ozone and suspended particulate matter.

### a) Ground level ozone

Photochemical smog (brown-air smog) is a mixture of primary and secondary pollutants formed under the influence of ultraviolet (UV) radiation from the sun. Consequently, hotter days predominantly lead to greater levels of tropospheric ozone ( $O_3$ ), in addition to nitrogen dioxide ( $NO_2$ ), peroxyacyl nitrates (PANs), and other air pollutants. In urban areas, traffic exhaust is the key source of nitrogen oxides and volatile organic compounds (VOCs). Temperature, wind, solar radiation, atmospheric moisture, venting and mixing are all factors affecting the emission of ozone precursors as well as the production of ozone (Nilsson et al., 2001a,b; Mott et al., 2005). Since its formation depends on sunlight, ozone concentrations are typically higher in the hotter summer months. Tropospheric ozone concentrations are projected to increase worldwide (Prather et al., 2003) and concentrations of ground-level ozone are increasing around the world (Wu and Chan, 2001; Chen et al., 2004).

Exposure to elevated concentrations of ozone is associated with increased hospital admissions for pneumonia, asthma, allergic rhinitis, other respiratory diseases, and premature mortality (Ebi and McGregor, 2008).

The Arab region is not exempt from this increase, especially in light of the increased use of fossil fuels and population growth in the Gulf countries. Arab cities, especially those with hot climates and frequent urban heat islands, are most likely to be affected. Populations of these cities would probably witness increased respiratory diseases as well as increased mortality and morbidity as a result of prolonged exposure to tropospheric ozone. Research on the effect of tropospheric ozone on human health in the Arab region is quasi-absent. Hence, the Arab region has to base itself on currently available international models and develop its own in such a way to deal with the many uncertainties that face this issue. These uncertainties include the extent of future emissions of ozone precursors, the degree to which future weather conditions could increase ozone concentrations levels, assumptions of population growth, energy use, economic development, regulations, and the implementation of these regulations.

### b) Suspended Particulate Matter

Suspended Particulate Matter (SPM) consists of a variety of solid particles and liquid droplets small and light enough to remain suspended in the air for long periods. They are well known to affect morbidity as documented in more than 2000 studies published in the last 15 years (American Lung Association, 2004). The most harmful forms are fine particles (with an average diameter of less than 10 micrometers) and ultra fine particles (with an average diameter of less than 2.5 micrometers) which if inhaled can reach the deep parts of the respiratory system (bronchioles and alveoli). Adverse effects include damage to the lungs, irritation of nose and throat, aggravation of asthma, and bronchitis. Toxic particulates, such as lead, polychlorinated biphenyls (PCBs) and cadmium, can lead to gene mutation, reproductive problems, and cancer. In the USA, SPM is responsible for 60,000 - 70,000 premature deaths a year (EPA, 1999a,b).

Using a modelling approach, Jacobson (2008) compared the health effects of preindustrial versus present-day atmospheric concentrations of  $CO_2$ . The study suggested that increasing concentrations of  $CO_2$  led to the increase of tropospheric ozone and  $PM_{2.5}$ , which increased mortality by 1.1% per degree temperature increase

over the baseline. It was found that 40% of this increase was attributable to tropospheric ozone and the rest to SPM.

Despite the known effects of ozone, SPM, and other temperature-enhanced air pollutants on human health, research relating to this topic is still scarce in the Arab region. Anwar (2003) points to air pollution as one of the most important health and environmental problems in Cairo. The Egyptian Environment Affairs Agency (EEAA) reports that air pollution is responsible for an average of 3,400 deaths each year in Cairo, in addition to about 15,000 cases of bronchitis, 329,000 cases of respiratory infection, and a large number of cases of asthma (UNEP, 2007). Increased air pollution is also observed in the main cities of Algeria, Jordan, Lebanon, Morocco, Palestine, Tunisia (IPCC, 2007).

Saliba et al. (2006) evaluated the variation of air quality indicators such as CO, SO<sub>2</sub>, O<sub>3</sub> and PM10 over the city of Beirut. Monthly concentrations for ozone (reported as 23 µg m<sup>-3</sup> in winter and 34 µg m<sup>-3</sup> in summer), CO, and SO<sub>2</sub> were found lower than the United States Environmental Protection Agency (EPA) air quality standards whereas PM10 levels were found to be higher. Vehicle-induced emission and winter heaters were the main sources for elevated CO and SO<sub>2</sub> levels respectively whereas elevated PM10 and O<sub>3</sub> levels were the result of several local and long-range transport phenomena.

Climate change is expected to exacerbate air pollution in the region. Hence, research on the potential effects of climate change on air quality, and consequently on human health, is needed in the Arab world.

### **Infectious diseases**

Infectious diseases are major causes of death, disability, and social and economic disruption for millions of people around the world (Global Health Council, 2009). Between 14 and 17 million people die each year due to infectious diseases - nearly all live in developing countries (WHO, 2002). Evidence on the associations between climatic conditions and infectious diseases is well established (WHO, 2003). Infectious agents lack a thermostatic mechanism,

making their reproduction and survival highly dependent on fluctuations in climate (Saab, 2009). This section will focus on vector-borne infectious diseases transmitted by arthropods, such as mosquitoes, ticks, sandflies and blackflies, and rodents. These morbidities are climate-sensitive and are the most studied in terms of relation with climate change. Other infectious diseases such as cholera and other water-borne illnesses are not covered in this section. These illnesses are also sensitive to climate change mostly due to lack of access to water and deterioration in quality of drinking water.

#### **i) Malaria**

Malaria is endemic to nine countries of the WHO Eastern Mediterranean Region, but with a low risk of transmission in the majority of the countries. In 2007, the estimated annual number of malaria cases in the Arab countries of the region was about 3 million, with the majority of cases reported in Somalia, Sudan, Yemen and Djibouti (WHO/EMRO, 2007).

Sudan has the highest burden of malaria in the WHO Eastern Mediterranean region with 2.5 million cases and 37,707 death cases reported for 2006 (WHO/EMRO, 2008b). Children and pregnant women are at a higher risk of contracting malaria. Pregnant women are susceptible to malaria with adverse outcomes of low birth weight, maternal anemia and abortions (Adam et al., 2005; WHO, 2008c). Yemen ranks second among Arab countries in incidence of malaria (WHO/EMRO, 2008b). Al-Taïar et al. (2006; 2008) report that severe pediatric malaria, which is endemic to the coastal plain as well as to the inland mountains, is a substantial burden to health services in Yemen.

Malaria has long been studied and it is known that "geographical diversity determines malaria variability in terms of endemicity, intensity of transmission and type of malaria" (WHO/EMRO 2008b). Climate change is projected to influence the geographical distribution and intensity of transmission of malaria, due to changing patterns of rainfall, humidity and particularly seasonal variation of temperature (Sachs and Malaney, 2002; IPCC, 2007). As an example, the falciparum malarial protozoa takes 26 days to incubate at a temperature of 25°C, while



at a temperature of 26°C this same protozoa takes only 13 days to incubate (Epstein 2004). A 2006 study done in East Africa has revealed that a 3% increase in temperature in a certain region can mean an increase of 30-40% of mosquito abundance (Khamsi, 2006).

Malik et al. (1998) report that in the southwestern part of Saudi Arabia transmission of malaria occurs throughout the year with peaks associated with the rainy season and hot summers. Al-Mansoob and Al-Mazzah (2005) investigated the role of climate on the malaria incidence rates in Yemen. They found significant associations between climatic factors such as temperature, relative humidity, rainfall volume and wind speed with incidence of malaria. Similarly, Bassiouny (2001) reported that favourable meteorological conditions (i.e., optimum temperature and relative humidity) led to the prolongation of the malaria transmission season to 8 months a year in Fayoum Governorate in Egypt. Hassan et al. (2003) confirmed these results and reported however that the most important predictor of risk in the Fayoum Governorate is hydrogeology. The study reported the spread of specific anopheles vectors in areas where they were previously absent.

In New Halfa, Eastern Sudan, a time-series analysis study (Himeidan et al., 2007) showed that temperature and rainfall are driving forces of the spatial distribution of the malaria vector *Anopheles gambiae*. In northern Sudan, surveys of breeding sites of the *Anopheles arabiensis* revealed a seasonal pattern for the larval population which appeared to be linked to the rise and fall of the Nile River level (Ageep et al., 2009). Similarly, Hamad et al. (2002) reported seasonal transmission of malaria in Eastern Sudan, increasing with onset of rainy season and high humidity.

## ii) Other infectious diseases

Other infectious diseases transmitted by vectors are also sensitive to climatic changes. The following are such examples:

- Dengue (Breakbone or Dandy Fever): This is an acute febrile disease caused by a flavivirus, which is transmitted by the bite of previously called *Aedes* mosquitoes (now named *Stegomyia aegypti*). Dengue is endemic

throughout the tropics and subtropics threatening approximately one-third of the world's population. Its transmission increases with high rainfall, high temperature, and even, as some studies show, by drought (IPCC, 2007).

- Cutaneous leishmaniasis (oriental sore or Aleppo Boil): The distribution of the phlebotomine sandfly vector responsible for the infection with cutaneous leishmaniasis has changed in the past years. Other sandflies have also re-emerged in certain parts of the world (IPCC, 2007).
- Schistosomiasis (Bilharziasis): This is a visceral parasitic disease caused by blood flukes of the genus *Schistosoma*. The schistosomes that affect humans are trematodes and they require freshwater snails as intermediate hosts. Schistosomiasis also may be affected by climatic factors, and there is some evidence that the 'freeze line' has moved towards the north due to warmer temperatures (IPCC, 2007). This was supported by Malone et al. (1994) who used temperature data from satellite imagery to show that the range of *S. mansoni* in the Nile delta, Egypt, is expanding in the southern delta due to new irrigation channels, a more reliable water supply and the physical-chemical stability since the completion of the Aswan Dam. These changes have all provided a better fit to the hydrologic niche of the parasite. Moreover, the *Bulinus truncatus* snail, which is the intermediate host of *S. haematobium*, is now able to tolerate several months of drought and high temperatures. The correlation between the density of *Bulinus truncatus* with weather variations was monitored by Khallaayoune and Laamrani (1992) in the Attaouia area in Morocco. It was shown that snail populations followed a cyclical pattern where high density occurred in summer. Temperature was considered to be the most important factor that influenced the fluctuations in snails' populations. Moreover, snails during the year of study (1987) were active throughout the year, due to the fact that the mean daily temperature was above 10°C throughout the year. Observations on the pattern of snail infection rates showed that the maximal rate of infection happened in summer where the mean daily temperature was high and contact with water most frequent (Khallaayoune and Laamrani, 1992).

- Diseases transmitted by rodents: These too tend to increase during heavy rainfall and flooding because rainfall and flooding increase the number of rodents. A good illustration would be the Hantavirus Pulmonary Syndrome (IPCC, 2007).

### III. ADAPTATION PRACTICES

The vulnerability of human health to climate change is a function of three factors: sensitivity which is a measure of the extent to which health, natural systems, and social systems are sensitive to climate change as well as the characteristics of the population; exposure to climate related hazards; and adaptation measures which are the measures applied to reduce the burden of a specific adverse health outcome. Arab countries may be low direct contributors to climate change but they are at high risk of its consequences, especially as it relates to health risks. Consequently, Arab countries must take adaptive measures to reduce the burden of disease or other related negative health outcomes related to climate change (Kovats, 2003). Those populations who do not or cannot adapt will be the most vulnerable to climate change.

Mitigation measures are implemented at multiple levels to prevent 'disasters' or minimize their impact. In the case of heat waves, for example, mitigation measures include adopting building designs that take into consideration future heat waves due to climate change especially in Arab cities, such as in the United Arab Emirates and the Sultanate of Oman, which are expanding at a very fast pace. Buildings should limit the frequency, intensity, and duration of high-temperature episodes. As cities grow and merge so do their heat islands. Urban heat islands in large Arab cities can be reduced through urban planning and environmental preservation such as reducing automobile use, enhancing public transportation, planting trees, protecting biodiversity, and the like. Encouraging more environmentally sustainable development by reducing dependence on cars, and cutting wasteful resource and energy use is a needed policy. Heat wave warning systems to warn the population about upcoming heat waves are also recommended. However, the effectiveness of warning systems for extreme events depends on individuals' awareness and their will-

ingness to take appropriate action. Individuals can reduce their exposure by adjusting outdoor activity, modifying indoor air temperature, or dressing properly. In the case of other hazards or geographic contexts, such as floods, community awareness and preparedness becomes very important if it is technically or financially difficult to construct flood embankments or create new flood overflow routes.

It is necessary that Arab countries implement measures at the country and regional levels in public health preparedness to face such calamities. In fact, such measures are still a priority to this region regardless of climate change considerations. A preparedness plan must address the three phases of a disaster: pre-disaster phase (e.g., mitigation; awareness; warning systems), disaster phase (e.g., response; health care facilities), and post-disaster phase (e.g., rehabilitation; long term impact; evaluation). At a minimum, the elements of a public health preparedness system must include the following:

#### 1) Hazard mapping

This is a crucial element of any preparedness plan where at-risk areas and vulnerable populations are clearly mapped. At-risk areas include arid lands, coastal cities prone to sea-level rise, areas around dams and irrigation projects, and overcrowded cities. Vulnerable populations include poor people who most likely have poor health with high infant mortality rates and low life expectancies, and tend to reside in areas or houses that are most vulnerable to climate change. The latter was illustrated in the latest flooding episode in Yemen which mainly affected the poorer populations. Populations in Arab countries that rely on non-irrigated agriculture are also likely to be vulnerable to climate change. Nomadic tribes living in the Sahara in North Africa and the Gulf area are also likely to be vulnerable to climate change.

Such information will help policy makers determine priorities and decide on the adequate provision and distribution of resources, including health care resources and facilities. Geographical Information Systems (GIS) are an important tool in this endeavour. GIS links together geographical information (such as geographic coordinates of a specific point or the outline of an administrative region) to some relevant information about

that location (size of population, available resources, potential hazards, number of people killed by malaria in a given year). This would allow different kinds of information to be linked for each time and place, the mapping of modifying factors and outcomes in space and time as well as trends in exposure, and the analysis of these sets of information relating to the same place at a given time. Such activities would allow Arab countries to have a robust database within a period of a few years.

## 2) Research

Research is needed to assess climatic changes and related health impacts in the Arab world. This will allow countries to better identify vulnerabilities and to evaluate the respective country's capacity to adapt to climate change. It is needed to estimate the burden and cost of climate change; information which might be necessary to convince governments to allocate budgets for mitigation and adaptation measures and further national research in the field.

Arab scientists are called upon to pool their expertise and resources and collaborate in defining a regional research agenda on climate change and health while accommodating sub-regional and national priorities. Priority research topics may include:

- Heat and health (especially in countries with hot summers): Factors relating to the adaptive capacity of vulnerable populations and the role of socio-economic conditions should be investigated. Longitudinal studies over extended periods of time may be the preferred type of studies in this case.
- Aeroallergens: This is especially needed as desertification is on the rise. Research here could also focus on the development of early warning systems for populations, especially the vulnerable and those with a predisposition. Weather reports could - for example- routinely include an analysis of air pollutants and aeroallergens.
- Malaria transmission: Despite the strong association between malaria expansion and changes in the transmission season (which may be caused by climate change), a number of uncer-

tainties still exist about how climate change will affect malaria. These uncertainties are mainly related to the complexity of malaria dynamics and the scarcity of historical data in relation to climate change, in addition to the role of socio-economic factors and other factors in the development of disease. So far, in spite of its endemicity in the region, only little research in the Arab region exists on the topic. Mapping the disease in time and space and analyzing patterns of presence versus absence is less data intensive than other methods and can therefore be used in countries where vector borne diseases are a health risk and whose research capabilities are limited.

- Water quality in coastal cities: The rise in sea water levels and increase of seawater intrusion into coastal aquifers threaten the quality of drinking water. A case in point is the city of Gaza where over-pumping has already caused seawater intrusion into freshwater coastal aquifers (Al-Ghuraiz and Enshassi, 2006).

GIS is an important tool in assessing the impact of climate change on health generally and on infectious diseases particularly.

## 3) Adapting health systems

Health systems in the Arab world need to be adapted and prepared to respond to the consequences of climate change. Building the capacity of the health sector is a long-term commitment which requires sound technical and managerial programs. The key issue is not to develop a separate system for each type of hazard but to build capacities within the health sector to face all types of risks emanating from climate change. This requires that all stakeholders in health (Ministry of Public Health, health-related governmental and non-governmental organizations, private health facilities, international health agencies and professional associations) be involved and prepared. Furthermore, preparedness of the health systems requires a multisectoral approach and coordination between all involved sectors, such as public works, transport, social services, housing, urban planning, water and electricity, is essential.

## 4) Capacity building

The above elements of a public health prepared-

ness system require a strong basis of training and capacity building for policy makers, scientists, and health professionals in disaster management, research, data collection and monitoring, and response to health emergencies. It also involves raising awareness among the general population, especially vulnerable populations.

#### IV. CONCLUDING REMARKS

Despite the deficiency in both data and research, there is growing evidence that climate change is contributing to the global burden of disease in Arab countries. The limited research available has shown that climate change plays an important role in the spread of vector-borne infectious diseases, such as malaria and schistosomiasis (Egypt, Morocco and Sudan), in affecting the seasonal concentrations of some allergens in the atmosphere, causing allergic reactions and pulmonary diseases (Lebanon, Saudi Arabia and UAE), and in the worsening of the public health impact of heat waves especially in Arab countries with hot climates.

Earlier in the chapter, the authors noted that poorer Arab countries currently carry the largest burden of the health impact of climate change. Some may question the contribution of climate change to this burden as compared to that of poverty and people's suboptimal living conditions. This delineation of contribution might be an interesting research question but as far as policy is concerned there is enough evidence for action-oriented policies to counteract the effects of climate change with special attention to the poorer populations. This is all the more so since health is central to sustainable development and to the achievement of the Millennium Development Goals (MDGs). If Arab countries are to achieve the MDGs and counteract the adverse effects of climate change, then various adaptation strategies, policies and measures need to be implemented. Reduction in greenhouse gas (GHG) emissions through the shift towards renewable energies and increases in energy efficiency will yield significant long term benefits for human health.

There is no shortage of human resources or global and regional financial resources in the Arab world. What is needed now is the will to act.

