CLIMATE CHANGE IMPACTS ON EGYPT

By
Mohamed M. Nour El-Din and **Laila Aabed**
Ain Shams University, Cairo – Egypt   National Water Research Center, MWRI, Egypt

In this paper, some of the impacts of climate change on Egypt will be presented. More attention is given to impacts on water resources and agriculture as they are related to each other and are affecting all other activities in the country. Also, adaptation policies will be discussed in brief.

1. Introductions and Background

Egypt lies in the northeastern corner of Africa, with a total area of about 1 million km^2. Figure (1) shows a map of the Nile basin and the location of Egypt, and Table (1) summarizes some basic statistics and population.

Figure 1: The Nile River Basin

The mean annual rainfall on Egypt is estimated at 18mm. It ranges from 0 mm in the desert to 200 mm in the northern coastal region. Temperature is extremely high, reaching 38ºC to 43ºC with extremes of 49ºC in the southern and western deserts.

Population growth is certainly among the most pressing challenges Egypt is facing in its development. The annual population growth rate decreased from 2.8% in the period 1976-86 to 2.1 % in the period 1986-96. In relation to arable land and water, Egypt's population density is among the highest in the world: 97% of the population lives on 4% (40,080 km^2) of land in the Nile Valley and Nile Delta, resulting in an average population density of 1,435 persons per Km^2. Prediction of population growth is relevant to water resources planning as they affect the demands for food and household water. Several prediction estimated the population in Egypt at 2025 to be in the range of 92 millions. This means that Egypt is facing a large increase in its population, which stresses the need for better management of all its available resources.

Table (1) Some Basic Statistics and Population

Physical areas:		
Area of the country		1,001,450 km^2
Cultivated area	2001	8.3 million fed
Cropped area	2001	15.2 million fed
Population:		
Total population	2001	65,070,000 inhab
Population density	2001	65 inhab/km^2
Rural population	2001	56%
Annual Population Growth Rate (%)	2001	2.02 %
Water supply coverage:		
Urban population	2001	93%
Rural population	2001	53%
Annual real GDP growth rate (%)	2001	4.9%
GDP Per Capita **(US$)**	2001	1190

The combined effect of rapid population growth in Egypt and rising living standards has led to a substantial increase in food demand. Horizontal expansion of agricultural lands has then become necessary to fill in the food gap. Apart from the small amounts of rainfall on the northern coast and the limited groundwater pumping in the western desert and Sinai, the Nile inflow is the main source of water in Egypt. It is a truism that the Nile is the most important source of water for Egypt, and it follows that the climate change effects will change the water policy in Egypt and will be one of important determinants of the balance between demands and supplies in the future.

The conventional water resources in Egypt are limited to the Nile River, rainfall, flash floods, and groundwater in the deserts and Sinai. Each resource has its limitation on use, whether these limitations are related to quantity, quality, space, time, or use cost. Egypt will have to optimize the use of these available resources in order to meet the increasing demands on water. Table (2) shows the annual water availability and water use by the different sectors in Egypt It shows that there is a deficit about 1.86 bcm that should be fullfilled through the development of unconventional water resources and improving the efficiency of water use in Egypt.

Table (2) : Annual Water Availability And Use In Egypt (1998)

WATER INPUT	Km^3	WATER USE	Km^3
Surface Water Resources	56.5	Agriculture (including. Evaporation.)	60
Renewable groundwater	4.8	Domestic	4.5
Agricultural drainage water (unofficial)	8.4	Industry	7.5
Reused treated wastewater	0.7	Navigation / Regulation	0.26
Total water input	**70.4**	**Total water use**	**72.26**

Source: MWRI reports

2- Climate Change and Impacts on Egypt

The future climate changes for the Mediterranean region in general have been investigated (Wigley 1993). The results predicted a warming of about 3.5° C spreading uniformly over the seasons, with most of the Mediterranean basin showing an increase in precipitation in winter. The projected change in precipitation between now and 2050 is +1mm/day. As for the Nile basin, we cannot yet predict with confidence the nature of future climatic changes. However, there are indications that such changes will be significant and possibly severe. Recent and predicted future precipitation changes over the Nile basin (Hulme 1989), and monitoring of the upper White Nile catchment, upper Blue Nile catchment, and Middle Nile Basin from 1880 to1989 show declines in total precipitation. Global circulation models (GCM) for 1861 - 1988 show an overall warming of 0.5° C for this period. Various GCM models have been applied to study the potential climate change impacts on the Nile Basin (Saleh et al. 1994).

