Chapter 30
Effects of Climate Change on Egypt's Water Supply

Gamal Elsaeed

Abstract Egypt is plagued by a water shortage as well as water resource management issues. Egypt, as a developing country, is at particular risk for being unable to provide clean drinking water and adequate sanitation systems for citizens, ensure sustainable irrigation, use hydropower to produce electricity, and maintain diverse ecosystems. The Egyptian Environmental Affairs Agency report notes that Egypt's fresh water budget runs a deficit: supply, which comes from the Nile (95%), precipitation (3.5%) and ground water (1.5%) is less than current demand. Egypt has available fresh water reserves of 58 billion m^3, but an annual water demand of about 77 billion m^3. This deficit is met through recycling treated sewage and industrial effluent (four billion m^3) and recycling used water, mainly from agriculture (eight billion m^3). An additional four billion m^3 is extracted from the shallow aquifer and three billion m^3 comes from the Al Salam Canal Project. Egypt is therefore in a situation where it must plan for several different future scenarios, mostly negative, if climate change results in increased temperatures and decreased precipitation levels. Even in the absence of any negative effects of climate change, Egypt is dealing with a steady growth in population, increased urbanization, and riparian neighbors with their own plans for securing future water needs. All of these will require Egypt to put water resource planning as a top national security priority.

Keywords Egypt • Climate change • River Nile • Water resources • Nile basin

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G. Elsaeed (✉)
Department of Civil Engineering, Faculty of Engineering, Shobra, Banha University, Cairo, Egypt
e-mail: gelsaeed@feng.bu.edu.eg

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30.1 Introduction

Any assessment of Egypt's water resources recognizes the country's enormous reliance on the Nile, which makes up about 95% of Egypt's water budget. Other sources of Egypt's water budget, precipitation and ground water, do not make up more than 5% of the available supply, although the effect of increases or decreases in precipitation near the sources of the Nile can have a larger than expected effect on Nile flows.

Egypt's total water budget is produced by a combination of three variables: the Nile (95%), precipitation (3.5%) and ground water (1.5%). The Nile produces 55.5 billion m^3, while the latter two variables combine to form safely about 2.2 billion m^3 of fresh water. In total, Egypt has available fresh water reserves of 58 billion m^3.

Egypt's annual water demand is about 77 billion m^3. The deficit between Egypt's water supply and demand must be met through recycling. The 19 billion m^3 deficit is filled by a combination of treated sewage and industrial effluent (four billion m^3) and recycling used water, mainly from agriculture (eight billion m^3). An additional four billion m^3 is extracted from the shallow aquifer and three billion m^3 comes from the Al Salam Canal Project.

Recycling is partly natural and partly intentional. Water reclaimed from agriculture is a natural process of drainage waters returning to the Nile. The remaining two sources of recycled water, the Al Salam Canal and extraction from the shallow aquifer, are manmade solutions to the deficit.

Consumption of the 77 billion m^3 in annual water demand in Egypt is mainly from agriculture (62 billion m^3). An additional 10% (eight billion m^3) is used as drinking water. Approximately 95% of the population relies on this water for drinking purposes. The remaining demand comes from industry (7.5 billion m^3).

The following paper will focus on the impact of climate change on water supply and the potential challenges Egypt will face in the future if the balance between water supply and demand is altered.

30.2 Vulnerability of Water Resources to Climate Change

Managing water resources will become a more complex endeavor with climate change. Analysis predicts that climate change will intensify and accelerate the hydrological cycle, which will result in more water being available in some parts of the world and less water being available in other parts of the world (most of the developing world). Weather patterns are predicted to be more extreme. Those regions adversely affected will experience droughts and/or possible flooding.

