

Climate, water supply, management and use in the Nile, a comparison

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Recently the International Panel on Climate Change (IPCC) published an updated report series that summarizes the research results to climate change over the last 5 years (IPCC, 2007). The conclusions in the reports confirm again that we should expect a historically unprecedented global climate change in the coming century. The cause of this change can be attributed to the emission of greenhouse gasses in the atmosphere. Confidence in trends and causes has increased to such an extent that it is currently also politically the most important environmental issue debated. This climate change will directly affect water supply through changes in rainfall, evaporation and river discharge. On the global scale trends are quite clear. Global temperature will rise between 1.5 and 4.5 degrees Celsius. This temperature rise will lead to an acceleration of the global hydrological cycle, meaning more rainfall and evaporation. On a regional scale the magnitude and even the trends of the changes will differ. There are areas that will become dryer and others that will become wetter.

With respect to water management climate change will lead to changes in both water supply and water demand. However, apart from changes in climate, water supply and demand in a country are determined by a number of other factors such as water use, land use, water allocation, water infrastructure such as reservoirs and distribution mechanisms often described by water agreements. This all is described as integral water resources management, illustrated by figure 1.

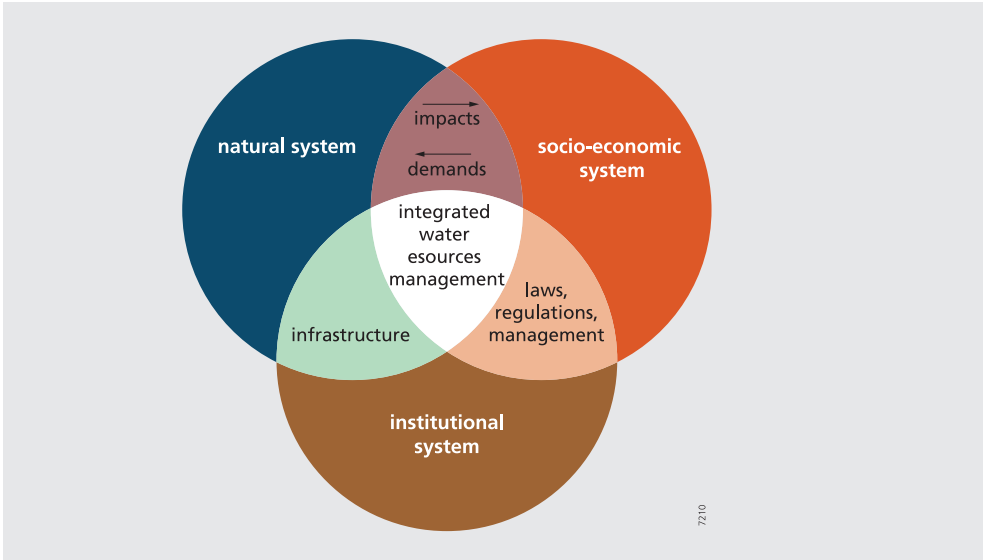


Figure 1 Analysis framework for integrated river basin management. Source: based on Loucks & van Beek, 2005

In this paper I explore the effects of climate change on the Nile discharge and compare these with other factors using the analysis frame work. The focus will be on the water management of Egypt, which is for 90 percent dependent on the Nile in terms of water resources. This exploration is brief, but extensive studies have been conducted on the various river basin management issues. Some of the studies were published in the scientific literature but a vast series of potentially very valuable studies, produced by many development aid projects, are still hidden in the cellars of the many institutes and ministries of different administrations in the Nile basin. Despite all good intentions expressed within the Nile Basin Initiative, it is still very difficult to obtain the information needed from the various Nile countries.

The natural system

Current conditions

The equatorial lake area and the Ethiopian highlands form the most important sources of the Nile (figure 2). The Equatorial lake area, source of the White Nile, supplies approximately 26 BCM (10^9 m^3) annually. The outflow from the lakes is nearly constant over the year as the lakes dampen monthly precipitation differences. However, the annual outflow is very sensitive to small changes in precipitation. Between 1960 and 1965 the outflow from Lake Victoria increased from 20 to 45 BCM, which could be attributed to a precipitation change above the lake of only 10 percent. North, the outflow from the equatorial lake area enters huge marshes in Southern Sudan where about 50 percent of the water evaporates (Suttcliffe and Parks, 1999).

