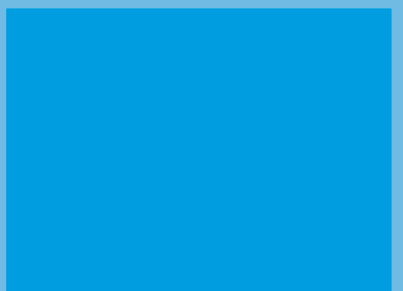
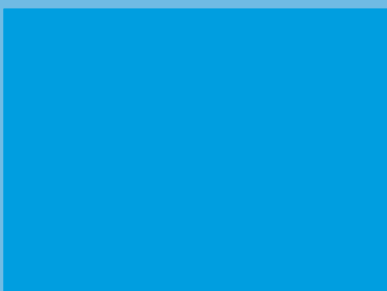
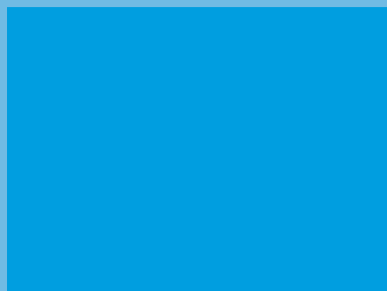


Climate Change and its Implications for the Nile Region



KEY MESSAGES

- There is overwhelming scientific evidence of a warming trend in the Earth's temperature, and consensus about the movement towards intensified extreme events such as floods and droughts.
- The Nile Basin is highly vulnerable to the impacts of global warming owing to a multiplicity of factors, and the basin communities have limited ability to cope with the negative impacts of climate variability.
- Nile flows are very sensitive to small changes in average basin rainfall, but the Nile Basin consists of a number of distinct sub-basins that each respond quite differently to possible climatic variations.
- Although the impacts of a global warming trend are not yet clear at regional and local level, the basin countries would do well to implement a number of 'no-regret' or proactive measures aimed at building resilience to current climate variability while enhancing adaptive capacity for future threats. A sensible approach for now would be to prepare for more variable conditions than currently recorded.
- A prioritized 'no-regret' measure is to expand water-storage infrastructure.
- The National Adaptation Plans of Action (NAPAs) and the early warning systems being developed in the Nile Basin countries represent a substantial effort but are insufficient to prepare effectively for a changing climate, given the scale of the threat.
- Climate-change adaptation measures will be most effective when undertaken in coordination with other riparians. Examples of joint measures to enhance the collective adaptive capacity include coordinated reservoir operation, promoting agricultural trade amongst the countries and between the basin and other regions, interconnecting power and transport systems, developing joint mechanisms for resource solicitation for climate-change programmes, and conducting joint research.

A farmer in Kobo district of Ethiopia surveys his drought-damaged crop.



CLIMATE CHANGE: AN EMERGING THREAT

Climate change is a serious threat, with potentially very adverse impacts on the socio-economic conditions in the Nile Basin, on its environment, and on the ongoing efforts to establish a mutually agreed upon mechanism to manage the shared Nile water resources.

Because of the high sensitivity of key economic sectors such as rainfed and irrigated agriculture, livestock production, and hydropower generation to the changing climate, the threat of climate change is worrying to the people in the Nile Basin. It could directly affect their livelihoods and food security, harm ongoing efforts to diversify national economies, and worsen public-health conditions. Ultimately, in the case of diminishing Nile flows and insufficient adaptation measures, it could result in resource conflicts and regional insecurity.

This chapter aims to inform readers of the seriousness of the threat posed by climate change to the basin, and hopes to provide guidance on what the basin countries need to do to minimize negative impacts of climate change. This chapter starts with a discussion on the long-term changes associated with global climate, and the man-made factors that have caused these changes. It reviews the efforts to understand and predict the future climate in the Nile Basin, and discusses the reasons why the basin is so sensitive to a changing climate. This is followed by an analysis of how climate change may alter the regime of the Nile and its tributaries, and how it could negatively impact the livelihoods of the peoples of the basin. The chapter reviews the climate-change adaptation measures taken by the Nile countries before closing with a discussion on the merits of regional cooperation to support efforts at nurturing climate-resilient growth.

The term ‘climate change’, as used in this report, refers to the significant and lasting change in the global weather conditions over long time periods (i.e. 25 years and longer) and mainly resulting from human activities. By contrast, ‘climate variability’ is used herein to refer to the intra-seasonal and inter-annual fluctuations in climatic parameters. Such variability is complex and hard to predict, and is caused by changes in forcing factors such as alteration in trade-wind patterns, variation in the seasonal extent of the ITCZ, and the periodic occurrence of El Niño Southern Oscillation (ENSO).

The term ‘climate-change adaptation’ is used herein to refer to the response that individuals and communities take to reduce their exposure to impacts of climate change, while ‘climate-change mitigation’ is concerned with actions to reduce human-related forcing factors of global warming, such as reducing atmospheric emissions of greenhouse gases. While aspects of climate-change mitigation will be discussed here, this chapter is mostly concerned with climate-change adaptation.

The parched landscape of Moroto District, Uganda.





CLIMATE CHANGE IS REAL




Evidence for climate change

A number of critical long-term changes in the global climate have been observed that seem beyond dispute. Average global temperatures have risen by 0.8°C over the last century. The temperature curve for Africa shows a similar pattern, with temperature rise accelerating in the last 30 years. Worldwide –including Africa – there are indications of a higher frequency and intensity of extreme weather events, while snow covers are declining in the northern and southern hemispheres. Perhaps the most visible evidence of climate change in the Nile region is the retreating glaciers and ice caps on the Rwenzori Mountains, and on the neighbouring mounts Kenya and Kilimanjaro.

Anecdotal evidence in large parts of the Nile Basin suggests an increase in the temporal variability of rainfall in recent years. It has been reported that the rainy season has become shorter and more intense, and subject to erratic onset and cessation, making it very difficult for farmers to plan the farming calendar. It is not possible at this point in time, however, to verify these reports and determine significant long-term trends in rainfall patterns in the Nile Basin because of insufficient empirical data.

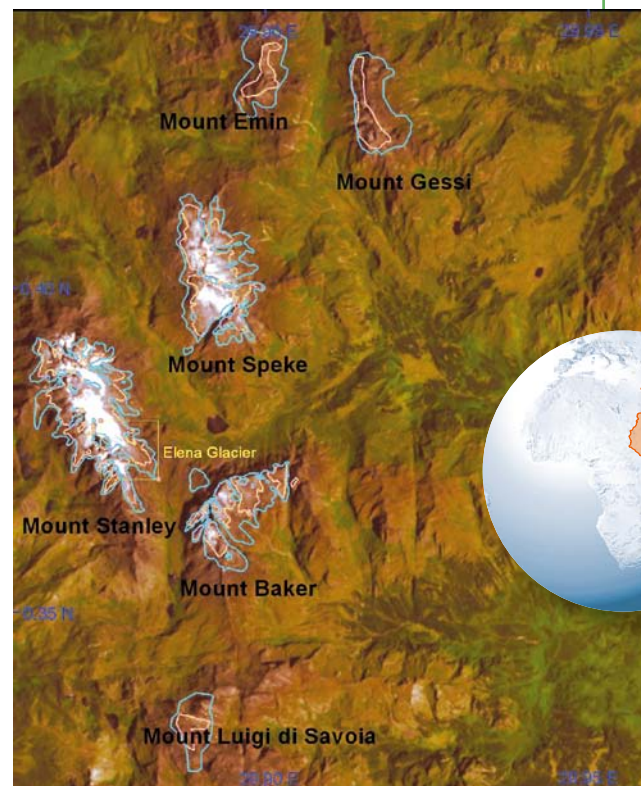
CHANGING GLACIER EXTENTS IN THE RWENZORI MOUNTAINS

1906, 1955, 2005

-  boundary in 1906, according to Duke of the Abruzzi scientific expedition
-  boundary in 1955, revealed by aerial photographs
-  glaciers shown in 2005 ASTER image