The Egyptian economy is largely based on agriculture. Water availability is the main constraint on the expansion of agricultural land. Despite having very high crop yields, Egypt still imports a large percentage of its food, which makes it vulnerable to hanges in the world food market. Yates (1996) and Strzepek et al. (1994) indicated large implications of climate change on the agricultural sector of Egypt. These effects are realized through two mechanisms; the change in agricultural production around the world changing crop production and prices, and the change in agricultural activities adapting to changes in water availability within Egypt.

2.1 Climate Change Impacts on Egypts' Water Resources

Climate change will have various effects on water resources and water management in Africa. The large variability in projected climate scenarios over Africa's most vulnerable river basin systems (such as the Nile) makes any policy reformulation in anticipation of climate change difficult. However, improved efficiency in irrigation systems and water use are strongly recommended modes of action because they will benefit the region regardless of the degree and direction of climate change. Detailed studies of the river basins are essential to provide adequate information for planning and negotiation purposes in this area that will continue to generate tension across many borders.

Egypt is defined under various criteria as water stressed country because of its low per capita renewable water resources availability. Over 95 percent of Egypt's current freshwater originates from the Nile. 'Natural' variability in Nile flows is critical for water supply because the balance between the availability of water and demand for water is very fine. During the decade of low flows in the 1980s, for example, Egypt's water use was secured because of storage in the High Aswan Dam reservoir and the availability of the upstream Sudan's unused allocation.

Being the most downstream country on the Nile, Egypt is affected by climate change impacts, not only within its borders, but also within the whole of the basin, which it shares with 9 other countries. Despite being at the low end of the river, Egypt is the largest user of the Nile water at present. Economic developments in upstream countries and adaptation measures are likely to put more pressure on water resources on Egypt.

The Nile Flow

The advantage of controlling Nile flows into Egypt, by virtue of the High Aswan dam, is that Egypt is largely isolated from seasonal variations in river flow that might occur due to climate change, which makes the total annual river yield the governing factor. Several studies (IPCC, 1998, Yates, 1996, and Conway and Hulme 1993) have concluded that the Nile basin is very sensitive to climate change. Very small changes in precipitation and/or evapotranspiration can result in huge changes in river runoff as happened earlier in the 1960s. The specific discharge of the basin is about 0.98 $L/s/km^2$ and its runoff-rainfall ratio is only 4% (Shahin, 1985 and IPCC, 1998). These are very low compared to other large rivers, e.g. the specific discharge for the Zambezi basin, whose area is about half of the Nile basin area, is 3.8 $L/s/km^2$ while its runoff-rainfall ratio is 12%.

Results from an earlier study (Yates, 1996) using 3 equilibrium experiments and one transient experiment show a wide range of changes. While three of the models indicated increases in Natural River flow at Aswan of more than 50%, the fourth model showed a 12% reduction. Temperature rise will result in increasing evaporation losses from Lake Nasser as well as increasing irrigation water demands. Considering such losses in addition to possible increases in Sudan abstractions, the study predicts changes in water availability ranging between –11% to +61%. These changes will have huge implications for the Egyptian economy as depicted in Yates' study and in an earlier study by Strzepek et al. (1994).

Table (3) shows the results of four climate change models that are GISS, GFDL, UKMO and LOWEND. These models considered the direct effects of CO2 and assumes unlimited water supply. The results shows the big range between different models that range from increase of the total Nile flows to up to 30% to a decrease to –77%. The results shows clearly the need for further assesments of the effects of climate change on the water resources of the Nile, also the need for further development of models that will decrease the projected uncertainty of current studies and models.

Table (3) : Results of Different Models on the Expected Impacts of Climate Change on the Nile Flows

Model	GISS	GFDL	UKMO	LOWEND
Nile Flows	+30	-77	-12	+18

A rainfall runoff model is used to do an initial analysis on the possible effects of climate change on the coming inflows to Egypt. This analysis is based on different outputs of possible change on rainfall patterns over the Nile basin.

The long term average rainfall over the basin is used as a key input unit for the simulation model. It is assumed that the future rainfall pattern will change in different scenarios as follows:

- There will be no change in rainfall pattern of the Nile basin and the long term rainfall pattern will prevail.
- The future rainfall pattern will be about 50% of the long term mean rainfall pattern
- The future rainfall pattern will be about 75% of the long term mean rainfall pattern.
- The future rainfall pattern will be about 100% of the long term mean rainfall pattern.
- The future rainfall pattern will be about 125% of the long term mean rainfall pattern.
- The future rainfall pattern will be about 150% of the long term mean rainfall pattern.

These scenarios have been simulated and different patterns of rainfall and different initial conditions of the soil in the Nile catchement area.

