Review of Climate Change Research in Egypt

By: Mohamed Nour El-Din[1]

Mohamed AA. Sayed[2]

Objective

The objective of this paper is to review climate change research activities on the main different sectors in Egypt. This review will be the baseline for determining activities of the proposed collaborated project: ICCAP.

I. Introduction

The Third Assessment Report of the IPCC states that the global average temperature is likely to rise above the 1990 level in a range between 1.4 and 5.8°C by 2100 (IPCC, 2001a). Some of this warming has already been experienced, although the associated impacts remain difficult to identify with certainty given the confounding factors of natural climate variability and social change. In fact, the longer-term impacts of climate change, will include shifting supply and access to key resources such as water. North Africa and the Southeastern Mediterranean appear to be highly vulnerable to climate change, but there are insufficient national or regional studies to reach precise conclusion. Egypt's vulnerability to climate change is acute. Rapid increases in population and urbanization will aggravate this vulnerability, given the strong linkages of the Nile River, Nile Delta, Coastal resources, and surrounding deserts. This paper reviews the most relevant climate change studies in Egypt that highlights some impacts and adaptation options to the three main sectors that are highly vulnerable: water resources, agriculture, and coastal zones.

II. Review of Research Activities on Climate Change and Water Resources in Egypt

The impacts of climate change on water resources supply, availability, and demand will have direct and indirect effect on a wide range of institutional, economic and social factors. The ability of society to adapt and the nature of these effects are not well understood because of the complicated and unpredictable nature of water resources. Besides, the impacts are non-linear, and water resources will be under additional stress due to population growth and competition for financial resources from other sectors, disputes, and water allocation priorities. Besides, present water systems are optimally designed to cope with current climatic conditions and therefore are sensitive to any changes in those conditions. In addition, the changes in the operating rules need to be closely and precisely examined to see if they can reduce the risks of being associated with a system of a fixed infrastructure and designs.

Egypt is always considered as a gift from the Nile. The Nile supplies Egypt with 95 % of its fresh water resources. The Nile River runs from its origins in the equatorial heights and the Ethiopian plateau for a distance of about 6,500 kilometers where it crosses 5 different

[1] Professor- Ain Shams University, Faculty of Engineering, Civil Engineering Department, Tel. 02-3375030, email: mhmdnour2@hotmail.com

[2] Manager, Hydrologist, Nile Forecast Center, Ministry of Water Resources and Irrigation, email:maaty_sayed@yahoo.com

climatic regions until it reaches its final destination in the Mediterranean. The runoff-index of the Nile is about 4 to 5 %, which is one of the lowest indices among all rivers. The hydrology of the Nile has been always of interest to many researchers who tried to understand its specific characteristics as the longest river in the world where the oldest civilization was developed at its final route in Egypt.

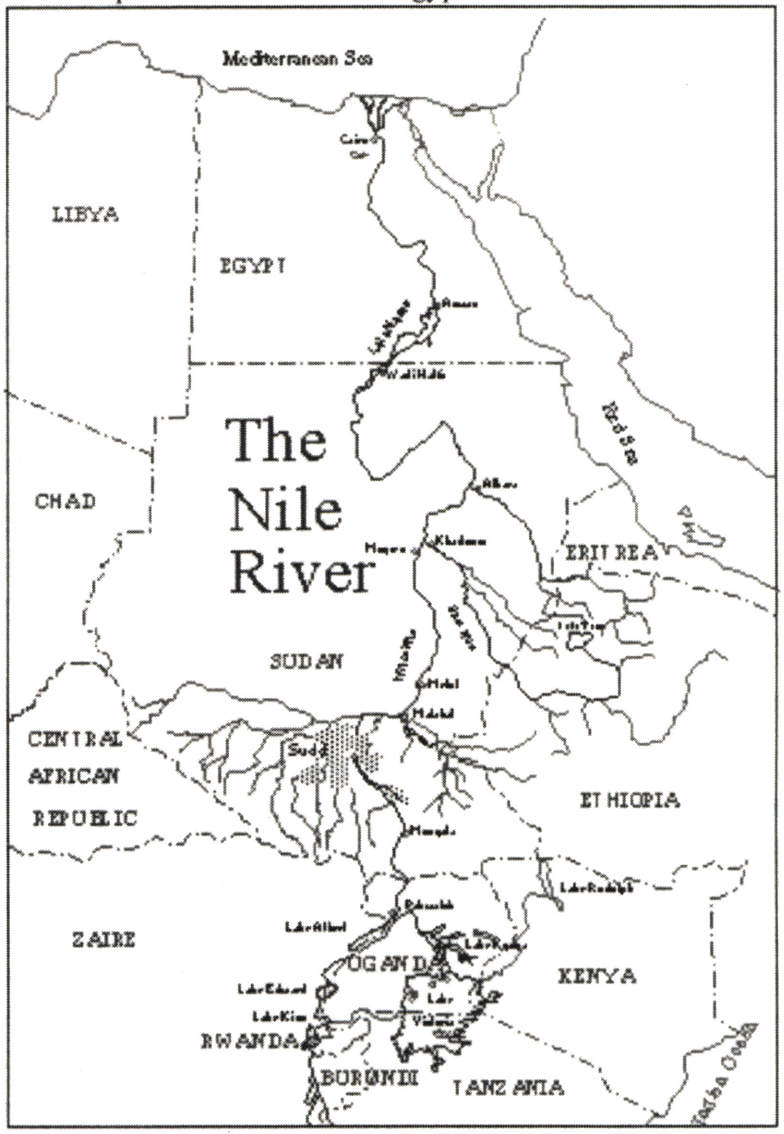


Figure 1: The Nile Basin

Although there are many climate change studies focusing on the expected variations in the Nile flows, they are not sufficient to assess the impacts with enough confidence. This is due to the imperfect knowledge of future rates resulted from human-made emissions, and how these future emissions will change the atmospheric concentrations of greenhouse gases. Besides, there are many uncertainties associated with timing, direction and extent of these climatic changes as well as their implications for societies. These uncertainties have great influence on the rational water-resources planning in the future. However, these uncertainties should not paralyze policy makers and water managers and stop them from rethink and re-evaluate current policies. The following paragraphs summarize some of the available literature regarding climate change and water resources in Egypt.

1- Eldreage at al. (1986) indicated that there was a progressive decline of 3 to 5 mm/year in the amount of rain falling over the Sahel zone since the beginning of the century. For the last 20 years, rainfall in most of the Sudan had dropped to some 70% of the normal average. Further analysis is needed to address this issue in relation with climatic changes

2- A study by Lema (1989) investigated climate elements, cryspheric observation of ice and mountain galleries, and hydrologic observations of river stage and lake levels over East Africa during the last one hundred years (1880-1980). The study showed that there was no indication of significant departure of rainfall from the average persisting for appreciable number of years. It was concluded that from four indicators of climatic change surveyed that there was no conclusive evidence of climatic change in East Africa during the period 1960-1990.