0 1 2 km

(Kaser and Osmaston 2002, Gumbrecht 2008)

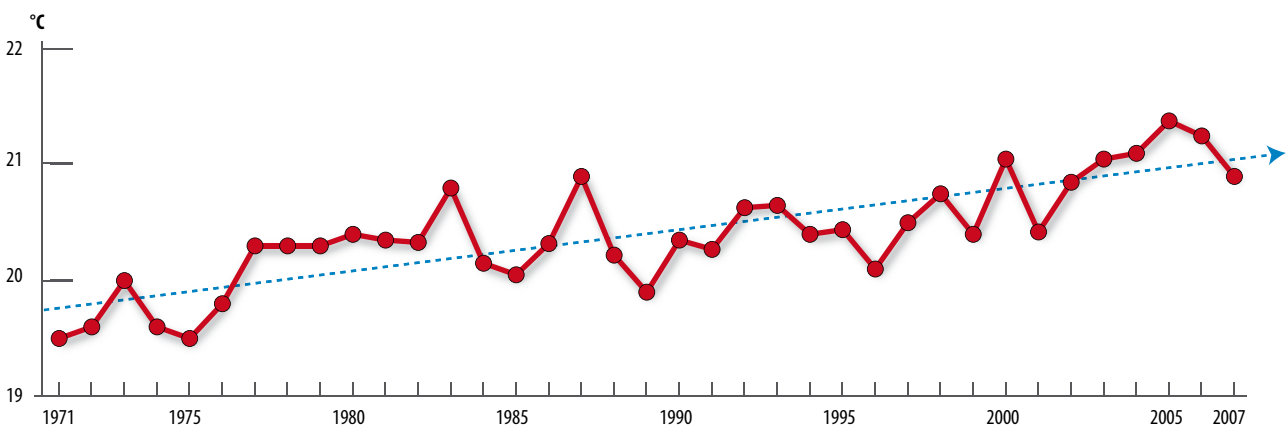


WARMING IN THE NILE REGION

1971–2007

-  mean annual temperature at Kigali Airport
-  trendline

(Source of data: Rwanda Meteorological Agency)



Human activities spur climate change

In the history of the Earth, long-term changes in global weather patterns have been common and were typically caused by external forcing factors such as variations in the Earth's orbit and in solar intensity, or by volcanic eruptions. However, there is consensus in the scientific community that the changing climate we are experiencing today is in large part man-made.


Since the beginning of the Industrial Revolution around 1750, the concentration of carbon dioxide – a major greenhouse gas – in the atmosphere has risen from 280 to 396 ppm. Most of this increase results from the burning of fossil fuels in the industrialized world, while Africa's contribution to this rise has been virtually zero. Even today, Africa produces only a fraction of the global annual greenhouse gas emissions. By contrast, for various reasons, the continent is highly vulnerable to the effects of climate change.

Possible impacts of a warming trend in climate

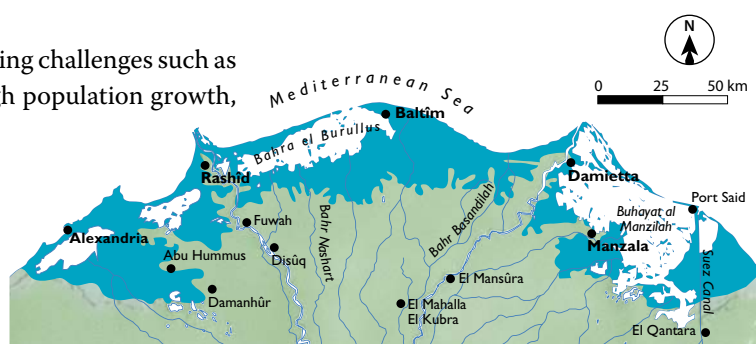
Climate change will manifest itself primarily through changes in average temperature and precipitation, which are important drivers of the water cycle and hence the seasonal occurrence and flows of water in soils, lakes, rivers, wetlands, and groundwater aquifers. Likely impacts of the continuing warming trend around the globe include:

- Higher evaporation and consequent increased losses from reservoirs.
- Higher evapotranspiration rates and rising crop water requirements leading to an increase in demand for irrigation water, and increased vulnerability to drought of rainfed agriculture.
- Hotter and longer dry periods which will increase drought risks, especially in dry regions.
- Higher frequency and intensity of severe rainstorms that will lead to increased flood risk and serious storm damage.
- Higher water temperatures in the Equatorial Lakes, which strengthen thermal stratification, increase algal productivity, accelerate microbial mineralization, and reduce oxygen dissolution, among other effects.
- Expansion of the range of vector-borne diseases such as malaria to higher altitudes due to warmer temperatures.
- Sea-level rise that could threaten the very productive Nile Delta and the cities along the Indian Ocean coast, such as Mombasa and Dar es Salaam.

Climate change exacerbates the impacts of existing challenges such as human-induced land-use changes, poverty, high population growth, and rising demand for natural resources.

 area that will be inundated by a 1-metre sea-level rise

(Source of data: WRI 2007)



NILE DELTA: POSSIBLE IMPACTS OF SEA-LEVEL RISE

The low-lying Nile Delta is highly vulnerable to a rise in sea level. While covering only 2.5% of Egypt's land area, it is densely populated and home to over one-third of the country's population. The rich arable lands provide between 30% and 40% of Egypt's agricultural production.

Global sea level has been rising at an average rate of 1.7 mm per year during the 20th century. This trend is expected to accelerate due to the thermal expansion of the oceans, and the melting of polar ice-caps.

Sea-level rise will seriously threaten the delta. The construction of the High Aswan Dam has led to reduced silt supply and subsequent erosion of the seaward front of the delta. The weakening of the protective off-shore sand belt, combined with higher water levels, will increase the frequency of flood events.

The problem of flooding is compounded by land subsidence – currently estimated at 1 to 5 mm per year – because of increased groundwater extraction for agriculture, and reduced siltation deposition.

It is estimated that a 1-metre sea-level rise could cause a loss of 4,500 square kilometres of cropland, and displace some 6.1 million people in the Nile Delta. Sea-level rise will further speed up saltwater intrusion, which will increase soil salinity and make formerly fertile lands unfit for agricultural use.



VULNERABILITY AND SENSITIVITY TO CLIMATE CHANGE

The region's climate is naturally variable

Among the features that characterize the Nile Basin are its varied terrain and the temporal variability of its climate. The year-to-year climatic variability is illustrated by the Nile's historical flow record. For instance, in the period 1913 to 1977, the annual discharge volume at Dongola – just upstream of Lake Nasser/Nubia – ranged from 42 to 103 bcm/year. This shows that large annual weather fluctuations are very much part of the 'normal' climate of the Nile Basin.