Figures 2 and 3 show the simulation results for flow patterns for different scenarios of rainfall variability that may result due to the effect of future climate change patterns compared to the long-term average flow. In simulating these patterns different initial conditions of the soil were done. The first condition is one extreme that assumes that the initial condition is dry soil, while the other condition assumes that the soil will be wet. 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 water volume will decrease by a range about (56-63%) based on the initial soil condition whether it is dry or wet. 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 to Egypt will increase by a range of (75 – 90%). The literature shows that this is the most expected scenario. The analysis shows also that if rainfall increases by 50% the volume of incoming water to Egypt will be about (150 –160%) increase than the long term average.

Obviously, climate change especially in the countries where the River Nile originates will affect the river flows reaching Egypt in different ways:

- Increase in precipitation, increase runoff and consequently increase the discharge of the river in the lower portion.
- The reduced consumption in the Upper Nile basin countries
- due to ample precipitation saves additional quantities for downstream users, i.e. Egypt and Sudan.

Water Demand

All components of water demand are likely to rise without climate change. Agricultural expansion, population growth and industrial development are currently increasing water demand. Temperature rise will cause crop water requirements to rise even more. Adaptations including efficiency improvement programs which will help curb the rise in demand but only to a certain extent. The overall system efficiency in Egypt is currently high through direct and indirect reuse of drainage water and treated sewage. Seepage from canals, agricultural lands, and pipeline networks feeds the Nile groundwater aquifer from which water is extracted further downstream.

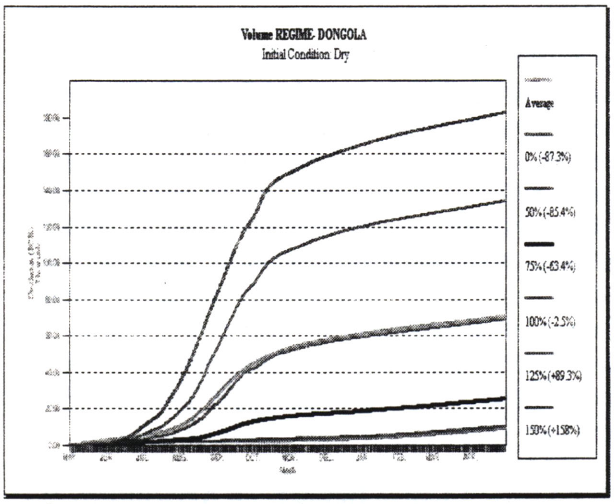

Figure 2: Flow Volume Simulation Results for Dry Initial Soil Condition

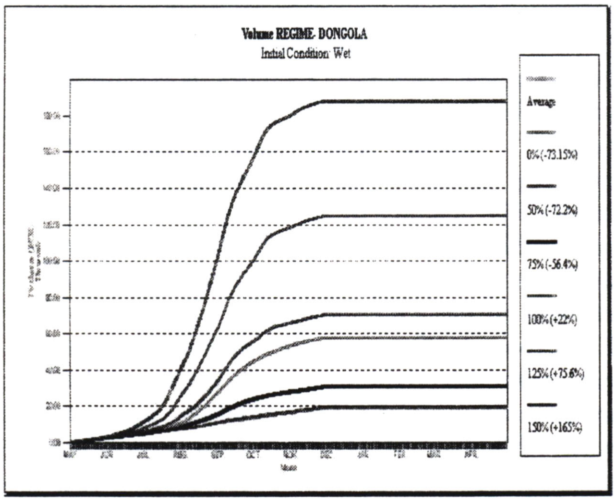

Figure 3: Flow Volume Simulation Results for Wet Initial Soil Condition

- Flood Risk

It seems unlikely that river flood risk would increase due to increased Nile flows as some models predict. Egypt is well protected by the High Aswan Dam. However, operating rules might need to be changed in accordance with changing flows and some degradation could occur in the Nile channel.

- Water Quality

The quality of water arriving at Aswan is generally good. However, there exist some water quality problems in the Nile through Egypt caused by the disposal of industrial effluents and untreated sewage. These problems are likely to be aggravated if the river flow is to be reduced by climate change as depicted by some models. In addition, temperature rise may affect the water quality of the several lakes along the river, starting with Lake Victoria and ending with Lake Nasser. There are currently no studies of such effects. Another unstudied factor that might affect the water quality in Egypt is the industrial development of upstream countries. It should be noted that increased nutrient levels are already affecting macrophyte populations in Lake Victoria.

