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Background Paper

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watersum

Sustainable Use of Transboundary Water Resources and Water Security Management Project

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Abstract

Climate change is among the global environmental issues that has received most attention across nearly all domains (political, media, scientific, and civil society). Although the Arab region does not contribute more than 5% to the causes of global climate change, its effects on the region will be very severe. In fact, the region is particularly vulnerable given already scarce water resources, high levels of aridity and the long coastal stretch threatened by the rising sea levels. Natural and physical systems in the Arab world are already facing heavy pressures, and these will only be intensified as temperatures in the region get higher and/or precipitation gets lower. Impacts of climate change and variability on water resource are evident in MENA region and increasing floods and droughts pose a challenge to water managers in all beneficiary countries.

The projected impacts of climate change (such as more extreme weather events, decreased precipitation and rising sea levels) will exacerbate the aridity and water scarcity problems in the region. There are severe environmental, economic, political and security implications. Climate change is expected to primarily affect precipitation, temperature and potential evapotranspiration, and, thus, is likely to effect the occurrence and severity of droughts and flash floods. An important question for the assessment of future impacts (i.e. socio-economic and environmental) is how changes in climate will affect the water budget components in Arab Region. Once the impacts on the hydrological cycle components are understood, then, the impacts of climate change on the hydrological extremes (droughts and floods) can be assessed. According to recent modeling studies, the Arab region will face an increase of 2 to 5.5°C in the surface temperature by the end of the 21st century. In addition, this temperature increase will be coupled with a projected decrease in precipitation of between 0 and 20%. The results for the region include shorter winters, dryer and hotter summers, a higher rate of heat waves, increased weather variability, and a more frequent occurrence of extreme weather events. Clearly, adaptation and mitigation strategies need to be researched, discussed, and implemented.

Higher temperatures will also increase the incidence and impact of drought in the region, threatening water resources and productive land. As this paper shows, drought frequency has already increased in Jordan, Algeria, Morocco, Syria, and Tunisia.

Recent droughts in Jordan and Syria were the worst recorded in many decades. In addition, increased precipitation variability and water resource availability directly related to climate change affect a number of the countries in the region.

A warmer climate brings with it increased climate variability, higher risk of both floods and droughts, and exacerbates the already precarious situation created by chronic water scarcity faced by most Arab countries. There is an obvious need for deep understanding of the climate change risks taking place in the watersheds located in arid and semi-arid regions. The situation in the Arab Region is even more critical and requires extreme attention from all levels of society. The Arab Region is an arid area, having a large spot of dry and desert land, suffer from limited water resources, and irregular distribution of precipitation.

The aim of this paper is to provide an overview on climate change impacts and adaptation in the MENA region focusing on the Arab region. Impacts of current climate variability and projected change are reviewed, the vulnerability of a number of sectors and regions is analysed and adaptation strategies are elaborated. Finally, the constraints, needs and concerns of Arab countries are discussed and conclusions and recommendations are developed.

1. Introduction

Climate change (CC) refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007a). Science established a causal effect between the acceleration of Green House Gas (GHG) emissions and CC effects (IPCC, 2007a), Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004.

Article 2 of the UNFCCC refers to the dangerous human influences on climate, in terms of whether they would allow ecosystems to adapt, ensure that food production is not threatened and chart a path of sustainable economic development. Global, national and local level measures are needed to combat the adverse impacts of climate change induced damages. In its most recent report, the Intergovernmental Panel on Climate Change (IPCC) concludes that "water and its availability and quality will be the main pressures on, and issues for, societies and the environment under climate change" (Bates et al., 2008). Over the past decade, evidence on global warming and the accompanying changes in the earth is mounting. The IPCC's fourth assessment report concludes that it is 90–99% likely that the rise in global atmospheric temperature since the mid- 19th century has been caused by human activities (IPCC, 2007a).

It is a well-established fact that the temporal and spatial variability of freshwater resources is very sensitive to possible changes that may occur in the climate mechanism due to global warming. It is assumed that the frequency of extreme hydrological events (floods, droughts) will increase in function of various climate change scenarios (Abdulla et al, 2009). Hydrometeorological hazards such as floods and droughts affect many regions of the world, but their impact in terms of lives lost and livelihoods disrupted tends to fall most heavily on the poor in developing countries. Climate change threatens to heighten these impacts in many areas, both by changing the frequency and/or intensity of extreme events and by bringing changes in mean conditions that may alter the underlying vulnerability of populations to hazards. The result in the decades to come may be an increase in the global burden of weather-related disasters: events that can threaten the sustainability of development processes and undermine progress toward poverty reduction.

Most of the Arab countries are located in arid and semiarid zones known for their scanty annual rainfall, very high rates of evaporation and consequently extremely insufficient renewable water resources. Sustainable Management of water resources is a must as water scarcity is becoming more and more a development constraint impeding the economic growth of many countries in the region. Due to the expanding population in this century together with the increasing per capita water demand and the huge socio-economic developments of the last three decades the need for sustainable use and integrated management of the region's scarce water resources has become an eminent condition for survival. Many of the surface and groundwater resources in the region are drawn from shared rivers and aquifers respectively, complicating the situation even further. The consequences of water scarcity and conflicts could lead to serious crisis and possible confrontations, if they are not looked at, and dealt with, from a mandatory and equitable sustainable approach.

For Arab Region, the future projections using climate models point to an increase in temperature and decrease in rainfall. Both present variability and long-term climate change impacts are most severe in the developing world, the segment of world that is least able to buffer itself against impacts. The impacts are particularly severe in countries, regions and communities where the capacity to cope with, and adapt to, the hydrological effects of climate variability will influence their overall development prospects.

Climate-related impacts on water resources are already being documented. Global climate models predict a warmer planet. For Arab Region, this could mean changes to our climate— specifically temperature, evaporation, rainfall, and drought. Changes in climate will also likely affect the availability of our water resources and our plans to meet expected demands for water in the future. For surface water resources, the connection between climate and water availability is clearer and more immediate, although it does have its complications, such as changing land use associated with climate change.

The implications of climate variability and climate change have not been fully taken into account in the current decision- making framework. Therefore, assessment of vulnerability and consequent risk to water resources due to climate-change impacts is necessary to work out proper adaptation and mitigation responses. The overall purpose of this study is to give a general overview of the studied impacts of the projected climatic changes in the Arab region, in order to address some key points in the way of adaptation and mitigation planning.

This paper is an attempt to shed some light on climate change and climate variability as phenomena that might affect water availability in Arab region and how vulnerable Arab countries can mitigate and adapt to their positive and negative impacts. This paper explored the risks to the Arab Region from the impacts of climate change over the next 30 to 50 years. For this purpose, the vulnerability of water resources to climate change in some Arab countries were reviewed and presented. Then adaptation measures were suggested, along with the current policies and their implications for the vulnerability of the different sectors. The proposed adaptation measures can be included as projects within each national action plan for climate change. The proposed projects have many cross-cutting issues with other sectors and therefore shall be compiled with similar projects under the same programs. Adaptation policies should be implemented to enhance and facilitate actions that will reduce Arab countries’ vulnerability and improve their resilience to climate change. For adaptation measures to be successful, leadership is required to inspire confidence and agreement among all levels of government, the private sector and civil society.

2. Arab Countries Contribution to GHGs Emissions

Every day, humans consume energy in the form of coal, oil, and gas—known as fossil fuels—to satisfy their daily energy needs. The constant burning of fossil fuels releases huge amounts of greenhouse gases (GHGs), into our atmosphere. GHGs that have the ability to trap the sun's energy on earth in the form of heat (similar to that of a greenhouse), and thus raise the earth's temperature in a phenomenon known as global warming. This warming causes changes in the earth's climate system that leads to climate change. Greenhouse gases are also emitted through deforestation, land use changes, and natural processes. Life on earth depends on a certain concentration of GHGs in the atmosphere in order to make the climate warm enough. There is a widely-held scientific conviction that the global climate is changing as a result of the combined anthropogenic forcing due to greenhouse gases, aerosols, and land surface changes. Many pieces of evidence have concluded with a high degree of probability that human activities have exerted a substantial net warming influence on climate since 1750 (IPCC, 2007c). Physical and biological ecosystems on all continents and in most oceans have already been affected by recent climate changes (IPCC, 2007b). It is now generally accepted that this climate change is the result of increasing concentrations of carbon dioxide, methane, nitrous oxide and other greenhouse gases (GHGs) in the atmosphere (IPCC, 2001b).