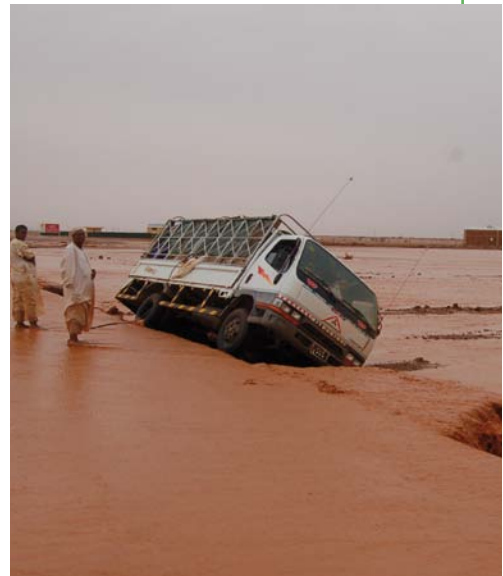
Traditional agricultural practices and livelihood systems in the basin have evolved over hundreds of years and have become well adapted to the uncertainty of the region's weather (see Chapter 5). In recent decades, however, population pressure, changing lifestyles, and very high rates of water use have combined to reduce the effectiveness of these customary coping patterns. Basin communities have found it increasingly difficult to deal with the negative impacts of climatic variability, and periodic floods and droughts have been accompanied by food shortages, loss of lives and property, destruction of public infrastructure, and disruption of socio-economic activities. Climate change will add further uncertainties to the existing climate variability, posing additional challenges for the basin's political leadership and water-resources managers.

Factors increasing the region's vulnerability to climate change

A number of factors render the Nile Basin particularly vulnerable and sensitive to impacts of global warming. Key factors include:

- High fragility of its natural systems: two-fifths of the basin consists of arid and semi-arid drylands.
- Dominance of poor and rural people in the upstream countries, who tend to be heavily dependent on sectors such as agriculture, fishing, and forestry that are highly sensitive to climate variability, and possess limited possibilities for diversification into less climate-sensitive sectors.
- A rapidly growing population that is putting unprecedented pressure on the natural resource base.
- High exposure to natural disasters, especially floods and droughts.
- High sensitivity of many of the Nile sub-basins to changes in annual precipitation.
- A prominent agricultural sector in the downstream countries that is almost totally reliant on Nile-fed irrigation.
- High dependency on hydropower for energy across the basin.

The Nile region has a very low level of economically developed infrastructure. There is low water-storage capacity, few water-control systems, and the transport, energy, information, and communication systems are not so advanced. These conditions constrain the adaptive capacity of the Nile countries, and combine with the factors above to increase the vulnerability of their economies to water shocks. The



The result of flash floods, north of Khartoum, The Sudan, June 2007.

situation is further compounded by the rundown state of hydroclimatic data collection networks, and by the weak institutions in the basin. Moreover, the finite Nile flows are now almost fully utilized, while the water-demand curve continues to rise steadily, leaving no buffers to accommodate possible flow deficits.

Dry regions are among the most vulnerable

Another of the factors that characterizes the Nile Basin is the large area of arid, semi-arid, and dry sub-humid zones. In these areas, potential moisture losses due to evaporation exceed rainfall. These zones are therefore particularly vulnerable to intensified drying when the weather gets warmer. A warming trend has the potential to increase wind erosion, lead to further land degradation, and pose a threat to the pastoralist lifestyle that dominates in the dry regions.

Rural women are at greater risk

Climate-change impacts are not gender neutral. Poor people are more vulnerable to climate change due to their limited adaptive capacities to a changing environment. But among the poor, rural women and girls are the ones most immediately affected. Rural women and girls tend to play a greater role in natural resource management and ensuring nutrition, and often produce, process, manage, and market food and other natural resources. They also trek long distances to collect fuel wood and water. Women are affected differently, and often more severely, from men, by climate change and natural disasters such as floods, droughts, and storms. This is due to gender-based discrimination against women, and unequal power relations between women and men, including in relation to access to assets and resources, intra-household inequities and related vulnerabilities, capabilities, and opportunities for adjustment.



The boundary between overgrazed sandy rangeland, and threatened rain-fed agricultural zone, The Sudan.



Carrying firewood is one of the many fatiguing and time-consuming tasks that poor rural women are responsible for.



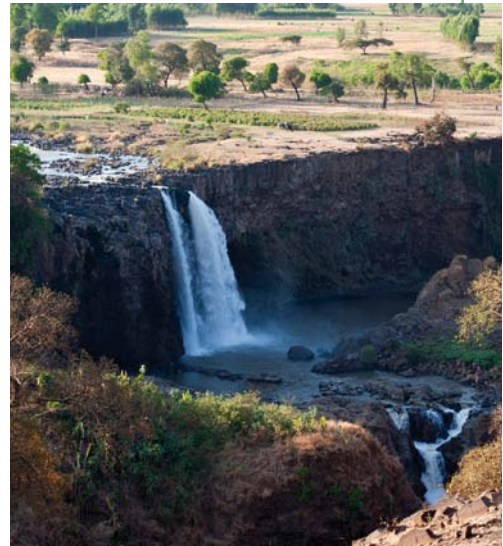
Different sub-basins are affected differently

The large Nile Basin is characterized by very uneven distribution of water resources, and consists of a number of distinct sub-basins each with a different hydrologic regime. Climate change will affect each sub-basin differently. Their combined response, which is not easy to predict, will determine how climate change impacts the flow of the Main Nile and the water availability of the downstream riparians. The Main Nile is particularly sensitive to the variability of runoff from the Ethiopian part of the basin. Possible climate-change impacts on the much smaller White Nile flows are attenuated by the Sudd and the other large wetland in the White Nile Basin, and will have a less pronounced impact on the water supply of the downstream countries.

An analysis of the hydrology of the Nile Equatorial Lakes reveals that rainfall and lake evaporation are the most important terms in the water balance. This makes the regime of the Victoria Nile particularly sensitive to small changes in either rainfall or evaporation, and thus to potential climate change. By contrast, the outflow from the Sudd in South Sudan is relatively insensitive to local changes in climatic parameters. This is because an increase in Sudd inflow leads to a greater surface area of wetlands, which in turns leads to higher evaporation losses, and vice versa. The variable extent of the wetlands mitigates the impact of possible local changes in rainfall or evaporation.

The regime of the Sobat–Pibor–Baro rivers shows similarities with the Sudd area. Increased river flow leads to higher spills to the Machar marshes and to a larger surface area of the wetlands, with consequent higher evaporation losses. The Sobat flow is, therefore, expected to be relatively insensitive to changes in average annual temperature or precipitation.

NeWater has shown that the Blue Nile (Abay) flows are more sensitive to changes in rainfall than to changes in evaporation. The reason for this is that the rainfall over the Blue Nile (Abay) is monsoonal and concentrated in a short period between July and September (*see pages 32–33*). Higher potential evaporation values in the remainder of the year do not affect the hydrologic regime because there is practically no water to evaporate in the October to June period.