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*Impact of Climate Change: Vulnerability and Adaptation*  
**Ecosystems and Biodiversity**

SALMA N. TALHOUK AND MAYA ABOUD



## I. OVERVIEW OF THE CURRENT STATUS OF BIODIVERSITY IN THE ARAB WORLD

The Arab world houses a unique biological diversity in terms of species and ecosystems represented by arid, semi arid, and Mediterranean biomes (Figure 1). The reported number of species currently harboured in the Arab world is listed in floras, compendiums, and country reports (Table 1). The richest countries documented in terms of plant diversity with more than 3000 species include Egypt, Lebanon, Morocco, Syria, Algeria, Tunisia, and Somalia, while animal diversity is highest with more than 5000 species in Algeria, Lebanon, Syria, and Tunisia (CBD national reports). The density is estimated at 1000-2000 plant species per 10,000 km<sup>2</sup> in Jordan, Lebanon, Morocco, and Syria and less than a 1,000 per 10,000 km<sup>2</sup> for the remaining Arab countries. The density of mammal species ranges between 21-50 animal species per 10,000 km<sup>2</sup> in Egypt, Iraq, Jordan, Morocco, Sudan, Syria, and Tunisia, with a high range of 51-100 in Lebanon and a range of less than 20 in the remaining countries (The Atlas of Endangered Species, 2005).

Many species in the Arab world currently face major threats which will be augmented in the future due to the repercussions of climate change. With respect to terrestrial biodiversity and more specifically plant biodiversity, according to the 2008 IUCN threat categories (Table 2), Yemen has the highest number of threatened species at 159 while the remaining countries either did not indicate any data or range between 0 to 17



species. With respect to animals, the countries with the highest number of threatened species according to the 2008 IUCN categories include Djibouti, Egypt, Jordan, Morocco, Saudi Arabia, Somalia, Sudan, and Yemen which all have more than 80 threatened animal species, with a maximum of 108 species in Egypt. An overall status of threatened species in the Arab world is summarized per specific taxonomic group in Table 3 (IUCN, 2008).

Marine biodiversity along the coasts of the Arab world shows significant threat levels in selected areas such as the highly threatened dugongs in Bahrain whose seagrass foraging grounds around the archipelago form the world's second largest dugong aggregation (a tightly linked group of dugongs, large marine herbivorous mammals, occupying the same area) after Australia. In

FIGURE 1

EXAMPLES OF SPECIFIC BIOMES IN THE ARAB WORLD

### Main biomes

- Desert
- Xeric shrubland
- Semi desert
- Mediterranean

### Sub-categories of biomes

- Temperate broadleaf and mixed forest with temperate grasslands, savannas and shrubland in Oman, Jordan and Syria
- Mediterranean forest, woodlands and scrub with scattered temperate conifer forest along the coastline of Morocco and Algeria
- Tropical & subtropical grasslands savannas & in southern Mauritania and Sudan
- Flooded grasslands & savannas in Egypt and Iraq

Sources: SEDAC-Map client; Biomes and Ecosystems, 2008



addition, dolphins and whales in international waters were classified in 2000 as critically endangered, endangered or vulnerable and numbered between 11-16 species on the northern coast of Morocco and between 6-10 species in the Mediterranean Basin, the coast of Mauritania, and the southern coast of Morocco (The Atlas of Endangered Species, 2005).

With the inevitable global phenomenon of climate change, freshwater biodiversity in the Arab world will be greatly impacted and many of these precious resources will not survive. Table 4b outlines the Arab countries with exceptional large areas designated as wetlands of international importance in accordance to the Ramsar Convention.

Ornithological diversity constitutes a major asset to the Arab world as well as a high risk area in terms of climate change impacts. Many Arab countries lie on important bird migration routes. Djibouti, which is a crossroad in the transcontinental North-South migration corridor, accommodates 1 million birds per year. Mauritania is home to the biggest wader population in the world and millions of migratory birds come to the country to stay through the winter months, while the Hawar Islands of Bahrain house the largest breeding colony of Socotra cormorant in the world. There are many threatened Marine Important Bird Areas in the Middle East including the eastern side of the Red Sea along the coastline of Saudi Arabia, both Eastern and Western coastlines of the Persian Gulf, along the coastline of the Gulf of Oman and Arabian Sea, along the Mediterranean coastline of Lebanon and Palestine, and within the Gulf of Aqaba. The number of threatened birds classified as critically endangered, endangered or vulnerable in 2004 ranged between 11 and 30 species in all Arab countries except for Lebanon, Libya, Qatar, Sudan, and Tunisia which have between 6 to 10 species recorded as threatened (The Atlas of Endangered Species, 2005). The number of threatened birds of prey classified as critically endangered, endangered or vulnerable in 2000 ranged between 5 and 6 species in Saudi Arabia, 3 to 4 species in Egypt, Morocco, Sudan, Djibouti, Jordan, Palestine, Syria Lebanon, Iraq, UAE, Kuwait, and Yemen, and in the remaining countries between 1 and 2 species (The Atlas of Endangered Species, 2005). In terms of the

TABLE 1 SPECIES NUMBERS ACROSS THE ARAB WORLD

Country	Plants	Animals
<b>Algeria</b>	3,164(a)	2,941 (b)
<b>Bahrain</b>	195 (b)	-
<b>Djibouti</b>	826 (b)	1,417 (b)
<b>Egypt</b>	2,076 (a)	-
<b>Iraq</b>	-	-
<b>Jordan</b>	2,100 (a)	-
<b>Kuwait</b>	234 (a)	-
<b>Lebanon</b>	3,000 (a)	4,486 (b)
<b>Libya</b>	1,825 (a)	-
<b>Mauritania</b>	1,100 (a)	1,417 (b)
<b>Morocco</b>	3,675 (a)	-
<b>Oman</b>	1,204 (a)	-
<b>Palestine</b>	-	-
<b>Qatar</b>	371 (b)	-
<b>Saudi Arabia</b>	2,028 (a)	-
<b>Somalia</b>	3,028 (a)	-
<b>Sudan</b>	3,137 (a)	-
<b>Syria</b>	3,000 (a)	2,518 (b)
<b>Tunisia</b>	2,196 (a)	2,244 (b)
<b>United Arab Emirates</b>	-	-

Sources: a) United Nations Environment Programme, 2005 (a) ; b) CBD national reports

TABLE 2 IUCN THREAT CATEGORIES (2008)

Abbreviation	Category
<b>CR</b>	Critically endangered
<b>EN</b>	Endangered
<b>VU</b>	Vulnerable

number of threatened seabirds classified as critically endangered, endangered or vulnerable in 2000 most countries either did not have any data or reported 0 species except for Iraq, Kuwait, Bahrain, Saudi Arabia, Qatar, the UAE, Oman, and Yemen which reported between 1 and 2 species (The Atlas of Endangered Species, 2005).

## II. AGRO-BIODIVERSITY AND SMALL ARAB COMMUNITIES

The Arab world is home to several Centres of Origin (aka Vavilov Centers of Diversity) which are geographical areas where a group of organisms, either domesticated or wild, first developed their distinctive properties. Until today Vavilov centres are regions where a high diversity of wild relatives to various crops can be found, representing the natural relatives of domesticated crop

TABLE 3 THREATENED SPECIES IN EACH COUNTRY BY TAXONOMIC GROUP

Country	Mammals	Birds	Reptiles	Amphibians	Fishes	Mollusks	Other Invertebrates	Animals	Plants	Total
<b>Algeria</b>	14	11	7	3	23	0	14	72	3	75
<b>Djibouti</b>	8	7	0	0	14	0	50	79	2	81
<b>Egypt</b>	17	10	11	0	24	0	46	108	2	110
<b>Iraq</b>	13	18	2	1	6	0	15	55	0	55
<b>Jordan</b>	13	8	5	0	14	0	49	89	0	89
<b>Kuwait</b>	6	8	2	0	10	0	13	39	0	39
<b>Lebanon</b>	10	6	6	0	15	0	3	40	0	40
<b>Libya</b>	12	4	5	0	14	0	0	35	1	36
<b>Mauritania</b>	14	8	3	0	23	0	1	49	0	49
<b>Morocco</b>	18	10	10	2	31	0	9	80	2	82
<b>Oman</b>	9	9	4	0	20	0	26	68	6	74
<b>Palestine</b>	3	7	4	1	1	0	1	17	0	17
<b>Qatar</b>	2	4	1	0	7	0	13	27	0	27
<b>Saudi Arabia</b>	9	14	2	0	16	0	53	94	3	97
<b>Somalia</b>	14	12	3	0	26	1	50	106	17	123
<b>Sudan</b>	14	13	3	0	13	0	45	88	17	105
<b>Syria</b>	16	13	6	0	27	0	6	68	0	68
<b>Tunisia</b>	14	8	4	1	20	0	7	54	0	54
<b>UAE</b>	7	8	2	0	9	0	16	42	0	42
<b>Yemen</b>	9	13	3	1	18	2	61	107	159	266

Source: IUCN, 2008

plants. Vavilov (1951) identified eight World Centers of Diversity of cultivated of which the Middle East is one of the regions identified and it includes interior of Asia Minor, all of Transcaucasia, Iran, and the highlands of Turkmenistan. The total number of species in the Mediterranean region is 84 species which falls in third place among the other centres after the Chinese and the Indian Centers with their 137 and 117 species, respectively (Perrino, 1988). The Mediterranean is the centre of origin of two fruit trees, the olive and carob tree, a large number of cultivated vegetables (30), spices (15), oil (6) and many of the old varieties of forage plants (11) (Perrino, 1988).

To ensure the long range success in continuing the evolution of genetic resources in the Arab world in response to climate change it is important to protect the diverse 'ancestral' genotypes in their country of origin from modern agricultural interference, in effect by 'freezing' the genetic landscape even to the extent of subsidizing 'primitive' agro-pastoral systems (Vallianatos, 2006). The responses of small communities to climate change by consistently constructing their livelihoods in a generally sustainable approach some-

times deliberately conserving or enhancing species and habitats should be seriously documented and strategically protected. Deliberate conservation of biodiversity by small communities is rarely evident for animal prey, particularly large game, whose very mobility often prevents local control over access and hence diffuses any benefits from restraint. In contrast most cases of deliberate conservation apply to plant resources or habitats. Subsistence-based small-scale societies are likely to respond to climate change by pursuing enhancement of the resources needed for livelihood and allocating subsistence efforts to the most rewarding areas and resources currently available. These choices will often have the effect of conserving habitats and biodiversity being impacted by climate change but they will not necessarily be designed to do so and may at times have the opposite consequence (Smith and Wishnie, 2000).

### III. SHIFTS IN SPECIES DISTRIBUTION RANGES IN RESPONSE TO CLIMATE CHANGE

The Arab world harbours native species that tol-

## RAMSAR CONVENTION

**The Convention on Wetlands**  
**An intergovernmental treaty**  
**signed in Ramsar, Iran, in 1971,**  
**that provides the framework for**  
**national action and international**  
**cooperation for the conservation**  
**and wise use of wetlands and**  
**their resources.**

Source: Ramsar Convention

TABLE 4

WETLAND OF INTERNATIONAL IMPORTANCE  
IN SELECTED ARAB COUNTRIES

Country	No of sites	Total Area (Ha)
<b>Algeria</b>	42	2,959,615
<b>Egypt</b>	2	105,700
<b>Iraq</b>	1	137,700
<b>Mauritania</b>	4	1,240,600
<b>Sudan</b>	4	8,189,600
<b>Tunisia</b>	20	726,541

erate strong heat and drought and these are likely to respond to climate change by either persisting in their current habitats or by shifting their distributions to relatively cooler or more humid areas at higher latitudes and/or altitudes. Shifts in distribution ranges have been recorded universally across a wide range of plant and animal groups and may be more dramatic for less widely studied taxa (Hickling et al., 2006).

At a global level, species native to the Arab world may expand their distribution ranges into higher latitudes. For instance, South Mediterranean species which are at the warm end of the European temperature gradient with both medium niche breadth and range size are predicted to lose proportionally less suitable habitats and to gain a substantial amount of new habitats in cooler areas outside the Arab world (Thuiller et al., 2005b). If this is the case, then dispersal ability would become a determining factor because it is the migration of competitive dry land species which may ultimately result in the loss of suitable climate space for European species in Europe (Rivedi et al., 2008).

At the regional level in the Arab world, both altitudinal and moisture gradients are expected to provide unique refuges for the last remaining populations. These refuges are special areas amidst predominantly arid and semi-arid lands that cater to niche ecosystems and harbour specialized species as well as species that are already at their ecological limit and as such are very vulnerable to climate change. Given the absence of published climate change prediction models for biodiversity in the Arab world it is important to draw on existing geo-referenced species distribution data to understand and predict species' response in terms distribution range shifts. In

this case, the use of hierarchical models which combine macro climate data including estimates of species' thermal and moisture tolerances as well as micro climate data gradients along which species are distributed is essential; otherwise altitude/moisture driven variability in mountains and near water bodies will not be captured and findings will be skewed towards documenting responses of species prevalent in the more common arid and semi-arid biomes (Rivedi et al., 2008).

Species vulnerability to climate change is therefore expected to be highest for unique species that are restricted in scope, and/or at the margin of their ecological tolerances. Examples of such unique situations include species that thrive at high altitudes under conditions of relatively moderate heat and/or moisture, as well as those that thrive near fresh water bodies and along coastal zones including islands. There are many species thriving in such unique habitats scattered within each Arab country such as the mangroves in Qatar, the cedar forests in Lebanon and Syria, the islands of Djibouti, the marshes of Iraq, the high mountain ranges of Yemen and Oman reaching 3,700 m and 3,000 m respectively, as well as the large rivers of the Nile (Egypt and Sudan), the Euphrates and Tigris (Iraq and Syria), and Yarmuk (Syria and Jordan).

Specialized species and ecosystem niches at their ecological limits are distributed along the extensive coastline of the Arab world, such as the mangroves of Egypt which are highly localized and have a limited tolerance for ecological pressures. Documented temperature changes in sea water in various areas along the coasts of the Arab world have led to the designation of the coastlines of Oman and Somalia as coral bleaching hotspots



(NOAA/NESDIS, 2009). Some areas such as the lower section of the Red Sea and southern section of the Gulf have shown an increase between 1 to 1.5o C. Other areas have displayed lower but still significant increases between 0.5 to 1o C such as the upper section of the Red Sea, Mediterranean Sea, Gulf of Oman and the Arabian Sea. Increases in temperatures will also significantly affect biodiversity along sandy beaches and coastal sand dunes; for example marine turtles that use the beaches of Bahrain, Lebanon, and Oman for nesting will be affected significantly as an increase in soil temperature will affect the ratio of females and males and thus have irreversible consequences on the survival of the species in these regions. Wetlands may be among the most sensitive ecosystems in the Arab world due to significant impacts of climate change that can be induced from even small degrees of change in the amount and seasonality of rainfall and evaporation.

High altitudes which provide refuges for many specialized species and niche ecosystems will undoubtedly witness distribution shifts and in some cases disappearance of species. Two coniferous tree species, the cedar of Lebanon and the silician fir reach their southernmost distribution limit in Lebanon and their distribution range will recede with increasing temperature to higher latitudes and altitudes in the region. Similarly the Juniper woodlands in Saudi Arabia which are currently concentrated in a narrow belt about 7,600 square kilometres in size at very high altitudes ranging between 2000 and 3000 m will be

significantly affected by climate change (National Report to the CBD). This impact has been noted whereby decreased humidity and rainfall has impacted juniper trees in the mountains of Jibal Ash-Sharah in southern Jordan and Hijaz Mountains in Saudi Arabia; the tips of these trees are drying up and seed regeneration has decreased (Al Eisawi, unpublished).

Prediction studies made in other parts of the world suggest that climate change will make it difficult for species thriving in unique microclimatic refuges to persist; in analogy to these predictions it is believed that species adapted to heat and drought and with broad distribution ranges in the Arab world will displace specialized species thriving in unique habitats and thus will cause them to lose all suitable climate space (Rivedi et al., 2008). For example, prediction models suggest that in South Mediterranean countries, mountain regions would experience a mean of 62% species loss and turnover showing a major change in floristic composition in time (Thuiller et al., 2005a). Furthermore, modelling studies predict that species tolerant to aridity will be the most stable and conserve their initial habitats and/or expand to new suitable habitats while species with narrow tolerance to higher temperatures would lose large proportions of habitats (40-60%) or migrate up slope towards new potential habitats if this is geographically available. Therefore, in contrast to species commonly adapted to heat and drought in desert and semi-desert biomes, the persistence of species in ecosystems such as riverine habitats, wetlands,



and mountains in the Arab world is constrained by water availability, temperature, and/or their substrate (Table 1). The potential of these ecosystems to respond to climate change by migration is therefore limited and their survival more doubtful.

#### IV. ECOSYSTEM COMPOSITION AND SPECIES VULNERABILITY TO CLIMATE CHANGE

Adaptations to climate change will alter entire ecosystems in terms of physical, chemical and biological features and/or alter species composition forcing species to disperse, adapt or face ultimate extinction. Wherever conditions favour large changes in the number of species that co-exist in a given area, or species richness, communities can be expected to undergo major reorganization. As a result protection of representative and/or ecosystems currently in existence will be problematic (Currie, 2001). Since species are generally expected to respond individually to climate change, there is potential for novel species combinations to occur, and for present day relationships to become increasingly decoupled (Thuiller et al., 2006). For instance the loss of the rarest species can be compensated by increased growth of the dominant species, whereas reductions in the density of the dominant species cannot be compensated by rare species.

In terms of species richness, although many studies show positive effects of biodiversity on ecosystem function, others do not. The reason may be related to the position of the species most affected by climate change. For instance, if the loss of species is at top trophic levels or a keystone species, then it may have particularly strong ecosystem effects. On the other hand climate change induced loss of species at different trophic levels or different species groups will be difficult to predict in response to climate change. It is quite possible, however, that over the short term (decades to centuries) species richness will decrease, even in areas where richness is predicted to increase in the long term: as climate changes, species that are intolerant of local conditions may disappear relatively quickly while migration of new species into the area may be quite slow (Currie, 2001).

Understanding species dispersal habits becomes essential since, with respect to the timescale considered by climate change predictions, dispersal habits can range from those that would be unable to disperse significantly to those that could readily disperse and establish. For example, species with large seeds will not migrate as quickly as species with lighter seeds or those seeds that can be dispersed by animals. Some simulation studies, however, show that many of the species whose potential distribution ranges change significantly will become non-viable because of delays in population responses to climate change (Miles et al., 2004). In general, species that currently have a broad distribution range will most likely have high dispersal ability while those that exist in few sites will likely have low dispersal ability and be more threatened by climate change driven disasters such as fires, droughts, and pest outbreaks. On the other hand, migrating species could experience multiple extinctions as they encounter anthropogenic land transformations or simply reach the mountain summit or water body edges.

Future predictions of species vulnerability will need to be based on analytical tools such as broad modelling frameworks that focus on the species suitable climate space through the use of bioclimatic envelop models which depend on the analysis of the complex interactions at different levels (Pearson and Dawson, 2003) and/or integrative sensitivity analysis modelling which examines the effect of climate change on individual species, especially those that are rare, threatened and climate sensitive as well as ecological processes (Hannah et al., 2002).