For the year 2000, the statistics showed that the world total GHGs emissions from all resources was about 33 thousand Tg (teragram), with Arab countries contributing about 4.2% of these total world emissions (WRI, 2005). As presented in Figure 1, the Kingdom of Saudi Arabia (KSA) is contributing the highest percentage of the total GHGs emissions from the Arab countries, followed by Egypt and Algeria (WRI, 2005). This relatively small contribution of GHGs of all Arab countries does not correspond to the projected impacts of climate change over the region (AFED, 2008). Despite the fact that Arab region was historically the lowest contributor to global warming, scientific projections indicate with a high degree of confidence that climate change will disproportionately affect it (AFED, 2008). As at 2004, the total share of the ESCWA region was limited to 3-4 per cent of global emissions. Water in the ESCWA region is central to both climate change and human development and most of the impacts of climate change will hit the region through its scarce water resources.

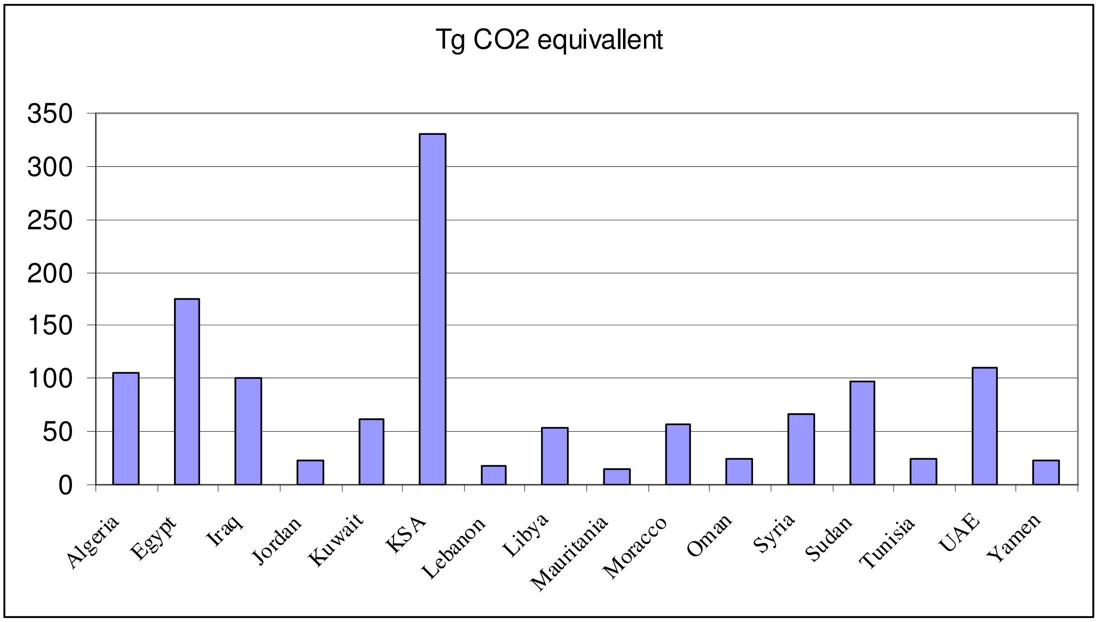

Figure 1: GHGs emissions of year 2000 from Arab Countries (WRI, 2005)

3. Climatic Trend in Wadi Systems in Arab Region

The Arab region stretches from Morocco and Mauritania in the west, through northern Africa and the Levant, to the Arabian Gulf in the east (Figure 2). Accordingly, 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, Djibouti and Comoros Islands.

Each of the above five regions has its distinct hydrological characteristics. This division will be followed in different sections of this study.

Al Mashrek region composed of three major basins. These are: the Jordan River Basin (Jordan, Lebanon, the Palestinian territories and Syria) and the Euphrates and Tigris River Basins (Iraq and Syria) and

Euphrates basin, which has a surface area of 450,000 km2. The Euphrates River is 2,735 km long. The river rises in Turkey and flows through Syria before entering Iraq on its way to the sea, where after it joins the Tigris, forms the Shatt al-Arab. The Tigris basin is shared by the same three riparians and with Iran as an additional basin country. The basin covers about 110,000 km2 and the river is roughly 1,900 km long. Before the confluence of the Euphrates and Tigris, the Euphrates and Tigris flow within Iraqi territory for about 1,000 km and 1,300 km respectively (Stockholm International Water Institute (SIWI), 2009).

Figure 2: Arab Countries

A key water source in the region is the Jordan River system (JRS)/basin. The JRS is composed of several hydrological units. The Upper Jordan is fed primarily by the Dan, the Hasbani, and the Banias Streams that combine to become the Upper Jordan River. The Dan Stream lies entirely within Israel. The Banias Stream originates in Syria but has been under Israeli control since 1967. The Wazzani Stream, originating in Lebanon, is the main source of the Hasbani. The Hasbani alone supplies about 25 percent of the Jordan River’s water. The Upper Jordan then flows into the Sea of Galilee (Lake Tiberias). The Jordan River Basin is of great importance to Jordan, the Palestinian Territories and Israel. Syria and Lebanon also contributes water resources to the basin, but rely much less heavily upon it from a water abstraction point of view. The Jordan River suffers from both over-extraction and severe pollution and salinity problems. This is especially significant in years of drought (SIWI, 2009).

Another important river in the region is the Litani River. This basin lies entirely within Lebanon. The Litani presently is not fully utilized. It is one of the only rivers in the area that continues to flow into the Eastern Mediterranean. Though not a shared water resource, the existing flow in the Litani River has reduced the need for Lebanon in the short term to divert greater quantities of water from the Wazzani and the shared basin of the Upper Jordan River.

The Yarmouk is the most significant tributary of the Lower Jordan River and reaches the River just below the Sea of Galilee/Lake Tiberias, which then flows to the Dead Sea (seven basins form the major Dead Sea Basin). The Yarmouk supplies all of the water of the King Abdullah canal, which supplies water for Jordan, largely for agriculture. The Yarmouk "drains territories in Syria and Jordan" and forms the border between Jordan and Syria. Further downstream, it forms the border between Jordan and Israel shortly before its confluence with the Lower Jordan River. From this point on to the Dead Sea, the Lower Jordan forms the border between Jordan and Israel, and then between Jordan and the Palestinian West Bank. Because "Israel, Jordan and Syria divert 95 percent of the water" that is supposed to feed the Lower Jordan River, the Lower Jordan has almost completely dried up. The flow that remains is fed by a few tiny springs and consists primarily of sewage and agricultural runoff, and is therefore quite polluted. The Jordan River Valley and the Dead Sea are cultural, religious, and heritage sites for the world. The Dead Sea has already shrunk by one-third of its size in the past 50 years, and without these flows, these sites will not remain as such.

The Nile is the longest international river system in the world. It flows some 6700 km through ten countries before reaching the Mediterranean Sea. The Nile Basin covers roughly 2.9 million km2, which is almost one-tenth the area of Africa (Gleick 1991). The river flows north for a distance of 6500 km from 4" S to 31" N latitude, and extends from 21" 30' to 40" 30' E longitude. The Nile and its tributaries (White Nile, Blue Nile) flow through Tanzania, Uganda, Rwanda, Burundi, Zaire, Kenya, Ethiopia, Sudan, and Egypt (Shahin 1985).

The linear warming trend over the last 50 years is recorded by 0.13ºC per decade (IPCC, 2007b). Furthermore, there have been an increase in the number of heat waves, a reduction in the frequency and duration of frosts, and an increase in extreme events frequency and intensity in many parts of the world. Regarding these global trends, the recent studies found that the Arab region experienced an uneven increase in surface air temperature ranging from 0.2 to 2.0ºC that occurred from 1970 to 2004 (IPCC, 2007a). In this section observed climatic trends in the different parts of the Arab region.