3- Gleick (1989) studied the fluctuation in the runoff of the Nile basin due to climatic changes. He stated that a clear view of the future climatic changes is obstructed by many uncertainties about the physical behavior of the atmospheric system, by poorly understood interactions between the atmosphere and the ocean, and by unanswerable questions about human behavior and action. He added that, where water resources are shared, as in the case of international river basins, the possibility of frictions varies from region to region, from disputes over water quality in humid regions, to competition for scare resources in arid and semi-arid regions.

4- Hulme (1989) analyzed the precipitation records for various catchments of the Nile river basin for any changes and found out that there would be a decline in precipitation totals in general and it would be minimal for the upper White Nile catchments. However, he suggested that the 20th century precipitation characteristics are unlikely to be a reliable guide for the 21st century precipitation. He emphasized the need for a greater flexibility in the Nile basin water management.

5- Conway and Hulme (1993) investigated the fluctuations in precipitation and runoff over the Nile sub-basins and their impacts on the Main Nile flow. It was concluded that the significant fluctuations of the historical discharge of the Main Nile were largely influenced by fluctuations in precipitation or runoff between the White Nile and the Blue Nile regions. They concluded also that it is not yet possible to predict future climate change with a high degree of confidence. There are large uncertainties in the climate scenarios derived from GCMs, particularly in the precipitation change. There is no universal method for ranking GCM's performance or reliability and so, for the present, there is no clear signal as to whether future Nile flows will remain unaltered, increase or decrease as a result of global warming. So, future Nile flows are critically dependent upon the chosen GCM scenario. However, the Blue Nile runoff is moderately correlated to Sahilian precipitation, while the White Nile precipitation responds more to changes in the Equatorial circulation.

6- Conway (1993) assumed a global temperature rise of 1° C by the year 2025. The seasonal increases in temperature and rainfall for the different sub-basins of the Nile according to three different models are given in the following Table (1).

Sub-Basin/Model	Temperature Increase (C)				Precipitation Change (%)			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
Lake Victoria								
GFDL (Dry)	0.63	0.69	0.64	0.67	25	-2.6	4.8	-3.3
GISS(Wet)	0.94	0.94	0.59	0.85	1.2	5.8	36.4	3.8
Composite	0.88	0.82	0.98	0.83	3.4	6.6	5.6	5.3
Equatorial Lake								
GFDL (Dry)	0.65	0.64	0.60	0.62	2.5	2.3	2.7	-0.5
GISS(Wet)	0.98	0.94	0.87	0.87	3.7	5.8	4.4	0.9
Composite	1.12	0.96	0.95	0.95	11.3	4.7	3.8	4.5
Sudd Swamp								
GFDL (Dry)	0.69	0.68	0.63	0.63	2.8	-1.7	2.9	1.8
GISS(Wet)	0.98	0.93	0.70	0.87	7.8	9.6	5.6	1.5
Composite	1.12	0.96	0.85	0.95	11.3	4.7	3.8	4.5
Blue Nile								
(Dry)	0.73	0.67	0.67	0.65	-3.1	-2.1	-1.1	-2.4
GISS(Wet)	0.96	0.86	0.64	0.87	12.94	14.4	6.4	1.9
Composite	1.10	1.00	0.94	1.00	.0	-1.1	2.6	3.6

Table (1): Seasonal Changes In Temperature And Rainfall In The Sub-Basins Of The Nile

7- Wigley (1993) presented a study of climate change impacts on rainfall over the Mediterranean region. The study concluded that a warming of about 3.5° C spread uniformly over the seasons would be the best guess, an expected increase in winter precipitation over most of the basin, and the projected precipitation in Egypt would decrease.

8- Saleh et al., 1994, initiated a research project to evaluate the climate change impacts on four main river basins including the Nile River. The main goals of the project were: i) to assess the physical and social elements that are sensitive to climatic changes , ii) to simulate the impact of climatic changes scenarios on water resources in each basin, iii) to assess and quantify the variations in the water resources related activities due to changes in the basin water supply, iv) to identify potential adjustments in basin management and planning. Three GCMs were applied to assess the climatic change effects on the basins. For the Nile basin, the available data for the period 1951-1980 was used as baseline conditions. GCMs were used for doubled CO2 and 4 degree Celsius warming with no change in precipitation and 20% increase and decrease in precipitation applied with the base period. Two GCMs showed reduction of 20 and 70 % in annual river flow at Aswan, while the other GCM showed 30% increase in Aswan flow. The study concluded that the Nile River flows throughout the basin are extremely sensitive to temperature and precipitation changes.

9- El-Quosy (1994, 1995) presented a study on the vulnerability of fresh water resources in Egypt to climatic changes. His study concluded that both water levels of lake Victoria have risen form an average of 11.05 m above msl during the period 1960-1990 to 12.22 m in 1990. The corresponding change of flows was from 660 m^3/s to 1200 m^3/s. The study also commented that it has been noticed that the frequency of droughts and their intensities has considerably increased during the past two centuries.
He also explained that deep groundwater in the Western Desert, Eastern Desert and Sinai Peninsula are all fossils and not directly affected by climatic changes. It is expected that shallow groundwater originating by seepage from the agricultural lands and the irrigation network in the northern Nile Delta is most vulnerable to climatic changes. Also, the seawater intrusion induced by climatic changes would affect the quantity of abstraction from the shallow GW wells. He discussed the possible increase in agricultural water requirements as a result of a rise in temperature. It is anticipated that due to the change in temperature patterns and the increase of carbon dioxide content, crop productivity would be higher as well. This would mean that climatic changes might cause increase in water demands but productivity per unit volume of water might also increase.

10- Strzepk et al. (1995) presented data on changes in temperature and rainfall in the Nile basin when the CO2 concentration in the atmosphere would double. They assumed that this is going to happen in the year 2060. The temperature and rainfall changes from 3 GCMs are given in table (2). Expected temperature changes are not uniform over the basin, with higher temperature rises in the more arid regions of Northern Sudan and most of Egypt and lower rises around the equator.