TABLE 5 STATUS OF PROTECTED AREAS IN THE ARAB WORLD

Country	Protected Areas as a % of Total Land Area (2004) <sup>a</sup>	National and International Protected Areas <sup>b</sup>
<b>Algeria</b>	5.1	104
<b>Bahrain</b>	-	6
<b>Egypt</b>	4.6	32
<b>Iraq</b>	0.0	10
<b>Jordan</b>	10.2	24
<b>Kuwait</b>	0.0	19
<b>Lebanon</b>	0.3	20
<b>Libya</b>	0.1	26
<b>Mauritania</b>	0.2	7
<b>Morocco</b>	0.8	81
<b>Palestine</b>	-	-
<b>Oman</b>	0.1	7
<b>Qatar</b>	-	4
<b>Saudi Arabia</b>	2.0	128
<b>Somalia</b>	0.3	25
<b>Sudan</b>	3.5	44
<b>Syria</b>	-	18
<b>Tunisia</b>	0.2	87
<b>UAE</b>	0.0	15
<b>Yemen</b>	-	-
<b>World Coverage</b>	6.1	-

Sources: a) United Nations Environment Programme, 2005 b) WDPA, 2009

## V. IN SITU CONSERVATION-PROTECTED AREAS AND THEIR ROLE IN MITIGATING THE IMPACT OF CLIMATE CHANGE

The Arab world has made major steps towards the designation of protected areas in each respective country (Table 5). Protected areas include both national areas which cover various ecosystems as well as international designations such as Ramsar sites, Man and Biosphere and World Heritage Sites.

Protection of unique ecosystems and species at their ecological limits highlights the importance of establishing protected areas of adequate span into substantial climatic (temperature/rainfall) gradients and to be linked by corridors of natural/semi-natural habitats (Eclcy et al., 1999). In situ conservation including national parks and bio-reserves are key conservation tools used to protect species and their habitats within the confines of fixed boundaries. In contrast, changes in species distribution ranges in response to climate change are expected to be highly dynamic

encompassing and sometimes sidestepping areas of protection. .

Conservation managers pursuing species richness as a goal unto itself may not be protecting desired ecosystem functions. Instead targeted strategies such as control of invasive species may be more easily accomplished by identifying and targeting functionally important types of species (e.g. bio-control agents or native competitors) than simply advocating increased species richness (Srivastava et al., 2005). For example national parks situated in desert and xeric shrubland biomes would be most sensitive to climate change as they will most likely experience a decrease in species richness. Protected areas situated in rare, patchy, and unique habitats may show a gain in floristic richness but would experience a change in species composition. If, for instance, habitat structure is changed due to the loss of keystone species, for example a tree species, to climate induced changes in fire regimes, this will have significant impact on fauna. Furthermore, the potential spread of species and their ability to track climate change beyond the boundaries of protected areas as in the case of the oryx, fox and other mammal species, will be unlikely without human intervention (Thuiller et al., 2006). For example, in Africa none of the 277 animal species examined were destined to extinction when full migration ability of species across landscape was assumed, and a maximum of 10 species when assuming no migration as these species would lose 100% of their suitable habitats. Furthermore, if a species becomes restricted to a few sites, then local catastrophic events could easily cause the extinction of that species; climate change can affect the susceptibility of animals to disease outbreaks, and particularly anthrax. Life cycles of ticks or other parasites are also particularly influenced by climate variation and could exacerbate risks of extinctions.

In situ conservation sites situated in xeric and desert shrublands are not expected to meet their mandate of protecting current mammalian species diversity within protected boundaries and instead may face significant losses of species diversity that are not compensated by species influxes. Even when significant species losses are not anticipated there may be repercussions because of indirect effects caused by the rearrangement of animal communities which

TABLE 6

DEGREE OF INFLUENCE ON THE TERRITORIES OF ARAB WORLD

Country	Percentage of total land area (including inland waters) having very low anthropogenic impact	Percentage of total land area (including inland waters) having very high anthropogenic impact
<b>Algeria</b>	84.25	0.58
<b>Bahrain</b>	-	-
<b>Egypt</b>	86.37	1.85
<b>Iraq</b>	9.51	2.08
<b>Jordan</b>	46.61	1.65
<b>Kuwait</b>	0.05	10.47
<b>Lebanon</b>	0.0	18.08
<b>Libya</b>	92.46	0.27
<b>Mauritania</b>	93.84	0.02
<b>Morocco</b>	17.90	2.04
<b>Occupied territories</b>	-	-
<b>Oman</b>	76.24	0.73
<b>Qatar</b>	-	-
<b>Saudi Arabia</b>	49.24	0.58
<b>Somalia</b>	-	-
<b>Sudan</b>	44.24	0.11
<b>Syria</b>	0.21	3.10
<b>Tunisia</b>	33.98	3.57
<b>UAE</b>	0.46	5.02
<b>Yemen</b>	49.09	0.17

Source: ESI, 2005

may alter existing competitive interactions and influence trophic dynamics with changes in predator-prey interactions (Thuiller et al., 2006).

## VI. CONCLUDING REMARKS

Agricultural activities and urban environment have high impacts on the natural environment and as such the conversion of natural vegetation for human activity has important ecological implications. The percentage of a country's land area that has low anthropogenic impact is a measure of the degree to which wild lands that are important for biodiversity conservation still exist in that country. The percentage of a country's land area that has high anthropogenic impact is a measure of the degree to which a country's land area is dominated by high intensity land-uses. The percentage of land impacted by anthropogenic activity in the Arab world has been documented to be the highest in Lebanon with 18.08% and Kuwait with 10.47%. Algeria, Egypt, Libya, Mauritania and Oman have the highest percentages of lands that are only impacted by anthropogenic activity to a low degree; the

percentages in these countries are above 70% and reach as high as 93.84 % and 92.46% respectively in Mauritania and Libya (Table 6).

The Arab world's acknowledgment of the serious implications of climate change on biodiversity and the status enjoyed by pro-active initiatives undertaken can be deciphered by each country's national reporting to the United Nations Convention on Biological Diversity (UNCBD). An analysis of two main questions in the UNCBD national reports reveals a bleak situation into the importance given to this issue and the action taken. On the question dealing with the implementation of projects aimed at mitigating and adapting to climate change that incorporate biodiversity conservation and sustainable use, only 4 countries have done so and 5 countries have such projects under development. The remaining 11 countries have not undertaken such projects, have not completed a national report to the CBD, or have not reported anything on this question.

The second question concerns countries' coordination efforts to ensure that climate change miti-



gation and adaptation projects are in line with commitments made under the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Convention to Combat Desertification (UNCCD). In response to this question, 7 countries reported having the relevant mechanisms and 2 countries stated that these mechanisms are under development. The remaining 11 countries stated they have not implemented such mechanisms, have not completed a national report to the CBD, or have not reported anything on this question.

More action is urgently needed in the Arab world with respect to properly and effectively responding to climate change. The number of species in the Arab world is low in accordance with their natural environment with total documented animal and plant species ranging from 9119 species in Lebanon to 2243 species in Mauritania. However, regardless of species richness, it is the measure of the relative changes in species diversity which will give insight into the vulnerability of a region with respect to climate change (Bakkenes et al., 2002). Although it is possible that dry-land species will be able to expand their distribution range, this is highly dependent on the species' dispersal habits and ability to over-

come natural or human created barriers or human caused land transformations.

In addition to studying and projecting species reaction to climate change, it is as important to predict which species would maintain their current distribution as the net species loss in arid and semi-arid areas would lead to collapse of already marginal dry-land communities. As such, the Arab region which is predominantly arid (Egypt is 96% arid, while Jordan is 80% arid and 80% of the Abu Dhabi Emirate area is desert) is especially vulnerable to significant species loss. There is no consensus on how to map environmental consequences of climate change. Locations affected least and those affected most under different scenarios provide a framework for designing conservation networks to include both areas at least risk (potential refugia) and areas at greater risk where the rate of climate change may outstrip the rate at which many species can respond to change resulting in altered ecosystems representing new assemblages that did not exist in the past and therefore do not have past analogues (Saxon et al., 2005). The impact of climate change would not solely affect the species directly but would affect complex associations such as species mortality from pest



outbreak which in turn may be due to the pest species, the amount of genetic variation and adaptability to current weather conditions in the pest population, predation levels for example by birds on the insects, and whether or not insecticides have been applied.

Countries in the Arab region must design and implement specific and tailored projects for mitigating and adapting to climate change. In the past, species survived previous climate change events as they were able to track their habitats though space. Unfortunately, today this is becoming extremely and increasingly difficult as humans have transformed or fragmented the natural world. As such the inhabitants of the Arab world should deploy significant and immediate efforts in order to provide species with the possibility to shift their habitats and adapt to climate change (Jansson and Dynesius, 2002).

In terms of protected areas management, there are two main strategies that should be applied in a parallel and complimentary manner in order to ensure maximum conservation coverage and efficiency. The first strategy is to add new protected areas to maintain species' representation targets and the second strategy refers to the management of species within protected areas in reference to and in coordination with other protected areas (and not simply to maintain the site's status quo) (Hannah et al., 2002). In the Arab world, it would be of significant importance to adopt and apply three main axes in protected areas planning, including the expansion of protected areas, managing outside the protected area and regional coordination of management actions (Hannah et al., 2002).

Last but not least, the Arab region as an inter-linked geographical entity should develop and implement regional mechanisms for coordinating activities in this field. Species range-shifts, impacts of extreme events and resources asynchronies often occur on regional scales so an effective climate change strategy must include mechanisms for coordinating conservation actions at the regional level across political boundaries and agency jurisdiction (Hannah et al., 2002). In order to tackle a global phenomenon with impacts on many levels and scales, regional coordination is a necessary element for effective and sustainable results.

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## *Impact of Climate Change: Vulnerability and Adaptation* **Infrastructure**

HAMED ASSAF





## I. INTRODUCTION

Infrastructure is the lifeline that supports all sorts of human activities - domestic, commercial, and industrial - in urban as well as rural settings. Transportation systems, coastal defence works, water supply and wastewater systems, electric generation facilities and oil and gas pipelines represent the bulk of infrastructure, which are expected to be impacted by impending climatic changes. Despite the significance of infrastructure, few studies have been conducted worldwide, and very few in the Arab world, to assess the impact of climate change and explore adaptation strategies. Consequently this assessment study is conducted based on reviewing literature mostly published in developed nations and extrapolating findings by analogy to the Arab region. The analogies are based on selecting studies pertaining to regions with similar climate, topography and urban settings.

Four categories of infrastructure are considered in this study: transportation, coastal protection works, water supply and wastewater systems, and energy generation and supply systems. The assessment looks at the impacts of climate change on these infrastructure systems and potential options for building and enhancing adaptive capacity.

## II. TRANSPORTATION INFRASTRUCTURE

Transportation infrastructure includes both networks such as roads and highways and facilities such as bridges, ports and tunnels (U.S. National Research Council, 2008). The transportation infrastructure in the Arab world is generally exposed to prolonged hot and extremely hot days, sandstorms, thunderstorms and dusty and windy conditions, and sea surges in the coastal regions. All these climatic conditions are expected to intensify, and to become more frequent and widespread under projected climate change scenarios.

The impacts of climate change on the transportation sector can generally be categorized into those related to the structural integrity of infrastructure and those affecting its operation. Adapted from the U.S. National Research Council (2008), these impacts can be summarized as shown in



Table 1. The projected increase in intensity and prolongation of very hot days can result in the softening of asphalt and consequent degradation of road pavement which affects its operation and increases risks of traffic accidents. These climatic conditions may lead to excessive expansion of bridge components and deformation of metal components such as rail tracks and bridge steel elements. Excessive heat decreases the efficiency of construction and maintenance activities, increases heat-related health risks to construction crews and commuters, and poses limits on the maximum loads of trucks and airplanes.

Based on work by the U.S. National Research Council (2008), Neumann and Price (2009) identify several measures to develop and enhance adaptive capacity in the transportation sector. Of relevance to the Arab region are changes in transportation operating and maintenance practices, design strategies, planning of capital investment, control on land use, adoption of new technologies and material, and development of information base and decision-support tools.

Preparedness to extreme weather conditions and events should be incorporated into routine operations with an emphasis on closer collaboration



TABLE 1 IMPACT OF PROJECTED CLIMATIC CHANGES ON TRANSPORTATION

Climatic changes	Impact on structural elements of infrastructure	Impact on operation of the infrastructure
Increases in frequency and intensity of very hot days and heat waves.	<ul style="list-style-type: none"> <li>Excessive expansion in bridge joints and pavement surfaces</li> <li>Decreased viscosity of asphalt which may lead to traffic-related rutting and displacement of pavement.</li> <li>Deformities in metal components including rail-tracks, bridge steel elements, etc</li> </ul>	<ul style="list-style-type: none"> <li>Limitation on the maximum load capacity of trucks and airplanes due to weakening of pavement.</li> <li>Harsh climatic conditions will reduce the effectiveness and increase the cost of construction and maintenance.</li> </ul>
Increase in sea water level / sea surges.	<ul style="list-style-type: none"> <li>Inundation of coastal transportation elements including roads, bridges, airports, etc.</li> <li>Erosion and deterioration of pavement, bridge support and its base.</li> <li>Costly adjustment in harbour and port facilities to accommodate tidal increases and more intense sea surges.</li> </ul>	<ul style="list-style-type: none"> <li>Frequent closure of coastal roads due to sea surges.</li> <li>Storm surges may disrupt operations and pose hazards to passengers of coastal airports (e.g., Beirut and Manama Airports).</li> </ul>
Increase in the frequency and intensity of sandstorms, thunderstorms, and windy conditions.	<ul style="list-style-type: none"> <li>Increased damages to road, rails and bridges.</li> <li>Increased risk of mudslide and rockslide in mountainous regions, such as in Lebanon.</li> </ul>	<ul style="list-style-type: none"> <li>Intense sandstorms in desert areas across the Arab world would cause disruption of road traffic and increase frequency of closures and accidents.</li> <li>Disruption of the operation of airports.</li> </ul>

Sources: Adapted from the U.S. National Research Council (2008).

with emergency management agencies. Infrastructure, especially critical components, should be designed on more robust standards. Considering the uncertainty in models of climate change impacts, infrastructure could be designed so as to have a shorter life span, thereby facilitating marginal improvements to provide flexibility in dealing with changing climatic conditions.

Integrated transportation and land-use planning can be an effective adaptation strategy in reducing the impact of climate change by restricting development and settlement in high-hazard areas. This can be implemented at the level of planning of new infrastructure or rehabilitation of those affected by climate change. The success of this approach is expected to vary from one country to another depending on the current level of development of hazard prone areas, integration of planning agencies and support for these changes which may not be popular among significant sectors of the society. Recent advances in monitoring technology,

information management, decision support systems and modelling, and development of new construction materials open up new opportunities for managing the impact of climate change and designing infrastructure elements capable of withstanding more extreme climatic conditions.

### III. COASTAL PROTECTION

Thermal expansion of sea water and influx of fresh water from melted ice sheets and glaciers occasionally accompanied with local land subsidence are destined to increase sea levels by the end of the 21st century to levels estimated between 19-59 centimetres according to IPCC figures; it should be noted that these predictions exclude "future rapid dynamical changes in ice flow" and the full "likely" temperature range (IPCC, 2007). Recent evidence of projected higher contributions from land-based ice such as the Greenland Ice Sheet indicates that sea level rise (SLR) at the end of the century could range



from 0.5 to 1.4 meters; with some studies showing that melting from ice sheets alone could cause SLR of up to 2 meters. Not only would SLR result in the inundation of highly populated and productive areas, but it would also accentuate the impact of sea surges leading to beach degradation, erosion of road bases, instability of bridges and harbour structures, in addition of posing serious hazards to coastal population.

These projections could have dire consequences for the Arab world considering the concentration of very significant proportions of population and economic assets in coastal zones in the major cities such as Alexandria, Casablanca, Algiers, Tripoli, Tunis, Beirut, Latakia, Jidda, Basra, Kuwait city and Dubai. In a study by the Organization for Economic Co-operation and Development (OECD) (Nicholls et al., 2008) Alexandria was currently ranked 9<sup>th</sup> in terms of exposed population (1.33 million) and 17<sup>th</sup> in terms of exposed assets (\$28.46 billion) among the world's portal cities. By 2070, the city is projected to be in the 11<sup>th</sup> place in terms of exposed population (4.38 million) and 20<sup>th</sup> in terms of exposed assets (\$563.28 billion).

Despite the gravity of this situation there are very few studies carried out assessing the impact of SLR in the Arab region (e.g., AFED, 2008: 129-131). One of these studies (El Raey et al., 1999)

provided an assessment of the impact of SLR on the two main coastal directorates in Egypt: Alexandria and Port Said. Current conditions and those for 0.25, 0.5 and 1 meter projected SLR were assessed. The study shows that these areas are highly vulnerable to SLR with the potential of forcing millions to permanently migrate out and result in losses in the billions of dollars to urban dwellings, recreational facilities, industrial assets and infrastructure.

Al-Jeneid et al. (2008) assessed the impact of SLR on Bahrain's archipelago. SLR of 0.5, 1, 1.5, 2 and 5 meters were considered. The findings underscore the vulnerability of Bahrain to SLR even for the lower SLR of 0.5 meters. This is mainly attributed to the concentration of population and commercial and industrial activities in the coastal areas. In particular, key industrial and commercial parks and infrastructure including main roads and highways are situated in low-lying newly reclaimed areas.

One of the dilemmas facing policy makers in dealing with the impact of SLR is striking a balance between the costly investment in developing and maintaining coastal protection works on the one hand and the difficulty in controlling and reversing urban and industrial growth in coastal areas on the other. For instance, it is deemed prohibitively expensive and socially disruptive to

move millions of inhabitants, recreational facilities, commercial and industrial establishments out of the coastal areas in Egypt (El Raey et al. 1999). Also costly is the development of comprehensive coastal protection schemes along Egypt's extended coastal line. In Bahrain, large investments have gone into developing reclaimed areas and few options are available to relocate potentially impacted populations and assets to the interior.

El Raey et al. (1999) explore several adaptation options including beach nourishment enhanced by groins, breakwaters, land use change and regulation and integrated coastal zone management (ICZM). The first two options represent structural measures with varying costs, while land use and regulation represent "soft" measures aimed at discouraging and reversing development in hazard-prone areas. The authors recommend adopting the latter option of ICZM which combines both measures in addition to raising public awareness, institutional cooperation and capacity building. The non-structural approaches are also emphasized by Kirshen et al. (2008) who conclude that in addition to being sustainable and environmentally friendly, they are flexible, no-regrets and co-benefit policies.

