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^3 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^2 in the case of the Zahrani river in Lebanon, and 2.8 million km^2 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^3/year of which 204 billion m^3/year are surface flows and 40 billion m^3/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^3/year) to one quarter for Sudan (18.5 billion m^3/year), three quarters for Egypt (55.5 billion m^3/year) and the remaining 10 billion m^3/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^3/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 virtually 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^3 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 influences 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 21st 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 rainfed 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.

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

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:

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.

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, 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 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.

REFERENCES

Agrawala, S., A. Moehner, M. El Raey, D. Conway, M. van Aalst, M. Hagenstad and J. Smith (2004). Development and Climate Change in Egypt. Focus on Coastal Resources and the Nile. Organization for Economic Co-operation and Development (OECD).

Allen, J.A. (2002). The Middle East Water Question, Hydropolitices and the Global Economy. London and New York: I. B. Tauris.

Arab Center for the Studies of Arid Zones and Dry Lands (Damascus), UNESO Regional Office for Science and Technology for Arab States (Paris) and the International Institute for Hydraulic and Environmental Engineering IHE (Delft). (1988). Water Resources Assessment in the Arab Region. IHP, Paris.

Assaf, H. (2009). Climate Change: Potential Impact on Water Resources in the Middle East and Adaptation Options. Research and Policy Memo #2, *Research and Policy Forum on Climate Change and Environment in the Arab,* Issam Fares Institute for Public Policy and International Affairs, American University of Beirut (AUB), Lebanon.

Baetting, M.B. (2008). 'Measuring Countries' Cooperation within the International Climate Change Regime', Environmental Science and Policy, 11:478-489.

Brown, O., A. Hammill, and R. Mcleman (2007). 'Climate Change as the New Security Threat: Implications for Africa'. International Affairs, 83(6): 1141-1154.

Chin, J. (2008). 'Coping with Chaos: The National and International Security Aspects of Global Climate Change'. The Journal of International Policy Solutions, 9:15-26.

European Environment Agency (2009). Environmental Terminology Discovery. At: http://glossary.eea.europa.eu/terminology/

Expert Consultation on National Water Policy Reform in the Near East Beirut, Lebanon 9 - 10 December 1996.

Fagan, B. (2005). The Long Summer, How Climate Changed Civilization, New York: Basic Book Publishing.

Fujihara, Y., K. Tanaka, T. Watanabe, T. Nagano, and T. Kojiri (2008) 'Assessing the Impacts of Climate Change on the Water Resources of the Seyhan River Basin in Turkey: Use of Dynamically Downscaled Data for Hydrologic Simulations', Journal of Hydrology, 353:33-48.

Giorgi, F (2006). 'Climate change hot-spots'; *geophysical Resources Letters*, 33, L08707.

Haddad, B.M. (2005). 'Ranking the Adaptive Capacity of Nations to Climate Change when Socio Political Goals are Explicit'. Global Environmental Change, 15:165-176.
Halwani, J. (2009). 'Climate Change and Water Resources in Lebanon', IOP Conf. Series: Earth and Environmental Science, 6.

Intergovernmental Panel on Climate Change - IPCC (2007). Special Report on the Regional Impacts of Climate Change and Assessment of Vulnerability.

Jorgensen, D. and W.Y. al-Tikiriti (2002). 'A Hydrologic and Archeologic Study of Climate Change in Al Ain, UAE'. Global and Planetary Change, 35:37-49.

Kouri, Jean (1995). Rainfall Water Management in the Arab Region ROSTAS, Cairo.

Personal Communication (2009). Investigating the Climate Sensitivity of Different Nile Sub-Basins, Thirteen International Water Technology Conference, IWTC 13 2009, Hurgada, Egypt.

Ragab R. and C. Prudhomme (2002). 'Climate Change and Water Resources Management in Arid and Semi-Arid Regions: Prospective and Challenges for the 21st Century'. Biosystems Engineering, 81(1):3-34.

Second Expert Consultation on National Water Policy Reform in the Near East, Cairo, Egypt 24 - 25 November 1997.

Spiess, A. (2008) 'Developing Adaptive Capacity for Responding to Environmental Change in the Arab Gulf States: Uncertainties to linking ecosystem conservation, sustainable development and society in authoritarian rentier economies', Global and Planetary Change, 64:244-252.

Strezpek, K.M., D.N. Yates, and D. El Quosy (1996). 'Vulnerability Assessment of Water Resources in Egypt to Climate Change in the Nile Basin'. Climate Research. 6: 89-95.

Thomas, R.J. (2008). 'Opportunities to Reduce the Vulnerability of Dry Land Farmers in Central and West Asia and North Africa to Climate Change Agriculture'. Ecosystems and the Environment, 126:36-45.

United Nations Environmental Program - UNEP (2005). Facing the Facts: Assessing the Vulnerability of Africa's Water Resources to Environmental Change.

علم المناخ – أوستن ملر تعريب د. محمد متولي – د. إبراهيم رزقانه.

الآثار المستقبلية للتغيرات المناخية – حالة مصر – د. عبيد شقوير، د. نهلة السباعي – قضايا مستقبلية – مركز الدراسات المستقبلية – مركز المعلومات ودعم اتخاذ القرار – مجلس الوزراء – جمهورية مصر العربية (2007).

عالم الفكر المجلد 37 اكتوبر – ديسمبر 2008 – الاحترار العالمي.