The Blue Nile, Sobat and Atbara drain the Ethiopian highlands, contributing in total an annual average of 75 BCM, of which 50 BCM is supplied by the Blue Nile only. The Blue Nile shows a strong monsoonal character with a flood peak between August and October caused by the seasonal migration of the Inter Tropical Converge Zone (ITCZ). The rainfall amount over the Ethiopian highlands can vary strongly from year to year and thus the runoff. The main control is the timing of and position of the jet stream. Several studies claim a strong correlation with El Nino and El Nina events (e.g. Eltahir, E.A.B., 1996).

The overall water balance of the Nile results in an average annual flow to Egypt between 84 and 92 BCM, depending on the time period considered. Over the period 1901-2001 the average natural flow, which is the flow assuming no water is used upstream of Egypt, is estimated at 87 BCM.

Scenario's for discharge changes in the Nile

In the water balance of the Nile can be written as:

$$R = P - E \pm dS$$

On the long term, the storage term dS will be close to zero and can be ignored. The rainfall term P and the evaporation term E are very much larger than the resulting runoff R . This means that small changes in rainfall or evaporation may very well result in relatively large changes in the runoff. This makes the Nile discharge very sensitive to climate change. The historical record of Lake Victoria illustrates this sensitivity. Sensitivity experiments for the Blue Nile using the hydrological model running at the Nile Forecasting Centre at the Ministry of Water Resources








-  river
-  floodbasin
-  existing dam
-  dam under construction
-  national boundary



Figure 2 The Nile basin. Source: based on MWRI, 2005

Table 1 Estimates of changes in precipitation over the Nile basin, High and low estimates are based on the median plus/minus 1 times the standard deviation of 11 climate models. DJF refers to December-February; JJA refers to June-August. Source: OESO, 2004

Year	Precipitation change (%)								
	Annual			DJF			JJA		
	low	central	high	low	central	high	low	central	high
2030	-0.9	1.5	3.87	-2.15	16.6	35.4	-10	-0.5	8.97
2050	-1.3	2.1	5.53	-3.09	24.0	51.1	-14	-0.7	14.39
2100	-2.3	3.7	9.67	-5.47	41.7	88.9	-25	-1.2	22.63

and Irrigation, Egypt suggested a runoff sensitivity of 3-4 times the rainfall change (Sayed, 2004).

Recorded trends in rainfall suggest a slight increase in rainfall in the equatorial lake area, which signal fades away going to the north where the trend is towards dryer conditions. Future rainfall projections derived from Global Climate Models on the Nile basin show considerable differences from model to model (E.g. Hulme (2001)).

At least two studies (OESO, 2003; Sayed, 2005) carried out a multi-model approach for projecting climate scenarios on the Nile basin. The OESO study focused on the climate only of the entire Nile basin, where Sayed (2005) included runoff from the Blue Nile region. Based on the results of 4 climate models Sayed suggested an annual rainfall change between -2.15 and +10.65 percent for 2030, which is a relatively large range compared to the results in the OESO study (Table 1).

In combination with the runoff sensitivity to changes in rainfall and evaporation, uncertainties in rainfall projections are multiplied when considering uncertainties in water supply projections for the Nile basin. Sayed (2004) suggests a change in Nile discharge between -14 and +32 percent for 2030. Applying the results of the OESO study, a study conducted by MWRI (MWRI, 2005) suggests the runoff changes shown in Figure 3.