Neumann and Price (2009) emphasize that although coastal defence infrastructure is designed to mostly protect private property, it is more cost effective to plan and develop it at a large collective scale. They emphasize, however, the importance of integrating coastal protection with land-use planning where development in hazard-prone areas is strongly discouraged through public awareness, regulation and/or increasing insurance premiums.

#### IV. WATER SUPPLY AND WASTEWATER INFRASTRUCTURE

Although generally under extreme pressure from rising demand and water scarcity, water supply systems vary across the Arab region from those mostly dependant on renewable freshwater resources such as those in Egypt, Lebanon and Iraq to those that are totally dependent on non-renewable fossil groundwater and desalination, namely the Arab Gulf states. Coupled with excessive growth in population and rising living stan-

dards, climate change will exacerbate water scarcity conditions across the Arab world. Most climate general circulation models (GCMs) project that North Africa and the Levant will undergo a persistent reduction in total precipitation coupled with rising temperatures, which will reduce available water resources (Assaf, 2009). Rising sea levels will increase pressure on coastal aquifers and will accelerate the on-going salinization in coastal aquifers such as those of Beirut and Gaza city. In Lebanon, climate change is expected to cause higher winter temperatures which will decrease snowfall, which will in turn reduce natural snowpack storage.

Adaptation to these changes is most optimally and sustainably achieved through an integrated water supply/demand management. Demand management involves raising public awareness regarding water conservation, using water pricing as an incentive tool to reduce consumption and rehabilitating water networks to reduce losses. Studies in the USA have shown that the reliability of water resources systems is largely dependent on storage capacities, which are key factors in maintaining system resiliency under the impact of climate change (Kirshen et al., 2006). Dam reservoirs make up most of the storage capacity worldwide and in many Arab countries with river systems including Egypt, Morocco, Syria and Iraq. Aquifer





recharge is increasingly being used to take advantage of excess winter runoff. It has the added benefit of reducing evaporative losses. Treated wastewater represents a valuable water source that can be tapped to supplement freshwater water resources. Tunisia and Egypt have invested considerably in wastewater treatment facilities and supply networks (EUROMED, 2009).

The projected increase in the intensity of rainfall events combined with reduction in hydraulic efficiency due to SLR in coastal areas is expected to result in more frequent sewer overflow, with associated public health problems, and flooding of culverts and roads (Infrastructure Canada, 2006). Also, more intense rainfall events and thunderstorms increase peak volume and sediment loading into wastewater treatment plants leading to inadequate treatment, reduction in efficiency and possible shutdown. Design criteria for wastewater elements need to be revisited to improve their resiliency under the impact of climate change.

## V. ENERGY GENERATION AND SUPPLY INFRASTRUCTURE

Although great emphasis is placed on the energy sector as the main source of GHG emissions, the impact of climate change on the energy generation and supply system is much less studied. One of the main assessment studies on the impact of climate change on the energy sector was commis-

sioned by the US Climate Change Science Program (US CCSP, 2007). The study provides a summary of the current knowledge about the impact of climate change on consumption, generation and supply of energy in the US. Information gleaned from this report and deemed relevant to the Arab world is summarized briefly in the following paragraphs.

Projected higher summer temperatures will increase cooling energy requirements, which are already a major item in the total energy bill of most Arab countries. In contrast, projected warmer winters will reduce heating energy requirements. However, these energy savings will be dwarfed by the increases in cooling energy requirements. This net increase in energy requirements will be tempered by savings to be gained through technological advances in improving the efficiency of energy intense equipment. A significant share of energy is used across the Arab world in groundwater abstraction, desalination, treatment, transfer and distribution. Projected climate change-induced declines in fresh water supplies and increase in demand in the region would increase energy requirements for all these activities.

Projected increases in average air and water temperatures and limited availability of adequate cooling water supplies are expected to affect both the efficiency, operation and the development of new power plants. The performance of gas turbines is particularly sensitive to ambient temper-



ature and pressure. A 30°C increase in ambient temperature, which is typical of diurnal changes in desert areas, can result in a 1 to 2% reduction in efficiency and a 20 to 25% decrease in power output; as these results are linear, smaller increases will likewise have considerable effects on efficiency and output (Davcock et al., 2004). Consequently, overall warming is expected to decrease total power capacity available and production cost. Increased water temperature will place strains on thermal plants.

Climatic changes are expected to impact renewable energy infrastructure. Decreased river runoffs will reduce hydroelectric output. This is particularly significant for countries such as Egypt, Syria and Iraq with large hydroelectric capacity. Changes in wind conditions will affect the performance and reliability of current and planned wind farms. Solar energy production is sensitive to cloudiness, which is expected to change across the region.

Projected increases in the activity of extreme weather events could lead to more downing of power transmission towers and lines, as well as disruptions in the operation of power plants and refineries. It could also impact trucking or shipping of fuel supplies, which disproportionately impact remote areas and small countries with no local energy resources such as Lebanon. Many power plants in the Arab region are placed only a few meters above sea level making them particularly vulnerable to damage from sea level rise and wave surges.

Enhancing the adaptive capacity of the energy infrastructure could be achieved through an integrated approach that involves utilizing technological advances to improve power plant efficiency, demand management, decentralization of power generation to spread climate change risk over a larger area, storm planning for power plants and refineries, and building strategic fuel reserves to manage disruptions to fuel supply and deliveries (Neumann and Price, 2009).

## VI. CONCLUSION AND RECOMMENDATIONS

Climate change is projected to significantly impact infrastructure across the Arab world.



Transportation infrastructure is generally vulnerable to projected increases in the intensity and frequency of hot days, storm activities, and sea level rise (SLR). Reliability of water supply systems will be impacted by expected reductions in fresh water supplies and higher average temperatures. Wastewater networks are particularly vulnerable to excessive rainfall events and SLR. Energy generation will be hampered by higher ambient temperatures which will reduce the efficiency and capacity of gas turbines, and reduce cooling efficiency of thermal plants. Energy distribution and transmission systems will be more prone to failure due to increase extreme weather events.

Integrated land use and infrastructure planning, water and energy demand management, the enhancement of the resiliency of infrastructure components to withstand climatic change, upgrading of design criteria and operations to incorporate the impact of climate change, utilization of new technology, and engagement of the public in the decision making and raising their awareness of climate change are key recommendations for developing and enhancing the adaptive capacity of infrastructure in the Arab world.

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## *Impact of Climate Change: Vulnerability and Adaptation* **Tourism**

ABDELLATIF KHATTABI



## I. INTRODUCTION

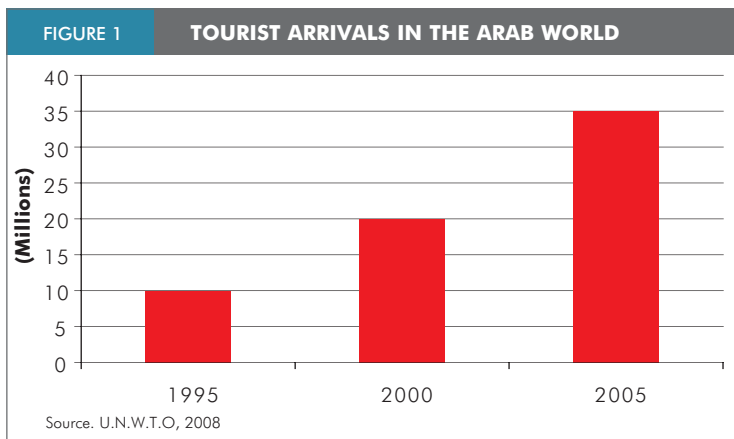
Tourism in the Arab world is becoming increasingly important given the natural, cultural and historic tourism potential of the region's countries. Tourism can be considered as a driving force for local economies and a source of foreign currency, particularly for countries whose energy resources are limited such as Morocco, Tunisia and Lebanon. Tourism could also be a lasting substitute for those countries that have economies based on non-renewable energy resources. However, like most other sectors of economic activity, the tourism sector is vulnerable to climate change impacts and might also contribute to or exacerbate it.

In fact, tourism is regarded as one of the economic sectors most sensitive to the potential impacts of climate change, as are the agricultural, environment and water sectors (Wilbanks et al., 2007).

This chapter highlights some issues related to tourism and climate change in the Arab world, and how these might impact these countries' economies. It also suggests some mitigative and adaptive actions which need to be taken either in the short, medium and long term, to lessen the vulnerability of this sector.

## II. TOURISM IN THE ARAB WORLD

According to statistics compiled by the World Tourism Organization (2008), international tourist arrivals at the borders of the Arab countries in 1995, 2000, and 2005 were as depicted in Figures 1 and 2.



Five Arab countries are among the top 50 most visited countries in the world. Saudi Arabia is ranked 21<sup>st</sup>, followed by Egypt (23<sup>rd</sup>) and Morocco (31<sup>st</sup>). Tunisia occupies the 34<sup>th</sup> position and Bahrain the 45<sup>th</sup> position. As Saudi Arabia is ranked the first destination in the Arab region, we have to clarify that the visitors to Saudi Arabia are almost exclusively pilgrims.

Figures from the World Tourism Organization on the evolution of international tourism receipts in the Arab countries are given in Table 1.

Five Arab countries are also among the top 50 in terms of tourism receipts. The first among them is Egypt which occupies the 27<sup>th</sup> position, followed by Morocco (31<sup>st</sup>) and Saudi Arabia (38<sup>th</sup>). Lebanon ranked 41<sup>st</sup> and the UAE occupies the 42<sup>nd</sup> position.

## III. THE TOURISM SECTOR AND THE CHALLENGE OF CLIMATE CHANGE

The relationship between tourism and climate has been studied for a long time, but it is very complex and remains difficult to define. The interest in the connection between tourism and climate change is quite new in the literature, but has been getting special attention in the last two decades, as the sector is simultaneously very vulnerable to climate change and is among the major sources of greenhouse gas (GHG) emissions. This duality refers on one side to the mitigation challenge and on the other side to vulnerability and adaptation issues.

The climate is a fundamental attribute of a tourism destination. It is a strong factor of motivation and satisfaction. However, the relationship between climate and tourism is very complex: the perception of what constitutes 'good weather' depends among others factors on the destination, the type of activity envisaged, and the tourist (age, health, etc.).

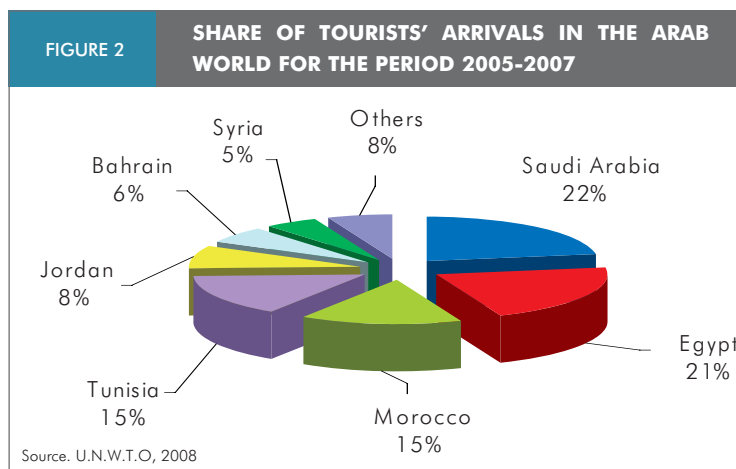
Several more or less successful initiatives aimed at modelling this relationship have been developed, one of which is the index of tourism comfort. It combines data on the average temperature, the maximum temperature, precipitation, sun and wind conditions, and humidity, to assign an index to a site, which reflects the degree of cli-



matic comfort that a tourist feels at a given site (Billé, 2007).

With reference to the evolution of the climate in the Arab region, several reports tend to highlight a trend of warming associated with a reduction in precipitation for most of the Arab countries. This trend is accompanied by intensification of extreme weather events such as droughts, storms, and heat waves (FAO, 2008). In Morocco, for example, it is expected that the arid part of the country will expand towards the north and northeast as was shown by the aridity index of De-Martou, computed on a set of stations all over the country for two different periods 1961-1985 and 1986-2005 (DMN, 2008) and a Statistical Downscaling Model of IPCC scenarios A2 and B2. Data showed increases of mean temperature, drought lengths, and the number of hot days, as well as a diminishing rate of rainfall (Driouech and Kasmi, 2008).

Moreover, according to the predictions of the IPCC (2007), the rate of climate change will 'most probably' accelerate with the continuation of GHG emissions at current or higher rates. Even using the most optimistic estimates, the annual volume of rainfall will decrease by 30% by the year 2050, the ocean average surface temperature will increase by 1.8°C to 4.0°C by the end of the 21<sup>st</sup> century, and the mean sea level will rise by approximately 3.1mm annually (IPCC, 2007).



The biological and physical reactions to this continuous warming of the oceanic temperatures, to water deficiency and to sea level rise can reflect on the index of climatic comfort (Ceron and Dubois, 2008).

Many Arab countries, including those belonging to the top 50 most visited countries in the world may witness the numbers of tourists diminishing and by consequence their tourism receipts decreasing, with Saudi Arabia being a likely exception as most of the tourists are pilgrims and are motivated by religious duty rather than touristic attractions.

Vereczi (2007) has shown the potential implications of climate change on Mediterranean desti-

**TABLE 1** INTERNATIONAL TOURISM RECEIPTS IN THE ARAB COUNTRIES

Country	International tourism receipts (billion U.S dollars)				
	1995	2000	2005	2006	2007
<b>Saudi Arabia</b>	-	-	5.4	4.961	5.228
<b>Egypt</b>	2.7	4.345	6.9	7.591	9.303
<b>Morocco</b>	1.3	2.039	4.6	5.967	7.264
<b>Lebanon</b>	-	-	5.5	5.000	-
<b>United Arab Emirates</b>	0.6	1.100	3.2	5.000	-
<b>Tunisia</b>	-	1.682	-	2.275	2.555
<b>Bahrain</b>	-	0.573	-	1.048	1.105
<b>Jordan</b>	-	0.723	-	2.060	2.312
<b>Sudan</b>	-	-	-	0.252	0.262
<b>Kuwait</b>	-	0.098	-	0.203	0.222

Source: U.N.W.T.O, 2008

TABLE 2 EFFECTS OF CLIMATE CHANGE ON MEDITERRANEAN DESTINATIONS

Climate change effects at the place of destination	Implications for the destination	Possible reactions of the market
<ul style="list-style-type: none"> <li>• Winters milder and wetter</li> <li>• Summers warmer and drier</li> <li>• Changes more pronounced in the Eastern Mediterranean</li> <li>• Increase of heat index</li> <li>• More days above 40°C</li> <li>• More arid landscapes</li> <li>• Impacts of sea level rise exacerbated by the low tides</li> </ul>	<ul style="list-style-type: none"> <li>• More severe risks of droughts and fires</li> <li>• Increasing water shortages</li> <li>• Increased personal exposure to heat</li> <li>• Beach degradation and loss of habitats due to sea level rise</li> <li>• More vulnerability to tropical diseases (e.g. malaria)</li> <li>• More flash flooding</li> <li>• Poor air quality in cities</li> </ul>	<ul style="list-style-type: none"> <li>• Improvement of summers in Northern Europe generates more domestic holidays</li> <li>• Less incentive to spend summer holidays in the Mediterranean</li> <li>• Increased incentive for spending holidays in the Mediterranean during the intermediate seasons</li> <li>• Increased incentive for southerners to travel to the North</li> </ul>

Source: Adapted from Vereczi, 2007

nations which involve a large portion of the Arab world. Table 2 gives some of the implications identified and how the market will react to adapt. There also exists a high sensitivity of coral reef ecosystems to climate change and for some areas in Egypt and Jordan, for example, this may have grave negative implications for these popular tourist attractions.

Figure 3 shows that there will likely be a decline of the index of tourism comfort in the Arab world in the coming decades. The areas currently classified as “good”, “very good” or even “excellent”, will be either “marginal” or “unfavourable” categories by the year 2080.

#### IV. VULNERABILITY OF THE TOURISM SECTOR TO THE EFFECTS OF CLIMATE CHANGE IN THE ARAB WORLD

The direct potential consequences of climate change will be increases in average temperatures of the sea and the air, of the sea level, of the frequency and intensity of heat waves, of droughts, and of extreme temperatures, and a decrease in precipitation. The indirect consequences will be coastal erosion, submersion of coastal zones, increased stress on ecosystems, salinity of the underground water table, droughts, soil erosion and landslides.

The vulnerability of the tourism sector to direct

and indirect climate change effects will be different from one part of the world to another, and will vary also with tourism practices. The climate determines the length and the quality of the tourism season and plays an important role in the choice of the destination and the expenditure of tourists (Scott, 2006).

In the Arab world, the direct impacts of climate variation on the tourism sector will be important (Becken, 2007), mainly because this region will be subject to an increase in the frequency of extreme weather events (e.g. droughts, heat waves) (IPCC, 2007), and the tourism sector is very sensitive to the variability and change of the climate.

The climate has effects on many environmental resources which constitute important assets for tourism development, such as biodiversity, landscape, level of water quality and quantity, snow conditions, etc. (Gossling and Hall, 2006). In many Arab countries, tourism is closely associated to these natural assets, some of which are severely impacted in various ways by climate variability and change. In coastal areas of northern Africa and the Middle East, there are also land and sea interactions that magnify dangerous heat conditions (Diffenbaugh et al., 2007). Summertime sea surface temperatures in the Mediterranean are expected to increase and make the region more suited to tropical cyclone development (Gaertner et al., 2007).

### **Water resources**

North Africa and the Middle East are almost universally recognized as the driest and least endowed with water resources regions of the world (Constantino, 2009). This situation consequently affects the economic and social development of the majority of the countries of this region. The average availability of water per capita approaches 7,000 m<sup>3</sup> annually per capita at the global level, whereas it is less than 1,000 m<sup>3</sup> annually per capita in this region (El Nagggar, 2007).

The expected potential evolution of the climate would have a significant impact on both the demand and supply sides of water.

The aggregated consumption of water for the tourism sector is not precisely known, but it is well recognized that the per capita consumption of water of a normal tourist is higher than that of a permanent resident. The tourism sector is one of the most demanding for water consumption, either for drinking and sanitation or for sustaining other services such as swimming pools, golf courses, and green spaces. This consumption varies according to the type of tourism activities and the level of comfort demanded.

The way in which this sector could be constrained and impacted by the regressive evolution of water resources and water scarcity could be felt at different levels of value chain. The pressure of tourism development on water resources can lead to conflicts of uses, mainly when diverting water from agriculture which ensures food security for local dwellers to an industrialized tourism activity, which is mostly profitable to tour operators and big companies.