Is Egypt vulnerable? The answer is yes. The Nile waters are highly sensitive to climate change, both in amount of rainfall and variations in temperature. And since these two factors are also interrelated, i.e., temperature changes affecting rainfall, it can be expected that climate change will take the form of changes in levels of

Table 30.1 Change of flow corresponding to uniform change in rainfall for Nile sub-basins

	Change in rainfall					
	−50	−25	−10	+10	+25	+50
Sub basin	Corresponding change in water flow (%)					
Atbarra (Atbara)	−93	−60	−24	+34	*84	+187
Blue Nile (Diem)	−92	−62	−24	+32	+78	+165
Blue Nile (Khartoum)	−98	−77	−31	+36	+89	+149
Lake Victoria (Jinja)	−20	−11	−4	+6	+14	+33
White Nile (Malakal)	−41	−28	−11	+19	+48	+63
Main Nile (Dongla)	−85	−63	−25	+30	+74	+130

Table 30.2 Nile flows under sensitivity analysis

Precipitation	−20%	−20%	−20%	0%	0%	+20%	+20%	+20%
Temperature	0	2	4	2	4	0	2	4
Flow (BCM)	32	10	2	39	8	147	87	27
% of base	37	12	2	46	10	171	101	32

precipitation as a result of changes in temperature, or other factors, and that the resulting effect on the Nile flows will be from moderate to extreme, with the latter scenario most likely in the long term.

In terms of levels of sensitivity of Nile flows, the Nile waters are separated into three areas, containing sub-basins: the Eastern Nile, comprised of the Atbara and Blue Nile, the Equatorial Nile, which is Lake Victoria at Jinja, and the Baba El Ghazal Basin, which is the White Nile at Malakal.

The range of sensitivity to rainfall differs from one sub-basin to another. The Eastern Nile is extremely sensitive, the Baba El Ghazal Basin moderately sensitive, and the Equatorial Nile only minimally sensitive. Table 30.1 summarizes the levels of sensitivity to rainfall in the different Nile sub-basins.

Nile water flows are also sensitive to temperature changes. The EEAA* report cites Hulme et al. [4] who argue that changes in temperature affect evaporation and evapotranspiration correspondingly. Increases in evaporation and evapotranspiration as a result of increases in temperature could reduce the levels of water flows in some Nile sub-basins by double or triple the percentage of evapotranspiration. Table 30.2 displays the results in the EEAA* report of a study by Strezpek et al. [7] on Nile sensitivity to temperature changes.

The sensitivity of Nile flow to climate change is strongly supported by the above data. For example, an increase in temperature of 4°C coupled with a 20% decrease in precipitation could decrease the flow in Nile by 98%. A slightly smaller increase in temperature (2°C) with the same reduction in precipitation could result in an 88% decrease in Nile flows. Thus climate changes have a potentially dramatic effect on Nile flows and thus on water resources for Egypt, which is heavily dependent on the Nile for its water supply.

30.3 Scenarios of the Effect of Climate Change on Nile Flows

Table 30.3 shows the results of three Global Circulation Models (GCMs) used in 1996 to estimate future Nile flows and cited in the EEAA* report. Variables in the studies include precipitation, temperature, increases in CO_2, and flow rate in Nile. An assumption in the models is that increases in CO_2 concentrations would result in increases in temperatures. Results indicate that even with increases in the amount of precipitation, Nile flows would decrease in two of the three scenarios as a result of rises in temperature.

The conclusions drawn from the above calculations are as follows:

- Contributions from the Equatorial Nile to downstream Nile flows can be reduced to zero by only minor increases (2.7–4.8°C) in temperature or minimal decreases (15–17%) in precipitation
- Water loss from evaporation and evapotranspiration, currently occurring to a large extent on the water surfaces and from vegetation on the Bahr el Ghazal basin would be even greater with any increases in temperature
- Climate changes would most likely result in the Eastern Nile retaining its essential role in preserving Nile flows

The EEAA* report cites a research model by Strezpek et al. [8], who developed ten different scenarios for Nile flows. Nine of the ten predict reductions in Nile flows from 10% to 90% by the year 2095. Even in the short term, by 2025 losses are estimated at 5–50%. Figure 30.1 shows the Strezpek models of changes.