3.1. Climatic Trends Al Mashrek Region

Previous studies investigated the weather records in Jordan showed an increase in the magnitude and frequency of extreme temperatures (Abdulla and Al-Omari, 2008). Higher temperature and lower precipitation are expected as a result of climate change: The main results of the local climate change studies are:

- Trend analysis reveal that there is a slight increase in the mean annual temperature

- Mean annual maximum temperature tends to increase slightly, but the mean annual minimum temperature tends to show higher increase

According to the Jordan's Second and Third National Communication to UNFCCC, the annual precipitation showed decreasing trends by 5–20 % in the majority of the stations in Jordan during the last 45 years, but very few stations such as Ruwaished in the extreme east and Ras Muneef in the northwest experienced an increase in the annual rainfall amount by 5 – 10 % (JSNC, 2009 and JTNC 2014). Larger rainfall amount with a decrease in the number of rainy days may lead to an increase in the daily rainfall intensity and, thus, increasing the chance of recording extreme precipitation values. On the other hand, many other stations experienced increasing number of rainy days associated with decreasing annual precipitation amounts (JSNC, 2009). In this case a smaller amount of precipitation will spread over a longer period of time and consequently the daily rainfall intensity may be reduced. Increasing trends in relative humidity of about 4–13% during the last three decades in the majority of the study locations are observed (JSNC, 2009).

Annual average precipitation is varied along Al Mashrek region. In Lebanon and Syria the average annual amounts of precipitation are 600 and 300 mm/year, respectively. Iraq and Syria are partially dependent 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 neighboring 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.

Winter precipitation in northern and north eastern zones of Syria showed a sign of decrease for the last five decades, while autumn precipitation increased at the stations that lie mostly in northern zone of the central Syria. Few stations statistically showed significant changes in spring and summer precipitation (Figure 3) (First National Communication of Syria to UNFCCC ((FNC_Syr), 2009). Trend analysis applied to seasonally average annual temperature series between 1955 and 2006 showed a widespread increase in summer temperature in all stations in Syria with prominent increase in coastal and western regions. On the other hand, winter temperatures showed a general tendency of decrease in Syria. This decrease is mostly noticeable in the costal stations with prominence in spring and autumn. The analysis of extreme events and indices showed significant increase trends in the annual maximum of daily maximum and minimum temperature, the annual minimum of daily maximum of the surface air temperature, the annual minimum of daily minimum of surface air temperature, the number of tropical nights, and the number of summer days. The latest denotes an increase in the number of warmer days and nights in the year.

Nevertheless, significant decreases trend in cool nights and days, and diurnal temperatures range were observed too (FNC_Syr, 2009).

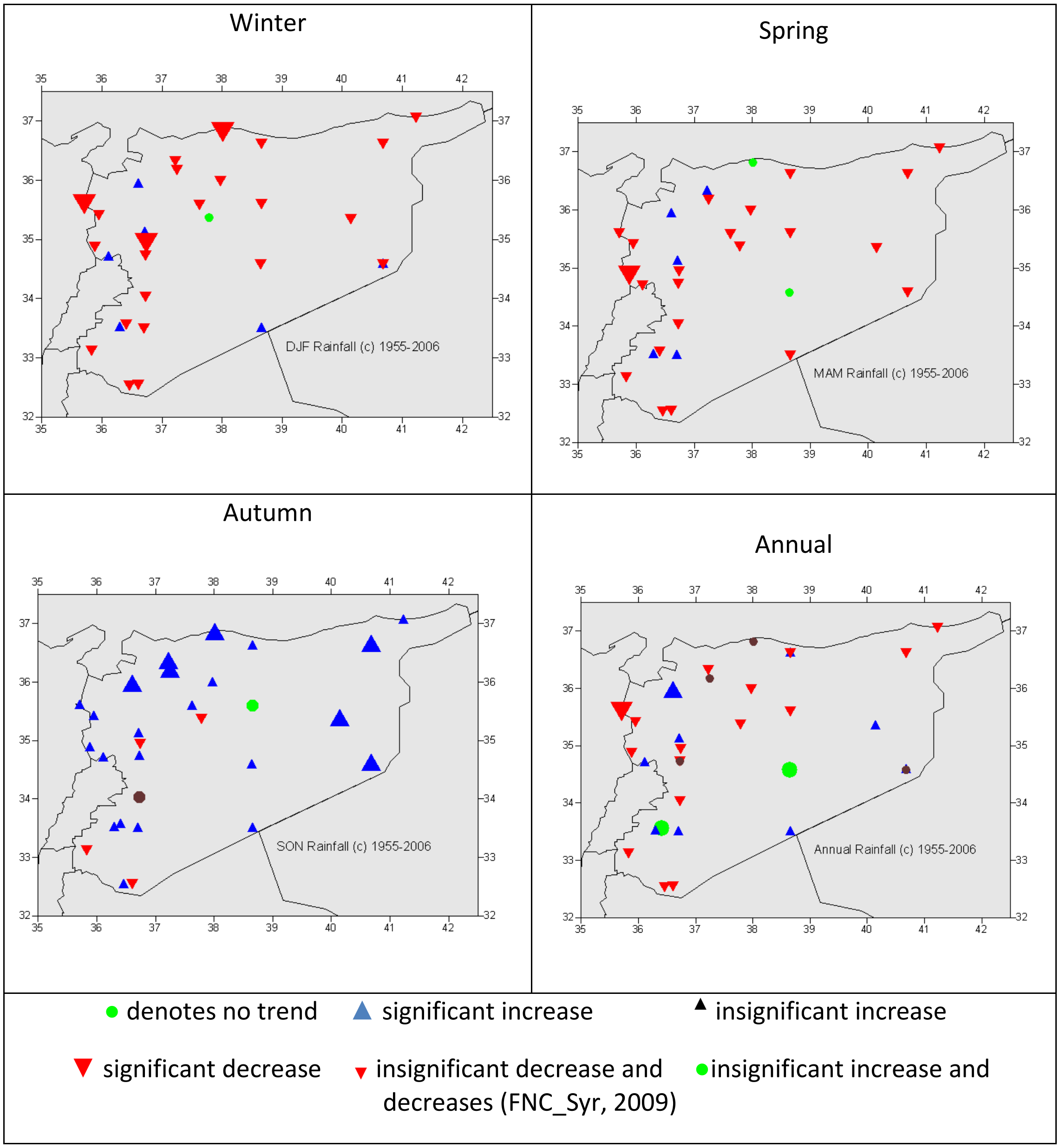

Figure 3: Seasonal and annual precipitation trends in Syria for the period 1955-2006

3.2. Climatic trends Al Maghreb Region

All five Maghreb countries depend mainly on rainfall and partially on modest groundwater reserves. Annual average precipitation is varied along the Al Maghreb region. This rate decreases gradually to be

300 mm/year by moving to northern and eastern parts of Mediterranean coast of Morocco and Tunisia. The average annual precipitation reaches 130 mm/year over North African countries.

Drought frequency increased during the last 20- 40 years in Morocco, Tunisia, and Algeria, and changed in Morocco from an average of 1 year of drought in every 5 year period, before 1990, to 1 year drought for each 2 year period (Karrou 2002, Abbas 2002, Mougou and Mansour 2005).

The first signs of changes already appear in this region through both the temperatures and the precipitation evolutions. Temperatures have increased by 1 to 2 °C during the twentieth century. In Morocco, the examination of the last three decades (1970-2000) show revealing signs of climate change: the frequency and intensity of droughts, unusually devastating floods, the decrease in the snow cover period on the peaks of the Rif and the Atlas mountains, the modification of spatial-temporal rainfall distribution, changes of itinerary and passage dates of migrating birds, the appearance of certain species of birds in the Rabat region that only used to be seen in the south of Marrakech, etc..

In Mauritania the summer months, temperatures exceed 38°C; in winters temperatures average around 24°C. Most rain falls during the short rainy season, from July to September, and average annual precipitation varies greatly. The climate of the Senegal River Valley in the far south contrasts with that of the Saharan and Sahelian zones. Rainfall is higher than in other regions, ranging from 400 millimetres to 600 millimetres annually, usually between May and September. In the northern two-thirds of the country, average rainfall is less than 100 mm where often, isolated storms drop large amounts of water in short periods of time. A year, or even several years, may pass without any rain in some locations

An increasing trend is apparent. Rainfall amounts registered, for example in Morocco, show a negative trend at national and regional scales. Nationally, spring rainfall has declined by over 40% since the 1960s. The drought seems to become more persistent over time. The maximum dry-spell length is found to be increasing during the rainy season, significantly so during the end of this season (February-April) where it has increased by 15 days since the 1960s. At the same time, the total number of wet days shows a negative trend revealing an increase in the annual dry day number. Many regions became more arid (According to the aridity index of De Martonne) between 1961-1985 and 1986-2005: namely Oujda, Taza, Kenitra, Rabat, Meknès. Annual total number of cold days (days with maximum temperature below 15 °C) shows a negative trend as well as cold wave durations.