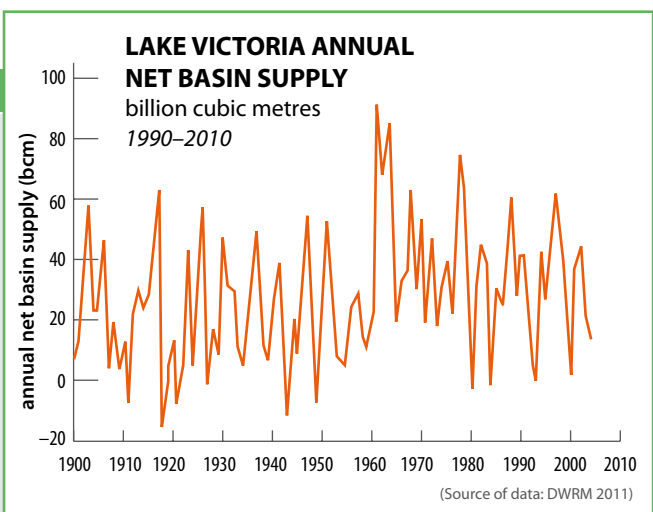
For part of the year, the Blue Nile (Abay) Falls are comparatively modest, but they turn into a raging torrent during the monsoon season.



The basin as a whole is sensitive to changes in rainfall. The potential impact of climate change on the Nile River regime is significant. Nile water flows are very sensitive to small changes in rainfall, as shown by the report of the NeWater Project, which indicates that a 10 per cent change in precipitation translates into a 25 per cent or greater change in runoff. This can be illustrated by comparing the period 1980–87 (which was comparatively dry) with the period 1993–2000 (which was comparatively wet). The total rain volume in the Nile Basin in 1980–87 was only 10 per cent lower than the total rain volume in 1993–2000, but the total inflow volume in Lake Nasser/Nubia was approximately 40 per cent lower in 1980–87 than in 1993–2000.

LAKE VICTORIA: CLIMATE SENSITIVITY

The principal components of the Lake Victoria water balance are over-lake rainfall and lake evaporation. For the period 1956–78 they contributed 85% and 78% of the water balance respectively, hugely significant when compared to the inflow from rivers and the outflow to the Nile. This makes Lake Victoria very sensitive to changes in precipitation and temperature, as demonstrated by the large inter-annual fluctuation of historic net basin supply. While the general warming trend of the global climate would lead to an increase of the evaporation rate, its possible impact on the rain regime on the equatorial plateau is uncertain. The impact of climate change on lake levels and the resulting Victoria Nile flows, therefore, has not yet been established. This applies both to the magnitude and direction of a possible change.



Changes in Lake Victoria outflow will first of all impact hydropower production on the Victoria and Kyoga Nile. It will also affect the extent and seasonal fluctuation of the Sudd wetlands in South Sudan. However, the wetlands will considerably dampen the effects of possible changes in the Victoria Nile flow on the Main Nile.





COMBATING CLIMATE CHANGE

Response of the international community

The international community has taken a number of measures to combat global warming and adapt to a changing climate. The measures include the establishment of the Intergovernmental Panel on Climate Change (IPCC), which is a scientific body tasked to provide a comprehensive scientific assessment of the risk of climate change, its potential consequences, and possible adaptation mechanisms. The establishment of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 was another important initiative. The UNFCCC is an international treaty, the objective of which is to stabilize greenhouse gas concentrations in the atmosphere at a level that could avert disastrous changes to the global climate.

In support of the UNFCCC treaty, the international community in 1997 concluded the Kyoto Protocol that established legally binding obligations for developed countries to reduce their greenhouse gas emissions. It should be noted that a number of important industrialized nations – including the USA – have not ratified the Kyoto protocol, while few signatories are expected to meet their targets. An important mechanism for meeting the Kyoto Protocol obligations is carbon emission trading through the Clean Development Mechanism (CDM). This allows emission reductions to commence in areas where it is cheapest to do so.

Response of the Nile countries

Given the continuing warming trend and the scale of the threat that it poses, Nile riparian governments have prepared National Adaptation Plans of Action (NAPA) that identify priority areas for urgent adaptation to climate change. These plans were put together through a systematic process based on an assessment of the projected change of the climate and its expected impacts, a detailed vulnerability analysis, and a subsequent inventory of possible coping mechanisms. The results were translated into specific policy targets and a list of practical climate-change adaptation projects for immediate implementation, for which funding is currently being sought.

Beyond NAPA, a number of Nile countries have prepared comprehensive National Appropriate Mitigation Action (NAMA) programmes. A good example is Ethiopia, which has set up the Climate Resilient Green Economy initiative. This builds on the country's current very low contribution to greenhouse gas emissions, and aims to acquire funding for sustainable and green development through the Clean Development Mechanism. Similar plans have been developed in other Nile countries.



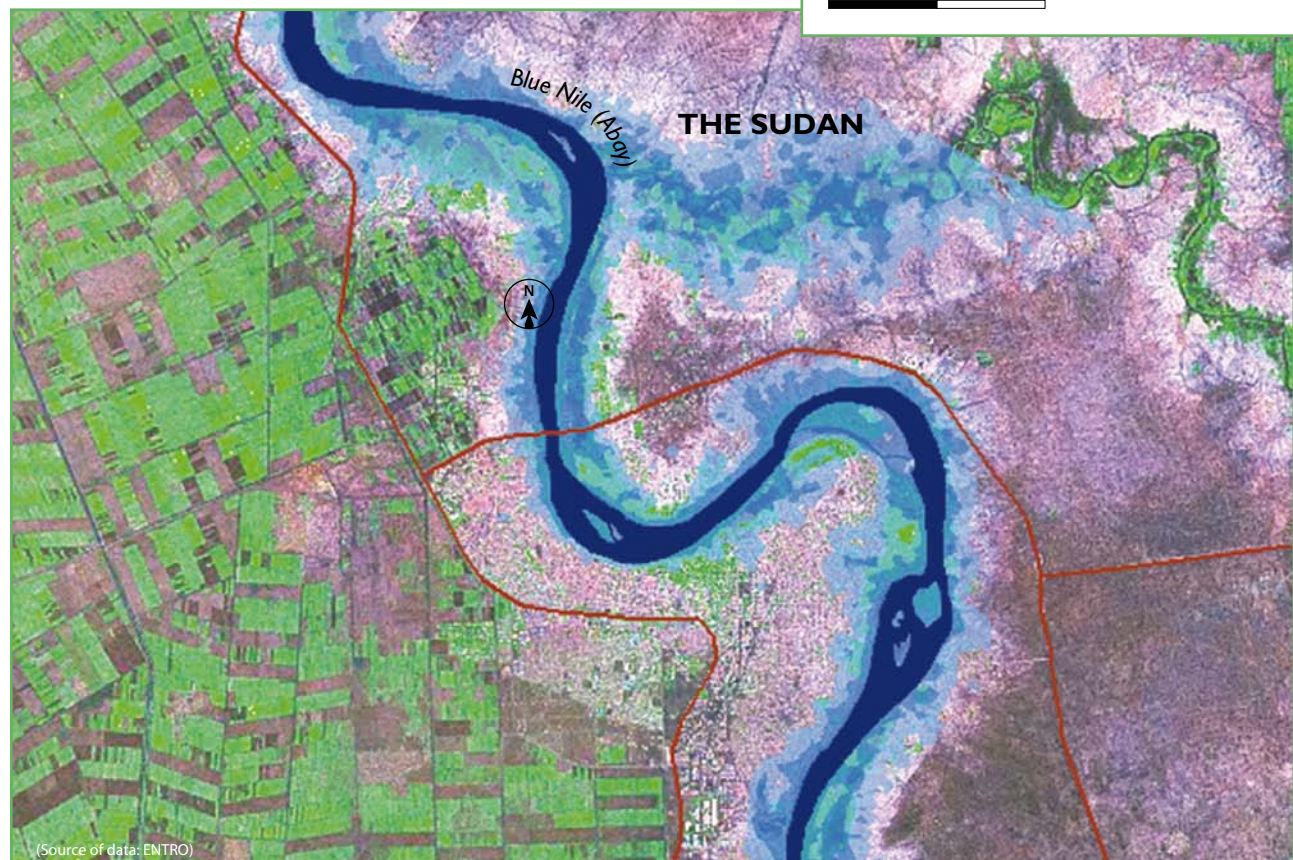
UN Secretary General Ban Ki-moon addressing the 2010 Climate Change Conference, Cancún, Mexico.