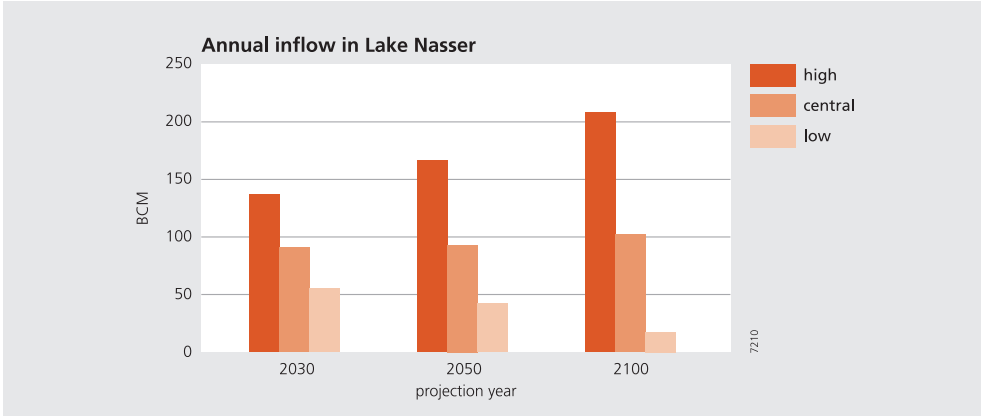


Figure 3 Scenario's for the Nile inflow into Lake Nasser. Source: MWRI, 2005

Table 2 Socio economical figures for the Nile basin

Riparian State	GNP per capita US \$	Global Poverty Ranking	Population		Population avg. annual growth 1990-95 %	Life expectancy
			1995	2025		
Burundi	160	4	6,4	13,5	3,0	49
D.R. Congo	264	21	43,9	104,6	3,2	52
Egypt	790	53	62,9	97,3	2,2	63
Eritrea	-	-	3,5	7,0	2,7	48
Ethiopia	100	2	55,1	126,9	3,0	49
Kenya	280	23	28,3	63,4	3,6	58
Rwanda	180	7	8,0	15,5	2,6	46
Sudan	493	38	28,1	58,4	2,7	54
Tanzania	120	3	29,7	62,9	3,0	51
Uganda	240	14	21,3	48,1	3,2	42

The socio-economic system

Table 2 provides some key socio-economical figures for the Nile basin. The figures clearly indicate huge differences between countries. Egypt is by far the most powerful country economically, having the highest GNP, life expectancy and population. All Nile basin countries apart from Egypt are in the list of least developed countries.

The Nile basin has a population of 172 million people. Projections for future population vary between 314 and 478 million with a medium estimate of 406 million (UN, 2003). It appears that even in the low variant the population in the Nile basin almost doubles between 2000 and 2050. The average annual growth rates for the low, medium and high variants in the Nile basin during the 50-year period are 1.35, 1.70 and 2.03 percent, respectively.

Current Irrigation demand and potential future water demand

Water demand growth is strongly related to population growth. In the Nile basin agriculture forms the major water demanding sector. Figure 4 clearly shows the relatively large irrigation demand from Egypt and Sudan as well as the huge potential irrigation demand in Ethiopia.

NBI conducted an inventory to the potential future water demand in the Nile basin. The inventory was based on a review of formal policy documents produced by the administrations of the riparian states, studies carried out by international agencies such as FAO and the UN as well as feasibility studies on irrigation development schemes and reservoirs. The study concluded that if the most feasible plans would be implemented in future, additional abstractions from the Nile upstream of Lake Nasser could grow to 30 percent of the average natural flow, approximately 25-30 BCM annually. Some of these developments are already being undertaken. Currently Sudan is erecting the Merowe dam between Khartoum and Wadi Halfa and the Tekeze dam in the Atbara and Ethiopia is developing the Karadobi dam in the Blue Nile. In the mean time Egypt is developing new irrigation schemes, the horizontal expansion schemes, such as the Toshka valley irrigation scheme and the Sinai scheme. In full operation the Egyptian plans would lead to an additional demand of 8 BCM annually (MWRI, 2005).

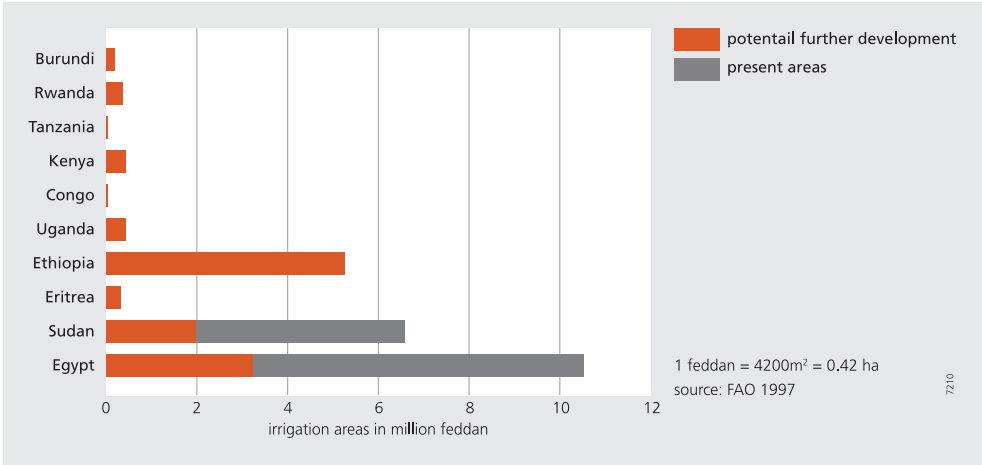


Figure 4 Irrigation areas in Million feddan (1 feddan = 4200 m² = 0.42 ha). Source: FAO, 1997

Potential for increasing the water supply by water infrastructure

Already since the start of the 20th century plans were made to make use of the water that currently evaporates in the marshes in southern Sudan. The idea is to drain these marshes, around the Bahr el Ghazal, Bahr el Arab and the Machar swamps (Sobat basin). This reduces the evaporation considerably and would increase the discharge of the White Nile. It should be noted that all these projects are heavily debated due to the ecological and undesired effects for the local inhabitants.