3.3. Climatic trends in Nile Basin Region

Egypt has the second lowest annual precipitation in the Arab region. During the period 1880 to 1989, the upper White Nile catchment, the upper Blue Nile catchment, and the Middle Nile showed a decline in total precipitation. The southern part of Sudan enjoys ample precipitation which can meet the prevailing evaporative demand; however, rain gradually vanishes north of the capital Khartoum. 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 m3/year) plus modest reserves of groundwater aquifers.

The Climate in Egypt has been changing in phase with global change, but with lower rates of variation. There is a downward trend in maximum temperature over the delta, over the northern part of Upper Egypt and over the extreme south of Upper Egypt. This downward trend has ranged from -0.02 °C to -0.06 °C / year. Minimum temperatures have markedly increased over Egypt. An upward trend has covered most parts of Egypt except over a small area in Middle Egypt. The upward trend has culminated in increases of +0.1 °C / year over southern parts of Upper Egypt. The main contributor to rising air temperature comes from the increase in night time temperature. During the night, temperature rises at a higher rate than at any other time. This upward trend has culminated in increase of +0.05 °C / year over the western part of Delta near the Mediterranean coast. This rise in night time temperature may be due to the effect of greenhouse gases and increasing water vapor in the boundary layer. Moreover the rise in surface air temperature in Egypt is about 40% of the global rise in surface air temperature. Rainfall has increased over the western coast of Egypt, by up to 3 mm/year.

3.4. Climatic Trends in the Arabian Peninsula

This is the poorest region with respect to water resources, where rainfall is rare by all standards. 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. 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 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.

Kuwait has the poorest water resources in the Arab region with average precipitation of 121 mm/year, total annual water of 0.02 billion m3/ year and a 100% dependency ratio. In the United Arab Emirates (UAE) the average annual rainfall over the period 1970-2001 is about 120 mm per year, with rainfall in the driest years being over 20 times below rainfall levels in the wettest years. Average monthly rainfall patterns fluctuate widely throughout the year, with most of the rainfall occurring between January and April when temperatures are lowest. These rainfall levels, while showing a large range across the Emirates in the winter months (especially the month of March), are uniformly very low across the UAE during the summer months between July and October (The United Arab Emirates Initial National Communication (UAE_INC), 2006).

Average temperatures also show significant variation across the UAE as well as over time. The annual average temperature is about 27°C over the 1970-2001 period. Average monthly temperatures for the UAE over this period show clear trends. The range in maximum observed monthly temperatures is highest in the summer months, reaching nearly 6 degrees Centigrade across the UAE. The range in minimum observed monthly temperatures occurs during the winter months, when there is about 11 degrees between the minimum temperatures throughout the country (UAE_INC, 2006).

3.5. Climatic Trends in the Sahel Countries

Somalia, Djibouti and the Comoros Islands are all dependant on rainfall with modest potential of groundwater. With regard to changes in precipitation, an average of a 25 percent decrease in rainfall has occurred over the African Sahel during the past 30 years.

This change has been characterized by a decrease in the number of rainfall events. A decrease in precipitation has occurred over the twentieth century, particularly after the 1960s, in the subtropics and the tropics from Africa to Indonesia (IPCC, 2001).

The Third Assessment Report (TAR) suggests that climate change is likely to be associated with increased water stress in much of Africa. Moreover, it reports that scenarios for the Sahel region, based on Hulme et al. (2001) are ambiguous (IPCC, 2001), reflecting the lack of information on the current state of water resources. An assessment by UNEP (2002), suggested that by 2050 rainfall in Africa could decline by 5 percent and become more variable year by year.

4. Projected Climate Change in Arab Region

In 2007, the Intergovernmental Panel on Climate Change—an international group of climate scientists—issued an assessment of projected climate change impacts around the world. This report, the Fourth Assessment Report (FAR), estimates that the average temperature of the Middle East region will increase by about 1 – 2 °C between 2030-2050. This would result in higher evaporation rates, causing soil degradation across large areas of land in the region. The Arab region is a vast zone of generally diverse climatic conditions, characterized by very low and highly variable annual rainfall and a high degree of aridity (FAO, 2002b). Most of the Arab region lands are classified as hyper-arid, semi-arid and arid land zones (WRI, 2002). Most recent assessments have concluded that arid and semi- arid regions are highly vulnerable to climate change (IPCC, 2007a).

For the next two decades, a warming of about 0.2ºC per decade is projected for a range of IPCC SRES emission scenarios. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1ºC per decade would be expected (IPCC, 2007b).

According to climate change studies, the Arab region will face an increase of 2ºC to 5.5ºC in the surface temperature by the end of the 21st century. This increase will be coupled with a projected decrease in precipitation from 0 to 20%. These projected changes will lead to shorter winters, dryer and hotter summers, a higher rate of heat waves, a higher level of weather variability and a more frequent occurrence of extreme weather events.

For Arab region, the future projections using climate models point to an increase in the mean annual temperature by 0.5 to 1.0 °C in 2030, by 1 to 1.5°C in 2070, and by 2.5 to 3.0 °C in year 2100. They also show a decreasing trend in annual precipitation by 10% to 20% in the Mediterranean region and northern of the Arab peninsula. Simulated ranges of warming for Arab region (IPCC 2007a), in the best scenario, By 2030, annual average temperatures are 0.5 to 1.0 °C higher over most of Arab region, By 2070, the increase in annual average temperatures will range from 1 to 1.5 °C, By 2100, the increase in annual average temperatures is predicted to reach 2.5 to 3.0 °C. Model results indicate that future increases in daily maximum and minimum temperature will be similar to the changes in average temperature.

In the worst scenario By 2030, annual average temperatures are 1 to 1.5 °C higher over most of Arab region, By 2070, the increase in annual average temperatures will range from 2 to 2.5 °C, By 2100 , the increase in annual average temperatures is predicted to reach 3 to 4.0 °C.

Preliminary climate change and climate variability scenarios for the Arab region indicate that rainfall in the region will become intense and dry spells will become more pronounced

Most Arab countries have submitted their initial and second national communication to the UNFCCC (Jordan in 1997, 2009, 2014), (Egypt in 1999), (Tunisia in 2001), (Bahrain in 2005), (The UAE, 2006), (Syria in 2009). Other countries submitted also their second national communication to UNFCCC such as Jordan (2009). Studies carried in these communication reports out are focused on the impacts of climate change on water resources, agriculture and livestock sectors. Water resources, environment and other related issues such as range land, and livestock are concluded to be most likely to be vulnerable to climate change.

5. Climate Change Risks on Surface Water Resources of the Arab Region

Most of the Arab countries are located in arid and semi-arid regions that are characterized by low and limited water resources and high evaporation. Arab Region is one of the world's driest, most water-scarce regions, depends on climate-sensitive agriculture. It is expected to face severe water shortages in the near future. Per capita renewable water resources in the region, which in 1950 were 4,000 m3 per year, are currently 1,100 m3 per year. Fresh water resources are less than 1,000 m3 per capita per year in nine out of 14 countries and this limited supply is currently being depleted at a rapid rate by the growing economic development in the region. Projections indicate that they will drop by half, reaching 550 m3 per person per year in 2050 (World Bank, 2006). The IPCC stated with high confidence that the Arab Region will suffer a decrease in water resources due to climate change (Kundzewicz et al., 2007). Unfortunately, comprehensive studies on climate change vulnerability and adaptation requirements are limited in most Arab countries. With climate change, water resources will be further stressed due to increased droughts and the anticipated increase in evaporation and evapotranspiration.

The main consequences of climate change related to water resources in the Arab region can, conceptually, be attributed to increases in temperature, lower soil humidity, higher evaporation-transpiration, shifts in precipitation patterns in terms of temporal and geographic distribution, extreme annual and seasonal variability, down-pouring and flash flooding, frequent droughts and desertification, less snow cover at high altitudes (mountain terrains in Lebanon, Syrian Arab Republic and to a much smaller extent in Iraq), and the possible damaging impact of future sea level rises on the near-shore fresh groundwater resources.

The overall picture that emerges from the limited literature on the region and from IPCC (2007a) projections indicates that water availability will be highly sensitive to climate change. Climate change will have significant impacts on freshwater; affecting both availability of freshwater and frequency of floods and droughts in the Arab region. Climate change might undermine national development plans, affect human security and livelihoods, significantly impact agriculture, tourism and industry and act as a push factor in population movements and migration.