For climate change adaptation to be effective it has to be mainstreamed into existing programmes and national development plans. This is now taking place across the board in the Nile countries. Governments have set up appropriate institutional arrangements and mandated dedicated entities to coordinate climate change issues. They have established special units – like the National Climate Change Activities Coordination Committee in Kenya – to provide technical advice to governments on climate change issues. Public awareness campaigns are being implemented, targeting all levels and sectors in society. Research programmes have also been planned to provide a better understanding of the drivers and implications of climate change at local and regional levels.

The role of civil society in efforts to combat the impacts of climate change has been recognized. They play a crucial intermediary role in connecting local populations to national interventions and funding opportunities, and disseminate knowledge and ideas about possible coping mechanisms. They also play a key role in capacity building and skill development, and provide the necessary leadership when needed.

In spite of the very substantial efforts made by the Nile governments and communities, the scope of the current climate change adaptation programmes and activities is not sufficient to deal with the scale of the threat, and these measures seem insufficient to prepare effectively for a changing climate.

Rising temperatures will increase the intensity of severe rainstorms that will lead to increased flood risk. The densely populated Blue Nile (Abay) valley in The Sudan is particularly vulnerable to damage to human settlements and economic activities because of flooding.





FOSTERING CLIMATE-RESILIENT GROWTH

The future climate of the basin

Global climate model projections predict that average global surface temperature will rise by a range of 0.3° to 6.4° Celsius during the 21st century. Increases in the amount of precipitation are very likely in high latitudes, whilst decreases are likely in most subtropical land regions. Increasing global temperature will cause sea level to rise, and is expected to increase the intensity of extreme weather events and to change the amount and pattern of precipitation. According to the IPCC, scientific uncertainties are mainly in the area of how warming and related changes will impact the water resources from region to region around the globe.

Many efforts have been made at understanding and predicting the future climate over the Nile region. The climate models give contradicting and wide-ranging results. While a warming trend is common in all models, some predict a drier and others a wetter climate, depending on which global circulation model (GCM) is used. The low resolution of the GCMs makes it very difficult to predict regional and local weather patterns. Thus, at this point in time, it is not possible to foretell how the climate in the Nile region or in particular sub-basins will develop.

Notwithstanding, climate scientists generally agree that further global temperature increases are inevitable, and that extreme events such as floods and droughts will intensify – though there is no agreement about the level of intensification. It is noted that a number of GCM runs suggest a wetter climate in East Africa and a greater likelihood of decreasing rainfall as one gets closer to the Mediterranean coast. Given the very wide range of the predictions, however, it is not possible to draw firm conclusions that can inform policy making at local or national level. Although subject to many uncertainties, the impacts of climate change on development in the Nile region can be expected to be diverse and significant.



Ethnic Somali pastoralists with their cattle and camels in Wajir, northern Kenya, 2011, an area suffering an extreme drought.

THE UNCERTAINTIES OF CLIMATE PREDICTION

A quantitative appreciation of the effects of climate change in the Nile region strongly depends on the choice of the climate model that is used. Many different models are available – and each one has produced many different climate scenarios. Unfortunately, the ability of the climate models to accurately predict the future weather at local or regional scale is very limited at the present time.

The very large uncertainties associated with climate models of the Nile Basin originate from a number of compounding factors:

- 1 Uncertainty about future emission of greenhouse gases
- 2 Difficulties in modelling the global climate at macro scale
- 3 The intricacy of down-scaling the model results to represent regional and local weather patterns.

With regard to point 3, it is important to realize that the present collection of GCMs has limited capacity to simulate the current rainfall patterns in the Nile region. Neither can they fully reproduce phenomena such as



PROJECTED CHANGES IN PRECIPITATION

According to SRES Emission Scenario Medium A1B

Percentage change projected by 2050s

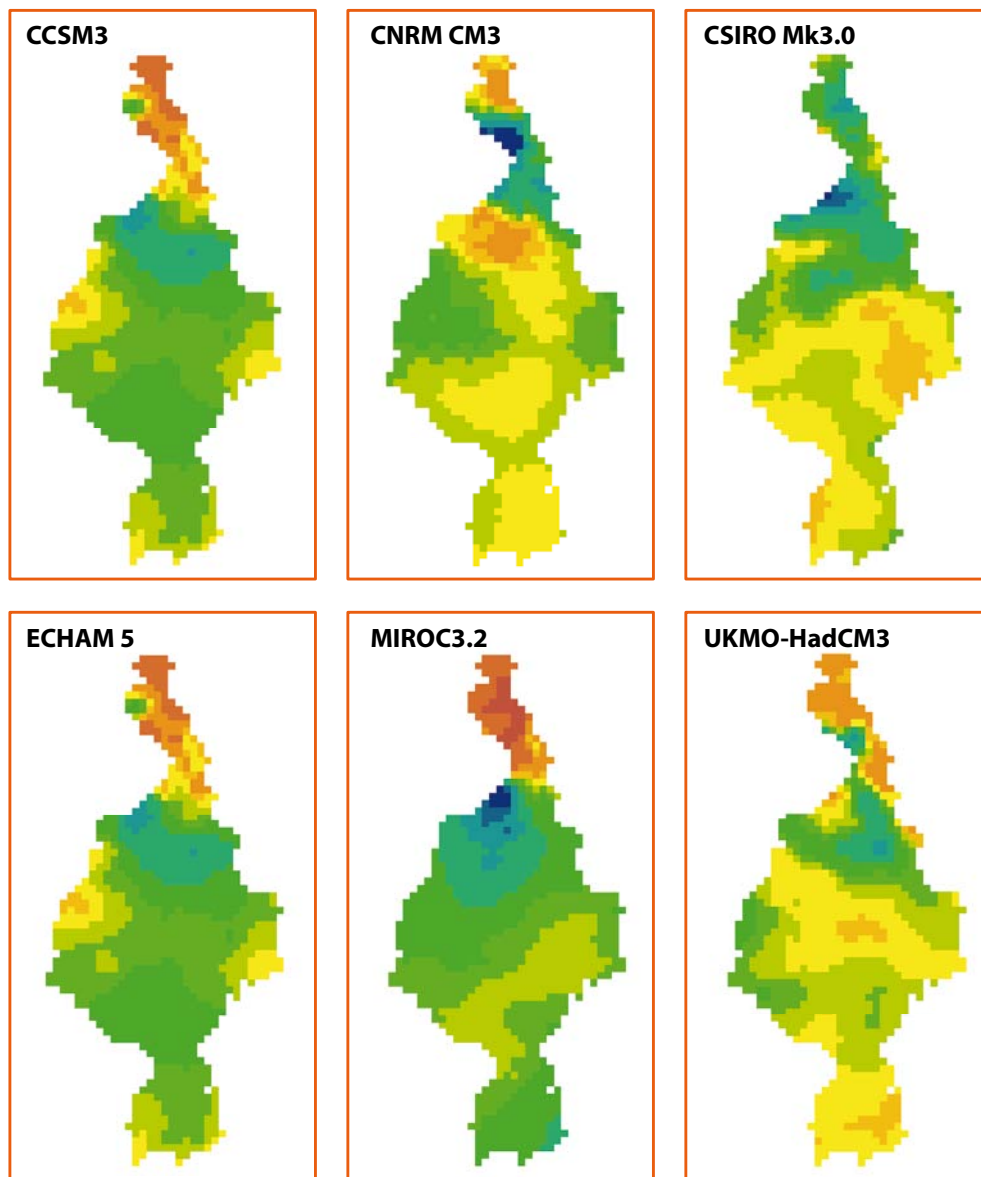
Decrease of:

- 59.0% – 50.0%
- 49.9% – 25.0%
- 24.9% – 10.0%
- 9.9% – 5.0%
- 4.9% – 0.0%

Increase of:

- 0.0% – 4.9%
- 5.0% – 9.9%
- 10.0% – 24.9%
- 25.0% – 49.9%
- 50.0% – 74.9%
- 75.0% – 94.9%
- 95.0% – 100%

(Map prepared by the NBI; source of data: www.climatewizard.org)



the El Niño–Southern Oscillation, or the migration of the Intertropical Convergence Zone (the ITCZ), which critically affect the weather patterns in the Nile region.

As a result, the projection of change in the weather at regional level differs very substantially from model to model. What all models agree on is a further increase in temperature, although the magnitude of change varies. For rainfall, however, not only does the magnitude differ substantially between the models, but also the direction of change.

To take into account the uncertainties in model results, IPCC suggests using at least three scenarios and developing an ensemble prediction system. In the Nile Basin, however, the very wide range of model results makes this approach not very practical. Arguably, in view of the large uncertainties in the predictions, the current set of climate models cannot form the basis for developing targeted and detailed climate change adaptation programs at local and regional scale for the Nile riparian countries.



Acting in the face of uncertainty

The contradictory results of the global circulation models with regard to the projected changes in rainfall make it very difficult to commit to specific investments in infrastructure or develop targeted adaptation measures and investments at this point in time. A sensible approach for now, therefore, is to prepare for more variable weather conditions than currently recorded. This approach will provide time to monitor the climate, and to react once a clear direction and magnitude of regional and local climate change can be established.

Taking actions in the face of uncertainties thus favours taking so-called 'no regret' measures that build resilience to current climate variability while enhancing adaptive capacity. Common 'no regret' measures mostly focus on increasing water-storage capacity; building human and institutional capacity; interconnecting power systems and food markets; building strategic redundancies across national sectors; diversifying economies and livelihood systems; and intensifying data collection to improve scientific understanding of the climate change phenomenon. These measures aim to provide a minimum capacity of infrastructure and institutions, backed by robust water information systems, to ensure that countries function productively in the face of climate vulnerability.

HYDRO-METEOROLOGICAL MONITORING

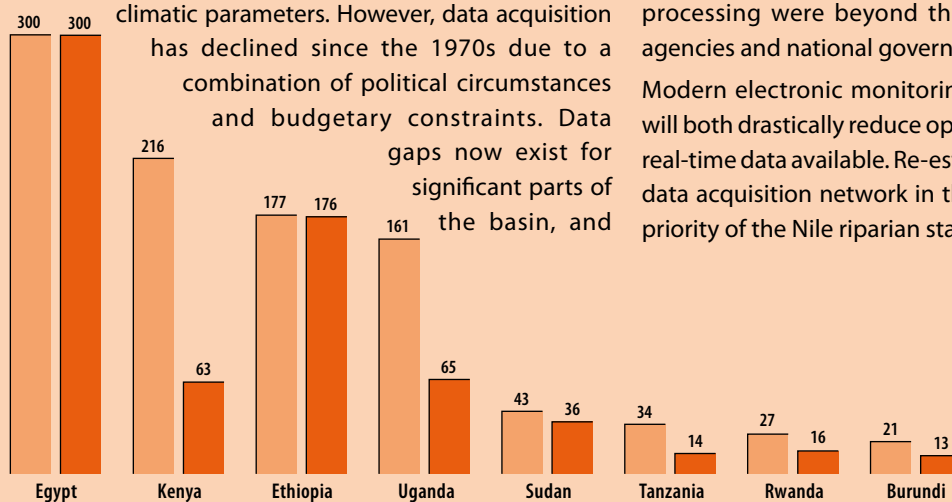
Accurate information about the weather and hydrological variables is a starting point when assessing the direction, pace, and magnitude of climate change.

The Nile is among the most studied rivers in the world, with records dating back over 1,000 years. For a large part of the last century, the basin was equipped with a quite extensive network of hydro-meteorological monitoring stations, providing a good coverage of reliable streamflow statistics and continuous records of key climatic parameters. However, data acquisition has declined since the 1970s due to a combination of political circumstances and budgetary constraints. Data gaps now exist for significant parts of the basin, and

for a number of critical sections of the river network. This lack of knowledge makes it difficult to validate climate models and predict possible climate change.

Data acquisition is complicated by the vastness of the Nile basin and the sometimes difficult terrain, but an analysis by the FAO in 2002 found that in areas not subject to security risks, the principal reason for declining monitoring activities was that the high operating costs associated with field visits, vandalism, and data processing were beyond the capacity of some water agencies and national governments.

Modern electronic monitoring equipment, fortunately, will both drastically reduce operating expenses and make real-time data available. Re-establishing a comprehensive data acquisition network in the basin needs to be a key priority of the Nile riparian states.



MAIN HYDRO-METRIC NETWORK

Number of stations
1970s & 2011

historic

currently operational

(Source of data: NBI WRPM 2011 and National DSS Specialists)

The term ‘redundancy’ as used above refers to the extent to which components of a system are substitutable. Having adequate redundancy helps to avoid over reliance on any one component of a system and allows the system to continue functioning even after failure or disruption of one or more of its components. Increasing redundancy at country level calls for diversification of national assets and infrastructure; maintaining ‘surplus’ capacity in vital sectors such as telecommunications, transport, and power generation; and finding alternative processes and response pathways that can be resorted to in the event of failure of the main components of a national system.

Implementing practical ‘no-regret’ measures

Climate-change adaptation and risk reduction are fundamentally about sound socio-economic development. Many of the ‘no-regret’ measures are essential elements of strategic actions to achieve sustainable development. Therefore, climate-change adaptation interventions need not be viewed as a stand-alone set of measures but as an integrated part of existing development programmes and policy initiatives. Climate change adds urgency and the need for renewed focus and careful prioritization.

Some examples of practical ‘no-regret’ measures include:

- Increasing per capita water-storage capacity by constructing reservoirs – both small and large.
- Interconnecting electricity grids and developing alternative power sources in regions with high dependency on hydropower.
- Introducing zoning and land-use planning to discourage people from constructing permanent settlements in floodplains and other areas subject to landslides and high flood risks.
- Expanding forests, and implementing measures to reverse deforestation.
- Increasing capacity for over-year food storage, and ensuring that facilities are well stocked.
- Establishing the physical and institutional infrastructure for intra-basin trade of agricultural produce to ensure that occasional local food deficits can be offset by surpluses from others regions.
- Mitigating the impact of drought by restoring soils and increasing their capacity to retain moisture.
- Promoting measures aimed at increasing water productivity and water-use efficiency in irrigated agriculture.
- Establishing grazing reserves and implementing measures aimed at limiting herd size to carrying capacity of pastures.
- Mainstreaming climate-change adaptation and mitigation in all national development sectors.
- Increasing general awareness on climate change.
- Increasing research into crop varieties, including disease- and drought-resisting varieties, high-yielding varieties, quick-maturing varieties, etc.
- Building capacity at regional and national levels for climate-change modelling and analysis, including downscaling of GCMs.