3. Climate Change Impacts on Agriculture

El-Raey et al.(1995) have identified some of the effects of climate change on cropping patterns and distribution in Egypt. Plant production is characterized in Egypt by two main features: diversification and intensification. In this way the agricultural calendar year (Nov-Oct) includes monoculture (orchards or sugarcane), double cropping (winter - summer season crops), and triple cropping (winter - early summer - autumn crops). The outcome of all these patterns forms an intensification index of more than 2.0. With the expected changes in global climate, drastic changes in the whole system of cropping are likely to occur. Consequently, the focus will be on more adaptive types of crops and/or modifications in the microclimates to cope with the expected changes. New dates for planting crops of different species or cultivars need to be investigated. Advanced dates for planting summer crops and delayed dates for planting winter crops should also be tested. Crop plants differ in their response to changes in CO_2 and temperature. Increases in CO_2 concentration increase the rate of plant growth. C3 plants respond positively to increased CO_2, while C4 plants, although more efficient in utilizing current CO_2 levels, are less responsive to increased CO_2 concentrations. The most important C3 plants are wheat, rice, and soybean, while C4 plants include maize, sorghum, sugarcane, and millet. Computerized crop models (e.g., DSSAT, IBSNAT and ICASA) have indicated that, at the national level, differences in areas devoted to the above crops are likely to occur due to climate change. Growing more small grains (wheat and barley) is advisable rather than more coarse grains (maize and sorghum). Rice areas could be increased, but the problem of water shortage will be a limiting factor.

Table (4) shows the results of four climate models on the some crop yeilds on the agriculture sector. These models considered the direct effects of CO2 and assumes unlimited water supply. The results shows that there will be general decrease in the yield of the mail crops, Maize, Wheat, Rice and Soybeans. The decrease will range fron –4% to –73%. The big range shows the importance of doing further studies for decreasing the uncertainty of the model results.

Table 4: Effect of Climate Change on Crop Yeild, Using 4 GCM Models

Sector	GISS	GFDL	UKMO	LOWEND
Maize	-19	-22	-18	-22
Wheat	-36	-31	-73	-4
Rice	-1	-4	-5	
Soybeans	-8	-30	-33	-4

An analysis on the vulnerability of Egyptian agriculture to climate change is based on the results of the crop simulation study, the perspective of changes in resources that affect the agricultural system is not included in the simulation study (e.g. the sea-level rise), and the problems and limitations of the current system (Rosenzweig and Hillel, 1994).

Previous simulation studies which extended and integrated site-based results to national yield and water consumption changes, projected that climate change could decrease national production of all crops (ranging from –11% for barley to -28% for soybeans) while incrasing crop demand for water up to +16% (Eid and El-Sergany, 1993; Eid et al., 1993; Eid et al., 1995). The results for this study are somewhat more pessimistic, with crop yield decreases ranging from about –20% to complete crop failures at the Upper Egypt site with the warmer scenario.

Different studies (Eid et al., 1992, 1993, 1994, 1995) concluded that, the impacts of climate change on national wheat and maize production would be severe, while the yield of cotton would be increased in comparison with current climate conditions. The expected change, excess/deficit, in major crop production in Egypt by the year 2050 due to climate change is presented in table 5. The output of the change in water demand for different crops, as a result of the simulated negative impacts of climate change, is represented in table 6 that show the total ET for each crop and the expected deficit or excess in crop water requirements. Also, simulation for wheat, maize and seed cotton yield for different cultivates, sowing date and nitrogen were carried out.

Table 5: Change In Major Crop Production In Egypt By The Year 2050 Due to Climate Change

Crop	Base yield (t/fed)	Area (M.fed)	Yield (M.t)	Change %	Deficit or Excess (M.t)
Wheat	2.17	2.12	4.63	-18	-0.83
Maize	2.72	1.68	4.6	-19	-0.87
Cotton	1.1	0.815	.903	+17	0.15
Sorghum	2.9	0.339	.705	-19	-.13
Barley	0.89	0.18	.124	-18	-.02
Rice	3.26	1.29	4.24	-11	-.47
Soybean	1.167	0.05	.059	-28	-.01

Source: Eid et al 1997 a,b,c,d

Considering the simulated negative impacts of climate change on simulated wheat and maize yield in the Delta, Middle and Upper Egypt regions, one can conclude that climate change may bring about substantial reductions in the national grain production (Eid et al., 1992, 1993, 1994, 1995). Also, climate change could increase crop water demand for summer crops (up to +16%) while, it could decrease slightly water demand for winter crops (up to –2% for wheat crop) by year 2050. The overall ET average change for the crops under study was 10%.