The question of the vulnerability of the Nile flows to amounts of rainfall upstream was demonstrated in a 2005 United Nations Environment Program (UNEP) (2005) [9] study cited in the EEAA* report. Gauging stations along the Nile measure water levels. Figure 30.2 displays a stream hydrograph charting the levels taken at the Atbara gauging station, established in the early twentieth century. Monitoring at the Atbara station was recorded for a 90-year period: (1907–1997). Over this period, water levels rose and fell but can be divided into three recognizable periods: rising slightly from 1907 to 1961; dropping sharply from 1962 to 1984, and recovering from 1987 to 1997 to pre-drop levels. What is significant is that these increases and decreases in water levels coincided with increases and decreases in the amount of flows from the Ethiopian highlands as a result of rainfall. This is strong evidence of the effect of upstream rainfall on downstream water levels.

A 2007 study by Bergen University in Norway under the Nile Basin Research Program (cited in the EEAA report), focuses on three sub-catchments of the Nile basin: the Atbara in Ethiopia near the border with Eritrea, the Kagera on the Uganda-Rwanda border, forming the Southwest of the Lake Victoria Basin, and the Gilgel Abbay in the Blue Nile Basin, which is the main feeder of Lake Tana in Ethiopia. Figure 30.3 shows the location of three catchments in red in relation to the Nile river, in blue.

Research conducted during the period August-December 2007 on these three sub-basins supported other research, such as that of Kite and Waitutu (1981),

Table 30.3 Nile flows under GCM scenarios

	Base	UKMO	GISS	GFDL
Precipitation	100	122	131	105
Temperature	0	4.7	3.5	3.2
Flow (billions m^3)	84	76	112	20
% of base	100	91	133	24

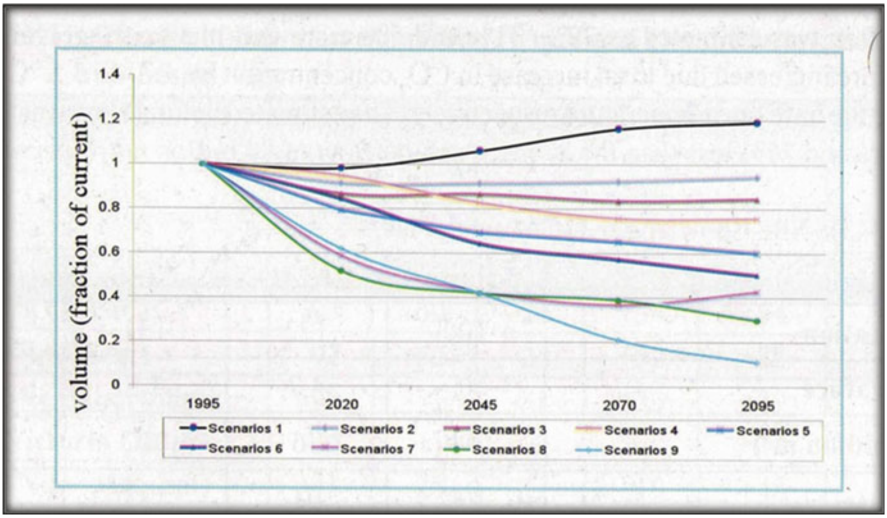

Fig. 30.1 Scenarios of changes in Nile flows (Strepzek et al. 2001) [8]