Model	Temp Increase °C	Rainfall Change %
UKMO: UK Meteorological Office	4.7	22
GFDL : Geophysical Fluid Dynamics Laboratory	3.1	5
GISS : Global Institute for Space Studies	3.4	31

Table (2): Change In Temperature And In The Nile Basin Under 2*CO2 Conditions

11- Conway and Hulmes; 1996, applied hydrological models of the Blue Nile and Lake Victoria sub-basins to assess the magnitude of potential impacts on the main Nile flows. The models were calibrated by simulating historical observation runoff and then driven with the temperature and precipitation changes from the three GCMs climate scenarios. A wet case, dry case, and composite case produced +15 (+12), -9 (-9), +1 (+7) percent changes in mean annual Blue Nile (Lake Victoria) runoff for 2025, respectively. These figures were used to estimate changes in the availability of the Nile water in Egypt by making assumptions about the runoff response in the Nile sub-basins and continued use of the Nile waters. Comparison of these availability scenarios with demand projections for Egypt showed a slight surplus of water in 2025, with and without climate change. However, if water demand for desert reclamation is taken into account, then water deficit occur for the present-day situation and also for the 2025 for dry case, and without climate change. Table (3) summarizes the findings of this study.

	Current climate		Changed climate Scenarios for 2025		
Water sources	1990	S3	Comp (T only)	GFDL (T only)	GISS (T only)
Total	63.50	71.60	72.50 (67.60)	66.20 (68.80)	80.80 (68.80)
Water Demand					
Total	59.20	57.70	57.70	57.70	57.70
Water surplus/deficit	4.30	13.90	14.80 (9.90)	8.50 (11.10)	23.10 (11.10)
Water demand for desert reclamation	5.20	14.30	14.30	14.30	14.30
Water surplus/deficit	-.90	0.40	0.30 (-4.40)	-5.80 (-3.20)	8.80 (-3.20)

Table (3): Current (1990) And Projected (2025) Water Availability And Demand Scenarios For Egypt (Km^3)

Note: S3 is future demand without climate change. Climate change scenarios taken from this study (Conway & Hulme 1996). Normal figure are based on mean for 1900-59,. T only = temperature change only.

12- Conway D. et. al. ; 1996, described the impacts on the future water availability in Egypt of driving forces operating at three different scales in the Nile basin: global (climate change), regional (land-use change), and river basin (water resources management). Global and regional driving forces are taken from an integrated model for the assessment of climate change and from the results of global climate model experiments. Regional hydrologic models of the large Nile tributaries are used to calculate the impacts on Main Nile discharges. River-basin driving forces are considered through a set of future water resources management strategies in Egypt. They concluded that the resulting combined effects of all three driving forces on future water availability in Egypt range from a large water surplus to a large water deficit by the year 2050. This range of results arises from uncertainties in the integrated modeling approach used and from the different ways Egypt may approach population growth, agricultural policy and human aspirations for greater water use in future. Table (4) shows the resulting combined effects of all three driving forces on future water availability in Egypt. While figure (2) shows the changes in temperature, precipitation, and land cover used in this study.

13- Sayed, M. AA., and Nour El-Din M.M. (2001), checked the sensitivity of the Nile Basin to changes in precipitation patterns under climate change variability. They did a simulation experiment of the Nile basin, assuming increase or decrease in rainfall patterns over the basin. The study concluded that the Nile is very sensitive to any changes in rainfall patterns. The scenarios have been simulated and different patterns of rainfall and different initial conditions of the soil in the Nile catchement area. The results indicated that if the adverse effect of climate change decreases rainfall patterns by 25% below average, Egypt will face stress on available inflow water and coming inflow volume will decrease by about (56-63%) based on the initial soil condition whether it is dry or wet, respectively. On the other hand if the effect of climate change is positive, i.e. rainfall will increase by 25% above average the flow volume that is expected to arrive Egypt will increase by about (75 – 90%).

Variable	Current	UKMO	GFDL	OSU	GISS
Temperature (PET), precipitation and land	84 (55.5)	96.08 (64.66)	87.31 (57.98)	87.06 (57.79)	94.45 (63.34)
Climate (temperature & precipitation)	84 (55.5)	92.23 (61.67)	81.84 (53.88)	82.09 (54.07)	89.84 (59.68)
Temperature only	84 (55.5)	80.06 (52.54)	79.59 (52.20)	79.26 (51.95)	80.95 (53.21)

Table (4): Shows the Estimated volume (km3) of main Nile discharge for year 2050 and Egypt's quota of Nile water according to the Nile Waters agreement with the four GCM scenarios and different combinations of climate and land cover changes applied.

III. Review of Research activities on Climate Change and Agriculture in Egypt

Intensive, multiple cropping and high occupation rates are normal agricultural practices in Egypt. More than 15 million acres of crops are cultivated annually on 8 million acres of land, giving an intensity index of more than 2. Egypt is already a major cereal importer, and demand is expected to increase. As a result, the country is vulnerable to deficits in food production resulting from climate change. The impacts of climate change on crop water requirements, planting dates, and agriculture production will have direct and indirect effect on a wide range of institutional, economic and social factors. The vulnerability of a region with reference to food security depends in one part on the size of the population, the productivity potential and the consumption pattern. Egypt, as other countries in the region, is considered vulnerable to food security due to the limited resources. The changes in temperature and precipitation predicted by GCM models will affect water availability, resource management, critically shaping the patterns of future crop production. Appropriate measures such as improvement of land and water management and adapted crops must be taken seriously to reduce the negative impacts on agricultural production. The expected impacts of climate change on agriculture could be summarized as follows:

- Increase of temperature and frequency of extreme events will reduce crop yield.
- Change of average temperature will induce altration of the distribution of crops.
- Increase of temperature will negatively affect marginal land and force farmers to abandon marginal land.