Implementing all projects would increase the Nile inflow into Lake Nasser by 19 BCM (based on Sutcliffe and Parks, 1999). Due to the data scarcity in the Southern Sudan region, the estimates are beset with uncertainties. In the early eighties of the last century, the digging of a canal, the Jonglei canal even started, but the work was abandoned due to the civil war in Southern Sudan.

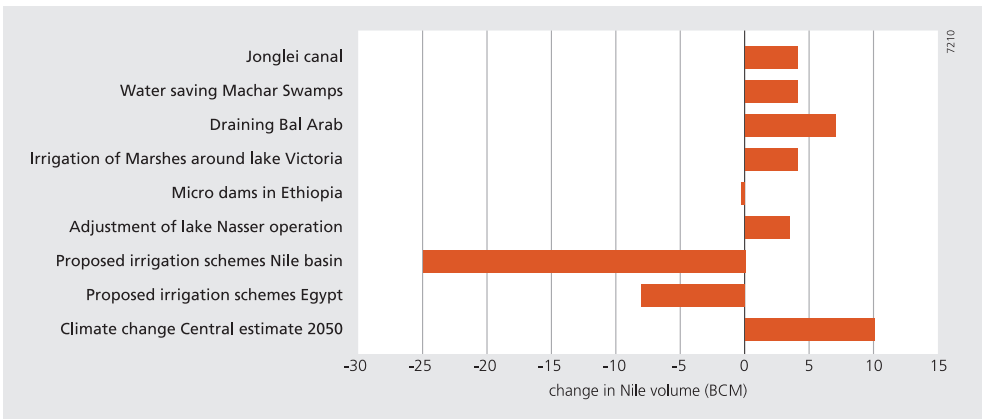


Figure 5 Effects of water saving projects, upstream developments and climate change (central estimate 2050) on the volume of the Nile

Apart from the huge water saving projects in Southern Sudan, water can be saved by reducing evaporation from Lake Nasser through operating the lake at a lower level. This reduces the surface area of the lake. When indeed Ethiopia develops the planned reservoirs, this would mean that the Blue Nile would be completely controlled. Managing the Blue Nile reservoirs and Lake Nasser in concert could save up to a maximum of 3,5 BCM as the evaporation losses in Ethiopia are much less than in Southern Egypt.

The Figure 5 shows the estimated effect on the Nile flow of the different future change. Obvious is the large potential effect of the proposed irrigation schemes. This effect exceeds the effect of climate change (central estimate) and all individual potential water saving projects.

Institutional setting, Water agreements in the Nile basin

Within the Nile basin three water agreements guide the river basin management.

- The first agreement was signed in 1929 between Egypt and Great Britain, where the last represented Sudan, Kenya, Tanzania and Uganda.
- In 1959 an agreement was signed between Egypt and Sudan that enabled the erection of the High Aswan Dam and regulated the water distribution between Egypt and Sudan.
- In 1993 an agreement was signed between Egypt and Ethiopia.

The main issues were:

Agreement 1929:

- no works will be undertaken on the Nile, tributaries and lakes which would reduce the volume of the Nile waters reaching Egypt
- Egypt has the right to inspect the implementation of projects
- all agree on Egypt's ancient rights of the Nile water
- Egypt has the rights to investigate along the whole length of the Nile, to the remote sources of Nile tributaries in these territories

Agreement 1959:

- interrelation with the agreement of 1929
- earlier acquired rights: 48 BCM/yr for Egypt and 4 BCM/yr for Sudan
- utilization of Nile waters after construction of the High Aswan Dam to be shared by Egypt (7,5 BCM/yr) and Sudan (14,5 BCM/yr)
- extra water from the Nile will be equally shared Sudan and Egypt on a 50/50 basis
- the construction of Rosairas reservoir in Sudan
- projects to minimize losses projects in Gabal and Zaraf lakes, Ghazal lake and its branches, Sobat river and its branches, and the White Nile Basin
- technical cooperation between both countries and with other Nile Basin countries
- establishment of the Permanent Joint Technical Commission (PJTC) of the Nile waters

Agreement 1993:

- both countries should not embark on any works on the Nile that could harm and affect other countries
- importance of safekeeping and protecting the Nile water
- compliance with international laws
- consultation and cooperation between both countries for utilization of the Nile water to increase water flows and to reduce losses

In practice the agreements divide the Nile water between Egypt and Sudan. It is not surprising that, due to the very restrictive character, particularly the 1929 agreement has been, and still is, debated between the riparian states. The extension of the use of Nile water envisaged in the former section is not possible within the boundary conditions prescribed by these agreements. Hopefully, the Nile Basin Initiative will facilitate a satisfying solution of this debate.