SOIL RESTORATION AND DROUGHT MITIGATION

Water availability for vegetation growth is determined by both rainfall and evapotranspiration, and by the water-holding properties of the soil. A moisture deficit caused by drought at a critical stage in plant growth leads to reductions in crop yields and forage growth.

The impact of droughts in large parts of the Nile Basin is aggravated by widespread soil degradation and generally low soil moisture-retention (partly because of low organic content of soils). Hence, rainfall ‘runs off’, instead of being kept where it is needed.

Improved land management that encourages soil restoration is a key component of an effective drought mitigation strategy. Where needed, it can be combined with water harvesting techniques to concentrate rainfall, and agro-forestry to create micro-climates characterized by lower evapotranspiration. These measures should effectively alleviate most of the impacts of shallow droughts.

Supplementary irrigation is typically limited to commercial farms that produce high-value crops, often for export. In the current socio-economic environment, its adoption as a general climate change adaptation measure seems not to be an economically viable proposition.

Women tending to seedlings in a tree nursery in Ethiopia.





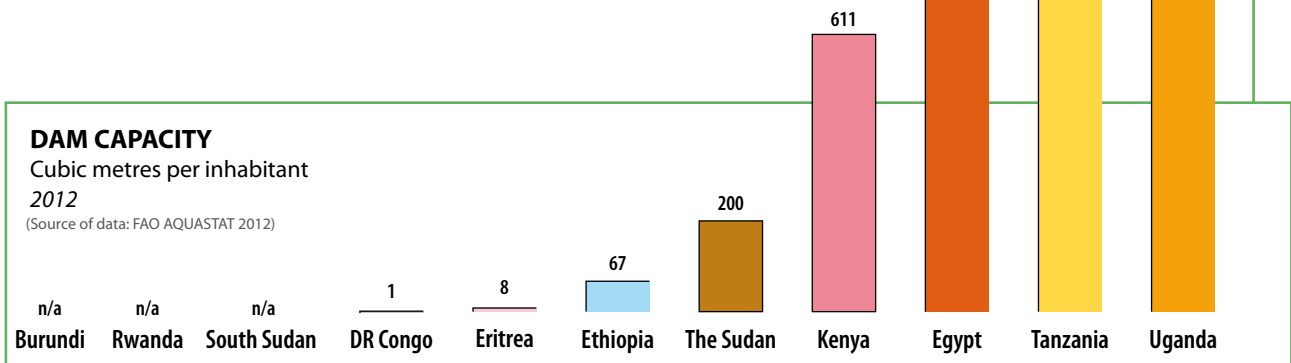
The above list of ‘no regret’ measures has substantial financial implications, which exceed the means of most Nile countries. There is clearly, therefore, a need for additional financing to support the efforts at climate-proofing the economies of the Nile riparian states.

Increasing water-storage infrastructure

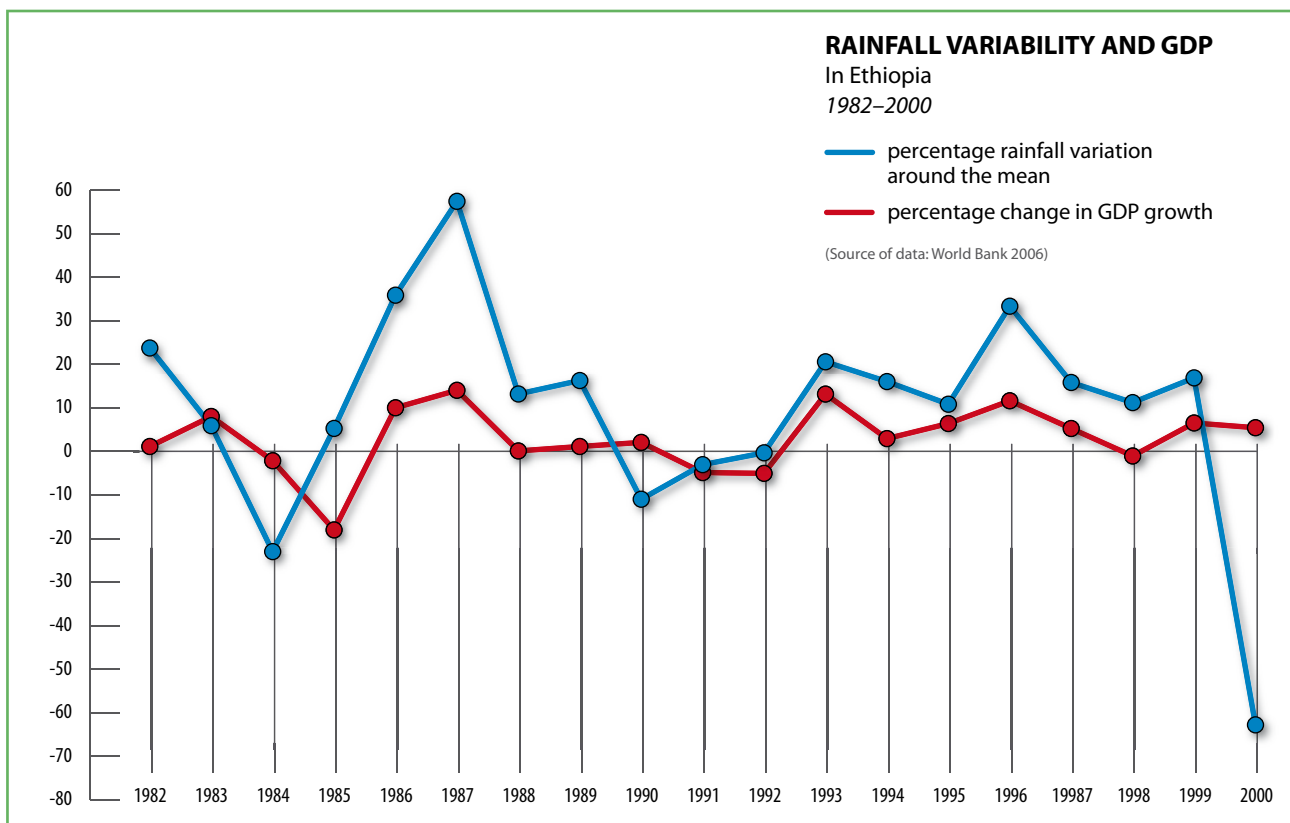
Water storage is the basis for assuring water productivity in the face of climate change. Water storage spurs economic growth and helps alleviate poverty by making water available when and where it is needed. For many millions of smallholder farmers in the basin, reliable access to water is the difference between plenty and famine.

When most people think about water storage, the first thing that comes to mind is large dams. However, many smaller-scale water-storage structures are equally effective and, in addition, relatively simple and cheap. Both large and small infrastructure projects need to be part of a balanced water-investment programme that provides reliable water supplies for human health, agricultural production, and economic activities, and that protects natural water and environmental assets. Development of large multipurpose storage facilities (often combined with hydropower generation) is necessary for mitigating the economic effects of hydroclimatic variability, for ensuring reliable water supply, and for optimally using available water. Small-scale approaches to water management improve the ability of the rural poor to cope with water shocks by increasing agricultural productivity and providing cost-effective water supply and drought mitigation.