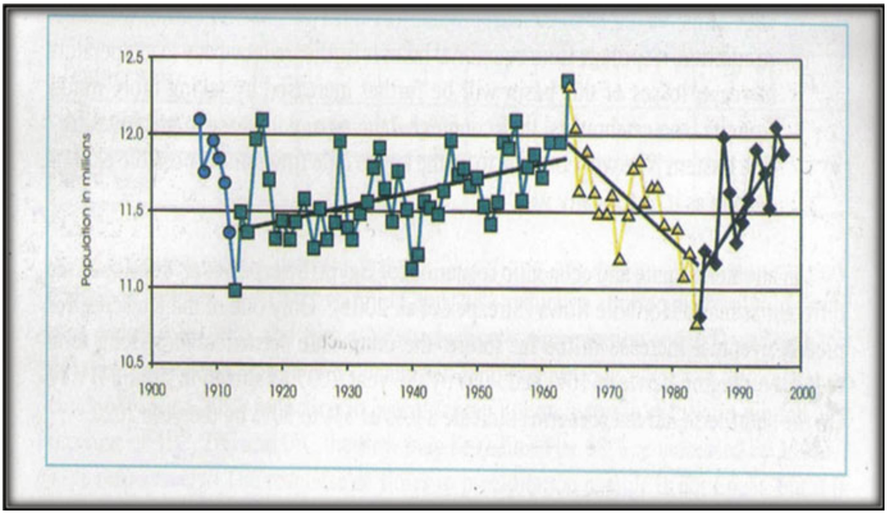

Fig. 30.2 Annual average stream levels on the Nile at Atbara (UNEP 2005) [9]

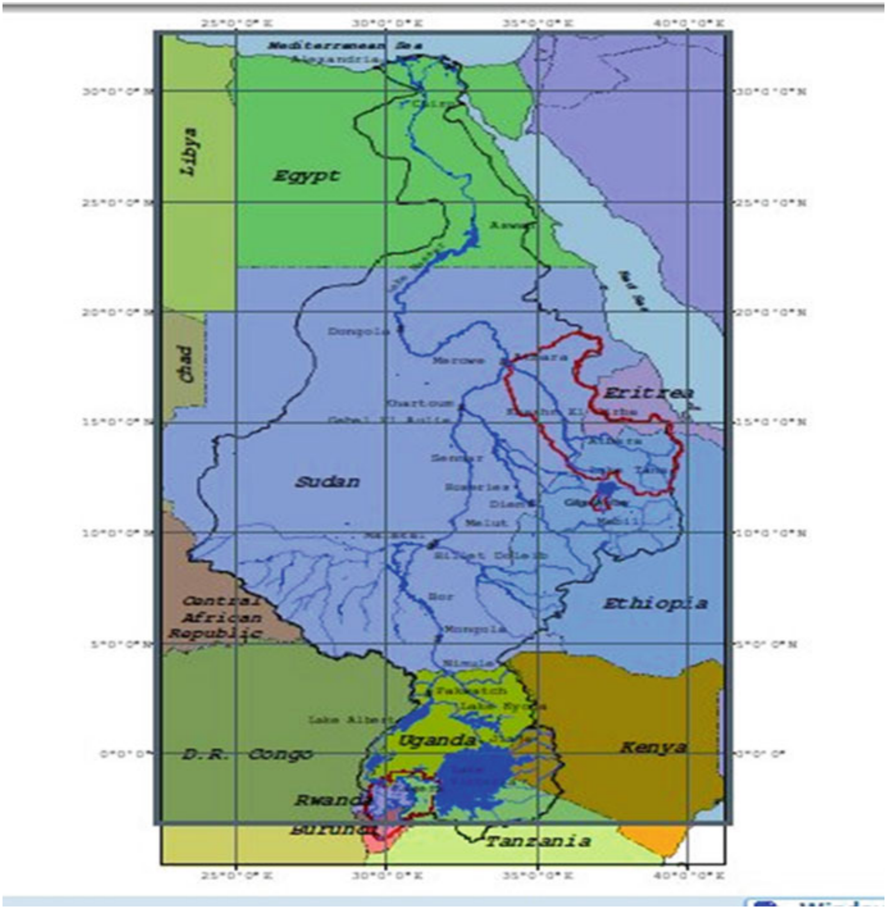

Fig. 30.3 The three sub-catchments of the Bergen University study [4]

studying the Nzoia River, a tributary of Lake Victoria. The results show that runoff is more sensitive to precipitation changes than to evapotranspiration. The Kagera catchment has a large base flow due to the regulating effect of the lakes and swamps in the sub-basin. Of the three catchments, the Kagera is the most sensitive to evapotranspiration and this may be due to its higher aridity [4]. The significance of this study is twofold: it is necessary to understand both the main features of each catchment and the sensitivity of each catchment to changes in rainfall and evapotranspiration because this assists countries in the Nile region to take more proactive measures in light of fluctuations in Nile flows as a result of fluctuations in rainfall.