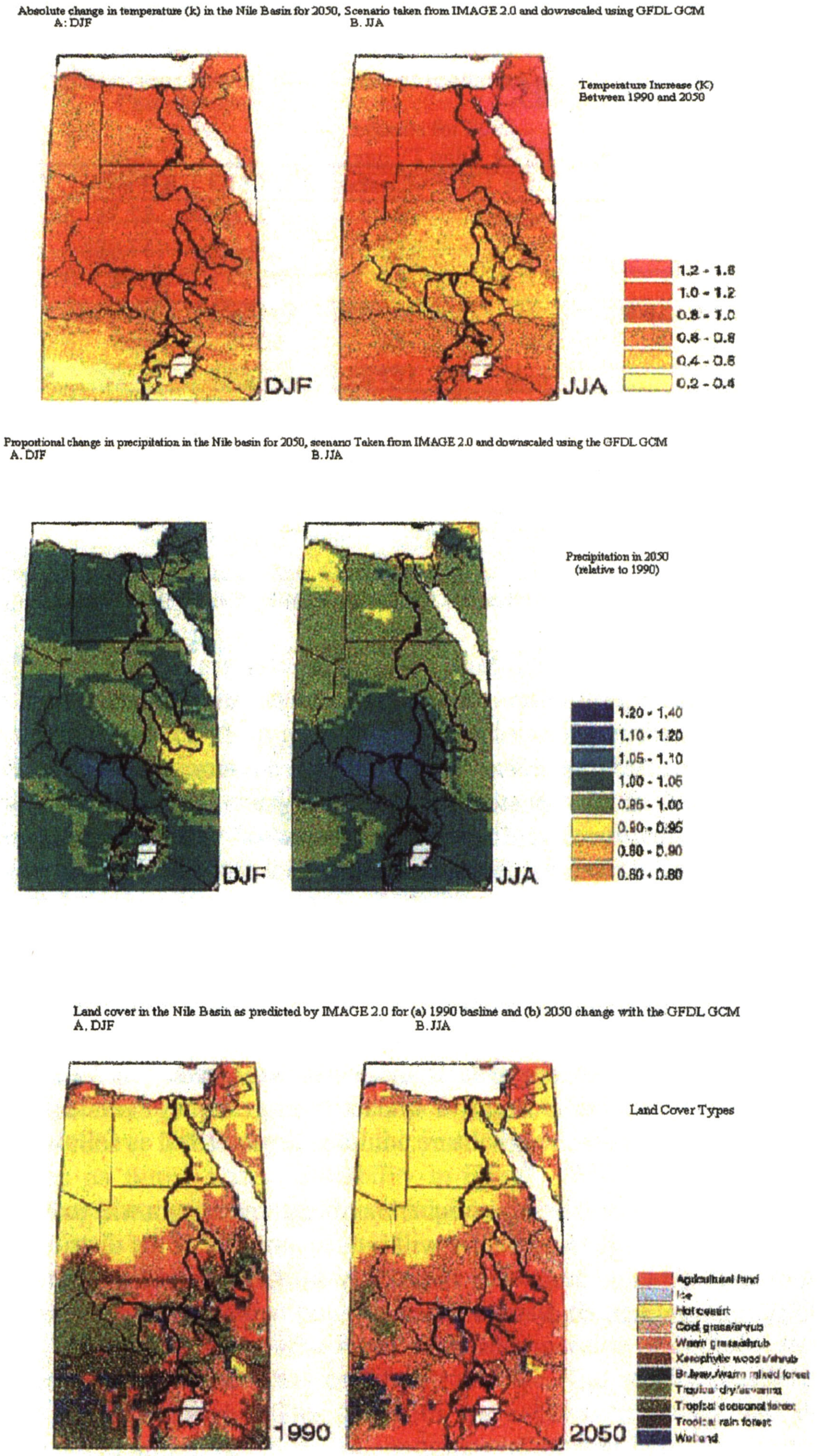


Figure 2: Estimated 2050 Values for Absolute Temperature and Precipitation Changes , And Predicted Land Cover Changes In The Nile Basin

- Shortage of water resources will also force farmers to abandon marginal lands, and increase desertification.
- Socio-economic impacts associated with loss of jobs and unemployment, loss of income, and may lead to socio-political unrest.

The following paragraphs summarize some work about the impacts of climate change on major crops in Egypt. This work would help in assessing the impacts as well as producing adaptation measures.

1. The potential impact of climate change on wheat, maize and cotton production in Egypt (country study; *Eid et al 1996*) was evaluated by simulating crop production under different climatic scenarios. This was done in case of wheat and maize, and by analyzing sensitivity to temperature in case of cotton in the three main agricultural regions of Egypt: Upper, Middle and Lower Egypt. Crop seasonal ET changes were estimated. Simulation of wheat and maize production was carried out under the transient model GF01 by the year 2010, 2030, and 2050. Under GCM climate change scenarios, yields of wheat and maize benefited from the direct CO2 effects. ET and water demands will be increased. According to the present simulation study in Egypt, the impact of climatic changes on national wheat and maize production would be severe, while yield of cotton would be increased in comparison with current climate conditions.

2. *El-Shaer et al (1997),* studied agricultural adaptation to climate change; they reported that if no timely measures are taken to adapt Egyptian agriculture to possible warming, the effects may be negative and serious. Egypt appears to be particularly vulnerable to climate change. A simulation study characterized the potential impact of climatic changes on two reference crops in the main agricultural regions, combining dynamic crop simulation models with climate change scenarios derived from three equilibrium general circulation models at the high level end of the IPCC range (4° C). Under the future climate, yields and water use-efficiency decreased in comparison to current climate conditions, even when the beneficial effects of CO2 were taken into account. On farm adaptation techniques that imply no additional cost to the agricultural system did not compensate for the yield losses with the warmer climate or improve the crop water-use efficiency. Economic adjustments such as the improvement of the overall water-use efficiency of the agricultural system, soil drainage and conservation, land management, and crop alternatives are essential.

3. *Eid, H. M. (1997),* studied the potential impacts of climate change on some field crops production and their ET to support the national action plan of Egypt. He found thate the recorded production changes of many crops for the year 2050 is ranging between –11% for rice to –28% for soybeans.

4. *Eid et al (2001)* reported that the assessment of vulnerability and adaptation to climate change in the different sectors is in need to generate and use the optimum

climate change scenarios. The climate scenario generator : MAGICC and SCENGEN was used in this study to calculate the annual mean global surface air temperature and global-mean Sea-level implications of emissions scenarios for greenhouse gases (GHGs) and sulfur dioxide (SO2). The results of simulation studies, shows that climate change could affect field crop ET and water needs by the year 2050 compared to their values under current conditions. Results indicated that CC could increase crop water demand for summer crops (up to +16%) while it could decrease slightly water demand for winter crops (up to 20%) by the year 2050.

5. Simulations with the climate change scenario on wheat and maize at several sites presented by *El-Shaer, H.E., et.al,.(1997)*, resulted in lower grain yields for both crops at al sites except for the northern sites. All GCM simulations included the direct beneficial effects of increased CO2 on crop yield and evpotranspiration. Figure (3a,b) summarizes the results of this study.