Most of the upstream Nile countries, even those with abundant water, have insufficient water-storage capacity. The per capita water-storage capacity in eight of the Nile countries is below 700 cubic metres per person per year, which is quite low compared to North America’s 6,150 cubic metres per person per year. The storage capacities for Uganda and Tanzania are higher than that of their neighbouring countries. This is not due to greater infrastructure development in the two countries, but to considerable storage of water in Lake Victoria, which is a natural reservoir whose outflow is regulated by the Owen Falls Dam in Jinja, Uganda.



Inadequate storage leaves farmers vulnerable to the vagaries of the climate. Ethiopia is one such example. Ethiopian farmers are heavily reliant on rainfed subsistence agriculture. The lack of storage infrastructure means farmers have limited ability to cope with droughts and floods, hence their agricultural production is greatly affected by variations of weather and climate. These variations, given the large contribution of agriculture to GDP, translate into fluctuations in economic growth, and are estimated to rob the Ethiopian economy of one-third of its growth potential. In Kenya, losses from flooding caused by El Niño in 1997–98 and drought caused by La Niña in 1998–2000 ranged from 10 to 16 per cent of GDP in those years.



Large dam projects within the basin are best located in regions with low evaporation rates and will require enhanced levels of cooperation and clear mechanisms for sharing costs and benefits (for those cooperatively implemented). Development of water storage infrastructure in the countries will need to be accompanied by measures to prevent or mitigate their possible negative impacts on the Nile environment.



NBI: CONTRIBUTING TO CLIMATE-RESILIENT GROWTH

All NBI activities, because they are aimed at improving water management under natural uncertainty, contribute to enhancing resilience to climate variability and change in the Nile Basin. The key NBI activities in this respect are the following:

Bridging the knowledge gap – NBI has commissioned many studies at sub-basin and basin-wide levels to improve understanding of the water-resources and socio-economic situation, vulnerability to climate change, appropriate coping measures, and feasible development options. Notable among these are the comprehensive regional assessments carried out by ENTRO, the multi-sector investment opportunities assessment (MSIOA) carried out by NELSAP-CU, the several river-basin monographs prepared by NELSAP-CU, and the basin-wide climate-change assessments carried out by the WRPM Project. Many best-practice guides, such as those on efficient water use for agriculture, and watershed management, have been prepared and widely disseminated to users in the Nile region. The study reports and other relevant documents are available to the public in the libraries operated by the NBI centres. They can also be downloaded through the web-based Nile Information System.

Strengthening basin monitoring and planning tools – NELSAP-CU is supporting the strengthening of hydrometeorological monitoring networks in the Nile Equatorial Lakes region, while ENTRO is operating a flood-forecasting and early warning system in the Blue Nile (Abay) sub-basin. A basin-wide planning tool – The Nile Decision Support System – was recently commissioned. A proposal is under development for the establishment of a strategic basin-wide water resources monitoring network.

Supporting science-policy dialogue – The NBI has been organizing the two-yearly Nile Basin Development Forum (which started off as the Nile 2002 conferences), which provides a platform for interaction and information exchange among scientists and policy makers from the region on various topical issues. The last Development Forum was held in November 2011 in Kigali and focused exclusively on climate change. The State of Basin (SoB) report is another tool being used by NBI to foster science-policy dialogue.

Facilitating expansion of the region's water and power infrastructure – Through the two Subsidiary Action Programs, NBI has for over eight years been supporting the identification, preparation, and

NBI's Joseph Terer (on extreme left), Project Manager for Mara Project, handing over hydrometric equipment to Tanzania government officials. Operating a basin-wide hydrometric network is one of the important measures for responding to climate change in the Nile Basin.



implementation of investment projects that aim to increase the region's economic infrastructure and enhance its adaptive capacity to climate change, while supporting poverty reduction, reversal of environmental degradation, and socio-economic development. Projects in the areas of hydropower generation and transmission, regional power trade, domestic water supply, agricultural irrigation, and fisheries management are at various stages of preparation and implementation.

Promoting watershed management – NBI's NTEAP Project implemented community micro-projects in all member countries. The micro-projects demonstrated best practices in watershed management and were located along transboundary river courses. Under the Subsidiary Action Programs in the Eastern Nile and Nile Equatorial Lakes region, tree planting, and runoff and drainage management, has continued. Critically degraded watersheds have been identified and proposed for restoration.

TRANSBOUNDARY-LEVEL ADAPTATION MEASURES

Preparing for climate change requires taking action at local, national, basin-wide, and global levels. The size of the basin, combined with its cultural, political, socio-economic, and climatic diversity argues for applying the subsidiary principle i.e. allowing the smallest, lowest, or least-centralized competent authority to take the lead role in implementing adaptation measures. Communities, lower-level governments, and central or federal authorities all have their role to play. However, considering the transnational and interconnected nature of the basin's natural resources, a number of climate-change adaptation measures will be most effective when undertaken in coordination with other riparians, as opposed to each country acting independently.

Possible measures at transboundary level include coordinated reservoir operation, strengthening inter-basin agricultural trade, interconnecting power grids, developing joint mechanisms for soliciting climate-change adaptation funds, operating joint hydrometeorological monitoring programmes, and conducting joint research.

In a system with multiple reservoirs such as the Nile Basin, reservoir operation has to be coordinated to maximize total system benefits, and mitigate the effects of extreme weather events such as floods and droughts. In a coordinated system, reservoir release rules are no longer one-dimensional, but will depend on the state, demand level, flood risk, and minimum flow requirement of other reservoirs in the system. Developing optimal release policies under these circumstances will require close day-to-day cooperation among the riparian states.

Very severe droughts may lead to crop failure, and will require institutional measures that may include insurance schemes, food



storage, local food aid, and others. Given the spatial variability of farming practices, dominant crops, soils, and other agricultural and climatic factors in the basin, it is likely that very severe droughts with extremely negative impacts will happen on a regional scale rather than a basin-wide scale. Hence, transboundary cooperation that strengthens inter-basin agricultural trade could mitigate the impact of periodic droughts and bring about a certain level of food security in the basin.

CONCLUSIONS AND RECOMMENDATIONS

While the Nile countries bear virtually no responsibility for the current human-induced changes in the global climate, they could be seriously affected by, and indeed are already suffering from, its impacts. The Nile region is particularly sensitive to a warmer and more variable climate because of the natural fragility of its climate conditions (large arid and semi-arid regions with delicate ecosystems), the large rural population that intimately depends on the water resources for its livelihood and food security, and because of the low resilience to climate shock of many of the rural poor.

The Nile countries are implementing a substantial package of measures to adapt to projected climate change. These efforts, however, seem insufficient, given the scale of the threat. Support from the international community is, therefore, required to fully climate proof the region. At the same time, it is recommended that the Nile countries allocate more of their own resources to climate-change adaptation. Failure to implement an adequate climate-adaptation programme could have very harmful impacts on the national economies, and could ultimately lead to resource conflicts and affect regional security.

In view of the large uncertainties still associated with the direction and magnitude of the changing weather patterns, it is recommended for now to prepare for a more variable climate than has been historically observed. A prioritized 'no-regret' measure is to expand water-storage infrastructure in the Nile region.



The parched landscape of Matheniko County, Uganda in 2009.