In addition, climate-induced resource scarcity could further tensions in the region's conflict-ridden areas, potentially escalating violence and political turmoil even beyond the region's boundaries. This is supported by the fact that 80% of surface water resources and 66 % of total water resources in the Arab region is a shared water resource. Higher temperatures and reduced precipitation will increase the occurrence of droughts, an effect that is already materializing in many Arab countries such as Jordan and Syria. Climate change will also require a more severe adjustment in the management of the region's water resources than any other region, since most of water resources are already being exploited for human uses.

Furthermore, climate change is expected to negatively impair water quality (pollution of surface water and seawater intrusion to groundwater aquifers). The expected changes will undoubtedly have impacts on all the socio-economic and environmental goods and services that depend on these variables either directly or indirectly. The consequences are far-reaching in the Arab region and are likely to be felt the hardest by the most vulnerable groups such as women, the elderly, children, the poor and disadvantaged.

Moreover, a warmer climate, with its increased climate variability, will increase the risk of both floods and droughts (Wetherald and Manabe, 2002). Drought affected areas will probably increase, and extreme precipitation events, which are likely to increase in frequency and intensity, will augment flood risk. Increased frequency and severity of floods and droughts will also have implications for sustainable development (IPCC, 2007a). Water shortage is already the main constraint in most countries of the region, and IPCC model simulations indicate that water scarcity may worsen substantially as a result of future changes in climatic patterns. The change in the value of surface runoff will depend on the changes in temperatures and precipitation, among other variables. A study conducted by Abdulla and AL-Omari (2008) showed that rising temperature by 2-4 °C in Jordan will reduce the flow of Zarqa river between 12 and 40 %.

Climate change may significantly degrade surface water quality that intense rainfalls may generate significant surface runoff that may carry significant sediment loads containing pesticides, fertilizers, and wastes. This will increase siltation in steams lakes and impoundments. Warmer water temperatures may have further direct impacts on water quality, such as reducing dissolved oxygen concentrations. Cold-water species, such as most salmon and trout, are particularly susceptible to warm water temperatures, and increasingly frequent warm water conditions could bring new challenges to the way managed river systems are controlled. Where stream flows and lake levels decline due to evaporative water losses, the salinity of surface waters, especially in lakes and reservoirs with long residence times could increase. These stresses on water quality will increase if climate change leads to longer dry spells.

6. Climate Change Risks on Groundwater Resources of Arab Region

There has been very little research on the impact of climate change on groundwater (Alley, 2001; Kundzewicz et al., 2007). There has been limited work on how climate change might affect groundwater in Arid and semi-arid regions including the Arab Region. Effects of climate change on recharge need to consider changes in precipitation variability and inundation (Khiyami et al., 2005). Locally, recharge is a function of the precipitation, both in amount and timing, the soil and vadose zone properties, evaporation, and transpiration. Recharge can also be greatly affected by changes in land use, such as going from grassland or woodland to agriculture. Outside of soil and vadose zone properties, climate change is expected to affect all of these factors. The amount and timing of precipitation was previously discussed.

Increases or decreases in evaporation are a function of temperature as well as humidity, which is tied to precipitation. Globally, increased CO2 in the atmosphere is expected to decrease transpiration (Betts et al., 2007, and Leipprand and Gerten, 2006, both as cited by Kundzewicz et al., 2007); however, transpiration will vary locally depending on the local changes in temperature, precipitation, and vegetation type. Local increases in evaporation and transpiration could cause increased salting of soils.

The IPCC noted that there is no ubiquitous trend in groundwater systems that can be directly correlated to climate change, primarily because of the lack of data (Kundzewicz et al., 2007). We believe this is due, in part, to the uncertainties in estimating recharge and teasing out what component of recharge is natural or influenced by land use change let alone changes in climate, especially when those changes, current and projected, are of a much less magnitude than natural variations. Furthermore, in many aquifers, it takes time for water to reach the water table, and the water that reaches the entirety of the water table represents an integration of past climatic conditions over years, decades, and perhaps centuries.

The consumption of groundwater is likely to become unsustainable. According to the IPCC the unsustainable depletion of groundwater will likely be worsened by reduced surface water infiltration in the Arab region. In addition, the increase in the intrusion of salt water to coastal aquifers from sea level rise will further reduce the availability of usable ground water (IPCC, 2007f). Climate change could affect groundwater resources by affecting recharge, pumping, natural discharge, and saline intrusion. Some of these effects are direct, and some are indirect. Recharge is an obvious parameter that is affected by climate change as it is closely tied to precipitation. If there is more precipitation, there will probably be more recharge, and if there is less precipitation, there will probably be less recharge. Moreover, sea-level rise will extend the area of saline groundwater, resulting in a decrease in freshwater availability for humans and ecosystems in coastal areas (Bobba, et al., 2000). In addition, groundwater recharge will decrease considerably in some already water stressed regions (Doll and Florke, 2005).

Climate change may have negative impact on the quality of groundwater. In coastal zones for example, changing recharge patterns, including reduced long-term recharge and/or temporally variably recharge, coupled with rising sea-level will increase the likelihood of seawater intrusion thereby degrading the water quality in the aquifers. Moreover, increase sea level would also lead to significant problems of dislocation of population. In Saudi Arabia, it is expected that the sea water level will increase by 50 cm and this will result in losing 3747 hectare of costal area. In Bahrain, raising sea water level will result in loosing 5%-10% of total area of the country.

Preliminary climate change and climate variability scenarios for the Arab region indicate that rainfall in the region will become intense and dry spells will become more pronounced. Increased rainfall intensity, is expected to lead to reducing infiltration and potential aquifer charge. The potential sensitivity of aquifer recharge to precipitation is summarized in Döll and Flörke, 2005 who showed that the increase in surface temperature and reduction in rainfall will result in 30-70 percent reduction in recharge in an aquifer located n the eastern and southern Mediterranean coast.

Groundwater supplies will be at great risk from rising sea levels in the ESCWA member countries. Higher sea level would cause seawater intrusion leading to salinization of ESCWA groundwater aquifers close to coastlines. Excessive withdrawal from aquifers will magnify the problem. Furthermore, many GCMs suggest greater precipitation variability and those downpours will become more intense. This would increase runoff and flash floods while reducing the ability of water to infiltrate the soil to recharge the aquifers (Case of hurricane Gono in Oman). Conceptually, seawater intrusion to coastal groundwater resources might pose a threat to Egypt, Lebanon, Syrian Arab Republic and Gulf States.

7. Climate Change Adaptation and Mitigation in Wadi Systems in Arab Region

Over the past decade or more the national and international focus has predominantly been on strategies to reduce greenhouse emissions. There has been, in many countries and in the international negotiations on climate change, an unwillingness to devote serious attention to adaptation strategies. Some level of climate change is inevitable irrespective of emission reduction strategies. This inevitability is reflected in the conclusion of the IPCC in their 2001 Assessment Report that adaptation is now a necessary strategy to complement emission mitigation efforts.

An adaptation strategy, to be effective, must result in climate risk being considered as a normal part of decision-making, allowing governments, businesses and individuals to reflect their risk preferences just as they would for other risk assessments. In this sense, adaptation strategies will fail if they continue in the long run to be seen in a 'silo' separate from other dimensions of strategic planning and risk management. To reach this point, however, is going to require a period of awareness raising, development of the science, and development of techniques for applying it in practical situations. This is a common path in developing public policy in 'new' fields. The first step is to identify priorities.

Many of human and natural systems are strongly influenced by climate. All of our natural ecosystems have evolved in variable, but generally slowly changing climate patterns. Industries and communities are also affected by climate factors. Climate can influence productivity and reliability of supply. The community also expects that our cities and infrastructure will cope with severe weather events efficiently and safely. Improved technical knowledge and modern communications are tending to increase understanding of the relationship between climate exposure and national welfare.

Although climate change is projected to have serious impacts on water resources in the Arab region, only modest efforts and steps are taken in scientific research related to mitigation and adaptation. The scientific community in most Arab countries still suspicions regarding climate change phenomena, and remains hesitant to acknowledge the risks. In addition, Arab countries like other developing countries has low adaptive capacity to withstand the adverse impacts of climate change due to the high dependence of a majority of the population on climate-sensitive sectors, such as agriculture and water resources sectors, coupled with poor infrastructure facilities, weak institutional mechanisms and lack of financial resources. Arab countries are therefore, seriously concerned with the possible impacts of climate change, such as:

- Water stress and reduction in the availability of fresh water due to potential decline in rainfall.
- Threats to agriculture and food security, since most of the agricultural activities are either rainfed agriculture such as the case of Jordan (where about 71% of its cultivated land is rainfed) or irrigated agriculture such as Egypt (where about more than 90% of its cultivated area is irrigated)
- Threats to biodiversity with adverse implications for forest-dependent communities.
- Adverse impact on natural ecosystems, such as wadi Systems, and coral reefs in Arab cities located at Red Sea, grasslands and mountain ecosystems.
- Impact on human health due to the increase in vector and water-borne diseases

The impacts of climate change are inevitable and raise issues of adaptation. Although climate change will affect virtually every sector and region, this part of the study looks at the water resources sector in the Arab countries to illustrate the nature of adaptation problems and policy research needs.