The EEAA* report cites Agrawala et al. [1], who concluded in an Organization for Economic Cooperation and Development study that Egypt's vulnerability in terms of water resource dependence on the Nile is tied to trends in population growth, land use, and agriculture and economic activity being almost exclusively focused along the Nile Valley and Delta. As demand increases, due to growth in population and any increases in temperature leading to greater evaporative losses of the country's allocation of Nile water, Nile water availability is likely to be increasingly stressed. Any activity upstream that added to the diminishing of available water resources in Egypt, whether manmade by upstream riparian countries or otherwise unaccounted for could seriously exacerbate this stress on Egypt. Countries downstream in the Nile basin, of which Egypt is by far the most populous and the most dependent on the Nile for its water needs, are sensitive to the variability of the runoff from the Ethiopian part of the basin, according to the International Water Management Institute (IWMI) together with Utah State University (Kim et al. [6]) and cited in the EEAA* report.

The report notes that future hydropower dam operation in the upstream part of the Nile basin may have an impact on the Nile basin if future climate scenarios materialize. They are summarized as follows:

- Climate changes in the form of more precipitation and higher temperatures in most of the Upper Blue Nile River Basin
- Higher and more severe low flows, but droughts of less frequency over the mid to longer term
- Minimal or negligible effect of dam operations on water availability to Sudan and Egypt

The results are, however, uncertain with existing accuracy of climate models. In other words, there is no clear indication that suggests any one specific scenario, and the region could take actions to produce hydropower, increase flow duration and increase water storage capacity without affecting outflows to riparian countries into the 2050s.

In summary, all studies clearly show that the results obtained of the impact of climate change in the Nile Basin are strongly dependent on the choice of the climate scenario and the underlying GCM experiment.

30.4 Other Vulnerability Indicators

It is easy to overlook factors beyond climate change that make Egypt vulnerable to water shortages in the future: The following looks at other consideration for Egypt and the Nile Basin.

30.4.1 Population Growth and Urbanization

Population growth and extension of inhabited areas increase wastewater disposal causing deterioration of river quality from upstream to downstream. Upstream excessive urbanization may result in increased flooding downstream due to the reduction in infiltration and evapotranspiration from natural vegetation and more runoff downstream.

30.4.2 Water Related Conflicts

Upstream Nile countries depend more directly on rain, which sustains forestry, wildlife, wetlands, rain-fed agriculture, fishing and groundwater recharge. For tail end countries, Nile water is the only source of irrigated agriculture and drinking water supply. The per capita share of water in the Nile Basin stands now at 1,000 m^3 per capita per year. This is expected to drop by 50% by the year 2050. Water problems upstream are related to drainage, flood protection occasional drought, infrastructure, while water problems downstream are mainly related to scarcity.

There is high potential for trans-boundary cooperation rather than conflict. Projects for decreasing losses and preventing flood hazards upstream could be developed to generate additional river flows for downstream countries.

30.5 Conclusions

The above discussion reveals the following important points:

- Natural flows in the River Nile Basin as a whole and in separate sub-basins are extremely sensitive to changes in precipitation and temperature increase
- Estimates of the order of magnitude of the effect of GHG emissions on temperature and precipitation rate are extremely uncertain
- Both high and low natural flows of Nile water have positive and negative impacts on the water system in Egypt. Higher flows require bigger storage capacity and a larger conveyance and distribution network. Reduced rates of natural flows limit the ability of the economy to cope with all development activities, especially agriculture, industry, tourism, hydropower, generation, navigation, fish farming and environment required for providing the ever growing population with potable and domestic requirements.
- Little has been published internationally on the effect of climate change on precipitation on the coastal strips running parallel to the Mediterranean and the Red Sea, except that stated by the IPCC (2007) [5] on the prediction of movement of the rain belt form north to south.
- Sea level rise will certainly affect groundwater aquifers in the Nile delta, in particular those close to the northern strip. These aquifers, although brackish, were considered future hope. However, increased salinity may cause them to be unusable.