The reduction of water flows and water stocks in lakes will lead to diminishing water quality by eutrophication and pollution. This situation will induce diminishing recreational value and will also lead to an increasing risk of water-borne diseases. With temperatures changing, new viruses or microbes will have a potential for development in the new environment, and this might affect the tourism flow and the economic importance of the sector.

Projections based on observations since the beginning of the 20th century in the northeast of

Morocco point out a further increase of water scarcity due to climatic and human pressures; sustainable long term development seems to be a challenge, in particular with regard to water availability and coastal tourism (Tekken et al., 2009).

### **Coastal zones and sea level rise**

The speed of sea level rise is neither uniform in the world, nor within the Arab world. Observations and future projections established on the basis of climatic models created by many researchers, including the IPCC (2007), indicate a potential increasing sea level in the Mediterranean by about 88 cm between the years 1990 and 2100.

Therefore, the Arab world countries located on the Mediterranean coast will be strongly threatened by sea level rise which could be accelerated by high tides and violent storms. Large coastal areas would disappear because of sea water immersion and coastal erosion (for example of the Nile delta and all low topography zones), and the salinity of coastal aquifers and rivers would increase (Fiona, 2004).

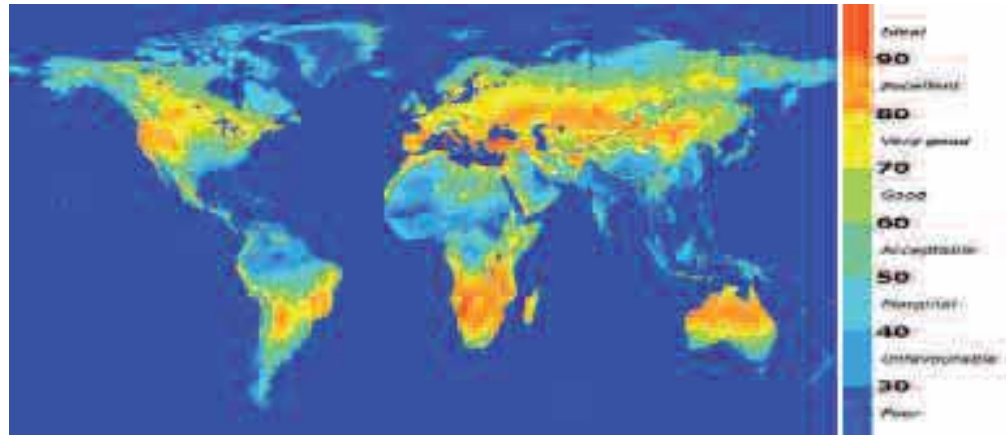
Letizia et al. (2008) have shown through a meteorological marine analysis of the Moroccan Mediterranean coast that the prevalent waves coming either from 270°N or 60°N can hit the coast at heights approaching 5m. The most threatened zones in the area include coastal wetlands, sandy beaches, a river mouth, basic infrastructure, harbours, a leisure port, habitations and one important seashore tourism resort comprising more than 27,000 beds.

The vulnerability of the Arab world's tourism sector is obviously related to that of the beaches and the infrastructure which constitute the basis of most presently promoted tourism in the area, mainly for the North African countries.

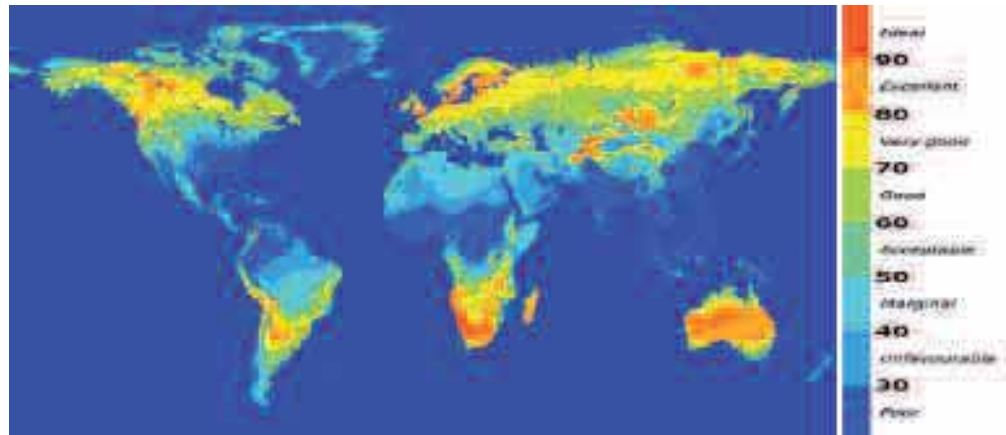
Analysis of shoreline evolution on the Eastern Mediterranean coast of Morocco, using aerial photos, has shown that in two pilot sites, the beaches were subject during the last two decades to continuous erosion at an average rate of 0.5 m/year (Amini et al., 2008). Each of the two sites contains a wetland of international importance. These ecosystems are vulnerable either to beach

FIGURES 3(a,b)

## THE EVOLUTION OF THE INDEX OF TOURISM COMFORT IN THE WORLD



a) Index of tourism comfort - Summer 2008



b) Index of tourism comfort - Summer 2080

Source: Ceron and Dubois, 2008

erosion or to sea level rise (Amini, 2008; Bellaghmouch, 2008). Boubekraoui (2008) and Ezzaher (2008) have evaluated the cost of the potential loss by immersion by sea level rise using the IPCC A2 scenario and have shown that most of the existing infrastructure and human settlements including the biggest newly built tourism resort in Morocco are at risk.

### **Biodiversity, desertification and ecotourism**

The landscape as well as environmental assets and amenities are essential for the sustainable development of the tourism sector. However, climate change could have an immense effect on the region's natural ecosystems and might worsen their state as a result of changes in tempera-

ture and precipitation which are expected to affect considerably the growth, strength, function and survival of these ecosystems (Laouina, 2008).

Moreover, vulnerability of the semi-arid and arid environments of the Arab world to the change induced either by climate or by land allocation, is expected to be critical and will be accompanied by an increase of the hydraulic stress and ecosystems degradation leading to desertification (Coelho et al., 2000). According to the 2008 AFED annual report, Arab Environment: Future Challenges, the cost of environmental degradation, including effect of climate change, in the Arab world will be around 5% of its GDP (AFED, 2008).

The Metap program (2006) of the World Bank



has estimated the cost of environmental degradation in coastal zones of four Arab countries, Algeria, Egypt, Morocco and Tunisia. In making the calculations, the local GDP per person at the local level was considered equivalent to the national average. This study concluded that the total annual cost related to environmental damage of a coastal zone in Egypt (Alexandria bay) is around \$232-355 million, which is 5.0 to 7.5% of the total GDP of the study area; in Morocco, it was estimated to be \$14-18 million, which is 3.7-4.7% of GDP in the region where the study was conducted (Lagoon of Nador area); in Algeria it was found to be \$22-53 million, which amounts to 3 to 7% of the GDP of the Algiers bay; and in Tunisia it was assessed to be \$38-72 million, or 1.3-2.3% of the GDP of the Soussa region. Some of these costs were attributed to a loss in tourism activity resulting from environmental degradation.

Some plant flora and fauna species of the Arab world may not be able to adapt to the accelerating rate of climate change which is exacerbated by the changes induced in ecosystems by the over-harvesting of natural resources or by various types of pollution. Some species might respond by migrating either in latitude or in altitude, but some might be condemned to extinction.

It is known that a change of the average temperature by only one degree will imply a radical disturbance of natural ecosystems. This will be due not only to the direct effect of temperature increase but also to the hydrous stress and other phenomena which may result from this temperature variation such as forest fires and intensive evapotranspiration (IPCC, 2007). The integrity of all types of biodiversity (genes, species, ecosystems and landscapes) will be impacted significantly, potentially even leading to chaotic situations. The ecotourism and in fact any tourism based on the natural environment in the Arab world will therefore be affected by climate changes.

### ***Tourism and local products***

A number of tourism activities in Arab countries are dependent on local products derived from the exploitation of natural resources. Climate change can, beyond a certain threshold, lead to the rarefaction of these resources, and might lead to

changes of local and indigenous practices for the production of local goods.

## **V. ADAPTATION TO CLIMATE CHANGE**

To date, there are only a few exploratory studies related to the relationship between tourism in the Arab world and the potential impacts of climate change. Research initiatives remain limited and it is necessary to better prepare this economic sector to face the challenges of climate change. There is the need to address many essential points which encompass a deep knowledge of tourism requirements and needs for climate and environment, and weather conditions; how different tourism products and services are sensitive and vulnerable to climate change; and a mapping of potential risks and threats with respect to climate change scenarios in different regions of the Arab world. This last point includes downscaling of IPCC scenarios, vulnerability assessment and adaptation options.

## **VI. CONCLUSION**

The Arab world's tourism sector is closely related to the landscape, environmental and cultural characteristics of the area and is by its nature strongly sensitive to the variability and change of the climate, either directly or indirectly. Destinations and preferences might be influenced by potential modifications from the normal conditions (hotter summers and winters, droughts, dryness and droughts, extreme weather events, scarcity of water, ecosystems degradation, etc.). The potential disturbances of tourism flows and destinations will result in large economic losses, primarily for countries whose economies are tourism-based. It must be noted that the exact trajectory of the changes and impacts is related to large uncertainties about tourists' behaviour. Serious efforts should be expended in order to identify other sustainable means of tourism which might be less sensitive to climate change and its effects such as cultural tourism. The capacities for adaptation of tourism destinations and actors will be highly variable (Ceron and Dubois, 2008) from one area to another and integrated and inclusive planning is a must for enhancing the chances of success for any course future tourism development might follow.

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# International Negotiations for a Post-Kyoto Regime

MOHAMED EL-ASHRY



## I. INTRODUCTION

Addressing climate change is one of humanity's most pressing environmental challenges, requiring urgent and concerted action. It is a complex, long-term problem, more than 200 years in the making. It is ubiquitous - there are few human activities that do not directly or indirectly contribute to it or are not affected by its impacts. Emissions anywhere cause warming everywhere; mitigation action anywhere helps everywhere also. Postponing mitigation action increases both damage costs and the costs of action that will have to be taken. While piecemeal efforts help, the scale of response required for an ultimate solution is so large that widespread collective action is essential.

This chapter is written with the target of giving the Arab negotiators as clear as possible a picture of what is happening and is likely to happen in the global negotiations of the post-Kyoto agreement, to help them take, if possible, unified positions at the Copenhagen negotiations.

## II. HISTORICAL BACKGROUND

We owe the discovery that greenhouse gases block infrared radiation to the Irish-British scientist John Tyndall. In 1859, he was the first to suggest that changes in their atmospheric concentrations could lead to changes in climate. The remarkably original Swedish scientist Svante Arrhenius, who won the Nobel Prize for Chemistry in 1903, was the first to publish (in 1896) estimates of how much increasing levels of atmospheric carbon dioxide would warm the atmosphere. He also developed a theory to explain earth's ice ages and other climatic changes.

For the next 60 years or so, the significance of Arrhenius's calculations remained by and large unrecognized. Painstaking scientific work for three decades and several scientific assessments led to the October 1985 International Conference on the Assessment of the Role of Carbon Dioxide and Other Greenhouse Gases in Climatic Variations and Associated Impacts, organized by the International Council of Scientific Unions, the World Meteorological Organization (WMO), and the United Nations

Environment Programme (UNEP) at Villach, Austria. This conference reiterated the consensus amongst scientists about the inevitability of global warming. The discovery that other trace gases add to the warming caused by carbon dioxide meant that significant changes could be expected within a lifetime rather than in some distant future. Abandoning their characteristic caution, scientists from 29 countries at this conference concluded that "human releases of greenhouse gases could lead in the first half of the 21<sup>st</sup> century to a rise of global temperature ... greater than any in man's history". They also urged 'active collaboration between scientists and policymakers to explore the effectiveness of alternative policies and adjustments.'

WMO and UNEP decided in 1988 to establish the Intergovernmental Panel on Climate Change (IPCC), as a joint program to provide policy-relevant but not policy-prescriptive advice. The IPCC published its first report two years later in 1990, establishing that emissions of greenhouse gases resulting from human activities were substantially increasing their atmospheric concentrations and that under a business-as-usual scenario, the 21<sup>st</sup> century would witness an increase in global mean temperature greater than any seen in the past 10,000 years. This Assessment strongly supported the recommendation of the 1988 International Climate Conference to the UN General Assembly to negotiate a convention to deal globally with the problem of climate change. The UN negotiating committee was established by the General Assembly in December 1990. This committee negotiated the UN Framework Convention on Climate Change (UNFCCC). More than 140 countries with differing interests participated in 16 months of difficult negotiations. It was signed by 154 heads of states, governments and delegations at the Earth Summit in Rio in 1992, including the United States, and entered into force in 1994. To date, 189 countries have ratified the Convention.

The framework convention does not mandate specific reductions in greenhouse gases-it only obliges the industrialized countries to 'adopt national policies and take corresponding measures' with the 'aim of returning' emissions by 2000 to their 1990 levels. In the negotiations leading to the convention, developing countries argued, and rightly so, that the primary responsi-



bility for action on climate change falls on the shoulders of the industrialized countries, which with only 20% of the world's population, have contributed about 75% of total CO<sub>2</sub> emissions.

As we now know, very few countries adopted the necessary policies and measures called for by the convention and greenhouse gas emissions continue to increase. Because energy consumption is so vital to industrialized countries, the barriers, both economic and political, to adopting the necessary policies and measures have been very high.

With implementation of voluntary measures faltering, the first Conference of the Parties to the Convention in Berlin agreed to negotiate a Protocol to define more precisely the emissions reduction commitments of developed countries. It took two years to negotiate the Kyoto Protocol (1995-97) and another 8 years for it to come into force, when countries representing 55% of the developed country emissions had ratified. The US declared its intention not to ratify the Protocol in 2001. The Kyoto Protocol set an initial target and a time table for reducing emissions by industrialized countries. Industrialized countries were to reduce greenhouse gas emissions by 5.2% below 1990 levels during the first commitment period of 2008-2012. For the U.S. it was a commitment of 7%.

While the Kyoto Protocol was intended as a first step in implementing the climate change convention, it would not have materially altered the long-term atmospheric concentrations of greenhouse gases. And for the U.S., emissions in 1997 were already 12% above 1990 levels. Accordingly, the reductions by the U.S. would have amounted to almost 20%.

As was expected, the chances of the U.S. ratifying the Kyoto Protocol became zero. What was not expected, however, was the Bush Administration's outright rejection of the Kyoto Protocol and the global concern over climate change. Rejecting Kyoto's provisions as they apply to the U.S. and proposing viable alternatives is one thing, taking several steps backward and arguing that we do not know enough to take action is another. The Administration's position was taken in spite of the IPCC's 2001 assessment report, which concluded that: 'there is new and stronger evidence that most of the warming

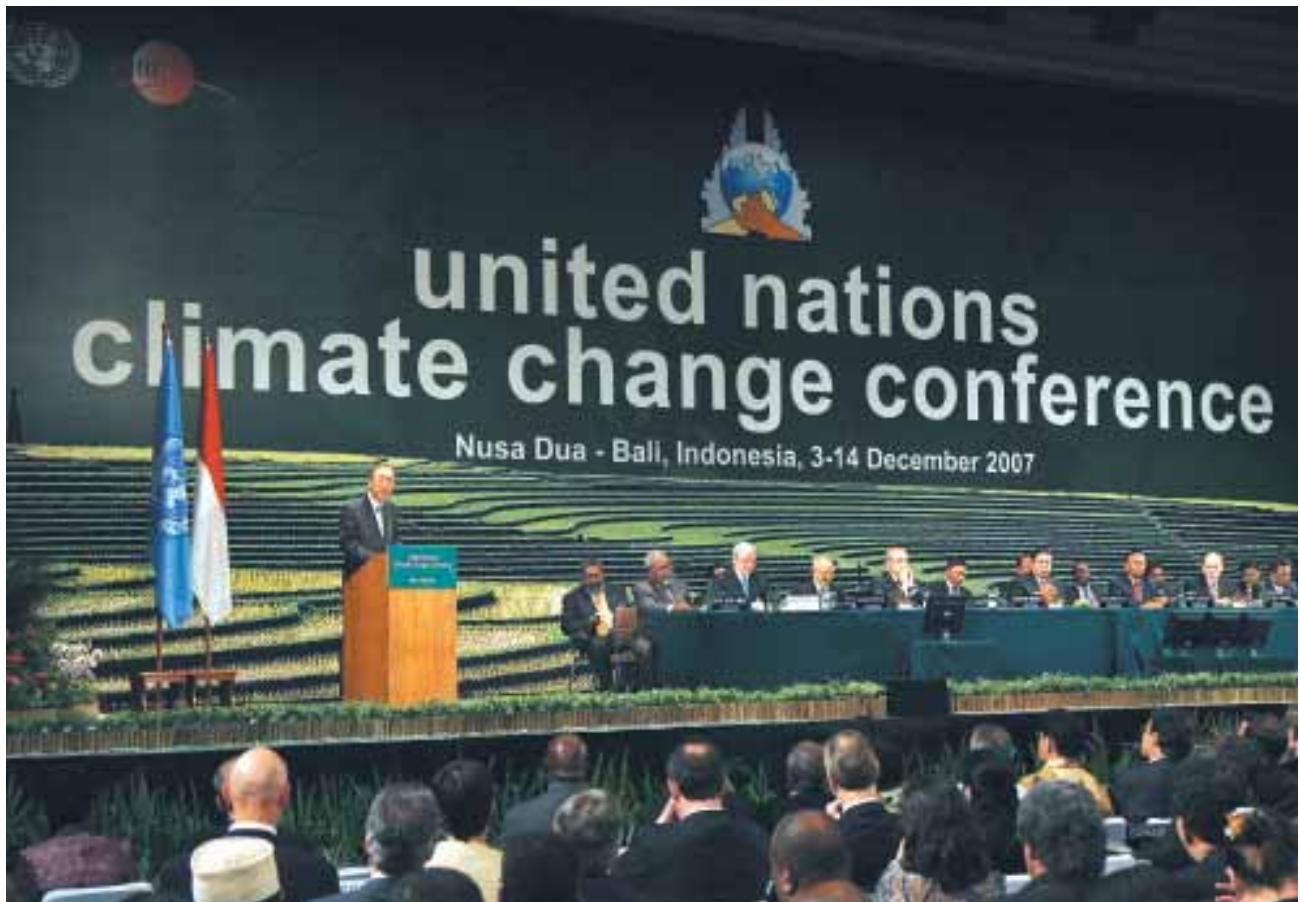
observed over the last 50 years is attributable to human activities,' and the US National Academy of Sciences report in the same year saying that "Greenhouse gases are accumulating in the Earth's atmosphere as a result of human activities, causing surface temperatures to rise. There is general agreement that the observed warming is real and particularly strong within the past 20 years".