The Council of Arab Ministers Responsible for the Environment has adopted at its 19th session held at the headquarters of the League of Arab States on December 5 and 6, 2007, the Arab Ministerial Declaration on Climate Change, which constitutes the basis for future action and reflects the Arab position in dealing with climate change issues, as follows (Arab Ministerial Declaration on Climate Change (AMDCC, 2007): In most Arab countries, comprehensive national policies to address climate changes have not been adopted to date. In the last two decades a range of acts, regulations and measures, policies and strategies directly related to water scarcity and indirectly related to climate change are developed and even adopted. But effective implementation of the climate change measures may require the development of response measures that are primarily designed to achieve other development objectives. Therefore, development of mitigation and adaptation strategies to protect water resources on Arab region required if national socio-economic goals are to be attained.

The aim of the mitigation and adaptation strategies is to develop a climate change policy that is specifically geared towards more vulnerable sectors in the country and to establish a public policy, which encourages and supports adaptation at local or community level and in the private sector. Another goal is the development of sustainable economic growth, which, in return, allows for a greater allocation of resources to the development of adaptive technologies and innovations. Expected outcomes from these proposed policy actions are as following:

- Reduction of the vulnerability;
- Adaptation to expected climate changes;
- Promotion of sustainable development;
- Reduction of poverty;
- Protection of the environment;
- Institutional strengthening;
- Capacity building on climate change;
- Establishment of the legal framework to address climate change;
- Public awareness on climate change.

In this study, adaptation measures were suggested, along with the current policies and their implications for the vulnerability of the different sectors. The proposed adaptation measures can be included as projects within each national action plan for climate change. The proposed projects have many cross-cutting issues with other sectors and therefore shall be compiled with similar projects under the same programs. Adaptation policies should be implemented to enhance and facilitate actions that will reduce Arab countries' vulnerability and improve their resilience to climate change. For adaptation measures to be successful, leadership is required to inspire confidence and agreement among all levels of government, the private sector and civil society

Prioritizing adaptation action requires the identification of vulnerable systems — human and natural such as water sector — the costs if these fail, the scope to reduce this risk, and the ability to capture any potential benefits. Vulnerability is a function of exposure to climate factors, sensitivity to change and capacity to adapt to that change. Systems that are highly exposed, sensitive and less able to adapt are vulnerable. Adaptation strategies therefore involve the identification of sectors/systems/regions vulnerable to change and an examination of the scope to increase the coping capacity of those systems — their resilience — which in turn will decrease that vulnerability. Prioritization will also depend on identifying vulnerable systems or regions whose failure or reduction is likely to carry the most significant consequences.

7.1. Adaptation measures for water resources sector

The availability of water is essential for many industries and other natural resources. Every major mainland city faces water stress already. In many cases climate change will increase these pressures through increased temperature and possibly lower rainfall combined with more frequent ENSO events. Dams could be susceptible to extreme rainfall events if these exceed historical design standards. Dam overtopping and failure can have catastrophic short and medium term effects in terms of human and economic losses.

Adaptation options for urban water and dams could include systematic inclusion of climate risk — on both the supply and demand side — in all major urban catchments. There is much work already progressing in this area. Similarly, collaborative work on assessment of non–conventional water supply sources — desalination, water recycling — and on demand management could be a high priority under the National Water Strategies.

The projected impact of climate change globally is likely to exacerbate the water stress and shortages in some part of the Arab region and also increased flooding in another part. Thus, there is a need to develop and implement adaptation measures. These strategies may range from change in land use and cropping patterns to water conservation, flood warning systems, crop insurance, etc.

Measures already adopted to counter the growing water scarcity in Arab countries such as water conservation and finding additional water sources (desalination and wastewater reuse), water demand management, will also serve as future adaptations to climate change. In their efforts to adapt to climate change and water scarcity problems, the Arab countries Ministries of Water issued water strategies and several policies to conserve water and seek alternative supplies. In addition to optimizing the use of rainfall-fed recharge in some basins to augment storage in the main basins to increasing water use efficiency, water harvesting systems, wastewater reuse, virtual water, and desalination were identified as potential adaptive measures to water scarcity.

The future strategies that will be formulated in Arab countries for coping with the climate change impacts on national water resources will be similar to the current strategies for coping with the ever increasing demands and shortages. A prerequisite to adaptation is the application of an Integrated Water Resources Management strategy at different levels of usage from individual households to local communities, and watersheds to catchments. The current strategies to adapt to the two extreme events, namely floods and droughts, will hold good even to the projected impacts of climate change. The present structural or non-structural measures of surface water storage will continue to be valid.

Improving the water availability through the year, soil and water conservation, equitable water distribution, traditional water conservation practices, and groundwater recharge, are examples of adaptation strategies.

There is no single ‘best’ coping strategy. The best choice is a function of many factors pertaining to economic efficiency, risk reduction, robustness, resilience, reliability, etc. The emerging technologies for short-term weather forecast for real-time water management and operations have a large potential to enhance the coping capabilities to climate variability and change. Such advancements will greatly improve the irrigation water management efficiency. Biotechnology holds promise that may help in increasing crop yields while reducing the water requirement and developing crops that are less dependent on water

Adaptation strategies for the water resources sector may be developed in response to results of the water resources management models, or be suggested as general guidelines to enhance the overall efficiency of the water resources operation. The sector has much scope for adaptation and has also shown capacity to adapt in the past.

Water vulnerability and adaptation to climate change should therefore be part of sustainable water resources environment and integrated development policies designed to:

- Build on the existing policies to protect water resources, the environment and economic development against current climate (the adaptation baseline)

- Make incremental changes to the adaptation baseline to mitigate effects from the direct and indirect climate change (climate change adaptation)

Taking into account the scarcity of water resources and their anticipated decrease in many Arab countries resulting from climate change, the following adaptation measures can be taken:

Regional cooperation

Mitigating climate change impacts necessitate the enhancement of regional cooperation, since this phenomena will have an impacts on all the countries in the Arab region. It is essential to establish regional early warning system which its main mission is forecasting and risk assessment of extreme events, i.e. droughts and floods.

Finalizing the shared water resources agreements

As it was previously mentioned climate change may also reduce shared water resources such as Euphrates and Tigris flow by as much as 30-50% (ESCWA, 2008). The same as well for other shared rivers with Lebanon and Jordan .In the meantime water demand will continue to increase in different countries sharing the same water bodies due to population growth and the increasing of atmospheric temperature which leads consequently to increase the evapotranspiration rate and to an increase in water demand for agriculture All these issues will be faced by the different countries of the region where most of the water resources are shared between them and raise the issue of equity and increase the potential for political conflict .

Surface Water Development

- Optimize the development and use of this resource through supply-enhancing measures, including surface and subsurface storage, minimizing losses by surface evaporation and seepage, soil and water programs, and protecting surface water supplies from pollution.
- Development of sustainable management plans for surface water in wadi systems, conversion of open canal systems to a pressurized pipe system, giving priority to modernizing and upgrading systems, and precedence to water projects which make significant contributions to meeting rising municipal and industrial demands.
- Dams are required for storing the floods during the wet winter season and releasing the water gradually during the summer season when the demand is high. Besides these "ordinary" reservoirs, so called desert dams (Water harvesting) help to increase groundwater recharge and to provide water for pastoral use. Use of Hafeers, contour bunding, gully plugging, and check dams and dykes should be promoted to catch rainwater and increase water available for agricultural use.

Groundwater Protection

Most of groundwater aquifers are exploited at more than double of their safe yield in the average. The sustainability of irrigation in the highlands and the Badia areas will be greatly endangered unless strict measures are taken to address this issue. As such, the development and implementation of an action plan is needed in order to ensure that plans for groundwater protection, management, monitoring and restoration are defined, integrated and managed in a cost-effective manner (JSNC, 2009).