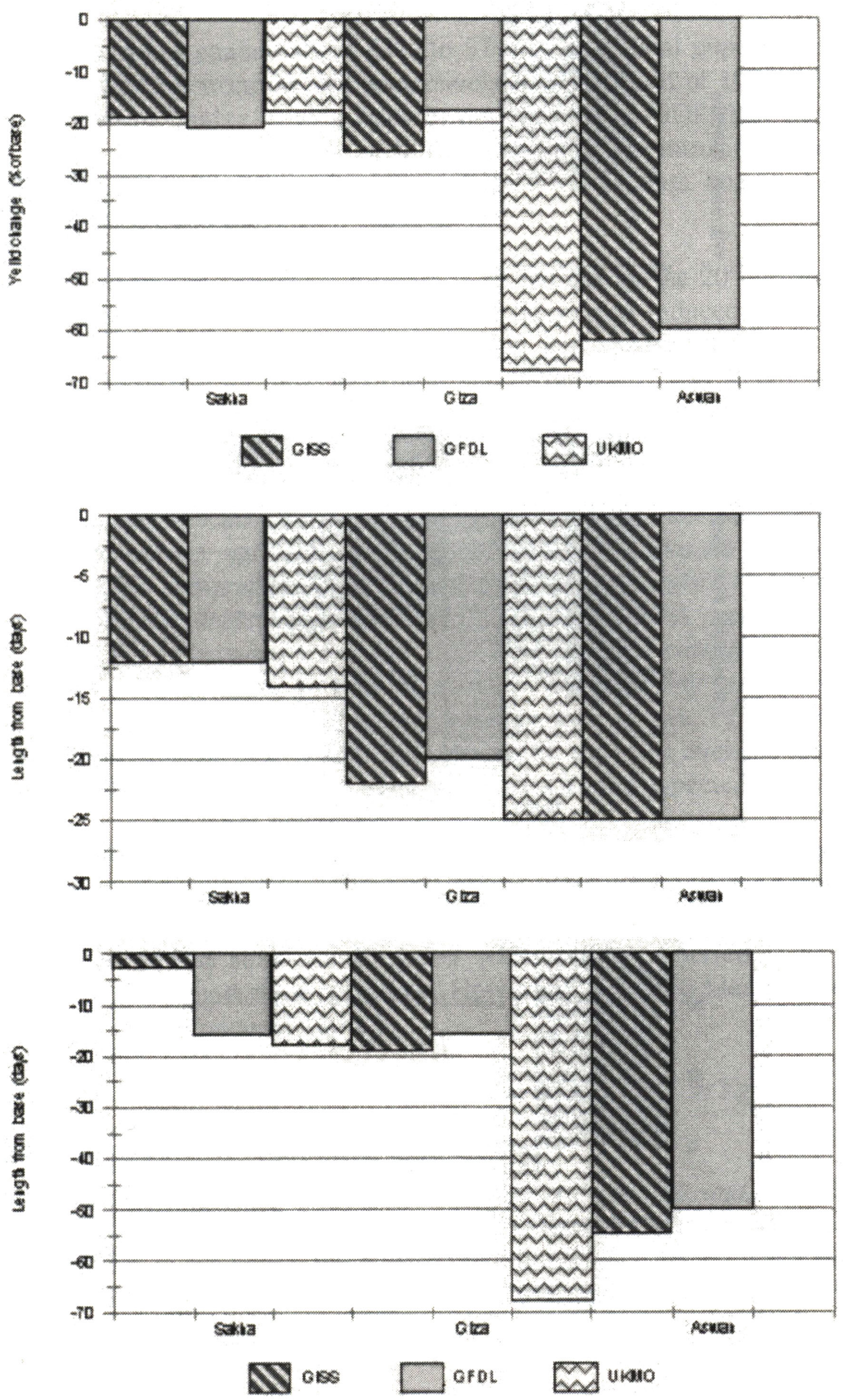


Figure 3a: Simulated Changes In Irrigated Maize Yield Season Length, And Water-Use Efficiency With The Climate Change Scenarios. Scenario Simulation Includes The Direct Effect Of CO2 On Crop Photosynthesis And Water Use Efficiency. CF Indicates Crop Failure