### III. POLICY-MAKING AND UNCERTAINTY

Much complexity and uncertainty surround climate change. Despite significant gains in the scientific understanding of climate change, uncertainties remain. Climate models are not usually designed to tell us anything about the evolution of the climate system in the short-term; rather, they are designed to simulate long-term (20-30 years) behaviour as accurately as possible. Also, while climate models can make reliable projections about change in global climate, their projections about change in regional climate are less reliable.

The key question, however, is no longer whether climate change is already happening and should be a central global concern. The key question is how climate change will manifest itself regionally and locally and what can be done about it. As governments prepare to meet the challenge of climate change they need to address the tradeoffs between near-term economic development and long-term sustainable development. They also need to devise effective strategies for dealing with climate change in the absence of full knowledge of regional impacts and the unsettling prospect of reaching irreversibility or tipping points of no return. The uncertainty associated with climate change projections is often cited as the reason for people's failure to accept the need to adapt to climate change. In the face of urgent short-term priorities such as hunger, poverty and disease, poor countries and communities find it particularly challenging to focus on adaptation measures when the predictions of impacts from climate change are not unequivocal. Uncertainty should not, however, be an excuse for inaction.

Decisions are regularly made in the face of uncertainty (e.g., investment decisions). Water-



resource managers are accustomed to planning and operating water facilities under conditions of uncertainty about future availability, weather variability, and projected water demand. In the face of documented evidence of long-term global climate change, water-resource managers have begun revising their long-term planning. Deciding on the need for, and type of, adaptation to climate change should be approached in a similar manner, and can involve using appropriate risk management approaches.

To respond to the climate change issue, governments at various levels must make a range of decisions about the appropriate level and design of mitigation and adaptation, and the funding level of research across many related disciplines. In a political world where decisions are often short-term and where leaders cherish a clear roadmap for action, the 'uncertain certainty' of climate change has hampered the translation of scientific findings into policy actions. In some countries, like the United

States under the Bush presidency, uncertainty regarding climate change was used as a basis for postponing action, which is usually identified as being 'costly'. But this idea is almost unique to climate change. In other areas of public policy such as terrorism, inflation, or vaccination, an 'insurance' principle seems to prevail. In other words, if there is sufficient likelihood of significant damage, we take some measured anticipatory action.

#### **IV. THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE**

The United Nations Framework Convention on Climate Change (UNFCCC) is the only umbrella treaty negotiated amongst countries to respond to the threat of global climate change. It took 16 months to negotiate (1990-1992), and two years to ratify (1994). About 140 countries participated in the negotiations that led to the treaty, and 189 countries have ratified it.

### **Objective**

The ultimate objective of the Convention (Article 2) is the ‘stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.’ The Convention did not define or quantify what is meant by dangerous, nor did it specify a time period for action, except to say that the level should be achieved within a time frame sufficient:

1. to allow ecosystems to adapt naturally to climate change;
2. to ensure that food production is not threatened; and
3. to enable economic development to proceed in a sustainable manner.

### **Principles**

Several principles were negotiated and enshrined in Article 3 of the Convention. We list them here in the order they appear in the Convention.

**Equity, Responsibility and Capability (Article 3.1):** Countries are to ‘protect the climate system . . . on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities.’ A strict application based on responsibility and capability would require a few countries to take most of the action. This principle led to a commitment by developed countries on providing financial resources.

**Cost-effectiveness (Article 3.3):** ‘Policies and measures to deal with climate change should be cost-effective, so as to ensure global benefits at the lowest possible cost.’ This principle led to the so-called flexibility mechanisms under the Kyoto Protocol (see below).

**Comprehensiveness (Article 3.3):** ‘Policies and measures should . . . be comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation, and comprise all economic sectors.’ Avoided deforestation and afforestation should be part of any solution.

**Commitments:** Based on the above principles, several commitments were negotiated and agreed upon. The following merit special attention:

**Emission Targets (Articles 4.2(a) and 4.2(b)):** Developed countries are to adopt policies and measures ‘with the aim of returning . . . to their 1990 emissions levels these anthropogenic emissions of carbon dioxide and other greenhouse gases’. These articles did not specify a time frame over which this return was to be accomplished and were superseded by the Kyoto Protocol. However, for those countries that did not ratify the Protocol but have ratified the Convention, this commitment still stands.

**Technology Assistance:** In Article 4.1(c), all countries agreed to ‘promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce, or prevent anthropogenic emissions of GHGs’. This provision was very important to developing countries during the negotiations. It is reiterated in at least 8 different articles of the Convention and in three different articles of the Kyoto Protocol.

**Financial Resources:** In Article 4.3, developed countries agreed to ‘provide the new and additional financial resources . . . needed by developing countries to meet the agreed full incremental costs of measures covered under Article 4.1’. Since ratification, however, these funding flows have been a tiny fraction of the amount needed to ‘green’ the energy sectors of developing countries.

## **V. THE KYOTO PROTOCOL**

The Kyoto Protocol took two years to negotiate (1996-97) and eight years to ratify (2005). Its purpose was to define more precisely the emissions reduction commitments of developed countries because those in the Convention were thought to be ‘vague.’ It has been ratified by 171 countries. The United States is the principal exception.

Article 3.1 of the Kyoto Protocol required developed countries to reduce their collective emissions of greenhouse gases by at least 5% below their 1990 levels between 2008 and 2012. However, this provision applies only to 35 ratifying countries and the European Union, representing less than two-thirds of the developed country emissions. Thus, successful implemen-

tation of the Protocol will reduce developed country emissions by only 3%, and global emissions by less than 2%.

To reduce the burden of compliance on developed countries, the Kyoto Protocol created three different 'flexibility mechanisms': a project-based mechanism within developed ('Annex 1') countries, also known as Joint Implementation (JI); a project-based mechanism involving developing countries - the Clean Development Mechanism (CDM); and international emissions trading amongst Annex I countries. The European Union started an Emissions Trading Scheme even before the Protocol was ratified to gain experience with carbon trading.

## VI. MARKET-BASED MECHANISMS

Market-based mechanisms are generally favoured by economists and welcomed by industry, as they tend to reduce the costs to industry (or countries) of complying with targets. However, effective trading approaches require an overall cap on emissions. Analysts are discovering that the administrative difficulties of implementation and enforcement of cap-and-trade systems amongst countries are not trivial. There have been published accounts of the weaknesses in the carbon offsets market with buyers paying either for reductions that do not take place or for reductions that would have taken place anyway. Partly for these reasons, some economists prefer the levying of taxes on activities that lead to the emissions of greenhouse gases.

Carbon taxes are easier to implement than cap-and-trade schemes, economically efficient, but politically difficult to legislate in some democratic regimes. A carbon tax would reduce carbon emissions and increase revenues. Substantial benefits could be gained from carbon taxes in all countries based on the 'common but differentiated' principle. In addition to emissions reductions, they would generate resources for the development of clean energy sources as well as for the cost of adaptation in poor developing countries.

The CDM was created to support low-carbon investment in developing countries. It allows both the private sector and governments to invest

in projects that reduce emissions (as compared to emissions that would occur in a baseline scenario) in developing countries, and provides one way to support links between different regional emissions trading schemes. However, it has encountered administrative and technical hurdles, and its future is clouded because of the uncertainty about the post-2012 regime. Initial CDM projects have been limited to a few countries, and a few gases, and have been plagued by bureaucratic procedures, with little contribution to sustainable development.

With its limited targets, timeframe, and participation, the Kyoto Protocol was never seen as a final solution to the climate problem. It was meant to be a first step, preparing for the broader engagement that will be necessary and establishing the legal, technical and institutional groundwork for future regimes, especially in international emissions trading.

Time and experience, however, have also revealed the limitations in the agreement - coverage of some but not all of the developed world's emissions, and inadequate provisions for monitoring and enforcement.

## VII. LAGGING NEGOTIATIONS

Because the Kyoto Protocol covered only the period from 2008 to 2012, it specified that negotiations for a second "commitment period" should begin seven years in advance - i.e., in 2005. However, the progress to date has been minimal. For example, the discussions at the Second Ministerial Meeting of the Gleneagles Dialogue on Climate Change in Monterrey, Mexico, in October 2006 pointed to the urgency of early action but failed to decide on a process for reaching a new agreement. Likewise, at the November 2006 Conference of the Parties to the UNFCCC in Nairobi, governments were unable to agree on a timetable for negotiating a post-2012 future despite widespread consensus on the diagnosis of the problem. This lack of progress increases the risk of failure in reaching an agreement to govern the post-2012 period. Those who have witnessed the glacial pace of these negotiations (and the North-South divide that appears to be widening) have identified several factors that may be contributing to this impasse.



### **Possible Reasons for the Impasse**

1. Democratically elected governments are held accountable for declines in economic performance (which might be caused by actions taken to mitigate climate change) but not for adverse impacts caused by even catastrophic climate-related events, which can always be blamed on natural variability. The classic asymmetry of future benefits vs. present costs poses difficulties for public officials.
2. In what are perceived to be zero-sum games, there is a tendency amongst all negotiators for brinkmanship-to wait until the last possible moment to come to an agreement, with the expectation of striking the best possible deal for one's side.
3. Any appreciable dent in the problem will require a significant (although manageable) amount of additional resources in the near-term (-1% of gross world product), some of which will necessarily flow from the North to the Global South.
4. There is a perception in northern countries that the countries of the Global South have changed from being appropriate aid 'recipients' to near-term competitors. There is political resistance to large North-South or West-East subsidies or resource transfers.
5. There is a perception in southern countries that there have not been good-faith efforts on the part of the Global North to deliver on principles and financial commitments that were negotiated and agreed upon previously.
6. Not all impacts of climate change will be negative, at least initially. There will be many losers but also some who might benefit. These countries are unenthusiastic about measures to mitigate climate change.

## **VIII. CRITICAL ISSUES**

### **Fairness - Differentiated targets and timetables**

The principle stated in Article 3.1 of the Framework Convention, concerning 'common

but differentiated responsibilities and respective capabilities,' requires that these must be based on equity. Article 3.1 also asserts that 'developed countries should take the lead in combating climate change.'

It is clear that any climate change agreement will be acceptable and sustainable only if it is perceived by all participating countries to be equitable or fair. The challenge has been that there is no broad agreement on the definition of equity or its dimensions. Some argue that it is unfair to require emissions reductions in some countries but not others. However, most observers say that requiring all countries to achieve the same percentage reduction in emissions in the same time frame would be grossly unfair. These observers add that those who have contributed to the buildup of greenhouse gases in the past 100 years should either have less entitlement going forward or should compensate the rest of the global community in some way.

'There is no single formula that captures all dimensions of equity, but calculations based on income, historic responsibility, and per capita emissions all point to rich countries taking responsibility for emissions reductions of 60-80% from 1990 levels by 2050' (Stern Review). It is feared by some, however, that limiting greenhouse gas emissions in developed countries may simply shift economic development and emissions growth to developing countries.

The concept of 'differentiation' continues to be an important one. For example, when the EU apportioned emission rights amongst its member states under its Kyoto obligation, the poorest countries, Greece and Portugal, were allowed increases of 25% and 27% respectively, much larger than others'. However, avoidance of 'dangerous anthropogenic interference with the climate system' cannot be achieved by developed countries alone. Limiting atmospheric concentration to 500-550 ppm (i.e., projected temperature rises of 2.5-3°C) will require a 60% reduction in global emissions by 2050, but compared to 1990 levels. Even an 80% reduction of greenhouse gas emissions in all OECD countries by 2050 would not achieve this goal without emission reductions by today's developing countries. To date, the most ambitious declared targets have been by the EU: reducing GHG emissions by 20% by 2020 over 1990 levels.

The EU would agree to a 30% target should other developed countries commit themselves to comparable emission reductions and more advanced developing countries adequately contribute in accordance with their responsibilities and respective capabilities.

All countries have a legitimate right to economic development, but that need not conflict with strategies to reduce emissions. Developing countries could vigorously promote measures to increase energy efficiency or decrease the carbon intensity of production (GHG releases per unit of GDP) and adopt renewable energy wherever it is the least-cost alternative. Carbon intensity of non-OECD countries has already been declining in the past 20 years at an average annual rate of ~1.42% per year (as compared to a world average of 1.25% and an OECD average of 1.1%), partly because services make up an increasing fraction of their economies. Despite carbon intensity declines, with economies growing at much faster rates, total emissions from developing countries will keep increasing. Increasing the rates of carbon intensity declines beyond recent historical rates would moderate this growth in emissions while enabling developing countries to continue to pursue their sustainable development objectives.

### **Adaptation**

While the developed world is largely responsible for the accumulation of greenhouse gases in the atmosphere, and some rapidly growing developing countries are adding to the burden, developing countries in general are the most vulnerable to climate change and least able to bear the consequences. Early climate efforts largely focused on mitigation; the next phase must also address adaptation. The most recent IPCC Report pointed out that vulnerability to climate change can be exacerbated by the presence of other stresses that are frequently present in developing countries.

Because the costs incurred for adaptation were thought to provide largely local benefits, were suspected to be large, were difficult to distinguish from 'regular' development, and smacked of compensation awarded for damages, industrialized countries have been reluctant to agree to substantial amount of funds (through the Global Environment Facility

(GEF), for example) for adaptation. But since any conceivable level at which GHG gases can be stabilized will be greater than the pre-industrial level, some amount of climate change is inevitable, which will impede development efforts, frustrate poverty alleviation programs, and exacerbate migrations from water-logged, water-scarce or food-scarce regions. It is that link to development and the Millennium Development Goals that prompts some observers to call for a significant role for development assistance (ODA) in financing adaptation measures (see below).

### **Technology Transfer**

There is an urgent need for developing countries that are growing at a rapid rate like India and China to do so in a climate-friendly manner. The infrastructure created in coal-fired power plants and energy-intensive industries has a long life (on the order of 40-50 years). However, the costs of more efficient and cleaner technologies are much higher (as much as \$100 million or more for an average 1 GW coal-fired power plant). In addition, issues of competitiveness and intellectual property rights have impeded the consideration of concessional terms for the transfer of clean technologies to developing countries, and the full utilization of knowledge. Yet it is important to all countries that clean energy technologies are made as widely available as possible (like generic medicines for HIV-AIDS, for example). It may also be beneficial to conduct research and demonstrate technology such as solar thermal and coal gasification in the South. A global research and development fund could either pay for patents or for licensing fees to enable cleaner technologies to be deployed in the South.

### **Finance**

The costs of adequately addressing the risk of climate change, according to the Stern Review, are of the order of 1% of gross world product (around \$620 billion). Some of that investment will be additional, and some will come from redirecting existing flows. Some funds will be required for increased assistance to developing countries for the adoption of energy efficiency and clean energy technologies, including bio-energy. Funds will be required, both in devel-

oped and in developing countries, for greening energy sectors, for adaptation, increased R&D and deployment of technologies.

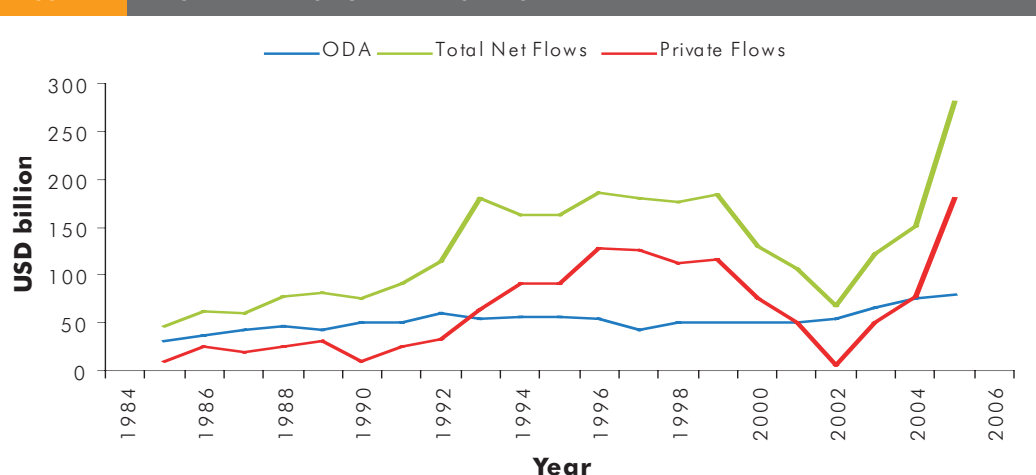
### Net North-South Flows

The net public and private resource flows from all developed countries to developing countries (including loans) amounted to about US\$ 280 billion in 2005, increasing from about \$150 billion in 2004 (see Figure 1 below). The increase came mainly because of an increase in private flows, which besides being fickle are concentrated in just a few countries. Official Development Assistance (ODA) amounted to just 0.25% of gross national income in 2005 (see Figure 2 below).

### Energy-Related North-South Flows

Most of the resources for energy development (~60%) are raised locally within developing countries. Energy-related flows (see Table 1 below) have averaged about \$7 billion a year between 1997 and 2005. This amount contrasts with a need of ~\$300 billion a year in developing and transition economies, as estimated by the IEA. According to the World Bank, this sum of \$300 billion would need to be augmented by \$34 billion a year to support 'green' energy development. The Stern Review similarly estimates the incremental amount at ~\$20-30 billion per year. Some of these funds could also finance the transfer of technology.

FIGURE 1 TOTAL NET FLOWS BY TYPE OF FLOW



Source: Prepared from DAC data, OECD website

FIGURE 2 ODA AS PERCENT OF GROSS NATIONAL INCOME



Source: Prepared from DAC data, OECD website

### IX. ALTERNATIVE PATHS- COMPREHENSIVE AGREEMENT OR PIECEMEAL SOLUTIONS?

It is possible that new leadership emerging in several countries in the next two years will end the global impasse. However, there is considerable dissatisfaction with the existing format of negotiations. As a result, those who despair at the prospect of getting an agreement amongst 190 countries have been both exploring alternative forums to discuss substantive issues, and proposing less comprehensive agreements amongst a limited set of players to begin reducing emissions immediately.

One such forum is the Gleneagles Dialogue on Climate Change, Clean Energy and Sustainable Development, launched at the G8 summit in July 2005 as an instrument whereby innovative ideas and measures to tackle these issues could be discussed informally among G8 and key developing countries outside the formal structure of the UNFCCC. The Dialogue involves 19 countries - the G8 plus Australia, Brazil, China, India, Indonesia, Mexico, Nigeria, Poland, Spain, South Africa, and South Korea, plus the European Commission. By 2012 these countries will represent between 75-80% of all global emissions.

Many different proposals have been made for partial or early solutions that would not require a

comprehensive, overarching agreement. These proposals can broadly be characterized as:

1. Country-based
2. Sector-based
3. Policy-based and
4. Measures-based

The following table gives a few examples of the narrower 'systems boundaries' being considered in these proposals.