In order to improve the groundwater situation in Jordan, the Ministry of Water and Irrigation is establishing an integrated program to assess the availability and exploitability of all resources at rates that can be sustained over long periods of time.

The mining of renewable groundwater aquifers will be checked, controlled, and reduced to sustainable extraction rates. The Ministry will further encourage the application of applied research activities, including artificial recharge to increase groundwater supplies, and the employment of new technologies that will optimize the operation and development of groundwater systems and promote its more efficient and feasible uses.

The existing laws in Jordan are strong enough to control the use of and protect groundwater resources. However, the application of these laws is still unsatisfactory, thus suggesting the need for future strengthening of law enforcement through adequate penalty system. The guidelines for the implementation of groundwater protection are being prepared. Implementation of these areas requires not only legal, but also technical and institutional support.

Priority action needed for groundwater resources protection in Bahrain are (Al-Jeneid et al. 2008):

(a) Formulation an integrated water resource management plans to rationalize water use and protect aquifers from being excessively salinized.

(b) Legalize and institutionalize reuse of sewage treated water

Enhance use and development of Non-conventional water resources:

Non-conventional water resources may be defined as water resources that are not readily available and suitable for direct beneficial use including wastewater reuse, water desalination, and weather modification. Enhance use of alternative water resources such as reuse municipal wastewater, use of seawater/brackish water desalination, and the use of submarine springs with significant flows are located along Lebanese and Syrian coastal Area. The most common source of non-conventional water is treatment of domestic and industrial wastewater. Wastewater reuse is becoming more popular throughout the world, particularly in arid and semiarid regions because it can reduce the environmental and health related hazards if planned properly and also in increasing the crop yields because of supplemental irrigation and the nutrients within the wastewater.

Jordan is a good example for using this source of water to alleviate the water scarcity problem. In the last 3 decades about 25 municipal wastewater treatment plants were operated in Jordan. The effluent of these plants is planned to be used for irrigation around the plants or discharged to wadis or reservoirs where it is diluted and utilized for agriculture.

Brackish water is another of non-conventional source of water that can be utilized after treatment. In order to further pursue the brackish water option, the ministries of water in Arab countries should assess the potential of brackish water resources in terms of sound technical, economic and environmental feasibility in all groundwater basins, and then conduct research and studies on desalination and on optimization of brackish water use in agriculture and industry.

Water Quality and the Environment

Arab countries have witnessed some deterioration in its water quality in the last two decades due to industrial pollution, overuse of agrochemicals, drainage water, overloading of wastewater treatment plants, over pumping of aquifers, seepage from landfills and septic tanks, and the improper disposal of dangerous chemicals by certain industries. Overloading of the existing waste water treatment plants due to high population growth and society development have further degraded the effluent from most wastewater treatment plants. The performance of many of the plants is inadequate, resulting in an effluent of low quality. This effluent may have an adverse effect on public health due to the presence of pathogens or the accumulation of toxins in soils irrigated using effluent. Furthermore, pollution of surface and groundwater due to seepage will result in the deterioration of the water quality of some water resources and will limit their use for different purposes. Enforcing standards for wastewater discharges to sewers, treated effluent and water for other uses is essential. Thus, the standards adopted should consider national priorities, economics, and availability of water supplies, as well as health and other environmental implications. Implementation of standards and their enforcement require facilities and expertise, which involve significant costs. Enforcement, particularly, requires commitment and coordination between many agencies and at many levels within the government. Adopting and implementing of guidelines for water used in irrigation by water ministries in Arab countries, in cooperation with the related ministries, increases the availability of water that can be used in irrigation.

Strengthening Water Resources Monitoring System

Enhance monitoring efforts to improve data for weather, climate, and hydrologic modelling to aid understanding of water related impacts and management strategies. In addition, databases that support water resources and environmental management should be integrated.

Measures to Improve System Efficiency

The overall efficiency of water resources system is low, due to losses in the system, system constraints, and inefficient farm practices, and also due to the constraints of funds and inflow patterns. In the precipitation increase scenario, adaptation measures to increase efficiency may include the adoption of better farm management and irrigation practices. Special care should have to be taken to control the high waters in the root zone which considerably reduce the acreage of the crop. Precision land leveling and proper field sizing may be required.

Implementation of integrated watershed management practices

Implementation of integrated watershed management practices can play an important role in the rationalization of resource use and allocation and protection of sources (both surface and groundwater) and use pricing and market mechanisms proactively to increase efficiency of water use. An effective and economically beneficial adaptation option lies in the construction of dams over all potential wadis. The finite nature of renewable fresh water makes it a critical natural resource to be examined in the context of population growth and climatic changes. Fresh water availability is dictated to a large extent by climate, and particularly by the timing and location of precipitation and by evaporation rates and varies tremendously from season to season. Watershed protection would also have benefits for groundwater storage and flood alleviation.

Urban Water Use

There is an urgent need to devise policies, both economic and structural, to practice water conservation in the urban areas to lower the rising pressure on the drainage and supply systems and to lower the pressure on sewage treatment, which has become essential for the preservation of water quality.

Flood Control

Flash floods have a varied impact on different areas (desert wadis and rural areas). Proper risk and vulnerability analyses for each flood prone area need to be carried out in the changed climate. For the vulnerable areas, current topographic maps are needed. The flood control authorities should keep up-to-date records of settlements and infrastructure development. A clearance from the flood protection agency may be required for erection of settlements and infrastructure in the new areas.

Research Programs

In Arab countries, few and limited studies were published in the field of climate change, and there are many gaps that still need to be filled in the future, especially pertaining to the vulnerability and adaptation of water resources, agriculture, and health sectors. Climate change studies are based in most cases on using modelling, remote sensing and projection techniques, but, due to the lack of facilities and low allocated funds for the Arab research institutions, the empirical and experimental techniques are still applied.

The assessment of climate change impacts, and vulnerability and adaptation to climate change, require a wide range of physical, biological and socioeconomic models, methods, tools and data. The methods for assessing the vulnerability, impact and adaptation are gradually improving, but are still inadequate to help policy-makers formulate appropriate adaptation measures. This is due to uncertainties in regional climate projections, unpredictable response of natural and socio-economic systems and the inability to foresee future technological developments.

Continuing research will lead to better and more precise information about the impacts of climate change on water resources over the Arab region. Using statistical and dynamic downscaling with regional model opens doors to generate high resolution climate change scenarios and to investigate their impacts on a regional scale.

Natural resource planning for the future is difficult without more significant and reliable data keeping in mind demographic variation and without an understanding of the phenomenological response of the biological ecosystem to climatic changes. There is a need for the development of mathematical models and research to find out the phenomenological responses of various subsystems of the environment in order to assess the impacts of climate change on sectors such as water resources.

Few and limited studies on mitigation and adaptation are developed in the Arab countries. In Morocco, a drought insurance program based on rainfall contracts is an important example of adaptation strategies, and it had a potentially significant benefit over the current scheme, minimizing drought hazard and protected the cereals production (IUCN, 2003). Shoreline protection along the northern coast of Egypt is another obvious example of an adaptation strategy (El-Raey, 1999).

Public awareness and Stakeholder capacity programs

Public awareness on the issue of climate change in the Arab countries is still in its early stage of development, and most of them highlighted the challenges they faced in improving it. The Arab society is not aware of the consequences of the global CC. Better environmental public awareness is needed. This process needs to be facilitated by individual public debates, increase media interest in the problem and intensify activities by nongovernmental organizations in this area. Public interest and support are crucial for the application of the long-term governmental strategy and CC policy. Few of the NGOs in the Arab countries are interested in the CC and its dissemination.

There is a need for capacity building to enable the environmental authority, to play a major role in planning, coordinating and implementing adaptation programs of action. Their capacity needs to be strengthened in terms of human, financial, technical and technological resources. These awareness could be achieved using means included, workshops, radio and television programmers, newspapers, films, pamphlets and web sites.

7.2. Barriers to increased adaptive capacity

Each country has its own specific barriers to the implementation of adaptation and mitigation measures, such as limitations in financial and technical resources, human and institutional capacity, its legislative framework, and public support. The most widely recognized barriers are considered below. Vulnerability and adaptation assessment in the first and second national communications carried out by various Arab countries have identified the following barriers to adaptive capacity.