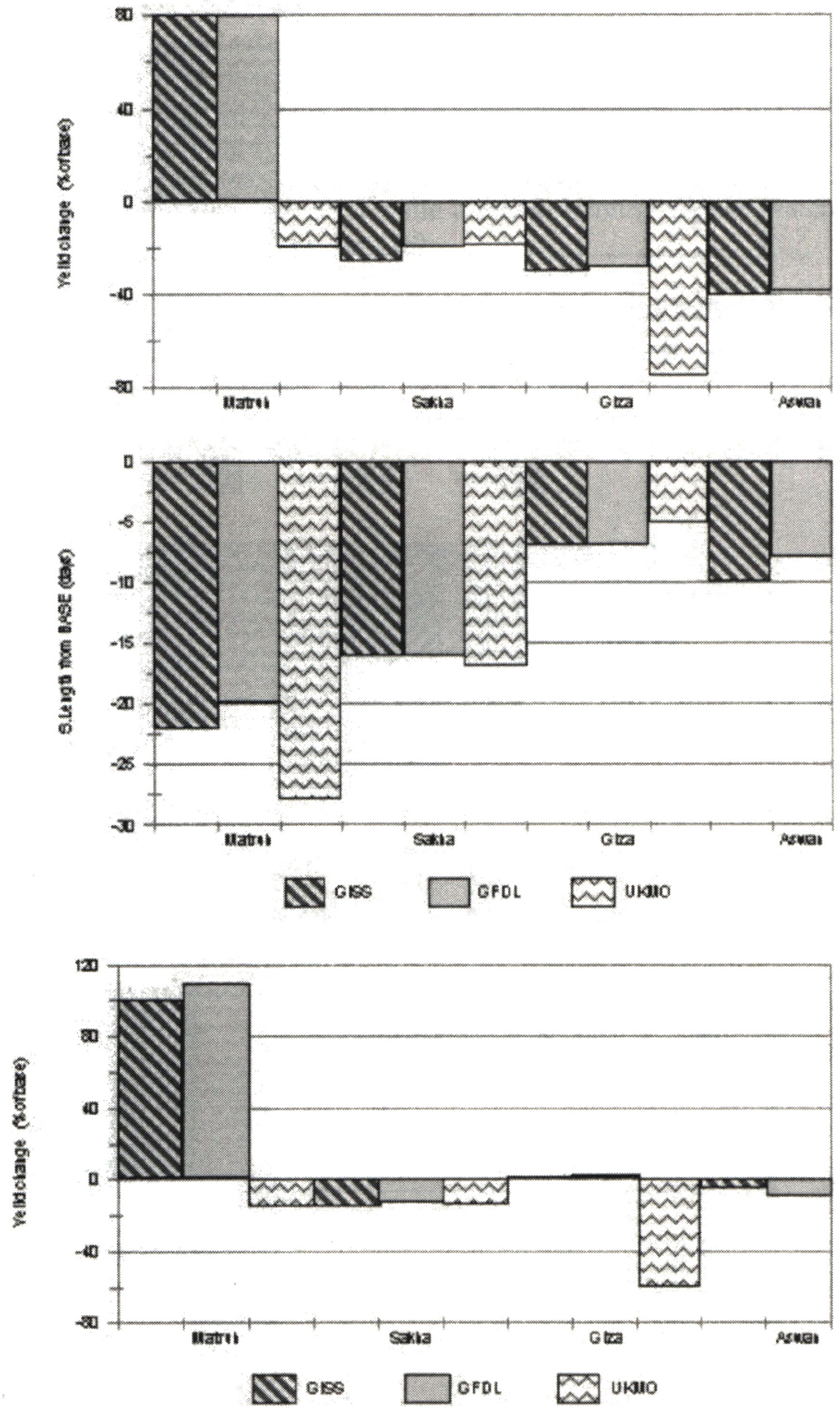


Figure 3b: Simulated Changes In Wheat Yield, Season Length, And Water Use Efficiency With Climate Change Scenarios. Wheat Is Rainfed At Matruh And Irrigated At The Other Sites. Scenario Simulation Includes The Direct Effects Of CO2 On Crop Photosynthesis And Water Efficiency. CF Indicates Crop Failure

IV. Review of Research Activities on Climate Change And Coastal Zones in Egypt

The world's coastal zones contain about 21% to 37% of the global population who lives within 30 km and 100 km from the sea respectively (Cohen. J., et al 1997). Also, many coastal locations exhibit higher growth rates in population and GDP than their national averages. A range of coastal hazards such as erosion, saline intrusion, flooding and widespread wetland destruction already threatens these developments. Sea level rise due to climatic changes adds another hazards to coastal areas.

It is well known that global sea levels rose 10 to 25 cm during the 20th century. This is expected to accelerate during the 21st century due to the human induced global warming. Assuming business-as-usual greenhouse gas emission and constant aerosols, the IPCC estimated that the global rise for 1990 to 2100 would be between 22 to 96 cm, with a mid estimate of 55 cm.

The coastal zone of the Nile Delta in Egypt is perceived as vulnerable to the impacts of climate change, not only because of the impact of sea level rise, but also because of the impacts on water resources, agricultural resources, tourism and human settlements. El-Raey, M. (1994), in his comprehensive study assessed the vulnerability of Alexandria city which lies on the Mediterranean coast, to expected sea level rise. A scenario involving a Sea Level Rise (SLR) of between 0.5m and 1.0m over the next century is assumed. He found that if no action is taken, an area of about 30% of the city will be lost due to inundation, almost 2 million people will have to abandon their homes, 195,000 jobs will be lost and an economic loss of over $ 35.0 billions can be expected over the next century. Rossetta City and Port-Said City are also vulnerable cities for the expected sea level rise.

Coral reefs, in the Red Sea, projected to be among the most sensitive ecosystems to long term climate change. Corals are especially sensitive to elevated sea surface temperatures. When physiologically stressed, corals may lose much symbiotic algae, which supply nutrients and colors. In this stage corals appear white and are referred to as bleached. Corals can recover from short term bleaching. However, prolonged bleaching can cause irreversible damage and subsequent mortality.

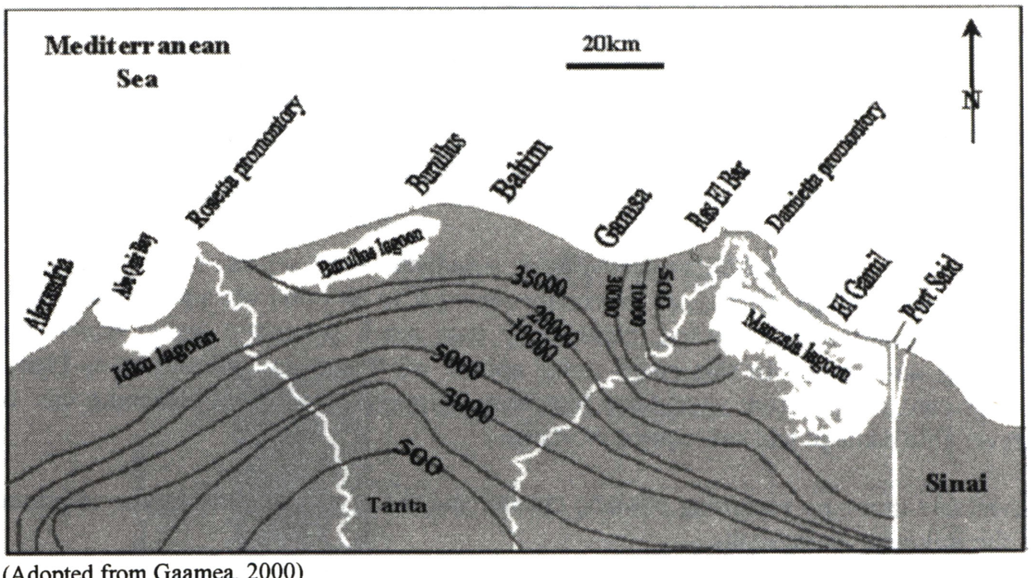
Available literature regarding climatic change and the coastal zone in Egypt is presented in the following paragraphs.

1- A joint research project between *the Coastal research institute and Delft Hydraulics (1992)* entitles "vulnerability assessment of accelerated sea level rise" showed that for a 1.0 m rise in sea levels, there would be a increase in the sea water intrusion in the Delta. The area subject to upward saline seepage increased from 5000 km2 to 7400 lm2 while the average salinity reached 2880 ppm instead of 2200 ppm.

2- *Sestini (1993)* confirmed in another study that quantity and perhaps availability of groundwater might become a serious problem in the lower Delta region due to salt-water intrusion.

The distribution of groundwater salinity in the lower Nile delta for the 50m depth below the land surface is shown in Figure 5, which shows a large belt of saline water near the coast followed by a brackish groundwater to south (Gaamea, 2000). This map reveal that the iso-contours of saline water from <35000 to <700 ppm is progressively shifted southward starting from Alexandria in the west to the east at Manzala lagoon-Port Said area, extending 50km from the coast.

Conversely, a relatively narrow salinity zone bounding the western part of the delta including Alexandria. This indicates that there has been a positive correlation between the spatial distribution of groundwater salinity and the RSL including subsidence, *i.e.*, high rates of subsidence is associated with saline water intrusion. Stanley (1997) has attributed the wider and more extensive groundwater salinity pattern in the Manzala lagoon area to the higher subsidence rates providing evidence that marine water intrusion toward the south and southwest is a function of subsidence. In theory, a rising of RSL would unbalance the groundwater salinity pattern, probably will shift the saltwater wedge inland even in coastally protected areas and this in turn may increase salinisation of soil profile and affect the agriculture landuse system in the lower delta. Consequently, the lagoon ecosystem, and hence fish resources, would probably adjust to gradually changed conditions of salinity.