Such proposals can involve multiple categories. For example, the Asia-Pacific Partnership on Clean Development and Climate includes six countries of the Asia-Pacific region (Australia, China, India, Japan, South Korea and the US) and the following sectors: power generation and transmission, steel, aluminium, cement, coal mining, buildings and appliances. It also includes an agreement to work toward promoting renewable energy. Thus, it combines elements of country-based, sector-based, and measures-based strategies.

Country-based approaches offer a simpler negotiating process and the potential to address a large share of the world's emissions - but they risk the creation of a two-tier world, dividing the world into those who have a seat at the table from those who do not; and breeding resentment and hostility.





Sector-based approaches can avoid competitiveness concerns by negotiating emissions targets for particular industries, including those located in developing countries - but like the other approaches offer only a partial solution.

Emissions-based approaches offer countries the flexibility to design emission reduction strategies that are most appropriate to their national circumstances. Smaller agreements offer the potential of early action-not waiting until 2012 for effective responses to begin, but starting on whatever is feasible now. If successful, these partial agreements could also be included at a later date under an umbrella of a climate change agreement.

## X. BALI ROAD MAP

In Bali, Indonesia, in December 2007, the Conference of the Parties to the Convention on Climate Change (COP 13) concluded with agreement on the 'Bali Action Plan.' The plan creates a process and a set of principles, with few specifics, for negotiating a post-2012 agreement. It calls for a long-term goal for global emissions reductions and various mitigation actions for developed and developing countries. Besides mitigation, it also includes adaptation, deforestation, technology development and transfer, and finance.

### **Mitigation**

In the Bali Action Plan, the Conference of the Parties (COP) recognized that 'deep cuts in global emissions will be required to achieve the ultimate objective of the Convention' and emphasized the urgency of action, 'as indicated in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.' The COP did not move forward on targets and timetables for emission reductions, but decided to seek agreement by 2009 on 'a shared vision for long-term cooperative action, including a long-term goal for emission reductions' to prevent dangerous anthropogenic interference with the climate system.

Decision 1(b)(i) calls on all developed countries to consider:

Measurable, reportable and verifiable nationally

TABLE 1 PROPOSALS FOR PARTIAL SOLUTIONS

Approaches	Examples
<b>Country-based</b>	Agreements between the top-emitting countries in the world, or alternatively, smaller geographic groups
<b>Sector-based</b>	Agreements on emissions reductions in specific categories – e.g., power, transportation, aluminium, steel, cement, appliances, buildings, forestry
<b>Policy-based</b>	Agreements to impose harmonized carbon taxes or reduce emissions intensity
<b>Measures-based</b>	Agreements on specific emissions reductions strategies – e.g., energy efficiency, renewable energy, development finance, land use regulation

appropriate mitigation commitments or actions, including quantified emission limitation and reduction objectives, while ensuring the comparability of efforts among them, taking into account differences in their national circumstances.

For developing countries, Decision 1(b)(ii) calls for the consideration of:

Nationally appropriate mitigation actions in the context of sustainable development, supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable manner.

Unlike for developed countries, there is no mention of quantified emission limitation or reduction objectives for developing countries.

### **Adaptation**

Decision 1(c) of the Bali Action Plan calls for enhanced action on adaptation, including consideration of:

- (i) International cooperation to support implementation of adaptation actions including through vulnerability assessments, prioritization of action, financial needs assessment, capacity-building and response strategies, integration of adaptation actions into sectoral and national planning, specific projects and programmes, means to incentivize the implementation of adaptation actions, and other ways to enable climate-resilient development and reduce vulnerability of all PartiesÖ;



- (ii) Risk management and risk reduction strategies, including risk sharing and transfer mechanisms such as insurance;
- (iii) Disaster reduction strategies and means to address loss and damage associated with climate change impacts in developing countries that are particularly vulnerable to the adverse effects of climate change;
- (iv) Economic diversification to build resilience.

Four of the six articles of Decision 1(e) of the Bali Action Plan called for enhanced action on investment in adaptation, including consideration of:

- (ii) Positive incentives for developing countries for the enhanced implementation of national mitigation strategies and adaptation action;
- (iii) Innovative means of funding to assist developing countries that are particularly vulnerable to the adverse impacts of climate change in meeting the cost of adaptation;
- (iv) Means to incentivize the implementation of adaptation actions on the basis of sustainable development policies;
- (vi) Financial and technical support for capaci-

ty-building in the assessment of the costs of adaptation in developing countries, in particular the most vulnerable ones, to aid in determining their financial needs.

In addition, the Conference of the Parties (COP) established an Adaptation Fund to finance projects and programs in developing countries. The Fund will complement other United Nations Framework Convention on Climate Change (UNFCCC) funds managed by the Global Environment Facility (GEF), as well as the Strategic Priority on Adaptation mechanism, which is part of the GEF Trust Fund.

The Adaptation Fund will be financed with a 2 percent share of the proceeds from the sale of certified emissions reductions under the Clean Development Mechanism (CDM), a formula that is expected to yield between US\$80 and US\$300 million per year until 2012. The Adaptation Fund will be supported by a secretariat (the GEF) and a trustee (the World Bank). The Fund will be supervised and managed by a 16-member Adaptation Fund Board whose members will be balanced regionally and between developed and developing countries.

### **Technology Development and Cooperation**

In a last-minute decision, some developing-country negotiators at the Bali Conference of the Parties proposed wording in the Bali Action Plan that links mitigation action by developing countries to 'measurable, reportable and verifiable' support by developed countries for technology, finance, and capacity-building.

Decision 1(d) of the Bali Action Plan calls for enhanced action on technology development and transfer to support action on mitigation and adaptation, including consideration of:

- (i) Effective mechanisms and enhanced means for the removal of obstacles to, and provision of financial and other incentives for, scaling up of the development and transfer of technology to developing countries in order to promote access to environmentally sound technologies;
- (ii) Ways to accelerate deployment, diffusion

and transfer of affordable environmentally sound technologies;

- (iii) Cooperation on research and development of current, new and innovative technology, including win-win solutions;
- (iv) The effectiveness of mechanisms and tools for technology cooperation in specific sectors.

### **Finance**

Decision 1(e) of the Bali Action Plan calls for 'enhanced action on the provision of financial resources and investment to support action on mitigation and adaptation and technology cooperation' including consideration of the following for developing countries:

- (i) Improved access to adequate, predictable and sustainable financial resources and technical support;
- (ii) Positive incentives for enhanced implementation of national mitigation strategies and adaptation action;
- (iii) Innovative means of funding to assist particularly vulnerable countries meet the costs of adaptation to the adverse impacts of climate change;
- (iv) Means to incentivize the implementation of adaptation actions on the basis of sustainable development policies;
- (v) Mobilization of public- and private-sector funding and investment, including facilitation of carbon-friendly investment choices;
- (VI) Financial and technical support for capacity-building in the assessment of the costs of adaptation.

## **XI. POZNAN**

The 14th Conference of the Parties was convened in December 2008 in Poznan, Poland. Expectations for the meeting were not high, thanks to the global financial crisis, the lack of leadership from the US, and the weakening of earlier commitments by the EU. While some

observers, mainly UN officials, argued that Poznan has set the stage for next the 2009 talks in Copenhagen, most of the major issues-mitigation targets and time-tables, funding for adaptation and technology transfer, and tropical deforestation-were pushed to Copenhagen.

Despite the lack of progress toward a comprehensive, post-Kyoto agreement, there was one promising development-the pledge by some major developing countries to reduce their carbon emissions-a shift from past positions. Brazil pledged to cut its annual deforestation rate by 70% by 2017, which could reduce the country's carbon emissions by 30-45% over the next decade. Mexico would reduce its emissions by 50% from 2002 levels by 2050 and South Africa's emissions would plateau between 2020 and 2025 and begin to decline between 2030 and 2035. Similarly, China will reduce its 'energy intensity' by 20% by 2010 and India will boost solar energy production. These pledges are voluntary and their implementation is largely dependent on the extent of financial assistance and technology transfer by developed countries.

Whether this, and the agreement on structuring the (small) Adaptation Fund, will pave the way toward a new global treaty remains to be seen. The core questions-how much developed countries will reduce their greenhouse gas emissions, what will the rapidly industrializing countries like China and India actually do to control their rapidly growing emissions, and how the poorer countries will be assisted in their adaptation efforts and in pursuing low-carbon development-remain untouched.

Many observers believe that the success of Copenhagen in 2009 hinges on the new leadership in the US. President Obama has said that he wants to return to 1990 emission level by 2020. He also believes that a US energy strategy to tackle climate change would contribute to improving the economy, and has called for a \$150 billion investment to create 5 million 'green' jobs in the next 10 years.

## **XII. CONCLUSION: THE ROAD TO COPENHAGEN**

Since December 2008, there is little agreement

on the key issues that have divided North and South negotiators so far, and scepticism that a comprehensive post-2012 treaty will be reached is growing. What is now clear is that developing countries will not accept commitments that imply significant restrictions on their economic growth. Such countries as China and India point with justifiable satisfaction to the rapid growth they have achieved in the recent past and the rise in living standards that has resulted. They support their position by pointing to the large percentages of their populations still living in extreme poverty and their need for rapid expansion in employment to absorb these labour surpluses. Developing countries believe that their economic growth must be supported by increases in energy use, although accepting the possibility that energy use per unit of production can continue to decline, as it has done up to now.

Therefore, despite pressure from developed countries, developing countries are highly unlikely to accept binding restrictions or national caps on greenhouse gas emissions comparable to those in the Kyoto Protocol for Annex I countries. Those will be seen as almost certain to restrict economic growth, because the base of renewable energy generation is small and both China and India are very dependent on coal for electric power generation. In the event these countries should prove willing to accept future national emission ceilings, they would insist that those caps would become binding only well into the future. In either case, a strategy that can lead to immediate action is sorely needed.

At the same time, the Annex I countries will not accept that the world's other major emitters continue with 'business as usual' as the underlying principle. Not only would this risk substantial leakage of emissions to the developing world, it would also imply major financial transfers from North to South, whether under the Clean Development Mechanism, a global emission trading system, or another cooperative arrangement. As the U.S. government made clear during the pre-Kyoto negotiations, it will not incur significant mitigation costs unless the major developing countries agree to undertake significant actions as well. If the United States refuses to act, other industrialized countries will be limited in their commitments as well.

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# Interrelation between Climate Change and Trade Negotiations

MAGDA SHAHIN



## I. INTRODUCTION

It is now generally accepted that climate change is the result of increasing concentrations of carbon dioxide, methane, nitrous oxide and other greenhouse gases (GHGs) in the atmosphere (IPCC, 2007). Arab countries collectively contribute less than 5% of the total world emissions of GHGs.<sup>i</sup> The Middle East and North Africa (MENA) region is the world's largest oil producing region, and oil, along with other fossil fuels gas and coal, is the largest GHG emitter. According to the International Energy Association (IEA), the world's energy needs stand to increase by over 45% above present needs by 2030, indicating an annual increase of approximately 6%. Carbon-intensive fossil fuels will continue to dominate the energy sector with oil remaining the primary energy source if business as usual is the prevailing scenario (IEA, 2007).

In December 2009, environment ministers and officials from 192 countries will meet in Copenhagen to attempt to negotiate a new international regime to battle the urgent threat of climate change. The existing framework, the Kyoto Protocol, has not yet succeeded in realizing the reductions commitments made by its Parties, and calls for incorporating climate change initiatives into the international trade framework have grown louder. While Kyoto has not been an overall success, it does provide Parties with enough flexibility to choose policy instruments to meet their commitments. Most importantly, Kyoto establishes positive measures to achieve its goals, namely technology transfer through the clean development mechanism (CDM), financial and technical assistance through joint implementation (JI), capacity building, and market based incentives, such as emissions trading.

Given the limits of the international trade regime which is not mandated to establish positive measures, a balanced multilateral environmental agreement (MEA) with its own tools and with its own dispute settlement mechanism for enforcement, taking guidance from the WTO framework, may be the ideal forum in which to navigate the climate change crisis. This chapter asserts that it is not solely through punitive regulatory mandates that climate change should be addressed, but also and inevitably through a combination of technology transfer and partner-

ships between industrial, oil-producing and other developing countries. Only a multilateral approach to climate change, outside the WTO, wielding both carrots and sticks, will allow these issues to be properly addressed.

## II. POST-KYOTO PROTOCOL AND WTO RULES

The Kyoto Protocol has drawn on the United Nations Framework Convention on Climate Change (UNFCCC) and Rio Principle 7<sup>ii</sup> to build its foundations, clearly defining UNFCCC Annex I countries as developed countries that must carry the sole responsibility for climate change mitigation during the first phase (2008-2012) of implementation. As long as trade measures in the Protocol do not breach the relevant criteria of the WTO, fulfilling the necessity test, effectiveness and least trade restrictive requirements in addition to the proportionality aspect,<sup>iii</sup> such measures will not be challenged by WTO members. Furthermore, reviewing WTO jurisprudence, such as the 1998 Shrimp-Turtle case,<sup>iv</sup> the organization's flexibility to accommodate national environmental protection policies becomes apparent, as well as the organization's refusal to sanction the imposition of unilaterally conceived measures extra-territorially. In the implementation of Kyoto, compatibility has been achieved with the rules and disciplines of the international trade regime, and a balance between its disciplines and those set out in Kyoto has been and should continue to be successfully cultivated. Any post-Kyoto agreement should aim for a similar design. It is important to emphasize that such a balance will at no rate inevitably compromise climate change mitigation measures.

Although the relationship between Multilateral Environmental Agreements (MEAs) and the WTO as such has been relegated to the margins of the negotiating agenda of the Doha development round, proponents of negative measures to combat climate change continue to press for the creation of specific WTO rules to accommodate the environment. For the Arab world, this push becomes particularly dangerous when energy, which has largely been a marginal issue in the WTO, comes under scrutiny directly through the occasional promotion by some of an interna-





tional accord on renewable energy trade within the WTO, and indirectly through the introduction of environmental goods and services (EGS), and through a call to legitimize the regulation of process and production methods (PPMs).

### III. ENERGY AS AN EMERGENT ISSUE IN THE WTO SYSTEM

It is well known that oil, as well as coal, have long been kept outside the purview of the GATT and subsequently the WTO trading system. This was not at the behest of the Arab oil-producing countries, the majority of which were not members in the GATT, and later, were certainly not deal makers or breakers in the WTO. The production of energy per se and its impact was never an issue in negotiations<sup>v</sup> for multiple reasons: the multilateral system was more concerned with addressing import barriers rather than export restrictions; such negotiations would fall victim to the politicization of oil as a strategic product;

and perhaps most convincing, negotiating energy in the trading system never constituted an interest to the developed countries, which were unilaterally setting the trade agenda. The developed countries were neither keen on exchanging concessions amongst themselves in oil or oil products, nor was it in their interest to pry open markets for oil. As such, the lack of interest on the part of the developed countries in subjecting energy to multilateral rules and regulations was the predominant factor in keeping oil and coal off the trade agenda.

Another attempt to address the related issues of oil and coal—the “Natural Resource-Based Products” group established at the beginning of 1987—was also a non-starter. The expectations of the group were overwhelming as it was mandated with a range of non-negotiable issues, such as the problems of dual pricing, access to supplies, restrictive business practices, subsidies in the coal sector and export restrictions leading to trade distortions. Moreover, energy production

and transport markets were dominated by trans-nationals and subject to heavy restrictive business practices (RBPs). It was taboo in the multilateral trading system to deal with the trans-nationals. As long as the WTO continues to shy away from regulating the practices of trans-nationals, it is hard to perceive how the energy sector is going to be monitored.

At present, calls for the creation of a multilateral agreement on energy within the framework of the WTO are being made. However, it is not the oil sector which is being scrutinized in this respect (ostensibly oil and coal remain trivial in WTO negotiations); it is rather the related issues of new and renewable sources of energy. Low-carbon energy sources—wind, biomass, solar—and their associated products are highly attractive to developed countries interested in seeking new market access.

The more developed countries invest in low-carbon energy sources, the greater their interest will be to negotiate them under environmental goods and services in the WTO and the more selective they will be in their trade of so-called non-green goods and services. This will have a direct bearing on the Arab world as a developing and an oil producing region. Despite the Arab world's minimal contribution to climate change through GHG emissions, Arab countries still have a vest-

ed interest to be part of any debate related to the interface between the WTO and the promulgation of rules and regulations on trade in energy, or on trade in new and renewable sources of energy directed at mitigating climate change.

#### IV. ENVIRONMENTAL GOODS AND SERVICES AND PPMs : THE ARAB PERSPECTIVE <sup>vi</sup>

Given the diversity of positions among Arab countries with regard to environmental goods and services and the related process and production methods (PPMs), it is vital to draw attention to the underlying complexities of the issue. The entire spectrum of new and renewable sources of energy lies within its context.

##### *Environmental Goods*

The Doha Ministerial Declaration<sup>vii</sup> paragraph 31-(iii) calls for “the reduction or, as appropriate, elimination of tariff and non-tariff barriers to environmental goods and services.” It is under this banner of environmental goods and services and the push to include EGS in Doha negotiations that new and renewable sources of energy, and by default, traditional energy sources, are cropping up. Due to the nature of agreements within the WTO, countries have the flexibility to







decide which environmental services should be targeted for liberalization at the national level in a country's schedule of commitments.<sup>viii</sup> This is not the case for environmental goods where tariff reductions would need to be applied to a common set of environmental goods agreed to by all WTO members.<sup>ix</sup>

Negotiation on the liberalization of environmental goods in the Doha round faces enormous challenges and to date its outcome remains undetermined, be it within the overall package of the Doha round or – if ventured by some – a stand-alone or plurilateral agreement within the WTO. No agreement has yet been reached on a boundary for EGS.

The extent to which energy will be incorporated into the trading system through the negotiation of EGS – if these negotiations are to see the light of day – depends upon how environmental goods' boundaries will be defined, and more precisely, whether end-use criteria and PPMs should be required to define environmental goods.<sup>x</sup> It is the prospect of the inclusion of PPMs in the definition of environmental goods coupled with the emergence in the developed countries of environmental policies, higher standards and regulations in value added energy sectors (chemicals and fertilizers, plastics, aluminium, and cement), and increasing levels of investment in renewable energy that is of particular interest to the Arab world.<sup>xi</sup>

### **PPMs**

PPMs, which refer to the way in which a product is made, have long been a controversial feature of

the trade and environment debate. In spite of GATT precedents that the 'likeness'<sup>xii</sup> of products (a litmus test to protect against discrimination) should not be determined on the basis of the method of production or production processes,<sup>xiii</sup> environmentalists have fought against this view, noting that PPMs are fundamental to minimizing the environmental impact of a product during its life-cycle.<sup>xiv</sup> As it stands, trade rules allow for distinctions between products solely on the basis of the end uses and characteristics of the products themselves. The introduction of PPMs into the definition of environmental goods aimed at climate change mitigation would then reverse this, allowing like products whose end uses and characteristics are the same to be treated differently. This would pose a significant challenge to the Arab world, whose production is dominated by carbon-intensive activity. Moreover, the introduction of PPMs here will certainly open the backdoor for member states to challenge 'likeness' elsewhere, essentially erecting trade barriers on the basis of loosely related production factors.