- Inadequate conveyance, collection and treatment infrastructure
- Poor or lack of industrial pre-treatment
- Poor or inadequate facility operation maintenance programs
- Inadequate access to technology
- Insufficient capital to fund a domestic wastewater pollution management program
- Limited human resources, equipment and facilities at water ministries as well as other related ministries
- Lack of coordination and poor exchanging of knowledge and experience among agencies associated with wastewater reuse as well as with national or municipal level planning programs
- Weak capacity in conducting surveys, assessments, investigations, and applied scientific studies to evaluate and predict health impacts caused by wastewater reuse
- Limited number of educational and awareness programs on safe wastewater reuse
- Lack of enforcement of existing regulations
- Inadequate inventory of communities use of treated wastewater
- Lack of classification for sensitive or unique water bodies, watershed, and habitats or ecosystem
- Poor or lack of monitoring to assess environmental progress
- Lack of stakeholder participation
- Limited studies on diseases associated with wastewater discharge or reuse
- Lack of financial resources to implement adaptation measures for climate change.

- Lack of a clear and specific legal and policy framework for climate change issues in the country. There is no legal framework that has been directed to ensure that climate change issues at various levels are properly institutionalized in the planning process. This is so, because most adaptation interventions that are identified to reduce the risks of increasing climate variability would require further “fine-tuning” of existing policies and programs to make them relevant and robust.)

- Lack of awareness of the extent of the problem as well as possible actions that could be taken, is the foremost amongst these barriers. This lack of awareness exists at all levels from national level policy makers to sectoral and local level officials as well as amongst civil society and the most vulnerable communities themselves. Therefore, awareness raising is clearly a major area of initial action to be prioritized.

- Lack of incorporation of climate change impacts in developing policies, plans and programs in some of the most climate sensitive sectors (e.g. water management, agriculture, disaster management, etc.). True the need for such integration is being slowly realized. Yet, the actual integration in planning, designing and implementation of then policies still exists and therefore needs to be accelerated considerably.

- Lack of adequate tools, knowledge and methodologies to provide guidance and advice to the people making their decisions. This is equally applicable at the technical level in different sectors, e.g. water management but also at the grassroots levels for the vulnerable communities themselves. Thus generating good knowledge, data, methodologies and tools (and then disseminating them) will need to be an important activity in the short term

- Lack of private sector involvement in issues related to climate change.

- Limited understanding of concrete or best practices/ activities of what constitute to be adaptation to climate change;

- Monitoring and evaluation plans including environmental impact assessments are weak and lack best standards and practices that consider climate change implications and climate as a non-static element. Current deliberate efforts to address the problem of climate change are more reactive than futuristic.

7.3. Toward strategies for adaptation to climate change in Arab Countries

Since climate change is so pervasive and may have an impact on all economic activities, it is clear that everyone is potentially involved in the development and implementation of adaptation measures. Thus a first question is: Who adapts? If adaptation is left to everyone the probability is that it will be left to no one. The more pertinent question therefore concerns the distribution of responsibility for adaptation.

How is a nationwide effort to be organized? Clearly a program of action that requires the involvement of everyone including all levels of government, the private sector and civil society will not happen unless leadership is provided. And such leadership must be sufficiently clear to inspire confidence and agreement. The simple admonition “Adapt!” will hardly suffice. On the other hand, a strongly directed, top-down approach is not likely to be acceptable to Canadians.

International research on adaptation policy provides some insights into this question. It is widely accepted that planned adaptations to climate risks are most likely to be implemented when developed as components of existing resource management programs, or as part of regional or national programs for sustainable development. For example, studies in the United States dealing with the water resources sector suggest that regional adaptive management is the most appropriate venue for developing strategies for coping with climate change. Adaptive management is essentially learning by doing, by conducting management experiments in consultation with resources users from economic, social and environmental perspectives. Other considerations are the development of risk management tools to help develop and evaluate adaptation options.

To develop a comprehensive National Action Programme on Climate Change (NAPCC) in Arab countries, the following points should be considered:

1) The future National Action Programme on Climate Change (NAPCC) should be not only aimed to meet the UNFCCC obligations, but also to set priorities for action and integrate climate change concerns into other national and sectoral development plans and programmes.

2) During the development of the NCCAP the lessons learned from past climate change and environmental planning efforts, are considered. These include:

- Integration with other development plans and programmes and measures that have multiple benefits
- Involvement of key governmental and non-governmental stakeholders.
- Practical orientation
- Flexibility of the plan in order to be regularly updated, to reflect changing circumstances.
- A high level of awareness among policymakers and stakeholders on climate change issues

3) The NCCAP should be developed as an integral part of other national and sectoral action plans and policy documents. Therefore, the success of the measures and actions that will be identified in the NCCAP will depend directly on the degree of integration of these national and sectoral development and action documents. Climate change concerns and problems are not reflected directly in these policy documents.

However, some of them include climate change matters. In case of the absence of such climate change related issues in a policy document, these issues should be taken into account in implementing activities under these programmes or plans. Existing environmental regulations, sectoral development policy documents, and other related laws need to be amended if this is required for adaptation or mitigation activities.

The passing of new laws or amendment of existing laws—in particular policy or development programmes or plans guiding different economic sectors—should follow national and sectoral strategies and policies related to climate change concerns.

4) The NAPCC should be based on pre-feasibility studies on climate change impact and adaptation assessment, GHG) inventories, and GHG mitigation analysis. The Action Programme should include a set of measures, actions and strategies that enable vulnerable sectors to adapt to potential climate change and mitigate GHG emissions. The underlying philosophy of these measures is that they should not adversely affect economic development and current lifestyles.

5) The implementation strategies in the NAPCC should include institutional, legislative, financial, human, education and public awareness, and research programs, as well as coordination with other national and sectoral development plans. Existing barriers to implementation should be also identified, as well as possibilities to overcome such barriers. Finally, the programme should consider several adaptation measures for water resources, agriculture, livestock, rangeland, costal resources, and human health as well as other related sectors.

6) Research activities should focus on systematic observation and monitoring of the climate system, development of climate scenarios, vulnerability assessment, potential impacts on ecosystems and society, and possible measures to adapt to climate change and mitigate GHG emissions at the national level. A regular update of findings and outputs using the latest scientific knowledge of global climate change problems will be critical. Based on comprehensive studies and analyses, the NAPCC should be revised from time to time in order to facilitate the implementation of country's policy on climate change.

7) It is recommended that a considerable amount of capacity building and institutional strengthening take place. Education and public awareness activities should be organized for decision-makers, technical experts, stakeholders, the general public, students, and school children. A regular review of the level of public awareness of climate change will be essential to increase public participation in the GHG mitigation

activities. Options for informal education in the field of environmental protection include use of mass media (newspapers, television, radio etc.) and organization of conferences and workshops for specialists, the general public and the press.

8) Social and economic instruments play increasingly important roles in the successful implementation of the NCCAP. Economic instruments could take a limiting (taxes) or promoting (subsidies etc.) approach. Limiting measures include pollution tax, input tax, product tax, export taxes, import tariffs, etc. Promoting measures may include subsidies, soft loans, grants, location incentives, subsidized interest, revolving funds, sectoral funds, eco funds, green funds, tax differentiation or exemption, investment taxes credits, tax relief for environmental equipment or investment, etc. Therefore, it is necessary to establish economic mechanisms and instruments to implement the NAPCC, and to introduce an appropriate legal framework.

9) The availability of funding sources is a prerequisite for successful implementation of the adaptation and mitigation strategies and projects identified in the NCCAP.

Possible sources of such funding include:

i. Government funds and resources

ii. Local and International Environmental funds

iii. Private sector investors

iv. Global Environmental Facility (GEF)

v. Clean Development Mechanism initiatives

vi. The UNFCCC and Kyoto Protocol Implementation Mechanisms such as Transfer of Technology, etc.

There are currently four different funds for supporting adaptation measures in non-Annex I countries: the Special Climate Change Fund (SCCF) and Least Developed Country Fund (LDCF) under the UNFCC, the Adaptation Fund under Kyoto Protocol and the Strategic Priority on Adaptation (SPA) of the Global Environment Facility.

Conclusions

This study recognizes an alarming deficiency in scientific and technological capabilities, as well as the political will to address and face problems posed by climate change in the Arab region. Not enough scientific facilities exist to study this phenomenon, insufficient funds are allocated to such research, and the studies that are undertaken still leave gaps to be filled. Climate change mitigation and adaptation need to be integrated into development strategies, and issues of planning, scientific capacity, stakeholder involvement, and public awareness need to be urgently addressed.