(Adopted from Gaamea, 2000)

Figure 4: Distribution Of Groundwater Salinity In Ppm. In The Lower Nile Delta For 50m Depth, Showing Incursion Of Saline Water Into The Northeastern Part And Brackish Water In The Northwestern Part Including Alexandria

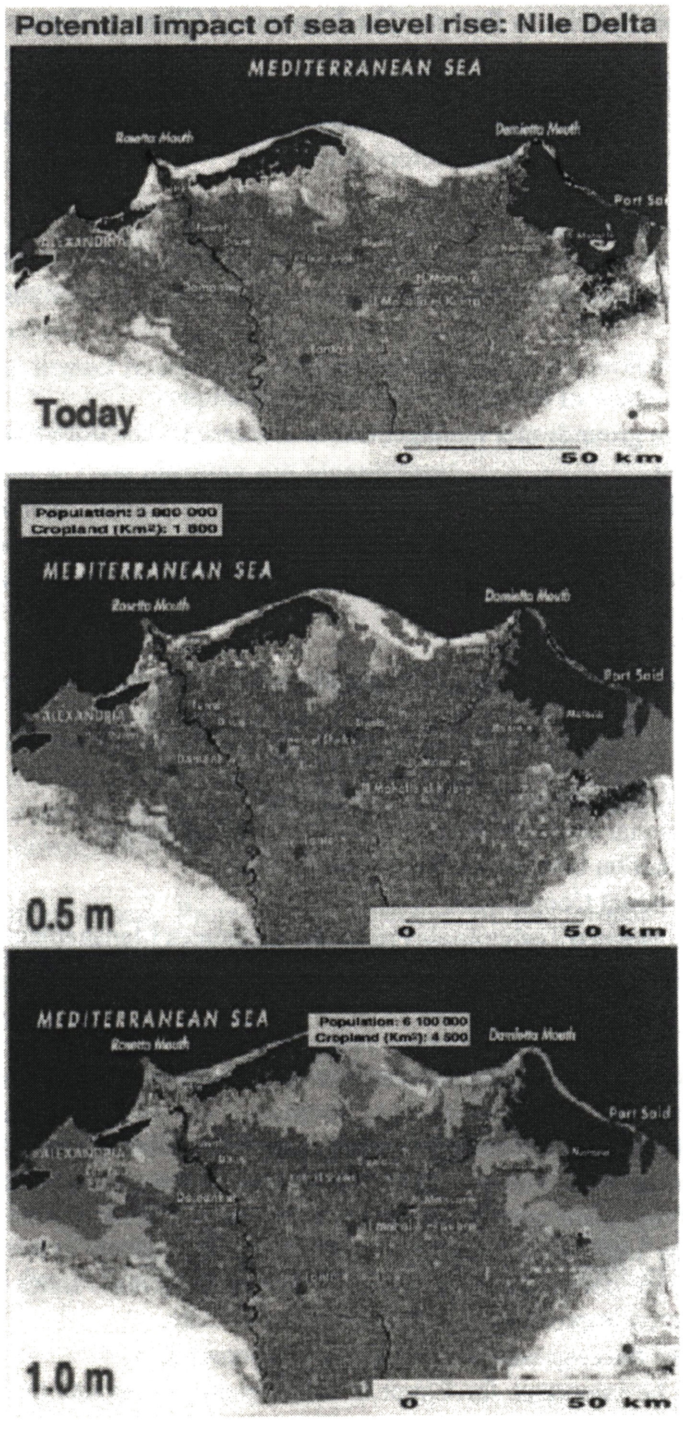


Figure 5 -A,-B,-C: The Nile Delta Now, 0.5 M And 1.0 M Sea Level Rise

V- Adaptation Policies to Reduce The Impacts of Climate Change

The review presented in this paper has proposed several adaptation measures to meet the impacts and challenges induced by the expected climatic changes. These measures can be summarized for the three main sectors as follows:

Water Resources Sector

The country has prepared a number of scenarios capable of enhancing water management in order to cope with different circumstances. These scenarios include but not limited to the following:

- Improvement of Rain water harvesting techniques
- Improve groundwater management to Increase abstractions (shallow and deep aquifers)
- Recycling of Water
- Desalination of Water
- Transportation of Water
- Rationalization of Water Use
- Public Awareness
- Continuous Monitoring and Evaluation
- Improvement of Water Resources Management practices:
- Integrated Water Resources Management
- Users Participation in Water Management
- Institutional Strengthening of concerned Organizations
- Coordination between different stakeholders.
- International Cooperation
- Use of Modern Technologies in Water Resources Management

Agricultural Sector

The adaptation policies include but not limited to the following:

- Use of alternatives existing varieties and optimization of the timing of planting,
- Increasing water and/or nitrogen fertilizer amounts
- Modifying plant population density in the field, fortunately these on-farm techniques that may imply few additional costs to the agricultural system, can partially up to completely compensate for the yield losses or increase more the benefit in case of cotton crop improvement with the warmer climate.
- Improve the crop water-use efficiency in some cases.
- It will be important for Egypt to develop new cultivates that are more adapted to higher temperatures.

Coastal Zones Sector

The evaluation and assessment of adaptation measures to the impacts of sea-level rise in the coastal zone is therefore necessary. There are several short-term and long-term options, which could be summarized as:

Short-Term Options:

- Beach nourishment
- Sand dune fixation
- Change of land use
- Environmental Impact Assessments before implementing new projects

Long-Term Strategic Options:

- Integrated Coastal Zone planning and Management
- Change of land use plans
- Upgrading awareness
- Development of institutional capabilities in monitoring and assessment

VI- Current Projects Relevant to Climate Change in Egypt

- Lake Nasser Flood and Drought Control / Integration of Climate Change Uncertainty and Flooding Risk (LNFDC/ICC) Project. The aim of the project is to assess the impacts of climate change on the Nile flows and examine different operating policies for upstream and downstream Lake Nasser.

- The Irrigation Improvement Project: The objective of this project is to improve irrigation management practices through adopting simple technologies by increasing the efficiency of water use and removing constraints in the water distribution system on agricultural production.

- The Water Boards project: The project aims at decentralizing the management of branch canals and conveys the operation and maintenance of these canals to beneficiaries through implantation of participatory water management groups. This will recover the cost of operation and maintenance.

- The National Water Resources Plane project: It aims at setting the national plane of water supply and demand till year 2017 through consideration of different stakeholders.