Set the priorities for water management

The second agreement distributes the water between Sudan and Egypt. Assuming this agreement valid in the future, the water share for Egypt would develop according to Figure 6.

This figure clearly illustrates the uncertainty with respect to climate change scenarios. The dry scenario would lead to conditions in 2100 where agriculture would be virtually no longer possible in Egypt. The wet scenario would double the average inflow in Lake Nasser, leading to a complete redesign of the water infrastructure in Egypt as the capacity of the Nile as well as the current canals will be insufficient to convey the water.

In 1997 the annual available water per capita in Egypt was 947m³. This reduces to 733m³ in 2017 (MWRI, 2005) and further to approximately 475 m³ in 2050 without taking climate change into account. Projections for population growth used here, envisage an increase of 1.35 – 2.01 percent annually. Using these figures this implies that Egypt’s population would grow to 136 – 191 million people in 2050. Assuming the lowest projection for population growth and the wettest climate scenario, the water availability per capita would reduce to 650 m³.

Measuring urgency of water management issues in an uncertain future can be done by a matrix that shows the **consequences** on a scale from *Insignificant* to *Catastrophic* and the **level of confidence** between *Almost Certain* and *Extremely Unlikely*. The **attention** paid to the issue varies between *Low* to *Extreme* depending on the combination. Table 3 shows that most issues described above have a more than moderate impact. However, if the focus is on the developments within the next 50 years, confidence levels vary considerably.

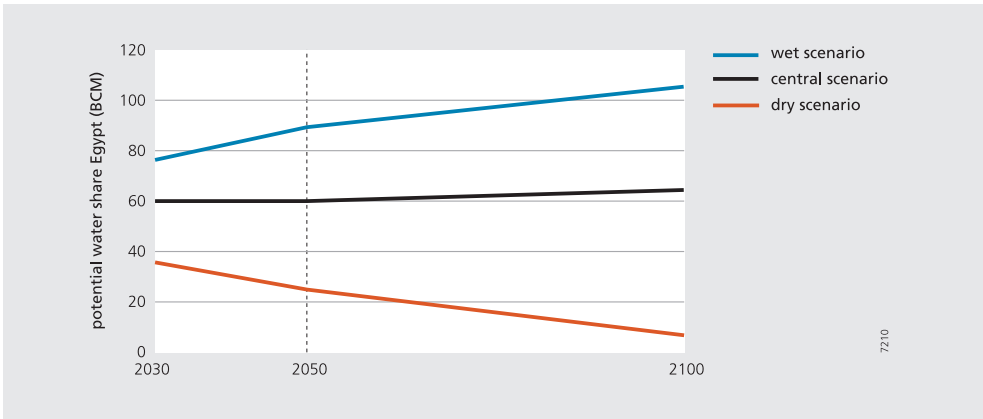


Figure 6 Potential water share for Egypt based on the Egypt-Sudan treaty of 1959, assuming climate change central, high and low estimate.

Table 3 Measure the urgency of the global changes as a function of consequences and likelihood

Likelihood of trend/occurrence	Consequences on water supply/demand				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain				Horizontal expansion projects	
Very likely		Water saving by managing Lake Nasser	Reservoirs in Blue Nile	Upstream irrigation schemes	Population growth
Likely	Micro dams Ethiopia	Water saving by Jonglei Canal		Climate change	
Unlikely			Other upstream water saving projects		
Extremely unlikely					

Population growth is the highest as both trend and magnitude are almost certain. The trend related to climate change has a lower level of confidence as the direction of the trend is still unclear.

Conclusions

The Nile basin riparian states are at the eve of huge changes in the basin. These changes are the result of population growth, the desire of economic development and climate change. All of these trends individually could lead to substantial changes in the Nile discharge and may have serious consequences for the water management. The main conclusions are:

The Nile discharge is very sensitive for small changes in rainfall and evaporation and therefore climate change can have major consequences.

The central estimate climate change scenario suggests wetter conditions, which is beneficial with respect to water supply. However, the extra water cannot compensate for the increase in water demand upstream. Only climate scenarios that envisage a trend to very wet conditions would supply sufficient water to compensate for the autonomous developments.

In terms of urgency, population growth should receive most attention. The potential consequences are larger than other trends. Moreover the very severe consequences are combined with a high level of likelihood.

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