Most of the crops are soil depleting (and with no replinishment by silt expected from HAD), thus demanding fertilizers, more chemical inputs and more water to sustain crop yields. This in turn shall lead to more pollution of the Nile water and expensive drainage water treatment, for making it suitable for reuse. This shall also result in more emissions of nitrous oxide, which, contributes to the cause of temperature rise. Drainage problem lead to reduced crop yields below potential insofar as they impede aeration, leaches nutrients, and induce water-table rise, salinization and need for expensive drainage.

A report on "Agriculture and Land Use change in Egypt sector profile"; (Mustafa et. Al 1997) states that; if climate change results in increased warming; droughts and evaporation, reduced flow of the Nile would further exacerbate Egypt's problems and the country could face an explosive situation. Quantified analysis of situation has shown that Egypt is expected to have a deficit of about 8.7 million ton of cereal (corresponds to a change of –11% in rice productivity, -18% in each of wheat and barley, -19% in each of maize and sorghum and –28% in soybean crop productivity) as a result of climate change.

Table 6: Change in ET and Water Requirements of Major Crops Due to Climate Change (million m^3)

Crop	Total ET	Change %	Deficit or Excess
Wheat	2730.3	-1	-27.303
Maize	2890.97	+8	-391.277
Cotton	2358.32	+10	+235.832
Sorghum	811.642	+8	+68.989
Barley	4703.45	+16	+752.551
Rice	109.67	-2	-1.096
Soybean	271.851	+15	+40.77
Total ET	21956.68		+1433.175
Total Water Requiremtns	36594.46		+2388.625

Source: Eid et al 1997 a,b,c,d

4. Climate Change Adaptation Programs in Egypt

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

5. Bibliography

1. Ahmed Mohsen, 1999, Sustainable development in the light of climate change, The First Global Environmental Experience Sharing Conference 24-26 September 1999
2. Alcamo, J. and Kreileman, E., 1996. The Global Climate System: Near Term Action for Long Term Protection. RIVM Report no. 481508001. Bilthoven, The Netherlands; Rijkinstitut voor Volkesgezonheid en Milieu.
3. Aru, A., 1996. The Rio Santa Lucia site: an integrated study of desertification. In: Brandt, C. J. and Thornes, J. B. (eds). Mediterranean Desertification and Land Use, pp. 189-206. Chichester: John Wiley and Sons.
4. Blue Plan, 1988. Futures of the Mediterranean Basin: Environment Development 2000-2025, Sophia, Antipols. Cited in: Baric, A. and Gasparovic, F. 1992.
5. Blitzer C. et al. 1992. Growth and welfare losses from carbon emissions restrictions: A general equilibrium analysis for Egypt. *The Energy Journal.*
6. Carter, T. R., and others, 1994. IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations. IPCC Working Group II. Available from: Department of Geography, University College, London.
7. Change, 1 (3), pp. 219-232.Sestini, G. 1993. Implications of climatic changes for the Nile Delta. In *Climatic Change in the Mediterranean*, ed. G. Sestini, 535-601.
8. Cotton, W. R. and Pielke, R. A., 1995. Human Impacts on Weather and Climate. Cambridge: Cambridge University Press.
9. Downing, T. E., 1992. Climate Change and Vulnerable Places: Global Food Security and Country Studies in Zimbabwe, Kenya, Sengal and Chile. Oxford: Environmental Change Unit.
10. 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.
11. Egypt's Climate Change National Action Plan, 1999.
12. Eid, Helmy M. 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.
13. El Quosy, Dia El Din. "Climate Change and Water Resources in Egypt." Paper presented during the Egypt- US Workshop on Global Climate Change, Cairo: 10-12 May 1999.
14. 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*.
15. El Raey, M. et al. Vulnerability Assessment of the Coastal Zone of Egypt to the Impacts of Sea Level Rise. Phase II US Country Study Program.
16. El Raey, M. et al, 1995, Inventory and Mitigation Options, and Vulnerability and Adaptation Assessment Interim Report on Climate Change Country Studies.
17. 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.
18. 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.
19. 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.

20. Metaxas, D. A., Bartzokas, A. and Vitsas, A., 1991. Temperature fluctuations in the Mediterranean area during the last 120 years. Int. J. Climatol., 11, 897-908.
21. Milliman, J. D., 1992. Sea-level response to climate change and tectonics in the Mediterranean Sea. In: Jeftic, L., Milliman, J. D. and Sestini, G. (eds). Climatic Change and the Mediterranean, pp. 45-57. London: Edward Arnold.
22. Milliman, J. D., Jeftic, L. and Sestini, G. (eds), 1992. The Mediterranean Sea and climate change - an overview. In: Jeftic, L., Milliman, J. D. and Sestini, G. (eds). Climatic Change and the Mediterranean, pp. 1-14. London: Edward Arnold.