Bibliography

Blue Plan, (1988): "Futures of the Mediterranean Basin: Environment Development 2000-2025", Sophia, Antipols. Cited in: Baric, A. and Gasparovic, F. 1992.

Carter, T. R., and others, (1994): "IPCC Technical Guidelines for Assessing Climate - Change Impacts and Adaptations1 (3), pp. 219-232. IPCC Working Group II",. Available from: Department of Geography, University College, and London.

Cohen, J.E., Small, C., Mellirger, A., (1997): "Estimates of Coastal population", Sceince 270.

Cotton, W. R. and Pielke, R. A., (1995): "Human Impacts on Weather and Climate", Cambridge: Cambridge University Press.

Conway, D. (1993): "The development of a grid-based hydrologic model of the Blue Nile and the sensitivity of Nile river discharge to climate change, unpublished PhD thesis, University of East Anglia, UK.

Conway, D. and Hulme M, (1993):"Recent fluctuations in precipitation and runoff over the Nile subbasins and their impact on Main Nile discharge", Climate Change, 25, pp. 127-151.

Conway, D. and Hulme M, (1996):"The impacts of climate change variability and future climate change in the Nile Basin on water resources in Egypt", water resources development, vol 12, No 3.

Conway, D., Ktol M., Alcamo, J., and Hulme M, (1996): "Future Availability of water in Egypt: the ineteraction of global, regional, and basin scale driving forces in the Nile basin, Ambio, A journal of the human environment, the royal Swidish academy of science.

Delft Hydraulics (1991): "Implications of relative SLR on the development of lower Nile Delta, Egypt", Pilot study for a quantitative approach, Final report. CRI.

Egypt's Climate Change National Action Plan, (1999).

El Shaer, H. M. and others, (1997): "Impact of climate change on possible scenarios for Egyptian agriculture in the future. Mitigation and Adaptation Strategies for Global Change", 1 (3), 233-250.

Eid, Helmy M., et al (1993a): "Climate change crop modelling study on sorghum". Annals agricultural Sceince, special issue, 1,219-234.

Eid, Helmy M.,et al (1993b): "Impact of climate change on simulated wheat yeild and water needs". 1st. conf. Egypt. Hung. Env. Egypt, 1993,p.309-312.

Eid, Helmy M.,et al (1994b): "Simulated soybean yeild and water requirements in relation to selected agronomic characters in Egypt". Proc. 6th conf. Agron., El-Azhar Univ. Vol. II:471-489.

Eid, Helmy M., (1996): "Country Study of Egypt: Vulnerability and Adaptation to Climate Change in Egyptian Agriculture": final report. Giza: soils and water research institute, Ministry of Agriculture.

Eid, Helmy M., (1997): "Support for the National Action Plan of Egypt: Assessment of Strategy and Policy Measures for Adaptation to Climate Change in Egyptian Agriculture": Final Report. Giza: Soils, Water and Environment Research Institute (SWERI), Ministry of Agriculture, February 1997.

Eid, Helmy M., (2001): "Climate change studies on Egyptian Agriculture", Soils, Watrer and Environment research institute (SWERI) ARC, Ministry of Agriculture, Giza, Egypt.

El Quosy, Dia El Din., (1994):"Climate change and Water Resources in Egypt", Paper present during the Egypt-US workshop on Global Climate Change, Cairo:10-12.

El Quosy, Dia El Din., (1995) :"Vulnerability Assessment of Water Resources in Egypt to Climate Change", Climate research Vol. 6 No.2.

El Quosy, Dia El Din., (1999) :"Climate Change and Water Resources in Egypt", Paper presented during the Egypt- US Workshop on Global Climate Change, Cairo: 10-12 May 1999.

El Raey, M., O. Frihy, S. Nasr, S. Desouki and K. Dewidar. (1992): Impact of sea level rise on the Governorate of Alexandria, Egypt. First Bahrain International Conference.

El Raey, M. et al., (1994): Vulnerability Assessment of the Coastal Zone of Egypt to the Impacts of Sea Level Rise. Phase II US Country Study Program.

El Raey, M. et al, (1995), Inventory and Mitigation Options, and Vulnerability and Adaptation Assessment Interim Report on Climate Change Country Studies.

Gleick, P.H. (1989): "Climate change, hydrology, and water resources", reviews of Geophysics, 27, pp 329-344

Gleick, P.H. (1991): "The vulnerability of runoff in the Nile Basin to climatic changes", Environmental Professional, 13, PP. 66-73.

H.M.El=Shaer, C. Rosenzwesq, A. Iglesis, Eid, M.H., and Hillel, D., (1996): "Impacts of climate change on possible scenarios".

Hulme, M. (1989),."Recent and future precipitation changes over the Nile Basin". In Proceedings of the International Seminar on Climatic Fluctuations and Water Management, 11-14 December 1989, Cairo, Egypt.

IPCC, (1996a): *Houghton, J. T., and others (eds).* Climate Change 1995: The Science of Climate Change. Report of IPCC Working Group I. Cambridge, Cambridge University Press.

IPCC, (1996b): Watson, R. T., and others (eds). Climate Change 1995:Adaptations and Mitigation of Climate Change, Scientific-Technical Analyses of Impacts. Report of IPCC Working Group II. Cambridge, Cambridge University Press.

IPCC, (2001): Watson, R. T., and others (eds). Climate Change Adaptations and Mitigation of Climate Change, Scientific-Technical Analyses of Impacts. Report of contribution of IPCC Working Group II. Cambridge, Cambridge University Press.

Saleh M., Strzepek K.M., Onyeji S.C., and Yates D., (1994), "An Assessment of Integrated Climate Change Impacts on Egypt", Working Paper WP-94-48, IIASA, Austria

Sayed, M., AA., Nour El-Din, M.M. (2001),"Adaptation of water policy of Egypt to mitigate climate change impacts", Proceedings of the Stockholm Water Symposium.

Sestini, G. (1993): "Implications of climatic changes for the Nile Delta. In Climatic Change in the Mediterranean", ed. G. Sestini, 535-601.

Shahin M., (1985), "Hydrology of the Nile Basin", Developments in Water Science No. 21, Elsevier, The Netherlands.

Stanley, D.J., and A.G. Warney, (1993): "Recent geological evolution and human impacts", science, 260.

Wigley, T. M. L. (1993):. Future climate of the Mediterranean Basin with particular emphasis on changes in precipitation. In Climatic Change in the Mediterranean, ed. G. Sestini, 15-44

Yates, D., (1996): "Integrating Water into an Economic Assessment of Climate Change Impacts on Egypt", Working Paper WP-96-31, IIASA, A