For the Arab economies, in addition to being reliant on carbon-intensive activities and traditional energy production, almost all are net importers of 'clean technologies' and their associated goods. In principle, trade measures are an important channel for the diffusion of climate mitigation goods. In reality, however, adapting solely trade measures aimed at carbon reduction will have significant adverse impacts upon traditional energy producers and fossil fuel exports, given the absence of positive measures designed to stimulate diversification, development, growth and transition toward low-carbon production



that vulnerable economies could negotiate in a post-Kyoto framework.

It would also be baseless to argue for a split between the negative and the positive measures in regard to climate change mitigation, as this will undermine the entire balance of a holistic approach, which is critical to our priority issue.

The Arab region has the most renewable energy resources in the world. If Arab countries only use 5% of their deserts to build concentrated solar power plants, they can actually satisfy the energy needs of the world. Arabs could export clean and non-exhaustible energy to the world as an alternative to oil and as a viable solution to climate change (Hmaidan, 2007). Significant technological and financial barriers, including transportation of energy from the desert and the huge-upfront costs for building the facilities to produce all this power, however, constitute immense challenges. Prospects of investment in co-operation with the developed markets are already on the horizon. It is important for the Arab region to capitalize on this new market but doing so will take time and the right combination of incentives, which will require the right regime.

## V. CONCLUSION AND RECOMMENDATIONS

Thus far, negotiations in the WTO have been rooted in a consensual framework designed to facilitate the liberalization of international trade in an equitable manner. Achieving a consensus on the role of the environment in general and climate change mitigation in particular through the WTO regime has proven to be a highly complex task. As we have seen, negotiating environmental goods and services is fraught with danger and ultimately can effect more damage than good.

It is difficult to imagine an agreement on a basic list of goods for cleaner technology and energy sources when PPMs are in tow and directly undermine the interests of the Arab world and most developing countries. Moreover, the absence of provisions in the WTO to aid developing and least developed countries to transition from unsustainable to environmentally friendly technologies and PPMs in fact undermines effective climate change mitigation by giving preference to those already equipped with such technologies.

For the Arab countries today, time is of the essence; the urgency and imminent risks of climate change

do not allow for complacency. The Arab region's minimal contribution to climate changing GHG emissions is dwarfed by the region's immense vulnerability to climate change, be it through rising temperatures, water scarcity, desertification, sea level rise, or even conflict (AFED, 2008). Like many other countries, Arab countries have a vested interest to push forcefully for an independent environmental system that houses a diversity of climate change mitigation policies and offers a mixture of positive and negative measures to achieve its ends. The following are recommendations for the Arab states to consider as they cooperate with other countries in the development of a new climate change mitigation framework:

- In addition to the well-known tools of trade policies, measures such as access to technology and finance and building of infrastructural capacities are essential for a fair and equitable outcome. These measures should be negotiated within the framework of a separate post-Kyoto MEA outside the purview of the WTO.
- Access to affordable clean technology to reduce emissions should be negotiated along the lines of the clean development mechanism (CDM) in the Kyoto Protocol, e.g. developed countries could provide financing for the mitigation and adaptation measures of the developing countries.
- Developing clean energy technologies should be a top priority; the abundance of alternative energy sources in the Arab world should be harnessed to facilitate climate change mitigation as well as economic development.
- Arab countries will also have to be very careful to ensure that any trade measures incorporated in the post-Kyoto Protocol are in conformity with the rules and disciplines of the international trade regime, i.e. fulfilling the relevant criteria of the WTO.
- It is essential for Arab states to reach a consensus amongst themselves on a unified position regarding the ongoing negotiations in the WTO on environmental goods and services as well as PPMs.
- Ultimately, the Arab world should seek to demarcate the boundary between a post-Kyoto MEA and the WTO.

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## NOTES

- (i) Compared to OECD countries whose share of emissions is 41.9%. See UNDP (2007/2008), *Human Development Report: UAE*, United Nations Development Program, New York. Available at: [http://hdrstats.undp.org/countries/country\\_fact\\_sheets/cty\\_fs\\_ARE.html](http://hdrstats.undp.org/countries/country_fact_sheets/cty_fs_ARE.html), accessed March 12, 2009.
- (ii) UN Conference held in Rio de Janeiro in 1992 on Environment and Development. Principle 7 stipulates that "In view of the different contributions to global environmental degradation, States have common but differentiated responsibilities."
- (iii) Report presented to Singapore 1st Ministerial Meeting (December 1996) paragraph 174 (i, ii, iii, iv, v)
- (iv) In the shrimp-turtle dispute case, the Appellate Body went as far as it could in trying to identify with the US' 'unilateral' ban on shrimp labeling it "as an appropriate means to an end", yet stopped short of giving its blessing for the erroneous application of the measure which proscribed the use of a specific fishing method in order to conserve sea turtles. It not only

criticized the measure as being 'unilateral' without any attempt on the part of the US to reach a consensual solution for the protection and conservation of sea turtles, but also found the measure to be 'discriminatory' as it favored Caribbean countries over Asian nations. See: United States—Import Prohibition of Shrimp and Certain Shrimp Products, AB Report, WT/DS58/AB/R (12 October 1998).

- (v) Even in the aftermath of the oil crisis after the ME 1973 war, when the US pushed to place the issue of export restrictions on the agenda of Tokyo round, it was resisted as a generic issue for its wider implications. See: UNCTAD (2000). Annual Report. United Nations Conference on Trade and Development, Geneva and New York.
- (vi) The Organization for Economic Co-operation and Development (OECD) has broadly defined environmental services as "services capable of measuring, preventing, limiting or correcting environmental damage such as pollution of water, air soil as well as waste and noise-related problems. Source: OECD (1996). The Global Environmental Goods and Services Industry. Organization for Economic Cooperation and Development, Paris. Environmental goods may encompass a wide array of products and technologies required to successfully perform the above environmental services. Available online at: (<http://www.oecd.org/dataoecd/11/10/2090577.pdf>)
- (vii) [http://www.wto.org/english/thewto\\_e/minist\\_e/om01\\_e/mindecl\\_e.htm](http://www.wto.org/english/thewto_e/minist_e/om01_e/mindecl_e.htm)
- (viii) In accordance with the General Agreement on Trade in Services (GATS).
- (ix) Gulf countries have been at the forefront in privatization and trade liberalization of the environmental services sectors. To varying degrees, these countries have deregulated and privatized their water, energy and solid waste management sectors. While trade liberalization has thus far been effected on a unilateral basis, several Gulf countries (Qatar, Oman, Saudi Arabia and UAE) have opened up to foreign investment multilaterally under the GATS. These countries include Bahrain, Kuwait, Qatar, Oman, Saudi Arabia and the United Arab Emirates. To a more limited extent, Jordan has partially opened its environmental services market, although not yet in the areas of water treatment and solid waste management. Certain member states, such as China and India, have proposed a similar treatment of EGS to that of services, wherein liberalization could follow a request and offer approach, or take place in the context of specific projects.
- (x) Statement by the Chairperson of the Special Session of the Committee on Trade and Environment to the Trade Negotiations Committee. TN/TE/2 (July 2002).
- (xi) ESCWA (2007). The Liberalization of Trade in Environmental Goods and Services in the ESCWA and Arab Regions. United Nations Economic and Social Commission for Western Asia, New York. E/ESCWA/SDPD/2007/WP.1. The study was presented at the 'Expert Meeting on Trade and Environment Priorities in the Arab Region' held from 11-13 November, 2007 in Cairo.
- (xii) In the past, GATT legal rulings on 'likeness' have been varied, and the construction of 'likeness' has not been the same in all rulings, however, generally distinctions of 'likeness' are measured on the basis of:
- 1) physical similarity,
  - 2) whether they are separated or classified as together in international customs tariffs
  - 3) whether consumers treat them as interchangeable (relating to consumer tastes, preferences, and habits)
  - 4) whether they have the same end uses.
- (xiii) In 1991 a GATT panel ruled against a U.S. regulation that barred the importation of tuna from certain fishing nations. The panel noted that the U.S. was distinguishing between tuna based on the method by which it was caught, favoring the product that had comparatively less impact on dolphins. The panel determined that the treatment of the tuna must be the same regardless of how it was harvested. See: GATT, Dispute Settlement Panel Report on US Restrictions on Imports of Tuna, (1991) 30 I.L.M. 1594 [Tuna I]. GATT, Dispute Settlement Panel Report on US Restrictions on Imports of Tuna, (1994) 33 I.L.M. 839 [Tuna II].
- (xiv) An end product usually goes through a number of stages before it actually reaches the market. For example: making paper requires trees to be grown and harvested, the wood to be processed, and the pulp to be bleached, and so on. The various processes will have different sorts of environmental impacts—on biodiversity, on forest-based streams and wildlife, on human health from chemical pollution of waterways, or in terms of air pollution and energy use. Other paper may be made from post-consumer waste, a different process involving a different set of environmental impacts. The end products will be the same—paper—but the production methods will have completely different environmental impacts. In cases where different production methods actually lead to different products, i.e. the papers must be used, handled, or disposed of differently, they are referred to as 'product-related' PPMs. See: UNEP, IISD (2000). Environment and Trade: a Handbook. United Nations Environment Program, International Institute for Sustainable Development, Canada. For our purposes PPMs will refer to non-product related unless otherwise noted.



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# Acronyms and Abbreviations

ABSP	Agricultural Biotechnology Support Programme
ACSAD	Arabic Centre for the Studies of Arid Zones and Drylands
AEPC	African Environmental Protection Commission
AEPS	Arctic Environmental Protection Strategy
AEWA	African-Eurasian Waterbird Agreement
AFED	Arab Forum for Environment and Development
AGERI	Agricultural Genetic Engineering Institute
AIA	Advance Informed Agreement
AIDS	Acquired Immunodeficiency Syndrome
AMCEN	African Ministerial Conference on the Environment
AMU	Arab Maghreb Union
AoA	Agreement on Agriculture (WTO Uruguay Round)
AOAD	Arab Organization for Agricultural Development
AU	African Union
AUB	American University of Beirut
BCH	Biosafety Clearing House
BMP	Best Management Practices
BOD	Biological Oxygen Demand
BU	Boston University
CAB	Centre for Agriculture and Biosciences
CAN	Competent National Authority
CAMP	Coastal Area Management Project
CAMRE	Council of Arab Ministers Responsible for the Environment
CBC	Community-Based Conservation
CBD	Convention on Biological Diversity
CBO	Community-Based Organization
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CDRs	Certified Emissions Reductions
CEIT	Countries with Economies in Transition
CEDARE	Centre for Environment and Development for the Arab Region and Europe
CERES	Coalition for Environmentally Responsible Economics
CFC	Chloro-Fluoro-Carbon
CFL	Compact Fluorescent Lamp
CGIAR	Consultative Group on International Agricultural Research
CH <sub>4</sub>	Methane
CHP	Combined Heat and Power
CILSS	Permanent Interstate Committee for Drought Control in the Sahel
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CMS	Convention on the Conservation of Migratory Species of Wild Animals



CNA	Competent National Authority
CNG	Compressed Natural Gas
CO <sub>2</sub>	Carbon Dioxide
CO <sub>2</sub> eq	CO <sub>2</sub> -equivalents
COD	Chemical Oxygen Demand
COP	Conference of the Parties
CPB	Cartagena Protocol on Biosafety
CRS	Center for Remote Sensing
CSD	Commission on Sustainable Development
CSP	Concentrated Solar Power
CZIMP	Coastal Zone Integrated Management Plan
DALYs	Disability-Adjusted Life Years
DEM	Digital Elevation Model
DESA	Department of Economic and Social Affairs
EAD	Environment Agency Abu Dhabi
EEAA	Egyptian Environmental Affairs Agency
EGS	Environmental Goods and Services
EIA	Environmental Impact Assessment
EITI	Extractive Industries Transparency Initiative
EMS	Environmental Management System
ENSO	El Niño-Southern Oscillation
EPA	US Environmental Protection Agency
ESCWA	United Nations Economic and Social Commission for Western Asia
EPI	Environment Performance Index
ESBM	Ecosystem-Based Management
ESI	Environment Sustainability Index
EU	European Union
EU ETS	European Union Emission Trading System
EVI	Environmental Vulnerability Index
FACE	Free Air Carbon Enrichment
FAO	Food and Agriculture Organization of the United Nations
FDI	Foreign Direct Investment
G7	Group of Seven: Canada, France, Germany, Italy, Japan, United Kingdom, United States
G8	Group of Eight: Canada, France, Germany, Italy, Japan, Russian Federation, United Kingdom, United States
GAPs	Good Agricultural Practices
GATT	General Agreement on Tariffs and Trade
GBC	Green Building Council
GBIF	Global Biodiversity Information Facility
GCC	Gulf Cooperation Council
GCM	General Circulation Model
GCOS	Global Climate Observing System
GDP	Gross Domestic Product
GECF	Gas Exporting Countries Forum
GEF	Global Environment Facility
GEMS	Global Environment Monitoring System
GEO	Global Environment Outlook
GHGs	Greenhouse Gases
GIS	Geographical Information Systems
GIWA	Global International Waters Assessment
GLASOD	Global Assessment of Soil Degradation

GLCA	Global Leadership for Climate Action
GM	Genetically Modified
GMEF	Global Ministerial Environment Forum
GMO	Genetically Modified Organism
GNI	Gross National Income
GNP	Gross National Product
GRI	Global Reporting Initiative
GRID	Global Resource Information Database
GWP	Global Water Partnership
HACCP	Hazardous Analysis and Critical Control Points
HDI	Human Development Index
HIV	Human Immunodeficiency Virus
ICAM	Integrated Coastal Area Management
ICARDA	International Center for Agricultural Research in Dry Areas
ICC	International Chamber of Commerce
ICGEB	International Center for Genetic Engineering and Biotechnology
ICM	Integrated Coastal Management
ICT	Information and Communication Technology
ICZM	Integrated Coastal Zone Management
IEA	International Energy Agency
IFA	International Fertilizer Industry Association
IFAD	International Fund for Agricultural Development
ILO	International Labour Organization
IMF	International Monetary Fund
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
IPF	Intergovernmental Panel on Forests
IPM	Integrated Pest Management
IPR	Intellectual Property Rights
ISO	International Organization for Standardization
IUCN	World Conservation Union (International Union for the Conservation of Nature and Natural Resources)
IWRM	Integrated Water Resources Management
IWMI	International Water Management Institute
JI	Joint Implementation
LADA	Land Degradation Assessment of Drylands
LAS	League of Arab States
LEED	Leadership in Environmental Design
LDCs	Least Developed Countries
LMBAs	Land and Marine Based Activities
LMEs	Large Marine Ecosystems
LMG	Like Minded Group
LMO	Living Modified Organism
LPG	Liquefied Petroleum Gas
MAP	Mediterranean Action Plan
MARPOL	International Convention for the Prevention of Pollution from Ships
MCM	Million Cubic Meters
MDGs	Millennium Development Goals
MEA	Multilateral Environmental Agreement
MECTAT	Middle East Centre for the Transfer of Appropriate Technology
MEMAC	Marine Emergency Mutual Aid Centre

MENA	Middle East and North Africa
MPA	Marine Protected Area
Mt	Megatonnes
MW	Megawatt
NBC	National Biosafety Committee
NBF	National Biosafety Framework
NEAP	National Environmental Action Plan
NFP	National Focal Point
NGO	Non-Governmental Organization
NPK	Nitrogen, Phosphates and Potash
NPP	Net Primary Productivity
OAU	Organization for African Unity
ODA	Official Development Assistance
ODS	Ozone-Depleting Substance
OECD	Organisation for Economic Co-operation and Development
PACD	Plan of Action to Combat Desertification
PCB	Polychlorinated biphenyls
PCFPI	Per Capita Food Production Index
PERSGA	Protection of the Environment of the Red Sea and Gulf of Aden
PICs	Pacific Island Countries
POPs	Persistent Organic Pollutants
PPM	Parts Per Million
PPM	Process and Production Methods
PTSs	Persistent Toxic Substances
PV	Photovoltaic
RA	Risk Assessment
RBP	Restrictive Business Practices
RCM	Regional Circulation Model
REMPEC	Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea
RM	Risk Management
ROPME	Regional Organization for the Protection of the Marine Environment of the sea area surrounded by Bahrain, I.R. Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates
RSA	Ropme Sea Area
RSGA	Red Sea and Gulf of Aden
SAP	Strategic Action Program
SCP	Sustainable Consumption and Production
SEA	Strategic Environmental Assessment
SLR	Sea Level Rise
SoE	State of the Environment
SPM	Suspended Particulate Matter
SRES	Special Report on Emission Scenarios
TOE	Tonnes of Oil Equivalent
TRAFFIC	Trade Records Analysis for Flora and Fauna in International Commerce
TRI	Toxics Release Inventory
TRIPs	Trade-Related Aspects of International Property Rights
UHI	Urban Heat Island
UN	United Nations
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development
UNCHS	United Nations Centre for Human Settlements (now UN-Habitat)

UNCLOS	United Nations Convention on the Law of the Sea
UNCOD	United Nations Conference on Desertification
UNCTAD	United Nations Conference on Trade and Development
UNDAF	United Nations Development Assistance Framework
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Population Fund
UNHCR	United Nations High Commission for Refugees
UNICE	United Nations Children's Fund
UNWTO	United Nations World Tourism Organization
US	United States
USCCCSP	United States Climate Change Science Program
USEPA	United States Environmental Protection Agency
UV	Ultraviolet (A and B)
VOC	Volatile Organic Compound
WBCSD	World Business Council for Sustainable Development
WCED	World Commission on Environment and Development
WCD	World Commission on Dams
WCP	World Climate Programme
WCS	World Conservation Strategy
WDPA	World Database on Protected Areas
WEF	World Economic Forum
WEI	Water Exploitation Index
WFP	World Food Programme
WHO	World Health Organization
WMO	World Meteorological Organization
WRI	World Resources Institute
WSSCC	Water Supply and Sanitation Collaborative Council
WSSD	World Summit on Sustainable Development
WTO	World Trade Organization
WWAP	World Water Assessment Programme
WWC	World Water Council
WWF	World Wide Fund for Nature