30.6 Adaptation

Egypt is a developing country, with a majority of its population dependent on government subsidies and other low-income support. This, coupled with higher than desired population growth, presents the government with immediate challenges that make it more difficult to justify placing long term water management needs at the top of their list of national priorities.

Research on adaptation to climate change has produced suggestions for initiatives, some structural, some soft, some on the local level, and others regional, requiring a consensus of some or all of the ten countries sharing the Nile basin. Following are some of the policies collected from the different sources of information of this document:

30.6.1 Adapt to Uncertainty

Maintain storage at Aswan High Dam at lower elevations and allocate other storage, to receive or absorb surplus water in the event of emergencies. Examples of other storage areas include:

- the Toshka and Qantara Depressions, currently dry
- the Qaroun and Wadi Natroun areas, where limited ground waters are collected
- the coastal lakes of Manzala, Borroulas, Edko and Mariout, which are salty,
- cultivated areas, particularly in highly elevated lands

30.6.2 Adapt to Increase of Inflow

Revive the plan to store in upstream lakes in light of the present development of the Nile Basin Initiative.

30.6.3 Adapt to Inflow Reduction

Egypt's per capita share of water will be reduced by half by 2050 even in the absence of climate change. Some of the measures that need to be taken according to the National Water Resources Plan (NWRP) developed by the Ministry of Water Resources and Irrigation are the following:

- Physical improvement of the irrigation system
- More efficient and reliable water delivery

- Better control on water usage
- Augmented farm productivity and raised farmers income
- Empowerment and participation of stakeholders
- Quick resolution of conflicts between users
- Use of new technologies of weed control
- Redesign of canal cross sections to reduce evaporation losses
- Cost recovery systems
- Improvements to drainage
- Change of cropping patterns and on farm irrigation systems

30.6.4 Develop New Water Resources

- Reevaluate in light of impacts of climate change previous upper Nile conservation projects to increase Nile flows
- Explore deep groundwater reservoirs in the Sinai Peninsula and the Western desert as potential sources of water if needed
- Promote rain harvesting as a possible solution to destructive Red Sea area flash floods
- Desalinate brackish groundwater
- Increase recycling of treated wastewater (both domestic and industrial)
- Increase reuse of land drainage water

30.6.5 Soft Interventions

- Promote public awareness
- Develop circulation models
- Increase research in all fields of climate change and its impact on water systems
- Encourage exchange of data and information between Nile Basin countries
- Enhance precipitation measurement networks in upstream countries of the Nile Basin

References

1. Agrawala, Shardul, Moehner A, El Raey, My Conway D, Van Aalst M, Hagenstad M, Smith J (2004) Development and Climate Change in Egypt, Focus on Coastal Resources and the Nile, Working Party on Global and Structural Policies, Organization for Economic Cooperation and Development, (OECD)
2. Conway D (2005), from Headwater Tributaries to International River: Observing and Adapting to Climate Variability and Change in the Nile basin. Glob Environ Chang 15:99–114

3. Egypt Second National Communication Report by the Egyptian Environmental Affairs Agency (EEAA), May 2010
4. Hulme M, Conway D, Kelly PM, Subak S, Downing TE (1995) The Impacts of Climate Change on Africa, SEI, Stockholm, Sweden
5. IPCC (2007) Climate Change 2007, Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK
6. Kim U, kaluarachchi JJ, Smakhtin VU (2008) Climate Change Impacts on Hydrology and Water Resources of the Upper Blue Nile River Basin, Ethiopia, Research Report 126, International Water Management Institute
7. Strezpek KM, Yates DN, El Quosy DED (1996) Vulnerability Assessment of Water Resources in Egypt to Climate Change in the Nile Basin, Climate Research 6: 89–95
8. Strezpek KM, Yates DN, Yohe G, Tol RJS, Mader N (2001) Constructing "Not Implausible" Climate and Economic Scenarios for Egypt, Integrated Assessment 2: 139–157, Integrated Assessment Society
9. UNEP (2005), Facing the Facts: Assessing the Vulnerability of Africa's Water Resources to Environmental Change